Vol. 1

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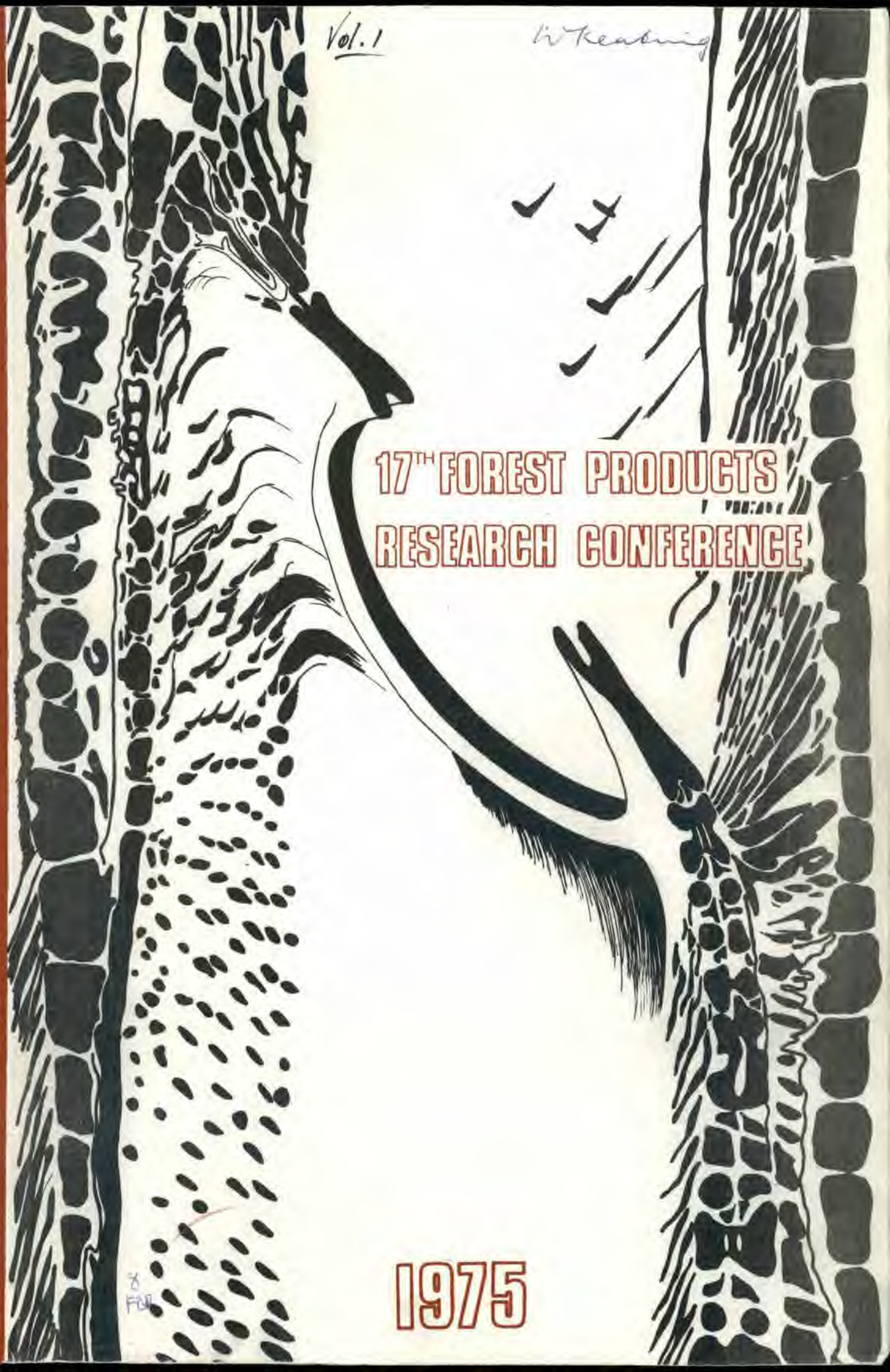

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Invited Paper 1

RESEARCH ON CONSERVATION OF POLES, PILES AND SLEEPERS

E. W. B. Da Costa

In the title of this paper, I have used the word "conservation" in place of the more conventional "preservation", partly because "preservation" has been so widely used for the prophylactic pretreatment of wood and partly because in our research we should think increasingly in terms of "conservation". In this I include not only conservation of individual poles by *in situ* treatment, but conservation of our capital in the form of existing transmission lines, fence lines and railway lines, by prolonging their life in every way and by more use of recycling. I allude also to conservation of our forest resources, by ensuring that our dwindling supplies of timber most suitable for sleepers in severe conditions, or for large durable poles, are used only in those applications and in those locations where their special properties are of most value.

I. Research on poles

IA - Soft rot in treated eucalypt sapwood

Research on poles in this Division has continued to be dominated by the problems posed by the unexpectedly rapid and severe development of soft rot in treated eucalypt sapwood, even at high initial retentions of CCA and other preservatives. Soft rot has been most serious in Queensland, with its large pole population of CCA-treated dense eucalypts, but also occurs in Papua New Guinea and in New South Wales. Examination of our stake tests suggests that it may be a problem in wet sites in Victoria. Research on this topic is also being carried out at the Forest Products Research Branch in Queensland, the Wood Technology Division in New South Wales and the Forest Products Research Centre in Papua New Guinea and several of the contributed papers deal with aspects of the problem. The detailed surveys and inspections made by constituent electricity supply authorities of the State Electricity Commission in Queensland have been of considerable help.

Work in the Preservation Group has concentrated on basic understanding of the development of soft rot; on the development of a satisfactory *in situ* bandage treatment for affected poles; and on the development of methods of early evaluation of both *in situ* and pre-installation treatments. It seems extremely likely, though not yet proved, that the failure of high retentions of CCA to prevent severe soft rot in the treated sapwood of dense eucalypts is due largely, if not entirely, to the uneven distribution of the preservative, which leaves large groups of fibres untreated and shows little penetration into the S_2 layers of cell walls. This distribution pattern has already been studied by Dr. Greaves in West Berlin as described in his contributory paper. When the Division's scanning electron microscope, with its excellent facilities for analysing elemental distribution on a sub-microscopic scale, is fully operational, research on the reasons for this uneven distribution and its contribution to soft rot attack can be rapidly advanced.

Invited Paper 1

Because soft rot normally attacks a pole from the outside inwards just below ground level, the logical method of control in affected poles is by application of a diffusible fungitoxic material to the outside of the pole, either as a brush-on coating or as a bandage. We believe that a bandage has better possibilities, as it allows larger amounts of material to be applied per square centimetre of surface and because it should stop the toxicant diffusing out into the soil. We have produced bandages based on a commercial absorbent cellulose pad ("Wettex") (5 mm thick) which we can load with 0.15 g/cm^2 of highly concentrated salt. If this were evenly distributed over a sapwood thickness of 25 mm, it would give a final retention of 60 kg/m^3 of preservative. In fact, this ideal state would not be attained, since the salt will continue to diffuse onward into the heartwood, even if at a greatly reduced rate, and will also be lost both by diffusing out into the soil below the bandage and by diffusing up the pole.

Conventional pole bandages used in Europe and U.S.A. for control of basidiomycete decay in poles are based on fluorine compounds, often bifluorides. These appear adequately toxic to the fungi occurring in soft rot in Queensland poles, but may diffuse so rapidly that effective concentrations in the critical zone may be short-lived. A more slowly diffusing compound, with some adsorption or fixation in the wood, may be preferable. The copper-fluorine-boron formulations patented by Mr. Johanson and described in his paper may be useful here. In fact, there are a wide variety of compounds which could be used effectively for this purpose and the final choice may be made on grounds of low cost and low health hazard, as well as efficiency. Whatever the compound used, it must penetrate the full depth of sapwood, preferably in a reasonably short time (e.g. within 3-6 months).

Even when soft rot is obvious only to a depth of 2-3 mm, the causal fungi may have penetrated the full depth of sapwood. Inhibition, or even killing, of the fungi in the outer layers of "sound" wood, either by a brush-on coating or by oxychar sterilization, will not prevent development of these deep-lying fungi and may encourage it. This is because oxygen supply may be a limiting factor on fungal development in wet sapwood, with the fungi in the outer layers acting as an "oxygen sink" and preventing oxygen from the relatively well-aerated soil from reaching the inner sapwood. It may be of some advantage to have an outer covering impervious to oxygen. Inhibition of soft rot in the outer layers of sapwood with its continued development in the inner layers would pose serious problems in pole inspection.

I would suggest a three-component bandage; (1) an absorbent matrix holding the toxicant; (2) an impervious outer plastic cover; and (3) a brush-on impervious coating to seal the join in the plastic (if it is not self-adhesive) and especially to seal the upper and lower edges of the bandage and to coat the pole well above and below the bandage and so reduce loss of preservative from the pole. The top of the bandage must be below ground level, especially in urban areas, to prevent vandalism and the possibility of children reaching the toxicant, even if this is a relatively safe material such as fluoride. It may be possible to add the toxicant, as a liquid concentrate to the absorbent matrix during or after its installation. The most difficult technical problem may well be the formulation and application of an impervious brush-on coating beyond the limits of the bandage. This must be impervious even to small mobile molecules and must be longlasting in soil contact. Suitable methods for application of the outer coating to a considerable depth are discussed in a later section.

Our evaluation of bandage treatments has at the time of writing been confined to laboratory screening of candidate fungicides, but field tests both at Highett and in collaboration with the Queensland Department of Forestry and State Electricity Commission will commence early in 1975. Laboratory tests suggest that the most effective treatments may be fluorine compounds and that copper compounds will be relatively ineffective. However, experiments with a number of copper compounds indicate that at very high concentrations, these may be both effective and fixed in the wood, whereas fluorine compounds are unlikely to be fixed. It is a situation where the preservative can escape from the pole into the soil and where the bandaging system can cover most of the critical area, fixable compounds have an advantage, but they may not be necessary where an impervious outer coating from above ground line to a considerable depth can prevent loss of preservative. As the electricity supply authorities in Queensland plan to open up each pole for inspection once every four years, it will be possible to apply a fresh bandage or outer coating fairly cheaply. However, we hope that with the development and proving of effective *in situ* treatments, it will eventually be possible to lengthen the period between inspections considerably.

1B - Centre rots in poles

This problem has been most serious in Victoria, in creosoted poles of relatively low natural durability, but probably occurs in other States also. It has been clear for some years that a number of creosoted poles were developing, within 10-15 years of installation, severe internal decay in a section near the groundline. It was at first thought that this decay might represent the continued development of heart rots present in the standing tree, but investigations by Mr. Neville Walters show that only one of the fungi isolated from decayed poles, namely *Piptoporus eucalyptorum*, is a known heart rot fungus. Most decay represents secondary infection, probably through large external drying checks developing in the pole after treatment. An initial survey by Messrs. Casserly and Murray of the State Electricity Commission of Victoria and a subsequent joint survey by Mr. Herd of the Commission and Mr. Barnacle of Preservation Group both show appreciable incidence of attack in poles treated over the period 1958-63. Unfortunately, it is difficult to assess from either survey the exact incidence of decay in poles of this period over all locations and conditions of use. More seriously, it is impossible to determine to what extent this is a historical problem. There is evidence that poles treated in the early days of the industry in Victoria showed a greater incidence of low retentions and poor penetration than poles being treated today and the latter may in fact give adequate service. Follow-up surveys are needed to check this point. The seriousness of even a low incidence of centre rots is not due to economic factors (though premature replacement of a key pole can be very expensive) but to the fact that sudden failure of a pole under stress can be dangerous, especially to linesmen but also to the general public.

As with soft rot in poles, it is not expected to be a difficult problem technically to arrest decay by *in situ* treatment with diffusing preservatives but the economics of such treatments are obscure. It would clearly be desirable to search for, and treat, all poles showing incipient or developed decay, but the lack of reliable methods of detection, discussed in another paper, make this difficult. Treatment of all standing poles would be a

costly business, especially as retreatment after a period of years would probably be necessary, but precautionary treatment of key poles, whose replacement would be very expensive, could be justified. Treatment of new poles, before or at installation, with diffusing preservative would be easier and more effective, but we do not yet know whether the incidence of centre rots in 1975 installations would justify the cost.

Since the rot is in the centre of the poles and since it is not proposed to open up all poles regularly for inspection, *in situ* treatments have been considered in terms of placing preservative in 2-4 downward sloping holes bored in the poles near ground level. Since the outermost heartwood is the most important for the strength of the pole and since tangential diffusion is slower than radial or longitudinal diffusion, these holes should not be radial, but in the form of an incomplete chord near the outer heartwood. Their optimum size and placing, in relation to fastest diffusion and acceptable levels of weakening of the pole, has still to be determined. As with soft rot in the sapwood, the best preservative should be selected after field and laboratory tests of toxicity and diffusion pattern. Since the distance to be covered by the diffusing preservative is much greater than for soft rot, and may extend downward for 1 metre or more from the point of application, faster diffusion is required, but a mixture of toxicant principles, some fast diffusing and some much slower, may be beneficial.

As with the soft rot problem, a key to the long term effectiveness of treatment may be the selection and application of a suitable outer coating to prevent loss of fungicide to the soil. This could be particularly easy to apply to new poles before installation since the full depth of the pole can readily be covered. As longitudinal diffusion is very much faster than transverse, it would be particularly important to prevent loss from the end of the pole, which can scarcely be re-coated and here the use of a permanent plate or shim of plastic or metal, should be considered. For initial treatment of poles, application of the preservative in a wide plugged hole bored axially from butt to above ground level before treatment and with a small side hole near ground line for replenishment of preservative, is being considered. For *in situ* treatment of both new and old poles, the possibility of using a bandage just below ground level, with an impervious coating, should not be overlooked. Such bandages are widely used in Europe and U.S.A. for treatment of creosoted poles. They would concentrate the preservative more uniformly in the outermost heartwood, and may be less affected by internal collapse checks, than other methods of application. Fumigants such as chloropicrin (encapsulated for ease of handling), should also be tested, (particularly in combination with an impervious outer coating), in view of their spectacular success in controlling centre rots in Douglas fir poles in U.S.A.

IC - Engineering problems in pole conservation

For *in situ* treatment of both soft rots and centre rots, any bandage or impervious coating should extend to a considerable distance below ground level. It is, however, extremely expensive to expose the surface of a pole to any depth by normal manual excavation, and the resultant damage to nature strips with poles in urban areas may be unacceptable. It should be possible to develop equipment which would remove the soil for a distance of 100-150 mm around the pole for a considerable depth, perhaps almost to the base of the

pole. (The pole may have to be supported during the operation). This would permit the application of an impervious coating or even a bandage, and possibly the removal of short cores for research purposes, to a depth of 3-5 feet. Backfilling with treated soil or with expanded polyurethane foam would be easy. The equipment might also be useful for termite barriers around poles.

Another important problem is that of strengthening, rather than replacing, condemned poles. At present, it is usual to replace 40-60 foot poles (carrying considerable hardware and conductors) which are completely sound except for a 2-4 foot section within 6-8 feet of the butt. Where guys, strainers, or side-lashed dummy poles are unacceptable on aesthetic or other grounds, would it be possible to splice a new butt to the pole, using perhaps a steel sleeve combined with adhesives? Certainly where a condemned pole is replaced, it should be possible to do so, rather than re-using it as a shortened pole.

II. Pile Conservation

Research on piles in the Preservation Group has been confined to piles in the marine environment. Here we have the problem that, to date, no treatment has been shown to protect eucalypt timbers from teredine borer attack in high hazard waters. From the biology of these borers, it could be inferred that as they develop in the wood, they become less susceptible to any toxic material therein, and hence the most promising method of control would be to prevent settlement and penetration of the young larvae. We propose to test, on small specimens of creosoted eucalypt sapwood, a number of highly concentrated molluscicides, bactericides etc., confined to the outermost layers of the timber or forming part of a coating system outside it. Because only a small depth of treatment is involved, use of materials of high cost per unit weight becomes feasible. The addition of an impermeable outer coating should enhance the permanence of the toxic agent.

Work is also continuing on the redistribution and leaching of CCA and other preservatives in sea water, since this is seen as a key to their limited effectiveness. Mr. McCarthy confirmed that the copper in CCA tends to accumulate in the outer layers of the wood, but the mechanism of this, whether by ion-exchange or by biological accumulation, is still being studied. We are also testing whether this accumulation is accompanied by a reduction in the toxicity of the copper. The Group has also agreed to cooperate in a test organized by the International Research Group on Wood Preservation (IRG) to test the effect of timber substrate on the performance of CCA against high hazards from teredine and other borers in exposure sites in several countries.

As regards terrestrial piles our main concern is with the increasing use of treated rounds as foundations for dwellings and other buildings. Press statements that these will last "indefinitely" are misleading, particularly in locations of severe soft rot hazard, with partly exposed piles, and with friction piles. Research on very permanent and effective preservatives for eucalypt sapwood may be more urgent here than for transmission poles, as replacement costs may be greater and *in situ* treatments much more difficult to apply. We should aim at less than 5%,

preferably less than 1%, failure in 50 years, a period often quoted (perhaps conservatively) as the design life of a house. It is doubtful if present treatments will achieve this with eucalypts, though they may do so with softwoods.

III. Research on Rail Sleepers

IIIA - Protection of rail sleepers from *Mastotermes* attack

Recent work on rail sleepers in this Division has been concentrated on problems associated with use of wooden sleepers in heavy-duty rail tracks recently built in the north-west of Australia for export of iron ore. The major problems are rapid weathering under the very severe climatic conditions and sporadic attack by *Mastotermes darwiniensis*. As an interim measure, the Division has recommended addition of 0.5 per cent dieldrin to the creosote-petroleum oil mixture used for Boultonizing and pressure treatment of jarrah and karri sleepers. Field tests are being made with organic arsenical concentrates, dieldrin and aldrin as additives to preservative oil treatments.

Suitable techniques have been developed for maintenance of *Mastotermes* colonies at our laboratory and for the testing of preservatives and of portions of preservative-treated sleepers against them.

A new method of incising using short blunt sprocket-chain teeth rather than incising knives has been developed under the name "brucising" and is discussed elsewhere. This method is being tested in the field both for its direct effect on preservative penetration and on weathering, and for its contribution to the treatment of W.A. sleepers by dip-diffusion with a concentrated arsenical formulation for protection against *Mastotermes*.

IIIB - Protection of sleepers from weathering

In climates such as that of the Pilbara region, it is probable that most failures of wooden sleepers will be by weathering, i.e. by breakdown of the top surface, loosening of fastenings and development of end splits under wide variations in temperatures, intense solar radiation and occasional wetting. Our present practice of treating sleepers with a heavy oil does much to reduce this, and should do more, as improved methods of incising and of boultonizing are developed (possibly combined with high pressure treatments) to give deeper penetration. Covering the upper surface of the sleeper with ballast, with fine aggregate, with treated plywood or even with a reflective paint may give good protection. Even repeated dressing of the upper surface or the track in general with a heavy oil would give considerable protection. These methods need testing under severe exposure conditions in the track, but it may be possible to obtain a more rapid assessment (e.g. of durability of coatings) from behaviour of sleeper sections in a large laboratory "weatherometer".

End splitting could also be minimized by coating the end portion of the sleeper, and the various means of doing so could again very likely be assessed by laboratory weatherometer behaviour of transverse sections. The use of mechanical restraint by strapping, gang-nailing, or dowelling to prevent or correct end splits also needs investigation.

There is scope for fundamental study of the mechanisms responsible for "brooming", checking or splitting, with quantitative assessment of the contributions of the various parameters involved. A better understanding should lead more rapidly to better control measures.

IIIC - Engineering aspects of rail sleeper research

In view of a prospective severe shortage of suitable sleeper timbers, both in Australia and overseas, every effort should be made to prolong the life of wooden sleepers to the limit. Apart from control of termite attack, decay and weathering, more attention should be given to preventing losses from end splitting (e.g. by dowelling or end-strapping sleepers either during initial treatment or in the track) or from rail cut and spike kill (by developing improved fastening methods). If the last two remain serious causes of failure, can they be reduced by shifting the rail seat along an over-length sleeper, or by inverting sleepers after a number of years use? In view of the high labour costs and unpleasant working conditions in the Pilbara region, the planned development of fast, mechanized methods of inspection, maintenance treatment and replacement of individual sleepers, groups of sleepers or lengths of track is an urgent need. (This could include use of specialized rolling stock, which move easily off the track when necessary.) Perhaps the most important immediate problem is the use of improved rail fastenings. A large number of types have been suggested, but there is a need to test these, either in selected sections of track or by accelerated laboratory tests using high speed mechanical vibrators. The possibilities of using other "softer" timbers for rail sleepers and of laminated sleepers should also be more fully exploited.

Clearly much of the research described in this section, and in the previous sections, is beyond the unaided scope of the Division of Building Research. It could, however, be carried out as a collaborative project with the various railway systems, with the newly-formed Railway Sleeper Association (Australia) as coordinator. One immediate requirement is more information on the quantities of various sleeper timbers available in the immediate future, with reasonably reliable projections of the quantities available say 10 years ahead. All this information must largely affect our research work, as well as the policies of railway authorities. For example, it is waste of research time to develop methods of protecting sleepers from biological attack for 20-30 years if they fail mechanically in 10-15 years or if the types of timber concerned become unavailable in a few years.

Invited Paper 2

THE PRODUCTIVITY AND UTILIZATION POTENTIAL OF AUSTRALIAN-GROWN SOFTWOODS OTHER THAN RADIATA PINE

W. J. Smith

Summary

In an evaluation of the productivity and utilization potential of Australian-grown softwoods other than radiata pine, assessments range from good to very high.

Caribbean and cypress pines are considered to have the highest potential; the former as a fast-growing, short-rotation crop with excellent wood properties for the tropics and sub-tropics, and the latter because of high volume availability and incomplete utilization.

Other species such as hoop, slash, loblolly and maritime pines offer good potential on a more restricted basis where specifically better adapted to prevailing growing conditions than the generally more highly productive Caribbean and radiata pines.

It is concluded that there is considerable potential for improvement of the productivity and utilization potential of these softwoods. Inhibiting factors and means for minimising their influence are discussed.

It is considered the magnitude and importance of this component of the Australian softwoods resource, and that of the cypress pine fraction in particular, may not be fully appreciated. They are estimated to comprise about 30% and 12%, respectively of the present total Australian softwoods cut. In addition, mill wood residues alone from the same source would provide an estimated 38% increase in Australia's total softwood pulpwood production; 58% if bark was included.

The most urgent needs for improvement in productivity and utilization are seen as the availability of an adequate supply of Caribbean pine seed, the development of less wasteful conversion systems, the recovery and effective utilization of forest and processing residues, and extension of the present limited utilization range of cypress pine.

The analysis is considered to justify a considerably increased emphasis on softwoods other than radiata pine in the national research and development programme, commensurate with their 30% contribution to Australia's softwoods production.

Introduction

Although approximately 70% of Australia's coniferous plantation area is stocked with *Pinus radiata* (Aust. Dept. of Agric., 1975), the remaining 30% constitutes a very large investment in an extensive and extremely valuable resource.

Invited Paper 2

A fact which may not be fully appreciated in view of the importance radiata pine has been accorded in national economic and research considerations is that, despite the high proportional area of radiata pine in coniferous plantations, about 93% of the total coniferous forested area is stocked with other Australian-grown softwoods. 89% of the area carries virgin and naturally regenerated stands of the indigenous cypress pine, and the relative importance of the growing space occupied by these 4,358,000 hectares of admittedly sparsely stocked but low-cost softwoods may have been underestimated in terms of their potential for development. Apart from that for the cypress pine area, these percentages are under-estimates, since the area occupied by *Araucaria* spp. and other components of the virgin indigenous coniferous resource in mixed forest associations has not been estimated.

Tasmania and Victoria, with less than 1% and 4%, respectively, of their softwoods area planted to species other than radiata pine, and the Australian Capital Territory, with about 7% of its much smaller area in other species, are probably the only Australian States or Territories which can afford to concentrate their undivided attention to that species. Even South Australia, which pioneered its high-volume establishment, has over 7% of its planted area in other conifers, mostly maritime pine (*P. pinaster*).

New South Wales has 17,900 hectares or 14.6% of its planted area in other species, mainly slash and loblolly pines (*P. elliottii* and *P. taeda*) but with 1,200 hectares under hoop pine and 5,000 hectares of various other species.

Western Australia has 50% (19,700 hectares) of its plantations in *P. pinaster* and the Northern Territory has no interest in radiata pine as growing stock.

Of all the States, Queensland has by far the biggest interest in species other than radiata pine as a plantation resource. Although there is a limited interest in the species for restricted locality planting, over 98% of the State's extensive softwood plantation area of 111,000 hectares is in other species. The major emphasis is on the southern yellow pine group, slash, Caribbean and loblolly pines (*P. elliottii*, *P. caribaea* and *P. taeda*) and hoop pine (*Araucaria cunninghamii*), the current areal ratio of the two groups being about 2:1 (Table 3 in Aust. Dept. of Agric., 1975). Behind these, *P. patula* ranks next in importance after *P. radiata*, with useful stands in limited localities.

The vast cypress pine resource is concentrated predominantly in New South Wales, Queensland and the Northern Territory (Table 2 in the same reference).

A more realistic indication of the importance of conifers other than radiata pine as an economic resource at the national and State levels than that given by the areal breakdown is probably provided by

the data in Table 1, showing regional and total production figures for the three main coniferous sub-groups, viz. (a) radiata pine, (b) cypress pine, and (c) other coniferous species. These have been subdivided into sawlog, plywood, pulpwood and other round timber components. The figures were extracted mainly from Annual Reports of the State Forest Services for the years shown or from data by Aust. Dept. of Agric. (1975). Although not for a common year, they are considered close enough chronologically and recent enough to be meaningful.

TABLE 1. AUSTRALIAN SOFTWOODS PRODUCTION BY STATES AND BROAD SPECIES GROUP AND USE CATEGORIES

Species Group, Use Category and Production Year	VOLUME PRODUCED IN YEAR SHOWN ($m^3 \times 10^3$)							
	S.A. [5]	N.S.W. [6]	QLD	VIC. [6]	W.A.	TAS.	ACT & N.T.	TOTAL
PRODUCTION YEAR [1]	'72-'73	'72-'73	'73-'74	'70-'71	'71-'72	'72-'73	'71-'72	
Pinus radiata							A.C.T. - [6 7 8]	
Sawlogs	591.9)	192.5	2.6	147.1	36.1)	14.7)	51.1	1036.0
Ply logs	19.7)	[7]		6.9	3.3)	)		29.9
Round Timber [2]	35.7)			15.6	0.8	3.1)		55.2
Pulpwood [3]	191.8	112.0	0.2	65.0	10.5	17.8	13.8	411.1
Sub Totals	839.1	304.5	2.8	234.6	50.7	35.6	64.9	1532.2
CYPRESS PINE							N.T. -	
Sawlogs)		154.2	106.2	N E G L I G I B L E			1.0	261.4
Round Timber [2])		[7]	[7]					
Sub Totals	-	154.2	106.2	-	-	-	1.0	261.4
OTHER SOFTWOODS [4]							A.C.T. - [6 7 8]	
Sawlogs	3.0)	35.8	164.3	6.2	10.4)	)	3.9	223.6
Ply logs	)	[7]	3.5	0.3	0.3)	)		4.1
Round Timber [2]	0.2)		Not Incl.	0.6	1.8)	Negligible)		2.6
Pulpwood [3]	1.0	20.2	57.3	3.0	27.5)		1.0	110.0
Sub Totals	4.2	56.0	225.1	10.1	40.0	-	4.9	340.3
TOTALS	843.3	514.7	334.1	244.7	90.7	35.6	70.8	2133.9

Footnotes [1] [2] [3] [4] [5] [6] [7] [8] - see page 5.

1 - Data taken from latest categorised source available to author at time of writing. Although not for a common period, the figures are considered indicative of relative volumes as categorised.

2 - Includes poles, piles, fencing and mining timbers.

3 - Generally includes hardboard and particleboard material within the accepted narrower context of the term.

4 - Includes virgin-growth indigenous material other than cypress pine.

5 - Proportions in radiata and other softwoods estimated on a proportion of total cut basis.

6 - Proportions in radiata and other softwoods estimated from planted area.

7 - Assumed predominantly sawlogs.

8 - Pulpwood data not available; estimated at 27% of saw and ply log figure as national average ratio.

From this information, it is noted that:-

(a) At the national level, of the Australian coniferous forest harvest,

(i) about 28% of the total and 32% of the sawlog component is in species other than radiata pine;

(ii) 12% of the total and 17% of the sawlogs are in cypress pine;

(b) At the State level, the relative importance of softwoods other than the predominant national species becomes far more evident. South Australia, Tasmania and Victoria and the A.C.T. could be regarded as almost exclusively radiata pine territory but, even here, there is probably up to 20,000 m^3 of other softwoods harvested. Western Australia's softwood plantation yield is approaching 100,000 m^3, with about 45% of it in species other than radiata pine.

On the other hand, Queensland and New South Wales, which together produce about 40% of Australia's softwoods and 43% of its coniferous sawlogs (31% if cypress pine is excluded), have a vital interest in the productivity and utilization potential of this part of their forest resource.

Sixty-four percent of their combined total softwoods cut and 70% of their softwood sawlogs (48% excluding cypress pine) are in species other than radiata.

After South Australia, New South Wales and Queensland rank second and third, respectively, as contributors to Australia's softwood productivity and, of New South Wales' 514,000 m^3 cut, 41% of its total and 50% of its sawlog component are in species other than radiata.

Queensland is virtually totally dependent on conifers other than radiata for softwoods. Of its 1973/74 cut of 334,100 m^3 in this type of material, over 99% was in other species. Any alteration to this percentage is negligible even if cypress pine is excluded from consideration.

The importance of cypress pine to New South Wales and Queensland is indicated by its proportional representation in those two States' softwood harvest as follows:-

(i) 30%, 32% and 31%, respectively of New South Wales', Queensland's and their combined total softwood cuts; and

(ii) 40%, 39% and 40% of their softwood sawlog cuts, in the same order.

RELATIVE SPECIES VOLUME PRODUCTIVITY

Table 2 shows the relative volume and dry wood weight per hectare productivity of slash, Caribbean and hoop pines as now planted in Queensland in comparison with an all-sites-planted average for Queensland-grown radiata and a well above average southern radiata equivalent. A comparison with average southern radiata would have been preferred but, as found by Miller (1974), suitable data for what might be regarded as such was not readily available. The slash pine data represents the expected average for genetically improved stock now planted as routine in areas of major planting. The Caribbean pine data is more representative of its growth in North Queensland; at a site index of 30 metres it is higher than that for average site indices of about 29 m and 26 m for central and south-east coastal Queensland, respectively. There are, however, sites in all three areas to which the data would apply.

Average Queensland-grown radiata, represented by the 21 m site index data, is undoubtedly well below the performance of average radiata in the southern States. Since it includes data from trials on sites which would not now be planted to radiata, it should be regarded as even a depressed Queensland average; there are some sites at higher elevations in south-east Queensland where its productivity is exceptional and considered equivalent to a well above average radiata site in the south, as shown by the data for the 33.5 m site index. This has been extrapolated beyond actual age 17 years from an apparently appropriate southern yield table to give some basis for evaluation.

The Caribbean pine data was extrapolated beyond its actual age of 23 years from slash pine yield tables adjusted for use with Caribbean pine.

TABLE 2. RELATIVE VOLUME AND DRY WOOD WEIGHT PRODUCTIVITY BY ROTATIONAL STAGES FOR FOUR QUEENSLAND-GROWN CONIFERS

(In using this Table, particular attention should be paid to footnotes and text).

Parameter	Species [1]	Age (Years) [2]						
		11-14	17-19	23-25	29-30	34-35	40	44-45
Actual Age (yrs) [3]	s	12	17	25	30	35	40	-
	h	12	17	25	30	35	40	45
	c	11	17	23	-	-	-	-
	r1	14	19	24	29	34	-	44
	r2	14	17	(25)	(30)	(35)	(40)	-
Site Index (m) [4]	s			25.9				
	h			24.4				
	c			30.5				
	r1			20.7				
	r2			33.5				
Mean annual merch. volume increment (m^3/ha/ann) [5]	s	8.89	11.69	14.49	14.14	13.02	11.55	-
	h	5.20	8.61	11.88	13.81	14.48	14.11	12.62
	c	15.15	20.42	21.23	(20.79)	(19.90)	-	-
	r1	7.28	9.28	10.47	10.95	10.84	-	9.65
	r2	20.64	23.31	(27.47)	(28.58)	(28.81)	(28.06)	-
Basic density (kg/m^3)	s	519	528	532	539	540		
	h	432	440	464	464	-		
	c	440	451	-	-	-		
	r1	429	439	440	443	447	446	
	r2	-	404	(432)	-	485		
Mean annual merch. dry wood weight increment (tonnes/ha/ann)	s	4.61	6.17	7.71	7.62	7.03		
	h	2.25	3.79	5.51	6.41			
	c	6.67	9.21	-	-	-		
	r1	3.12	4.07	4.61	4.85	4.85		
	r2	-	9.42	11.87	-	13.97		

Footnotes 1 2 3 4 5 - see page 8.

1 - s = average improved routine slash pine as now planted; h = average unimproved routine hoop pine as now planted; c = average unimproved routine Q'ld Caribbean pine; r1 = average Q'ld radiata pine on an all-sites-planted basis; r2 = based on data for a Q'ld site considered equivalent to a well above average southern Australian site, extrapolated at an appropriate M.A.I.; similar data for average southern radiata not readily available.

2 - actual age used in M.A.I. calculation shown in Table.

3 - productivity data extrapolated beyond ages shown.

4 - see text and 1 above re applicability of indices used;

5 - based on volume to 10 cm top diameter under bark. Values from extrapolated data in parentheses.

The productivity of radiata pine on very good sites in the southern States and in New Zealand is of the order of 26-28 m^3/ha/yr., with a rotation of maximum M.A.I. stated to be 25 and 30 years, respectively, for Australian Site Quality III and New Zealand Site Quality II (Miller 1974). From Table 2, however, the maximum M.A.I. rotation age for the Australian site quality referred to seems to be more like 35 years.

On average sites now planted, it appears that the only Queensland-grown conifer with a growth potential at all comparable with that of radiata pine is Caribbean pine. Hoop pine has an average M.A.I. peak of 14.5 m^3/ha/yr. at around 35 years, and slash pine 14.5 m^3/ha/yr. at about 25 to 30 years, whereas Caribbean pine (var. *hondurensis*) peaks at around 21 m^3/ha/yr. at about 23 years on an admittedly above average site (S.I. 30.5 m). Comparable data for what might be regarded as more average sites in Central Queensland was not available, but would be expected to show a lower M.A.I.peak at slightly later age. More detailed data is presented in Hawkins *et al.* (1972), in which it is also stated that, where maximum volume yield is the objective, short rotations of about 25 years are indicated for this species in areas of major planting in Queensland. Average M.A.I.'s would be lower in south-east Queensland, but earlier growth increments to 36 m^3 and 12.7 tonnes dry wood weight/ha/yr. at age 12 years have been recorded for good sites in North Queensland (Smith, 1973).

It has been stated (Sessions, 1974) that clear-felling at 18-20 years after a thinning at 6-10 years is a recommended practice for Caribbean pine plantations in Jamaica. Where maximum productivity with a major emphasis on sawlog production is required, as is currently the case throughout Queensland generally and particularly in its highest yielding Caribbean pine regions, support for the adoption of shorter rotations than for other conifers here is lent by a comparison of data for 19 year old Caribbean, slash and radiata pines shown in Table 3. This data could be considered as representing (a) genetically improved slash slightly below the average for stock now planted as routine in areas

of major plantings; (b) unimproved Caribbean pine now planted as routine in Central Queensland; and (c) well above average quality southern Australian radiata pine.

It is noteworthy that, even at 19 years, only 39 stems/ha failed to meet the sawlog prescription in average Caribbean pine, compared with 148/ha for the above average radiata. In the example shown, despite the superior overall volume and dry wood weight/hectare productivity of the higher site-quality radiata, the Caribbean pine had, at the same age, a larger number of sawlogs per hectare of slightly larger average diameter and about the same percentage recovery per unit volume. Only greater log length for the radiata enabled it to retain its advantage in terms of sawn yield/hectare. A direct comparison with "average" radiata would have been most interesting.

The volume productivity of cypress pine in Queensland after silvicultural treatment has been estimated by Hawkins and Muir (1968) to range from 1.4 - 2.8 m^3/ha/yr. Johnston (1973) has calculated that, with optimum thinning for maximum standing value increment, the mean merchantable volume increment for an average cypress pine stand over a rotation of 110 years is 1.37 m^3/ha/yr.

These are very low rates of increment compared with that for other Australian-grown softwoods and, with increasing harvesting of this resource, could be a cause of concern to forest management, especially in New South Wales and Queensland, where it constitutes such a high proportion of the total cut and even more of the sawlog component.

The large area afforested in cypress pine appears to be the saving factor at present. Although the Queensland cut of this timber was at rates equivalent to from 0.04 - 0.11 m^3/ha/yr over periods of from 11 to 22 years to 1971 for four major cypress areas, the growing stock increased over the same period at a rate equivalent to from 0.06 - 0.18 m^3/ha/yr, (Yorkston, 1975), giving a nett mean annual standing volume increment ranging from -0.03 to 0.17 m^3/ha/yr. While one of the four areas showed a production deficit, the others either broke even or improved in standing volume.

However, the cypress pine cut for 1973/74 was 33% higher than for 1970/71. Even without any further increase (and this could reasonably be expected), it is evident that, if the same areas are to be operated, the positive nett incremental margin remaining in some of them could be expected to diminish.

Nevertheless, the present annual Queensland cypress pine cut represents only 0.062 m^3/ha over the total area classified as cypress pine forest, so that less than 5% of that area would need to be of "average" quality to allow the present cutting rate to be sustained from annual merchantable volume increment on Johnston's (1973) figures.

The potential for further utilization of this resource is apparent, even without any further attempts to improve the productivity of the large area it occupies.

TABLE 3. A PRODUCTIVITY COMPARISON OF CARIBBEAN, SLASH AND RADIATA PINES AT 19 YEARS

(In reading this Table, particular attention should be paid to footnotes and text).

Parameter	Slash Pine [1]	Caribbean Pine [2]	Radiata Pine [3]
Present Site Index (m)	24.4	29.0	36.3
Predominant height (m)	20.9	24.7	31.4
Average G.B.H.O.B. (cm)	74.2	78.5	77.5
Stems per hectare	837	929	1008
Sawlogs per hectare [4]	808	890	860
Total volume/ha (m^3)	228.2	318.9	437.1
Mean stem volume (m^3)	0.27	0.34	0.43
Mean annual increment (m^3/ha/yr.)	12.0	16.8	23.0
Basic density (kg/m^3)	521	470	404
Dry wood weight yield (tonnes/ha)	118.9	149.9	176.6
Dry wood weight yield per annum (tonnes/ha)	6.3	7.9	9.3
Total sawlog volume/ha (m^3)	225.0	313.7	424.3
Average sawlog volume (m^3)	0.28	0.35	0.49
Estimated sawn yield (%)	42% [5]	43% [5]	43% (Est.)
Sawn volume yield (m^3/ha)	94.5	134.9	182.4

Footnotes 1 2 3 4 5 - see page 11.

1 - Based on stock slightly below the anticipated average for genetically improved slash pine now planted as routine in areas of major planting.

2 - Representative of unimproved Caribbean pine now planted as routine in Central Queensland.

3 - Based on data at 17 years for an exceptional Queensland site considered equivalent to a well above average southern Australian site, extrapolated to 19 years at an appropriate M.A.I.; similar data for average site quality southern radiata not readily available.

4 - Logs 60 cm + g.b.h.o.b. to 10 cm top diameter under bark.

5 - Percentage of true volume, from actual recovery studies.

Attention has been primarily focussed on Caribbean and cypress pines because of their volume increment and volume availability, respectively. Other species merit reference.

Western Australia's secondary conifer, maritime pine (*P. pinaster*), is apparently a reasonable if not outstanding producer, with mean annual increments of 8.9 m^3 and 4.0 tonnes per hectare at 14 years (from data in Bevege, 1975), and meets a need on sites not suited to radiata. It is undoubtedly not at peak M.A.I. at 14 years and, like hoop pine and some Site Qualities of radiata (see Table 2), will exhibit better potential at later rotational stages.

A number of productivity and wood quality comparisons of several species, varieties and provenances within and between locations and site indices in Queensland have shown the benefit to be derived from such trials as a guide to management.

The results of several of these, in which Caribbean pine varieties have been evaluated with one another; Honduras Caribbean pine (var. *hondurensis*) with slash pine over a range of site indices and locations; its response to latitudinal, elevational and climatic changes checked; and the performance of a slash x Honduras Caribbean pine hybrid assessed, have been summarised in Smith (1973).

In these trials, generally at ages 12-19 years (36 years in one varietal comparison), the adaptability of Caribbean pine (in particular, var. *hondurensis*) as a high-yielding softwood over an extremely wide range of ecological conditions is well indicated. Volume and dry wood weight yields ranging from 138 to 429 m^3 and 59 to 153 tonnes per hectare at 12 years have been recorded, depending on location and site quality.

Average percentage sawn board recovery from 18-19 years old Honduras Caribbean pine was slightly higher than for matched plots of slash pine in south-east Queensland and average yields of saleable sawn boards per hectare 48% higher, despite poorer average stem form

for the unimproved Caribbean pine. The effect of the usual positive relationship between log girth and percentage recovery compensated the larger average girth Caribbean pine logs (see Table 3) for the negative effect of their poorer form. The potential for a further sawn yield improvement of 5% of true volume from straighter stems in genetically improved Caribbean pine has also been estimated (Smith, 1973).

In limited varietal trials at 15 years and 34-36 years, vars. *bahamensis* and *caribaea* have shown considerable productivity potential in some regions. In one small trial aged 15 years on south-east Queensland coastal lowlands, var. *bahamensis* showed an advantage of 20% and 16% over var. *hondurensis* in volume and wood weight yields respectively, and the mean annual girth increment of var. *caribaea* surpassed that of var. *bahamensis* by about 20% at the higher elevated Imbil location in a 34-36 years old trial.

Improvements in productivity anticipated through more effective site utilization following evaluation of trials such as these are indicated by the increasing emphasis being given to Caribbean pine in Queensland's planting programme. It constitutes about 6% of the total softwoods area planted to date but last year's planting comprised 12% Caribbean pine and, whereas the ratio of var. *hondurensis* : var. *bahamensis* : var. *caribaea* was 7.9 : 1.2 : 0.9 of the species total to 1971, current programmes envisage a varietal ratio of 4 : 1 : 1 (Hawkins et al., 1972). The Caribbean pine component of the overall planting is expected to increase as seed supplies become more readily available.

The highest yields for Caribbean pine have been obtained in the tropical coastal strip, with maximum productivity in both volume and wood weight on abandoned farmland sites in the far north highlands. However, it has also been found to be a consistently higher producer than its main competitor, slash pine, on a wide range of site indices over three main planting localities in south-east Queensland. On the same sites of intermediate quality at 18-19 years, Caribbean pine gave 45% and 29% higher volume and wood weight yields per hectare, respectively, than slash pine (Smith, 1973).

The potential of the slash x Honduras Caribbean pine hybrid produced in Queensland offers the best prospects for higher yields there, particularly since early problems in securing adequate seed supplies seem closer to solution (Nikles, 1975). At 13 years at Beerburrum in South-east Queensland, it outproduced both parental species on both "ridge" and "swamp" sites by from 24% to 64% and improved quality slash pine by 14%-27%. The hybrid's relative volume advantages over Caribbean pine would have been somewhat lower and over slash pine somewhat higher than those for wood weight production.

Genetically improved slash pine stock from seed orchards, now used exclusively for Queensland planting in this species, increases both volume and wood weight production to age 14 years by 18.8% and 18.5%, respectively (Nikles and Smith, 1969). It seems a reasonable assumption that similar genetic gains can be expected for Caribbean

pine when such improved stock is available. However, the production gap between Caribbean and southern Australian radiata pine could still remain as long as radiata tree breeders continued to chase its probably similar capacity for improved yields, demonstrated by results of trials communicated to Nikles (1970) by C. K. Pawsey of the Forest Research Institute, South Australia. Hoop pine has also shown very encouraging genetic gains in young (10 years) progeny trials in Queensland (Queensland Department of Forestry, 1974).

Some results for trials covering other species are given for comparative purposes in Table 4.

Apart from the general superiority of Caribbean pine, the results of such limited but continuing evaluations illustrate that species diversification on a selective locational basis has a positive role to play in increasing yields per unit area planted. The two varieties of slash pine and loblolly pine rank as quite reasonable producers on the right sites, with other silvicultural considerations complementing this factor in choosing planting stock. Shortleaf pine (*P. echinata*) should not be excluded from consideration for some sites on its limited trials here. On the other hand, patula and ocote (*P. oocarpa*) pines are evidently not competitors for the available growing space.

Hoop pine plantations in North Queensland rainforests are giving good volume increments of the order of 13.7 - 14.9 m^3/ha/yr at 15 years, 21.7 at 19 years, and 21.2 at 32 years (Volck, 1975). For silvicultural reasons, this indigenous rainforest species appears to be a better prospect than exotics such as Caribbean pine on rainforest type soils except on former farmland, where the latter has been an outstanding producer.

From a study of the performance of eight hoop pine provenances at age 25 yrs at two locations in south-east Queensland, the advantages accruing from correct choice of seed-source were evident. Dry wood weight yields ranged from 91-182 and 174-254 tonnes/ha at the two locations, with similar ranges in relative volume. Provenances with superior productivity at both locations were differentiated, as well as some evidence of genotype/environment interaction effects which could be exploited.

Possibly the greatest potential for improvement in volume yields per hectare is in the vast cypress pine areas. While recognising that the economics of any changes in silvicultural policy in this low-cost naturally regenerated resource need careful consideration, there are appreciable apparent advantages from species diversification in these areas.

The reasonable to good survival and much faster growth rates of some of the exotic conifers in trials in parts of the cypress belt suggest the feasibility of reforestation of at least denuded areas with exotic conifers. Cypress is very slow to regenerate after fire and, despite the far better fire protection now available, there could be areas where the exotics' more rapid growth could prevent or minimise

Invited Paper 2

TABLE 4. PRODUCTIVITY COMPARISONS FOR SOME SPECIES AND VARIETAL TRIALS IN SOUTH-EAST QUEENSLAND

Age, Locality and Parameter	*P. caribaea* var. *hondurensis*	*P. elliottii* var. *elliottii*	*P. elliottii* var. *densa*	*P. taeda*	*P. echinata*	*P. patula*	*P. oocarpa*
(a) 19 yrs, Beerburrum:							
Site index (m)	29.6	26.5	25.0	23.8			22.6
Volume (m^3/ha)	423	296	317	285			172
Dry wood yield (tonnes/ha)	189	146	158	131			75
(b) 19 yrs, Beerburrum:							
Site index (m)	29.6	27.4		28.3			20.7
Volume (m^3/ha)	330	347		388			167
Dry wood weight (tonnes/ha)	148	166		177			68
(c) 25 yrs, Maryborough:							
Site index (m)		22.9		18.9			
Volume (m^3/ha)		301		211			
Dry wood yield (tonnes/ha)		157		105			
(d) 33 yrs, Beerburrum:							
Site index (m)		24.7		24.4	22.9		
Volume (m^3/ha)		572		491	339		
Dry wood weight (tonnes/ha)		306		259	165		
(e) 25-26 yrs, Yarraman:							
Average site index (m)						22.3	
Volume (m^3/ha)						260	
Dry wood weight (tonnes/ha)						101	
(f) 22-26 yrs, Benarkin:							
Average site index (m)						24.0	
Volume (m^3/ha)						315	
Dry wood weight (tonnes/ha)						116	
(g) 34-43 yrs, Pechey:							
Average site index (m)						17.7	
Volume (m^3/ha)						162	
Dry wood weight (tonnes/ha)						74	

erosion problems. The possibility that former grazing land could become available should also not be ignored. In such selective circumstances, enrichment of the cypress belt yields with exotics may justify the cost of establishment. It at least merits consideration. Promising species for particular regions include slash, radiata, Caribbean (vars. *bahamensis* and *caribaea*), and drought-resistant Texas strains of loblolly pines. Although many of the trials are quite young, a few limited ones in slash and radiata at 25 years have given M.A.I.'s of 4.01 and 5.09 m^3/ha/yr. which, while low by preferred coastal conifer standards, are three times as productive as average treated cypress stands at 110 years rotation.

An additional benefit from the suggested enrichment planting is the greater flexibility in utilization offered by the other softwoods compared with cypress pine. A local source of stock for furniture, joinery, mouldings and similar applications to supplement the basically constructional cypress pine would be welcome.

VALUE PRODUCTIVITY POTENTIAL

Optimum volume productivity, which has been stressed in the preceding section, is only equivalent with optimum value productivity where full recovery is practicable.

This is not practicable at present, whether the product be in sawn, pulped, peeled, sliced, flaked or chipped form.

Avoiding for the present consideration of the full-tree and complete-tree utilization concepts (see Keays, 1974 and references therein), and concentrating on that material regarded as merchantable (only about 60% of the dry weight of a tree is in its merchantable bole), the recoverable fraction of that material and its value varies greatly depending on such factors as the end-use, methods of conversion, log size and quality.

For Queensland-grown softwoods under present commercial conversion practice, the average sawn recovery throughout a rotation is about 42% of the merchantable bole's true volume. Slash, Caribbean, cypress and hoop pines average around 40%, 42%, 43% and 44%, respectively. This is of the same order as the figure of 40% in dry finished lumber reported by Wahlgren (1974) for U.S.A. softwoods.

Veneer production in similar material ranges from 38% to 64% (varying inversely with billet length), with an average around 48% of true volume, to which should be added a small supplement from the residual core.

In both these instances, volume is the primary consideration and weight of no consequence, except insofar as it may affect subsequent utilization of the end-product.

Recoveries from pulping operations are often considered by those not sufficiently familiar with the pulp and paper industry to be much higher than they really are, because of the apparent complete volume utilization. This ignores the largely unutilized and unrecovered lignin, hemicellulose and extractives components.

Hence, pulp yields are generally quoted as percentages of dry wood weight, and the data presented in this form in this paper assume more significance than volume yields in this context. Depending on the process used, pulp yields vary from about 49% of the dry wood weight input in chemical pulping such as the kraft process, through 60% - 80% for semi-chemical pulping, to 80 - 95% for chemi-mechanical pulps.

Useable volume recoveries achievable in conversion to particles for reconstitution in solid form are at the upper limit of the pulping range, varying from 80% to nearly 100%, depending on the proportion of "fines" used in the end-product.

For sawlog and plylog production, recovery increases directly with log girth and symmetry so that, in any situation not entirely roundwood oriented, the rotational stages for optimum volume and value productivity generally do not coincide. The higher value of larger logs for these sections of industry extends the maximum value productivity age further, particularly in regions such as Queensland without a sizeable pulpwood outlet.

However, general world shortages of forest products and escalating costs of replacing annual harvests emphasise the necessity to secure maximum yields of useable material in minimum time and indicate the desirability of a closer look at ways and means of decreasing the gap between maximum productivity and maximum value increment rotation ages.

There should be no gap, even now, for pulpwood type utilization. As has been shown earlier in Tables and text, while environmentally-induced faster growth generally reduces dry wood weight per unit volume, the higher volume increment usually (but not invariably) over-compensates to give higher M.A.I.'s in dry wood weight as well as volume. Evidence is rapidly accumulating in the literature that this faster-grown material, with its more conformable fibres, is quite suitable for general purpose softwood pulp applications.

For sawlogs, conventional conversion and utilization practices have imparted a higher value to larger logs giving higher percentage yields of larger section constructional material free from potentially troublesome heart, wider boards for joinery and cabinetwork, and clear or nearly-clear material for plywood face veneers, joinery and furniture.

Management has aimed at meeting these industrial needs by such softwoods plantation practices as selective thinning to increase the size of residual stems, selective pruning to provide a higher proportion of clear wood, and retaining stems beyond optimum volume productivity rotational stages.

It is suggested that technological developments have reduced, to some extent at least, the weightings which should be allocated to the original determinants. For example, high-temperature drying of weighted, counter-twisted stacks of heart-in material has practically eliminated any of the distortion problems it may have presented. Larger cross-sections are now readily obtainable by glued lamination of small-dimension stock of lower quality. Wide-board demands are now met largely by reconstituted particleboard or by plywood. There

is still a need for clear softwood face veneers, despite the increasing emphasis on structural plywood production.

Clear or near-clear softwoods for joinery, mouldings and similar uses are also still required, but it seems quite probable that pressed and/or extruded reconstituted wood mouldings could soon remove this item from the clear timber list or at least reduce its importance.

The economics of pruning has frequently been debated. Current practice in softwood plantations in Queensland has, in general, aimed at restricting the central core of knotty wood in a select fraction of the stands to about 15 cm diameter in the lowest 6.4 m log length.

The effect of this pruning on value recovery varies with conversion method and is affected by the degree of knot occlusion and deviation from log straightness. In limited trials with slash pine in Queensland, there was more benefit from peeling than sawing, as would be expected. With short billets (1.3 m), the practical effect of the knotty core was restricted to about 15 cm in most but, in longer lengths (2.6 m), it was usually 20 cm or rather more.

In comparative sawing studies on pruned and unpruned slash pine stems from 19.4 - 42.0 cm d.b.h. over bark (full merchantable stem length), the pruned stems showed advantages in recovery only from the 27.5 - 32.3 cm diameter class. A weighted average value index figure for the pruned stems in this girth class was about 10% higher than for the unpruned ones, due to a better graded quality distribution. In addition, overall recovery was higher (Alcock, 1975). The tops of pruned stems have also been observed to give an overall recovery higher by about 3% of true volume than unpruned whole stems of comparable size to the tops.

Further evaluations of the economics of pruning are urgently needed. Costs of this operation have risen so fast in Queensland that, in the absence of conclusive justification for continuing the former prescription, the general upper pruning level, for exotics at least, is to be dropped from 6.4 m to 5.2 m.

There are some obvious instances where pruning would be wasteful. Since its main aim is improving the proportion of high-appearance grade material, the high incidence of another defect in a species could negate its value. An example is Queensland-grown *P. patula*, in which about 50% of the sawn board volume from three areas has resin-pockets (Eccles *et al.*, 1975). Pruning of this species under similar growing conditions would appear pointless unless justifiable by the production of higher strength material. Such justification seems economically improbable.

On the other hand, extension of pruning on a selective within-stem basis in the sawlog fraction, regardless of species, could give appreciable increases in saleable volume recovery, value recovery and utilization potential.

Invited Paper 2

Fully encased loose and unsound knots are a serious cause of degrade in softwood milled products, whether in radiata, cypress pine or other Australian-grown conifers (Standards Assn. of Aust. 1973, 1964, 1969).

They result from the enclosure of dead branches as the tree grows. While partially encased knots from live branch enclosure are common, they are not as serious a defect because they are sound (i.e. free from decay) and tight by virtue of being at least partially intergrown. Depending on relative timber durability, rates of growth and variable capacity for branch bark retention, dead knots may be encased or unencased, sound or in degrees of unsoundness. They can appear sound and tight when freshly sawn, but become loose in seasoning, machining and/or service for several reasons.

In a recent study of the effect of dry, bark-encased knots in cypress pine logs in Queensland (Queensland Department of Forestry, 1974), it was found that the percentage of the sawn board output rejected because of loosening of this type of knot after seasoning was up to 9.6%, varying with area and type of forest (recut or virgin), and the effect of any unsound knots was not evaluated in this study. The affected branches could possibly have been mainly fire-killed during stand development.

With the other far less durable softwoods, the adverse effect of unsound knots on volume and value recovery would undoubtedly be greater, and intensification of research effort directed at establishing the economic effects of <u>failure</u> to selectively prune within stems could be at least as useful to forest management as evaluating the effects of established pruning prescriptions.

It is suggested the results could not only quantify limits for pruning of the select fraction intended to provide estimated clear wood needs, but also justify extending pruning prescriptions to provide for the removal at regular intervals of all dead or moribund branches to a specified height in a large proportion of the currently unpruned fraction of all softwood stands. It is envisaged that special attention be directed to checking the feasibility of this proposal in cypress pine, which has no prescribed pruning, even if only after fires or any branch-killing fungal or insect outbreaks.

It is evident that the maximum economic advantage from pruning for <u>clear-wood</u> production is to be derived in an appearance-grade plylog situation, with much less in sawn conversion, and that application of the more modern chip-'n-saw conversion technique would decimate it within the pruned section.

However, the advantages of wider scale pruning of dead and moribund branches would apply in all these conversion situations in improving not only saleable volume but average graded value recoveries.

In considering the effects of thinning on volume and value, it has been stated that, in some logging situations such as hoop pine plantations in Queensland, scattered selective thinning methods seen

are often apparently below optimum efficiency to the point where they would adversely affect stand value return (Koch, 1974). It was indicated the extraction methods seemed not only unduly slow and labour-intensive per unit volume removed, but that damage to residual stems in extraction could affect their recovery through insect and fungal attack. The comment seems to justify attempts to at least check the relative efficiency of present and alternative harvesting techniques.

Volume and value losses due to attack in damaged and freshly-felled stems by insects such as the hoop pine stump weevil (*Mitrastethes australiae*) and the hoop pine jewel beetle (*Prospheres aurantiopicta*) have an as yet unquantified depreciative effect on the volume, value and utilization potential of this conifer.

The effect of the cypress pine longicorn (*Triticosmia latecostata*) and jewel (*Diadoxus erythrurus*) beetles on cypress pine returns and utilization are probably even greater. The direction of entomological research towards minimising these losses would be worthwhile. Of several other factors influencing volume and value yields and utilization potential, several are generally applicable and others more specific.

FACTORS INFLUENCING UTILIZATION POTENTIAL

(a) Conversion Techniques

Present techniques for producing framing and boards are wasteful, as indicated by the approx. 40% of true volume yields generally applicable to softwoods.

An increase of at least 15%, with improved quality as well, is promised by the edge-glue-and-rip (EGAR) system (Wahlgren, 1974), in which logs are through-sawn to maximum width 50 mm flitches, dried, edged, edge-glued to panels and resawn to required widths avoiding strength-reducing edge defects. The method allows the production of larger structural cross-sections from smaller-diameter trees in short-rotation crops and has obvious cost advantages over the more conventional glued-laminated method of producing similar material. The process should also lend itself to the production of board-stock. It could, with a suitable adhesive and glueing technique, even be capable of satisfactory application in the conversion of cypress pine, a timber with unusual glueing problems for a softwood.

Research effort in sawing technology, aimed at reducing sawn waste by reducing kerf thickness and enabling finer tolerances to be applied, could be profitable. Any advances in this field in recent years seem to have had little effect. It may be that the efficiency ceiling of saws in this respect has been attained.

Peeling, particularly to thicker veneers of the order of at least 6 mm, and parallel lamination with end-overlap to give long-length, wide framing and board stock for subsequent re-sawing, should increase recovery to possibly 60%.

Probably the ultimate in terms of minimising sawdust, machining and edging waste would be the so-called "Press-lam" process (Wahlgren, 1974), in which the log is sliced into 13 mm thick sheets, instant-dried and instantly parallel-laminated, with a reported yield of 65%. The feasibility of adapting this to local softwood production, deleting the instant-drying part of the process, and using sliced stock up to 25 mm or more thick, is indicated in work reported by, e.g. Peters *et al.* (1969) and Koch and Woodsen (1968).

These methods for the production of larger cross-sectional structural members and wider boards with higher volume and value per hectare yields, appeal with all of our softwoods, but particularly so with cypress pine, a resource in which such material is rarely obtainable directly from standing stock. In view of the rare capacity for development of large untapped reserves of this material, devotion of a substantial research effort to improving its productivity and realizing its full utilization potential is strongly recommended. Some of the specific areas requiring attention, including the species' glueability and its peeling potential will be referred to later herein.

(b) Seasoning Techniques

Compared with hardwoods, Australian-grown softwoods present few seasoning problems in wood outside a small juvenile core. With minor variation between species, the plantation-grown exotics such as slash, loblolly, Caribbean, maritime and radiata pines all have similar average shrinkage values from green to 12% moisture-content of about 2.8% radially (quarter-sawn) and 4.8% tangentially (back-sawn).

The indigenous hoop, bunya and kauri pines shrink somewhat less, averaging about 2.3% radially and 3.4% tangentially. Cypress pine has unusually low shrinkage, with comparable figures of 2.1% and 2.8%. This unusually low differential shrinkage is a factor minimising behavioural problems with this timber in seasoning.

The only serious seasoning problem with Australian-grown conifers has been that caused by a tendency for material sawn to include or close to the heart to twist in conventional air or kiln drying due to spiral grain effects.

Although the core of wood with immature or juvenile characteristics may technically extend over the first 25 years' increment, it can be regarded for practical purposes as being usually contained within a 100 mm "heart" from the viewpoint of limitations in conversion, seasoning and utilization (Smith and Smart, 1972).

In the much slower-grown cypress pine, it is considered the "heart" in this same sense, if sound, could be regarded as being encompassed within perhaps 25 mm and certainly not more than 38 mm.

High-temperature drying of all softwoods except cypress pine in counter-twisted, weighted, stripped stacks has become a common but far from universal practice in Australia. Many smaller operators still use the more conventional methods.

When employed, all stock is usually sawn to the basic dimension for final use and high-temperature dried, regardless of whether or not it includes pith. Perhaps consideration should be given to the relative economics of this as contrasted with the alternative of segregating only that component with potentially troublesome heart for this seasoning technique and processing the remainder by the possibly less costly more conventional kiln-drying method.

An adaptation which seems almost certain to be profitable is suggested by the EGAR (edge-glue-and-rip) and through-sliced conversion methods already referred to.

It is suggested that material through-sawn or sliced to required thickness be high-temperature dried in weighted stacks, using the much greater flitch width to secure better restraint than is possible with the narrower dimensioned stock. Labour costs in stack handling should be appreciably lower. Following the highly successful commercial application of the "in-flitch" seasoning technique to air and conventional kiln-drying of rainforest timbers and the openforest hardwood, brush box (*Tristania conferta*), this should be tried with the much faster-drying conifers for the possible benefit of producers without the capacity or wish to extend their capital investment by high-temperature drying installations.

"In flitch" seasoning by conventional processes would be applicable to cypress pine, but if looked at solely from the viewpoint of shrinkage-associated problems, could be expected to give lesser benefits than with other conifers because of its low shrinkage and the relatively small problem with twist in this species. For the same reason, high-temperature drying of cypress is not justified.

However, as with all softwoods, one of the main benefits of seasoning framing sizes is in enabling more efficient use of the original timber volume through application of the appreciably higher strength of seasoned timber in design. This is generally 25% or more higher than for unseasoned timber of the same grade and, in a timber with an unusually low strength/weight ratio for a softwood such as cypress pine, could be an especially important consideration.

As an example, for the two base grades comprising the predominant volume framing production in this timber under the Australian Standard (Standards Assn. of Aust., 1974), permissible spacings for bearers and spans for joists in cross-sections generally used in Queensland for the common 2.1 m and 3.0 m sub-floor design grid systems, could be increased by from about 7% - 11% in seasoned timber of the same grade and size (Standards Assn. of Aust., 1971). Any utilization economies effected would be compounded by the smaller shrinkage allowances necessary, compared with other conifers.

In-flitch seasoning could be expected to reduce spring and bow by in-flitch growth-stress relief, with a consequent improvement in sawn recovery value.

For glulam and "EGAR" production of deeper sections, seasoning is essential.

(c) Machining Problems

The machining problems of Australian-grown softwoods can be considered on a species group basis.

It has been and still is common practice with cypress pine to produce milled products from unseasoned timber in both Queensland and New South Wales, despite legislation restricting the sale and use in both States of such unseasoned milled products as being detrimental to consumers.

Problems with knot chipping and loosening and with torn grain have been claimed in machining seasoned timber, but these have been shown (Jones, 1968) capable of practical solution and a few major producers are now machining seasoned material as standard production procedure. Apart from those knot-associated problems attributable to dead branch retention and capable of solution silviculturally, any difficulties in machining cypress pine are considered to have been resolved for those prepared to apply them.

The other indigenous softwoods, especially hoop pine, are characterised by exceptionally good machining properties by virtue of their remarkably uniform texture, except for chipping problems with this group's hard-resin-impregnated knots. This is accentuated beyond its real significance by dead and unsound branch enclosure effects but is a real problem even in sound knots in this instance. With decreasing supplies of clear wood from virgin growth and restricted pruning for clear wood production, research work directed towards formulating recommendations for machining knotty hoop pine without chip-out would be valuable.

The main machining problems with the exotic conifers in general are ridged or raised grain and "shelling". The causes, largely associated with high earlywood/latewood density differentials and a frequent failure to apply machining technological solutions already developed, have been discussed previously (e.g. Smith and Gough, 1969).

However, the question is raised here as to whether shelled grain, particularly that exhibited as arris splinter development in such material, may be being accentuated by high-temperature drying through excessive double-cycled stressing at the latewood/earlywood boundary (the zone of maximum shear stress potential), in taking moisture content quickly down below and then back up to equilibrium moisture content again during the process. This type of defect seems to be appearing rather more frequently after machining slash and loblolly pines since high-temperature drying was introduced. If this was objectively confirmed, some modification of drying schedules or machining prescriptions may be desirable.

The problems experienced in machining sound knots should be almost entirely eliminated where peeled or sliced conversion supplanted sawing, with a resultant further increase in value recovery.

(d) Mechanical Properties

As a structural material, the potential of the Australian-grown conifers ranges from satisfactory to exceptionally good.

The best basis for direct comparison is probably that proposed by Pearson (1965) and developed by Kloot (see e.g., 1973), providing for a seven-class (S1-7) unseasoned and an eight-class (SD1-8) seasoned species strength-grouping system, applicable to specified quality grades in the allocation of species/grade stress ratings for design use.

Strength groupings allocated or estimated for several of the more important softwoods are shown in Table 5.

This indicates that, at the same graded quality and moisture content, all the other Australian-grown softwoods listed are equal or superior in strength to radiata pine, with slash pine strongest in the unseasoned condition and, with hoop pine, strongest in the seasoned state. The marked increase of the latter from green to dry is noteworthy.

As indicated in the Table, the estimate for seasoned Caribbean pine is considered to be a conservative one. This is supported by the density comparisons given in Tables 2, 3 and 7, particularly the unusually low earlywood/latewood density differential.

The relatively high degree of uniformity in the wood of this species and other anatomical characteristics related to mechanical properties (Smith, 1973) are indicative of wood with mechanical properties more like those of hoop pine than any of the other high-volume exotics. The tendency for continuous growth throughout the year by this species in Queensland (Smith and Fett, 1975) also greatly reduces the likely effect of latewood/earlywood boundaries as potential planes of weakness contributing to lower strength, when compared with the xylary development of most, if not all other exotics.

Because of higher incidence of knots and associated grain deviation and its usual presentation in the unseasoned condition, the predominant available material in cypress pine has an average stress grade rating lower by from two to four stress grades than that of the predominant quality seasoned material available for other Australian-grown conifers. Higher stress ratings from the dispersion of defects effect in seasoned laminated-type members should be highly advantageous in this species.

Another method of overcoming the problem would be by using seasoned cypress core-stock in composite laminated members with higher-stress-rated softwoods in the more severely stressed outer layers.

The performance of cypress pine in service as framing over periods well in excess of 60 years also suggest that its strength as indicated by tabulated data in the Australian Standard Light Timber Framing Code (Standards Assn. of Australia, 1971) could have been considerably underestimated. A programme of basic work in this area seems justified by its past proven performance standards and the vast extent of the resource.

TABLE 5. STRENGTH GROUPINGS FOR SOME AUSTRALIAN-GROWN SOFTWOODS

Species	Strength Group	
	Unseasoned	Seasoned to 12% m/content
radiata pine	S6 [1]	SD7
cypress pine	S6	SD7 [2]
Caribbean pine	S6	SD7 [3]
loblolly pine	S5	SD6
hoop pine	S6	SD5
slash pine	S4	SD5

1 - not normally used as unseasoned framing in States of major occurrence.

2 - not normally used seasoned for framing at present.

3 - believed to be a conservative estimate (see text).

At the more general level, difficulties associated with the development of fully reliable relationships between strength-on-edge and stiffness-on-flat have been referred to elsewhere (Smith and Greve, 1975). The amount of work and time required in developing these for each species is a cause for concern, and the broad confidence limits which have to be set about calculated regression lines for practical predictive purposes seem to be wasteful of part of the structural potential of components tested.

It seems there could well be greater benefit, particularly immediate benefit, and especially for cypress pine framing producers, in the wider application and improved development of an edge-applied proof-loading system similar to that already in commercial use on smaller-dimension framing by a Queensland softwoods producer. This could be operable on a deflection basis for predetermined cross-sections as a non-destructive system, using the higher and more directly applicable correlation between M/R and M/E on edge.

Some applied indication of the high structural potential of Australian-grown conifers other than radiata pine is given in Table 6, showing the minimum cross-sections required for seasoned timber of what is believed to be the basic available stress-grade for each, under the same commonly applied Queensland loading conditions. This was abstracted from Ryan *et al.* (1974).

TABLE 6. COMPARISON OF SEASONED SOFTWOOD SUB-FLOOR STRUCTURAL SIZES REQUIRED FOR THE SAME LOADING CONDITIONS IN COMMONLY AVAILABLE BASIC GRADES

Member	Spacing and/or Span (m)	Minimum Cross-Section Required (mm)		
		Radiata pine (F7)	Loblolly pine (F8)	Slash and hoop pines (F11)
Bearers	2.1 x 2.1	170 x 70	140 x 70	120 x 70
	3.0 x 3.0	Over 240 x 70 [1]	240 x 70	240 x 70
Floor Joists	2.1	120 x 35	120 x 35	120 x 35
	3.0	140 x 45	140 x 35	140 x 35

[1] - Size required beyond the limits of the Table provided.

The lack of size differences in some instances in this Table, particularly for floor-joists at 2.1 m span in such different stress-rated material, provides little incentive for up-grading a basic production line or, alternatively, suggests a possible advantage from interpolation of an additional smaller but adequate dimension in the higher strength product. The next step down, from 120 mm to 90 mm width, in the Table provided was the largest one in the Table.

In view of rapidly increasing interest in softwood poles and piles in lieu of or to supplement supplies of traditional hardwoods, there is considered to be an urgent need for evaluation of the stress-ratings applicable to poles in the major softwoods other than radiata pine.

Although stress-ratings relatable to unseasoned strength groups have been published in the Australian Standard Timber Engineering Design Code (Standards Assn. of Aust., 1972), to the author's knowledge no actual pole-size tests have been conducted on Australian-grown softwoods other than those reported for radiata pine by Boyd (1964) and, as the latter concluded, the correlation between the strength of poles and small clear specimens was poor, with pole strength generally high compared with that of the clear specimens.

The derivation of basic working stresses for use in pole and pile design for slash, loblolly, hoop, Caribbean, maritime, patula and cypress pines would be of real value in improving their utilization potential. Round timber use gives 100% utilization of that portion of the commercial bole, with virtually no conversion cost. The poorer form of unimproved Caribbean pine suggests lower pole yields per hectare than for the other softwoods at present. The greater taper of cypress pine stems is to its disadvantage for this use, but it has long been in service as such in areas of local occurrence, and the apparently appreciable strength advantage accruing from use in round form could expand the utilization potential of this high volume, highly durable but comparatively low strength and currently relatively restricted use-range material.

(e) Textural Uniformity

The higher the earlywood/latewood density differential, the greater the degree of intra-growth ring non-uniformity, and the greater the tendency for problems in machining, fabrication, and utilization. Percentage latewood is another factor contributing to textural uniformity.

In these respects there is great variability between our softwoods. All the indigenous conifers, including cypress pine, have so little latewood they can be regarded as being almost the ultimate in clear-wood uniformity.

The variability within the exotics undoubtedly has a considerable effect on their utilization potential and some indication of this is shown in Table 7.

Slash pine is probably the most non-uniformly textured Australian-grown softwood from the information available, in terms of both percentage latewood and earlywood/latewood density differential. Its mean basic density is more like that of a lower-density Eucalypt such as mountain ash (*Eucalyptus regnans*) or a rainforest timber such as yellow walnut (*Beilschmiedia bancroftii*), and the within-ring variation ranges from that of white cheesewood (*Alstonia scholaris*) in the earlywood to that of the open-forest hardwood, brush box (*Tristania conferta*) in the latewood, a 96% increase.

On the other hand, of those with high productivity potential, Caribbean pine is outstanding in being relatively uniform. It has a very low average latewood percentage (18%) and the within-ring density varies only by 48%, half as much as for slash pine. A practical comparison is the degree of variation exhibited between kauri pine (*Agathis* spp) and cypress pine (*Callitris* spp).

Radiata pine, with an average latewood percentage of only about 15% but of a density 78% higher than its earlywood, could be regarded as intermediate in textural uniformity.

Loblolly and maritime pines tend to be closer to slash pine in this respect.

The effects of density differentials on machining and mechanical properties have been discussed. High differentials also contribute to poorer paint-holding properties in weather-exposed situations, nailing and glueing problems and to non-uniform preservative retention.

In any pulping process, a more uniform raw material can be expected to present fewer problems in pulping, and provide stock with more predictable properties. Hence, purely from the viewpoint of desirable clear-wood uniformity, the indigenous conifers (including cypress) and Caribbean pine have excellent utilization potential.

TABLE 7. AVERAGE DENSITY AND PERCENTAGE LATEWOOD DATA FOR SOME AUSTRALIAN-GROWN CONIFERS

Species	Source	Age (yrs)	Parameter				
			Mean Basic Density (kg/m^3)	Average Earlywood B/D (kg/m^3)	Average Latewood B/D (kg/m^3)	E/wood:L/wood Density ratio	Average % Latewood
hoop pine	Qld	20	442	2	2	2	3
cypress pine	Q., N.S.W.	4	573	2	2	2	3
slash pine	Qld	19	483	352	689	1:1.96	35.6
loblolly pine	Qld	19	454	349	647	1:1.85	34.0
maritime pine	W.A.	20	480?	4	4	4	30.0?
radiata pine	S.A., Vic., Tas., ACT.	21	427	352	658	1:1.78	15.0 (est.)
Caribbean pine	Qld	19	444	400	593	1:1.48	17.8
patula pine	Qld	21	393	4	4	4	19.1
kauri pine	Qld	4	394	2	2	2	3

1 - Based on oven-dry weight and soaked volume.

2 - Not determined because of negligible latewood.

3 - Negligible.

4 - Not known.

(f) Preservation

With the exception of cypress pine, which has exceptional truewood resistance to attack by fungi, termites and other sawn timber insects, and marine organisms, all of the other Australian-grown conifers have low inherent durability and attendant preservation problems where there is a destructive-agency hazard.

However, again with the exception of cypress pine, all are quite readily treatable with a wide range of commercial preservatives, both oil-based and water-soluble, to retentions suitable for all hazards. Some problems with "patchy" treatment by fixed multi-salt preservative processes have been observed but these are not considered likely to seriously affect utilization potential.

Soft-rot attack, although observed in treated round timber in southern States, is not as prevalent as in those of treated hardwood, and slash pine telecommunication poles CCA-treated to somewhat above normal hardwood in-ground retention levels have been in service for over ten years with no problems.

For marine piling, hardwood CCA-treated by current commercial processes has failed prematurely in service. In comparative trials, CCA-treated softwoods have given excellent performance, with service under high Teredinid hazard conditions in the Brisbane River in excess of 12 years without significant depreciation. In some other areas, only high-arsenic formulation CCA has given satisfactory service.

This field of softwoods utilization offers considerable scope for expansion. However, there are some factors which merit consideration.

Cypress pine has high inherent truewood resistance needing no treatment and is not uncommonly used untreated in some situations. However, its relative fissility in driving and low permeability of the sapwood with the fixed multi-salts present some problems. It is quite readily treatable with oil-based preservatives.

From subjective observations in Queensland waters, any extended use of softwoods into static marine situations can be expected to be accompanied by changes in the importance of wood-boring marine organisms other than the Teredinid shipworms as destructive agencies and determinants of service life.

Modiolus, *Martesia* and particularly the more destructive Crustacean, *Sphaeroma* exhibit a preference for softer material, even to the point of selective boring in earlywood rather than latewood in oyster-stakes in the case of *Sphaeroma*. For this reason, protective measures against these, such as were formerly applied to inherently Teredinid-resistant hardwoods, may need to be intensified in some situations where treated softwood marine piling is used. Cypress pine, being denser, would be far less affected than the other softwoods, particularly than those with very low-density, wide earlywood bands, and has, in fact, given excellent service, untreated, when subjected to this hazard.

Of those softwoods requiring preservative treatment, the more uniformly-textured species with low latewood percentage and earlywood/latewood density combinations could be expected to be capable of more uniform and, hence, more effective treatment.

Preservative retentions, usually expressed as "x" kg/m^3, will evidently be most concentrated in the more readily penetrable earlywood than the latewood, especially where the density differential is high, but the question arises as to what constitutes effective treatment.

Because of preservative-containing void-volume and cell wall penetrability differences between species of differing density and/or structural type and between growth zones within a species, given nominal preservative retentions can give appreciably different cell wall retentions not only between species but within the same piece of timber.

In general, uniformity of treatment is relatable to textural uniformity, and the indigenous conifers and Caribbean pine should, on this basis, be much more uniformly treatable than the other softwoods.

Within reasonable limits, earlywood/latewood retention differentials found in commercial practice would be expected to have little practical effect on resistance to attack by insects and marine organisms, but could affect resistance to wood-destroying fungal attack. Effective decay-resistance for hoop, Caribbean, radiata and slash pine could be quite different at the same nominal retention, and research to establish the possibly variable required retention levels for each species or that for the limiting species in a group is needed.

The susceptibility of hoop pine and other members of the family Araucariaceae to attack by the Queensland pine beetle (*Calymmaderus incisus*) within a geographically rather small but high volume use area of coastal south-east Queensland is a factor tending to restrict its utilization. The insect's normal range is between latitudes 24° 51' and 28° 19'S on the coastal strip east of the Dividing Range in Queensland, and attack is normally confined to timber unenclosed in construction or unprotected by a film finish or a preservative and is not initiated until several (often 10 to 20 or more) years after installation (Watson and Smith, 1974).

With present constructional practices, wall framing and cladding is not liable to be attacked, but sub-floor and roof framing is (unless the latter is under a metal roof generating inhibiting temperatures).

The likely increased use of the highly stress-rated hoop pine (see Table 5) in seasoned, solid normal glulam or "EGAR" framing stock makes it essential for the provision of satisfactory but low-cost protection against this insect, preferably one which can be applied in the restricted area in which it is required.

While normal impregnation treatments with oil-based general preservatives, the fixed multi-salts or boron compounds are satisfactory, full impregnation is considered unnecessarily wasteful, and the prescription of protective treatment of finished stock by "momentary" dip or in-situ application with an oil-based or emulsion-type residual insecticide (preferably stained for identification purposes) should provide adequate protection. Any small risk of infestation through cut ends or breached treated zones could be covered by the specification of similar in-situ treatment thereof.

The Queensland pine beetle does not attack the exotic conifers, on present records.

The wider application of non-durable softwoods in some constructional situations has been inhibited in the past, in Queensland at least, by the requirement that framing only partially-protected from the weather, such as that in unsarked external timber-clad or asbestos-cement-clad walls, be in relatively durable material.

The results of a survey of the serviceability of lower-durability softwoods and rainforest timbers in Queensland houses reported by Greve (1975) have established that certain faults in design and constructional practice are predominantly responsible for observed premature decay of members in service in such situations. The consequent formulation of minor low-cost modifications to previous practice now enables the confident recommendation of untreated lower-durability softwoods for such external wall framing with less restriction on utilization.

A firmly entrenched tenet in wood technology is that the sapwood of any timber is never durable in ground or weather. While an adherent of this principle in general, it is the writer's opinion that, as with most generalisations, some qualification is necessary, particularly if this one is not to be allowed to seriously affect the utilization potential of a major softwood resource, cypress pine.

It is contended that, just as truewood durability varies with species, so also does that of sapwood, although not necessarily in the same relative order. From subjective observation, the in-service durability of cypress pine sapwood is so relatively high as to justify its untreated use in exposed to the weather out of ground situations, especially in general constructional framing and boards where regular maintenance painting is normal procedure.

The high-durability reputation of cypress pine has been founded as much on its long-proven serviceability records as on comparative laboratory trials, and the log size and conversion methods applied to this species have long dictated that a high proportion of all sawn and milled material used in exposed framing and boards has undoubtedly carried some sapwood without apparent serious detriment.

Exposure trials to establish soundly-based out-of-ground as well as the present in-ground durability ratings are urgently needed, and these should include the sapwood of some of the more durable species such as cypress pine, to possibly prevent unnecessary waste of material or treatment costs.

(g) Glueing

The major glueing problems inhibiting optimum utilization of Australian-grown softwoods are those associated with the prescription of suitable adhesives or techniques to allow (a) the satisfactory use of cypress pine in particleboard, conventional glulam, "ECAR"-type stock, and conventional plywood production and adaptations of the "Press-lam" thick-sliced laminated member production technique; and (b) the satisfactory glueing of CCA-treated softwoods, particularly for weather-exposed out of ground use as plywood or glulam. The second problem is much less inhibiting than the first. Phenol-resorcinol-bonded laminated structural members in softwoods including the southern yellow pine group to which slash, loblolly and Caribbean pines belong, treated both before and after lamination with oil-borne preservatives including pentachlorophenol, have given an exposed service life of up to at least 20 years in the U.S.A. (Selbo, 1965).

However, the water-borne fixed multi-salts more commonly used here are stated to be incompatible with the waterproof adhesives needed for exposed use unless special precautions are employed (Cokley, 1975). Although phenolic-resin-bonded plywood has been CCA-treated after assembly and used successfully, overseas experience with other water-borne preservatives in exposed glulam structural members has been far from encouraging (Selbo, 1965), with in-service failure associated with movement effects causing checking and at least partial delimination.

Nevertheless, resorcinol-formaldehyde resin-bonded CCA-treated radiata pine members are now in use in exposed and semi-exposed situations in southern States and the other conifers should be no less capable of this application.

The need for caution in glueing preservative-treated timber is drawn to attention in the Australian Standard for Glued Laminated Structural Timber (Standards Assn. of Aust., 1972) and precautions employed include sanding or methyl-ethyl-ketone (acetone) treatment of CCA-treated surfaces immediately prior to glueing (Cokley, 1975).

In any event, there are apparently suitable alternative preservative/adhesive combinations allowing the satisfactory exposed use of glued laminated softwoods.

Cypress pine, because of its callitrol content, is difficult to glue satisfactorily with the currently more commonly used adhesives, the urea-formaldehydes and the phenolic resins.

However, well-bonded plywood was produced over 25 years ago in Queensland from both peeled and sliced veneers with casein as the adhesive.

Casein is stated to be an extremely reliable adhesive for long-term use in fully-protected situations (Cokley, 1975), and it is suggested that, unless some more attractive alternative is offering, a serious research effort be directed towards applying this long-used, low-cost adhesive in the development of the largely untapped utilization potential of cypress pine.

All variants of the lamination techniques referred to earlier could then be applied to provide larger cross-sectional members and wider boards for fully-protected structural use and plywood for under-cover use.

Most importantly, there seems no reason why particleboard production with casein as the adhesive should not be feasible. This would provide an outlet for the currently virtually unused non-sawlog stand component and for much of the conversion waste residue, which currently represents 57% of merchantable sawlog volume. Any objections to the use of this adhesive in structural-grade particleboard for flooring and similar uses could be met by the provision of a moisture-proof skin or film on the under-surface as a safeguard against moisture effects, which should not occur in any case in normal good constructional practice.

The currently more conventional urea-formaldehyde and phenolic-resin type adhesives could also probably be employed in realizing the utilization potential of cypress pine with the development of suitable techniques. Waterproof adhesives such as the phenolic-resin type would be essential in exposed use.

Some measure of success has been achieved by glueing immediately after machining but long-term bonding is not always good (Cokley, 1975).

Glueing immediately after "de-greasing" of surfaces with suitable solvents could be a profitable area for research, with more likelihood of the adhesive penetrating sufficiently to remain effective in long-term bonding.

Similarly, in particleboard production, dip or soak shallow-penetration "de-greasing" of chips or flakes could facilitate use of the more commonly employed adhesives in this product. Any problems due to possible need for the evaporation of solvent from the stock in an in-line production process should be capable of resolution.

(h) Nailing

The softwoods other than cypress pine present no serious mechanical problems in nailing that cannot be resolved by the application of overseas experience and research on the exotics and work by the CSIRO's Divison of Building Research on radiata pine. However, there is still a need for appropriate recommendations applicable to common structural situations to be more specifically formulated and disseminated within the industry.

Cypress pine splits in nailing close to the ends much more readily than most other timbers and any introduction of seasoned framing would make it even more necessary than at present for the provision of special nails for use with this species. Truncated (chisel-pointed) nails were successful and available over 25 years ago but seem to be no longer in local production.

(i) Finishing

The paint-holding properties of softwoods in exposed situations improve directly with their degree of textural uniformity.

Species such as slash and loblolly pines can be expected to exhibit earlier general paint film breakdown at latewood/earlywood boundaries when used as exterior cladding than would hoop and Caribbean pines. The relatively high intra-ring density differential of radiata pine would also pose problems in this respect. Latex paints (especially of the acrylic type) seem to give better performance on such timbers than the less resilient film finishes (see, e.g. Zicherman and Thomas, 1972).

The exotic conifers have a high incidence of pitch streaks. These are particularly prevalent in slash pine, occurring to varying degree in up to 36% of the sawn boards, but are present also in loblolly, Caribbean, radiata and other exotics at lower levels of incidence.

They can give problems by "bleeding" through normal paint systems in exposed situations, and the use of aluminium-based "spot" primers has been found effective.

The latter are also effective and generally necessary in sealing cypress pine knots in similar cases.

To obviate the need for a general and a "spot" primer on the one wall for optimum paint life with cypress pine and pitch-streaked exotic softwoods, the development of a general-purpose primer which would effectively seal the streaks and cypress knots while performing its basic function would be of real value.

Knots in softwoods other than cypress appear to present no serious finishing problems and, with cypress pine, much of the knot "show-through" on cladding is due to the widespread practice of machining and fixing boards in the unseasoned condition. Subsequent shrinkage of wood along the branch-stub causes the knot to stand out from the surface. It is considered that the seasoning of boards before machining would reduce the apparent effect of this painting problem.

(j) Pulp Properties

The pulping potential of Australian-grown softwoods in general has been adequately demonstrated, but the single known experimental trial and very restricted commercial use of cypress pine as a pulpwood source, together with the extent of the resource, indicate its potential for development and the need for more extensive trials.

The results of recent comparative sulphate pulping trials of slash, loblolly, Caribbean and hoop pines from Queensland and radiata pine of southern origin have been reported by Watson *et al.* (1971). The pulps produced compared favourably with good quality long-fibred commercial pulps from other species for use in a wide range of unbleached and bleached kraft pulp applications. Pulp yields were slightly higher than for radiata pine. At constant commercial freeness levels, slash, loblolly and Caribbean pines had almost identical properties, with slightly lower burst and tensile strength but markedly higher tear strength than hoop and radiata pines.

Faster-grown material in genetically improved exotics could be expected to have improved bond strength due to probably more conformable fibres, with more than adequate tear strength due to the existing high margin in this respect.

Slash, loblolly and Caribbean pines are already being admixed satisfactorily in small-scale commercial semi-mechanical (neutral sulphite) pulping in Queensland.

Although not tried here for chemical, semi-chemical or groundwood pulps, the lower-density, uniformly textured patula pine, with its long, highly-conformable fibre type, should provide excellent material for these applications. Any such outlet possible should be exploited, because of the limitations imposed on its utilization in appearance-grade milled products by the high incidence of resin-pockets (Eccles *et al.*, 1975). Despite the small areas planted in patula and its general unsuitability for other than very restricted future planting in Queensland, cutting of existing stock gives a sizeable short-term crop which comprised 13% of the State's total exotic coniferous harvest in 1973/74.

Hoop, slash, patula and cypress pines have also been successfully admixed in commercial chemi-mechanical pulping by the Masonite process in Queensland in the production of a high-quality, pale-coloured hardboard.

The higher average basic density of slash, loblolly, Caribbean and maritime pines compared with that of radiata (Table 7) confer some advantage in processing for pulp in terms of higher pulp yields per unit volume input into a digester, but this could be counterbalanced by higher chemical costs on the same basis and/or higher refining costs to achieve given pulp properties. In the overall view, there may be little or no difference in realized value production here.

In trials by Phillips *et al.* (1967), maritime pine from Western Australia gave good yields of satisfactory sulphate, neutral sulphite semi-chemical and refiner groundwood pulps. Its sulphate pulp properties were similar to those for Queensland-grown slash, loblolly and Caribbean pines. From these and other experimental trials and local and overseas commercial practice, there seems no doubt that all of the exotic softwoods and the indigenous rainforest conifers can produce pulps suitable for a wide range of end-uses by most processes.

Cypress pine, however, seems to offer the greatest potential for increasing Australia's softwood pulpwood productivity if the economic problems posed by the relative remoteness of the resource from established pulping installations and its lower yields per hectare can be overcome.

An intensive effort to overcome these problems is certainly justified by the fact that, based on the estimated availability of 41% of the original log wood volume in slabs and edgings from present cypress sawing operations alone in Queensland and New South Wales, 106 800 m^3 of suitable softwood pulpwood is not being utilized.

This represents a potential increase of about 20% in Australia's present total softwood pulpwood production from current cypress sawmilling waste alone (See Table 1). The increase would be appreciably higher if sawlog operational forest residues were added and could, as has been pointed out earlier in this paper, be maintained on a sustained yield basis if even less than 5% of Australia's cypress forests were classifiable as of "average" quality.

The higher mean basic density of 573 kg/m^3, compared with the other softwoods, gives a further bonus in potential dry wood weight availability and potential pulp yields per unit volume.

A pulping trial of Queensland-grown cypress pine by the soda process, conducted in Western Australia about 50 years ago, gave about 43% yields of pulp with good properties when compared with those of "an imported Kraft pulp" (Swain, 1928).

Proper evaluation of the pulping potential of this species, with and without bark, by a range of processes is considered a matter of urgent importance.

When it is considered that chips for pulp production are being economically transported from Tasmania and Western Australia to Japan, it is surely not beyond the bounds of feasibility that they could be transported to a pulping installation in south-east Queensland or north-east New South Wales.

(k) Residue Availability and Utility

About 58% of the wood in the true volume of the merchantable softwood sawlog harvest is in processing residues largely unused. A relatively small quantity, in Queensland at least, is gainfully processed in the south-east corner of the State for hardboard and particleboard production or used horticulturally, with some as fuel. In addition, approximately 20% of the total standing softwood bark-on volume is in bark (Greve, 1973), for which the only current market is as a landscaping mulch. Even the latter is largely confined to exotic coniferous bark in south-east Queensland. Appreciation of the potential of wood and bark forest and processing residues as a valuable and largely untapped resource is rapidly developing, as indicated by the volume of literature appearing on this subject (e.g. Wahlgren, 1974; Keays, 1974; van Vliet, 1971; Ironside, 1970; Greve, 1973).

It has been demonstrated that softwood bark contents of up to 20% in pulp (including that for hardboard production) and 25% in particleboard can be used effectively, despite some limitations on mechanical and physical properties for certain product applications (see e.g., Greve, 1973; Currier and Lehmann, 1971; Auchter and Horn, 1973).

The most profitable outlet for these residues is evidently in pulped and chipped form for reconstituted products such as paper, container-board, hardboard and particleboard, and it may be that the magnitude of the available resource is not fully appreciated.

The annual wood volume of residual slabs and edgings from the conversion of softwood sawlogs other than radiata pine is estimated on 41% of sawlog volume to be about 198 000 m^3, 95% of it concentrated in Queensland and New South Wales. If converted to such uses, this would provide an increase of 38% in Australia's total softwood pulpwood production and allow for an estimated increase of 15% in the nation's total pulpwood production from all sources (hardwood and softwood) for paper, container-board, hardboard and particleboard requirements, on the 1971/72 figures reported by the Australian Dept. of Agriculture (1975).

If the unused bark volumes were added, these percentage increases would be of the order of 58% and 35% respectively.

As indicated elsewhere (Smith, 1975), it is considered that the realization of the utilization potential of this resource could depend, to a large extent, on initial laboratory-scale and follow-up commercial-scale demonstrations of the applicability of overseas

results to our own material. It is felt these should be initiated immediately with major volume species, accompanied by more fundamental studies to check for between-and within-species differences affecting utilization. Present indications are that, for certain pulp and board products, there may be no need to separate bark and wood, since the 20% of tree volume comprised by the former is apparently within useable limits for admixture. For more exacting use, separation by initial debarking, flotation or similar procedures, batch processing, and subsequent admixture to pulps by prescription or as a corestock to wood particles in particleboard production, may be necessary.

Some basic work on Queensland-grown coniferous barks has already shown percentage fibrous components of about 50% for slash and hoop pines and established basic density, moisture content and fibre-length values by species, age and position in stem (Greve and Bell, 1975). Extension of such work is needed but, it is suggested, is not a necessary pre-requisite to the proposed utilization evaluation trials.

The feasibility of recovering pine oils, resins and related products from exotic softwood forest and processing residues deserves serious attention in view of their increasing cost to Australia as imports with a cost approaching $4,000,000 in the year 1973/74. The best prospects for development in this sphere appears to be through the use of mobile forest residue harvesting in conjunction with logging operations in the slash, loblolly and Caribbean pine plantations of Queensland and New South Wales, using material of the same species as those employed in the highly profitable U.S.A. naval stores industry.

PRODUCTIVITY AND UTILIZATION POTENTIAL SUMMARY BY SPECIES

The preceding analysis of the relative productivity, value and utilization potential of Australian-grown softwoods other than radiata pine has necessarily involved comparisons with the latter, as the major single contributor to Australia's softwood harvest and the timber on which most of the research effort in the sphere of softwood utilization and its ancillary disciplines has been expended

These comparisons have shown that, if useable wood volume and wood weight yields per hectare were the sole determinants of relative utilization potential, then the only other Australian-grown conifers which can approach it in these respects are Caribbean pine and, on a more restricted areal basis, hoop pine on North Queensland rainforest sites.

Those States with average to good quality radiata sites are indeed fortunate, but there are vast areas of Australia in which the species' potential as a good producer ranges from limited to non-existent and other species assume a major role through better adaptability to prevailing growing conditions.

Examples include Caribbean pine in Queensland, maritime pine in Western Australia, hoop pine on tropical and sub-tropical rainforest sites and Cypress pine in the dry inland areas.

There are also other factors affecting value yields and utilization requiring consideration and, on these counts, some of the other softwoods have advantages over radiata pine in certain applications.

In the main, only the major volume softwoods other than radiata pine have been considered in detail, largely through lack of readily available information on the productivity and properties of minor species as guides to their utilization. However, it is hoped the range of yields and wood types covered will allow extrapolation of the data, suggestions and conclusions herein to these minor species.

The following summary, by species, indicates the considered productivity and utilization potential of the species dealt with in some detail in this paper, and of any factors inhibiting their realization. Possible means for overcoming or minimising the effect of these inhibitory factors have been discussed earlier in this paper.

(1) Caribbean pine (*P. caribaea*)

This species has the best potential of all of the Australian-grown softwoods other than radiata pine, not only in terms of recoverable volume and dry wood weight yields per hectare per unit time, but also because of its demonstrated adaptability over a wide range of sites from far North Queensland to northern New South Wales, and wood characteristics making it eminently suitable for the full range of general softwood uses.

Caribbean pine has a very high productivity rivalling that of good site-quality southern radiata pine.

It is an unusually early-maturing species in terms of both mean volume increment/hectare/annum and some important wood characteristics, and its apparent capacity for management as a crop for early pulp thinning and final multiple-use clear-felling at about age 23-25 years offers decided advantages.

Increases in sawn timber and veneer yields of the order of at least 5% of true volume are expected through genetic improvement of the present poor form of unimproved stock and of the order of about 24% or more through use of the slash x Honduras Caribbean pine hybrid.

The wood is remarkably uniformly textured for an exotic, with not only low latewood percentage but an unusually low earlywood/latewood density differential. This offers advantages in machining, preservative treatment, glueing, nailing and paint-retention in the weather.

It is suitable for general constructional use (preservative-treated where weather-exposed), treated poles and piles (when to straightness requirements), plywood, glulam, furniture, joinery, boat-building, hardboard, particleboard, and pulp and paper production.

Factors considered to be inhibiting realization of its full utilization potential include several common to all of the softwoods, such as:

(a) wasteful conversion methods giving unsatisfactorily low recovered framing and board volume and value recoveries, especially in the case of pruned stems;

(b) the need to check for possible further benefits derivable from the application of in-flitch seasoning in high-temperature drying and in conventional kiln and/or air seasoning processes;

(c) the need for the development of improved or alternative methods for the mechanical proof-loading of structural members, preferably by edge-loading;

(d) the need for the evaluation of stress-ratings applicable to poles in the main softwoods other than radiata pine;

(e) the need for constructional design modifications to reduce decay hazards;

(f) the need for the formulation of preservative prescriptions which ensure necessary effective retentions throughout the material (this is not an inhibiting factor with the indigenous conifers, and is considered to be less important with Caribbean pine than most other exotics);

(g) the need for effective long-term serviceability glueing techniques for CCA-treated, weather-exposed material, especially large-dimension structural material;

(h) the need for revised pruning prescriptions aimed at minimising the adverse economic effect on recovery of defects caused by dead branch enclosure;

(i) the need for specifically formulated nailing recommendations for common structural situations;

(j) the need for a general-purpose paint primer which will effectively seal pitch-streaks in weather-exposed use (not applicable to the indigenous softwoods);

(k) the need for economic recovery of the large volume of wood and bark in forest and processing residues, with the necessary developmental work to facilitate its effective use, particularly for pulp (including hardboard) and particleboard production.

Additional needs for Caribbean pine are:

(i) increased supplies of good quality seed; and

(ii) the evaluation, by standard test procedures, of its Strength Grouping for general structural use.

(2) Hoop pine (*Araucaria cunninghamii*)

This species gives quite good yields which, compared with slash pine on site qualities regarded as average for both species, are lower in both volume and dry wood weight than for slash at rotation ages of around 25 to 30 years. However, relative volume yields favour hoop pine on longer rotations. On good sites in North Queensland, its productivity at about 20 years can approach that of good quality southern radiata pine at the same age, and prospects for considerable genetic improvement through provenance selection and seed-orchard stock are excellent. Its main advantage in productivity is that it is generally better suited silviculturally to plantation establishment on high-quality rainforest sites than Caribbean pine. The latter, however, could be preferred on former farmland in rainforest areas, where its early productivity would compete with the best radiata.

Hoop pine and the other indigenous rainforest softwoods are the ultimate in textural uniformity, with latewood negligible and indistinct. They also exhibit exceptionally little within-stem variation in basic density radially or vertically. Average stem form is excellent and sawn recoveries somewhat higher than for all of the other softwoods.

Internode length is generally greater than for the other conifers, but the capacity for using this to practical advantage is limited in general framing and board situations with present conversion methods and product quality standards. It is of advantage, however, and could be exploited in shorter-billet peeling.

Its strength/weight/ratio is very high and the timber exhibits well above-average increase in basic working stress-ratings from green to seasoned condition.

From the viewpoint of wood properties, its utilization potential over the full spectrum of softwood applications can be regarded as the standard for evaluating all other Australian-grown conifers.

Factors considered to be inhibiting realization of its full potential are those generally applicable ones listed under Caribbean pine above as (1)(a) to (e), (g) to (i), and (k), together with the following specific ones:

(i) A need for modified surfacing techniques to minimise degrade due to chip-out of the hard-resin-impregnated knots;

(ii) apparent disadvantages in the tabulated distribution of at least some of the member size/span/spacing combinations in the present Australian Standard Light Timber Framing Code, tending to minimise the species' high seasoned strength-rating advantage;

(iii) the need for modified harvesting techniques to reduce logging costs and to minimise any degrade of retained stems due to insect and fungal attack associated with logging operations;

(iv) the need for a low-cost surface protective treatment against the hoop pine beetle in coastal south-east Queensland.

In general, factors (i), (iii) and (iv) apply also to bunya and kauri pines.

(3) Slash pine (*P. elliottii*)

This species ranks second in plantation area only to radiata pine, although the total area afforested in hoop pine is undoubtedly greater if the remaining natural stands are included.

Its volume yields per hectare per annum, although quite good, are appreciably below those of Caribbean and radiata pines and, even though improved by its higher basic density, so also are its dry wood weight yields. Its maximum incremental volume rotation on suitable Queensland sites of average quality is about 25 to 30 years. Except on high-moisture sites in southern Queensland, it cannot compete for productivity with Caribbean pine and has a much more limited latitudinal planting range.

Its wood properties, although similar to those of U.S.A. material where it is employed as a general-purpose softwood, tend to be more like those of a lower-density Eucalypt hardwood. Its non-uniform texture, compared with the indigenous softwoods such as hoop pine and with Caribbean pine, is a disadvantage in some applications but not one likely to be of any serious detriment to its softwood-type use.

It has the highest strength-grouping of any Australian-grown conifer and is, consequently, eminently suited to structural applications.

The full range of uses previously listed for Caribbean pine apply.

Factors inhibiting realization of its full utilization potential are the generally applicable ones listed under Caribbean pine above as (1)(a) to (k), as well as the following more specific ones:

(i) the need for the development of design data specifications for constructional use capable of more effective utilization of the species' high strength rating; and

(ii) the need for the use of surfacing prescriptions which will minimise degrade due to raised, ridged and shelled grain.

(4) Maritime (*P. pinaster*) and loblolly (*P. taeda*) pines

Although not an outstanding producer compared with radiata and Caribbean pine standards, the apparent adaptability of maritime pine for quite reasonable productivity on quite large areas for planting in Western Australia make it a significant future contributor to the Australian softwood resource.

Loblolly pine has shown productivity potential for selective planting on sites to which trials have shown it to be well adapted.

Their utilization potential is considered to be similar to that of slash pine. Loblolly pine has a high-strength-rated wood for a conifer, but with structural advantages somewhat lower than for slash pine. Although no mechanical data was available for maritime pine, its basic density and wood samples seen suggest the same comments would apply to this species.

In textural uniformity, they approach slash pine, and would have the same full range of softwood uses.

The same factors inhibiting utilization potential would apply to these species as to slash pine, as listed under (3) above.

(5) Patula pine (*P. patula*)

Patula pine has shown quite reasonable volume yields on limited sites in south-east Queensland, but any future planting in Queensland will be very restricted. There are firm indications that its physiological adaptability is strained in most situations planted in this State. It may be adaptable in some southern States but seems a very unlikely competitor with radiata pine there.

The lower-density, uniformly textured wood is quite strong for its weight, features which augur well for its utilization potential under better growth conditions. However, in Queensland-grown material, the very high incidence of resin-pockets seriously degrade the value of about 50% of its sawn volume for use in constructional boards, furniture, joinery, plywood and similar applications.

Even in resin-pocket-affected material, patula pine is suitable for constructional framing, treated poles, structural plywood, general-purpose plywood with defect free material or other species as face-veneers, hardboard, particleboard and pulp and paper production. A lower proportion of the recovery than for other Queensland grown exotics is suitable for high-appearance-grade constructional boards, furniture and joinery, but some of the "fall-down" is satisfactory for lower-grade use in these applications. Where resin pockets are as prevalent as in Queensland patula, the benefits of pruning for clear-wood production are negated.

Factors inhibiting the utilization potential of patula pine are those listed under Caribbean pine as items (1)(a) (except for the comment regarding pruned stems), (b) to (e), (g), (i) and (k), and the following additional ones:-

(i) its generally poor adaptability to Queensland growing conditions;

(ii) the very high incidence of resin-pockets; and

(iii) the need for evaluation of its Strength Grouping by standard test procedures.

(6) Cypress pine (*Callitris* spp)

In spite of its very low mean annual volume increment, cypress pine is considered to have the highest potential of all Australian-grown conifers for improvement in immediate and continuing use as a softwood resource. This is because of its high current and continuing availability and present limited utilization.

Although its volume increment per hectare is very low, the areas involved are so extensive as to provide a large incompletely utilized reserve of usable wood.

The timber is one of the most durable and lowest-shrinkage softwoods available anywhere, but is knotty and with a low strength/weight ratio for a conifer.

Its present use is almost entirely as constructional framing and boards, but other applications include poles, piles, fencing, boat-planking and decking, and (to a very limited extent), furniture and hardboard production.

Avenues seen for extended utilization include structural laminated members, plywood, hardboard, particleboard and pulp and paper production.

Factors inhibiting realization of its full utilization potential include these general ones listed under Caribbean pine items (1)(a) (except for the comment regarding pruned stems); (b) (deleting the reference to high-temperature drying); (c), (d), (h), (i) and (k) and the following additional specific ones:

(i) the low concentration of the resource per unit area, the large operational distances involved within stands, and distance of the resource from present markets and likely sites for the processing or shipment of stock for reconstituted products. These are not considered insuperable problems;

(ii) the need for the formulation of suitable adhesives for use in glulam, plywood and particleboard production;

(iii) the need for re-evaluation of its strength-grouping and/or the development of design data specifications which will allow more effective use of its commonly available stress-rated material;

(iv) the need for re-evaluation of its sapwood durability for out-of-ground weather-exposed use;

(v) the need for a dual-purpose paint-primer/knot sealer;

(vi) the high incidence of in-stem damage by jewel and longicorn beetles; and

(vii) the need for pulp and particleboard production trials.

(7) General

It should be noted that those factors listed as items (1)(a) to (c), (e) to (i) and (k) under Caribbean pine as considered to be inhibiting realization of the full utilization potential of Australian-grown softwoods generally, are also considered applicable to radiata pine.

CONCLUSIONS

It is concluded that:

(1) All of the Australian-grown conifers other than radiata pine grown in any appreciable volume have productivity and utilization potentials ranging from good to very high. Those with the highest potential are the two with the fastest and the slowest growth rates, viz. Caribbean and cypress pines respectively: Caribbean pine, because of very high productivity rivalling that of good site-quality radiata pine, wide adaptability outside radiata limits, capacity for management as a short-rotation (25 years) two-stage crop, and a high quality general-purpose wood with a rare degree of textural uniformity; and cypress pine, because of its high-volume availability as a low-cost naturally regenerating resource with a use-range currently so unnecessarily limited as to make its development not so much a challenge as a responsibility.

(2) In the eastern States at least, with restricted localized exceptions, Caribbean pine can be regarded as an earlier-rotation age, high-yielding replacement for radiata pine for general planting extension into the sub-tropics and tropics, with its average productivity tending to increase with decreasing latitude. As even unimproved quality seed supplies become more readily available, it might be expected to displace slash pine as the predominant softwood planted even in south-east Queensland.

(3) Other species with good potential in more restricted areas, because of specific adaptability to local growing conditions, include maritime pine on non-radiata sites in Western Australia, hoop pine on high-quality tropical and sub-tropical rainforest sites, slash pine on high-moisture sites in southern Queensland, and loblolly pine in some parts of Queensland and northern New South Wales.

(4) Patula pine has very limited potential because of physiological and associated wood quality limitations, at least in Queensland.

(5) There is considerable potential for improvement in the productivity of the softwood resource, through judicious selection and sitting of species, varieties, provenances and inter-specific hybrids, the use of genetically improved planting stock, and (although not discussed in this paper to any extent) other improved silvicultural practices. More critical evaluation of established comparative trials and the wider establishment of such trials would be helpful as guides to management.

(6) The magnitude and importance of the softwoods other than radiata pine as contributors to the national economy and their special significance in New South Wales, Western Australia and Queensland are probably not fully appreciated. At about 30% of the total Australian softwoods cut and from 41% to 99% for these three States, they constitute a very valuable and, in Queensland's case, vital resource.

(7) The significance of cypress pine as a vast, incompletely used softwoods resource has probably been under-estimated in the same context to an even greater degree, with about 17% of the nation's total softwood sawlog volume and 30% of Queensland's and New South Wales' softwood harvest for all purposes in this species at present. Its unrealized potential is emphasized by the fact that this harvest is generally well below replacement rates in even the relatively small proportion of the cypress area being operated.

(8) For realization of the maximum productivity and utilization potential of the softwoods, means for reducing the present gap between maximum volume and estimated maximum value increment rotation ages are needed.

In an exclusively reconstituted wood products marketing situation, there would be no gap, but an appreciable one exists on a sawlog and plylog market. This can be greatly reduced by improved log processing systems allowing the production of long-length, large-dimension framing and board stock from smaller-diameter, shorter-rotation crop trees, with saleable recoveries expected to increase from 40% to around 65%.

(9) Cypress pine has great potential for increasing Australia's softwood pulpwood productivity if economic problems posed by distance from existing pulping plants and by less concentrated wood volumes per hectare can be overcome.

(10) An intensive effort should be made to salvage and use effectively the large volume of processing and forest residues from Australian-grown softwoods other than radiata pine. Sawmill woody residues alone would provide an increase of 38% in Australia's total softwood pulpwood production, suitable for reconstituted products such as paper, hardboard and particleboard. If bark was added in proportions found to be acceptable for many uses, this proportion would be lifted to about 58%. An estimated 20% increase would come from using only the woody mill residues from present cypress sawmilling operations.

(11) Early testing of the applicability to Australian-grown material of the results of overseas trials evaluating bark utilization potential in pulp and board uses is considered necessary if they are to be commercially applied with confidence.

(12) There are several other factors inhibiting realization of the full productivity and utilization potential of this resource. Some are generally applicable to all of the softwoods discussed, others

more specific. These indicate a need for wide-ranging research activities in the fields of silviculture, entomology, harvesting, conversion, seasoning, machining, timber mechanics, constructional practice, glueing and paint technology, pulp and particleboard technology, utilization generally, economic surveys and resource market development. Items in these areas requiring attention have been indicated in the preceding section "Productivity and Utilization Potential by Species". Those probably meriting most urgent consideration are the need for an adequate supply of Caribbean pine seed; the need for far less wasteful conversion systems; the need for recovery of forest and processing residues and their effective utilization in reconstituted products; the development of suitable adhesives for cypress pine; and extension of the present limited utilization range of cypress pine.

(13) The available resource is, with some limitations indicated for particular species, suitable for the full range of general-purpose softwood uses such as structural and constructional applications, plywood, glulam, furniture, joinery, boat-building, hardboard, particleboard and pulp and paper production.

(14) The present value and the potential for further development of the resource represented by the Australian-grown softwoods other than radiata pine shown by this analysis justify considerably increased emphasis in the continuing national research and developmental programme to a level at least commensurate with its present 30% contribution to the nation's total softwoods production.

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Invited Paper 3

TIMBER AND DOMESTIC STRUCTURES

N. H. Kloot

It was rather more than coincidental that I chose, as the title of this paper, the name of our Group in the Division of Building Research. For some 35 years this Group, under other names in the now defunct Division of Forest Products, has held a somewhat unique position in relation to the structural use of timber in this country.

Firstly, it has been responsible for the major portion of the research work conducted on Australian timbers in the determination of their mechanical properties and other technical information relating to the use of timber as a structural material. Secondly, it has been solely responsible for the strength grouping of timbers, for deriving working stresses, and for determining the levels of the various factors by which the basic working stresses are to be modified for service conditions. And thirdly, it has had thrust upon it the responsibility for specifying design criteria, in particular those relating to framed domestic construction. I believe, in the interests of the timber industry and of the building industry, and in the public interest generally, that this authoritative position based on technical competence, experience, and complete impartiality should be maintained. Certainly it would be in no one's interests for the chaotic situation to develop as it did in the United States when the Madison laboratory relinquished its similar authoritative position in these matters.

However, after some 45 years or more in which the Group and its predecessors have actively researched the fields of timber mechanics and timber engineering particularly as they relate to the area of major use of timber, namely domestic construction, it might well be asked and indeed should be asked "is a continuing major research effort in these fields justified?"

Consider, firstly, the basic data, the mechanical properties of timbers. It is true that there are literally hundreds of species for which we have little or no useful information. It is also true that the vast majority of these are of very minor, if any importance, and are never likely to become important. Should any presently minor species develop some significance, the amount of testing necessary to put it into the right pigeon-hole as regards strength properties, shrinkage and other physical properties should be quite small.

From the design point of view, having had a great deal to do with the development of Australian Standard CA65 - Timber Engineering Code, I would be the last to claim that its recommendations are perfect in all respects. This is in spite of the fact that the Code is acknowledged to be one of the best of its kind in the world at the present time. It is, however, my considered opinion that even though these recommendations will be improved and refined with time, such improvements and refinements are unlikely to significantly improve efficiency in the structural use of timber, particularly in house construction.

I would make much the same sort of comment in regard to CA38 - Light Timber Framing Code. There are quite a number of points that various

interested parties would like to see clarified or improved in this Code. In theory, refinement of the Code is possible by studying the load-sharing between members in a three-dimensional structure. However, in my opinion, such a study to be useful would be extremely costly whilst the benefits to be gained are likely to be only marginal. I believe that, by the time we have completed our projected series on low-rise domestic and similar structures, most of the short-comings of the Light Timber Framing Code will have been dealt with. At that stage, I feel it is likely to be some years before our Group is called on for a further major effort in this field. I accept the argument that a sound and viable standard is one constantly under review, constantly being improved. But at the same time, a standard subjected to major revision at frequent intervals soon loses the confidence of its users. I would remind you that Pamphlet 112 underwent only one major revision in some 30 years. Unfortunately, it so has the confidence of building authorities and builders that we, the authors, have had tremendous difficulty convincing them that the document is obsolete.

Superimposed on the question as to whether the Engineering Code, the Light Timber Framing Code and others related to them require a continuing major research effort, is the matter of structural grading. One must, I feel, question the need and the desirability of putting a great deal of extra money and time into preparing, reviewing and refining some of the best codes and standards in their class anywhere, when the fundamental requirement that timber be structurally graded is not, with one or two notable exceptions, being met.

There can be no doubt that the major obstacle to the widespread adoption of CA38 has been the general lack of structurally graded timber. Further, the credibility of these codes and of ourselves as the people responsible for their technical background is open to question when we talk about, design with, and provide reams of engineering tables for a material which, with one or two notable exceptions as mentioned before, hardly exists.

Turning now to another area, our experience in the developmental field, of difficulties and frustrations over many years does not lead me to consider this field as one deserving a greater concentration of effort. I have, at previous Conferences, referred to specific development projects that have aroused little but passing interest in the timber industry at the time, and how, any time from 7 to 10 years later, the industry suddenly develops an interest in a particular project and wants all the answers yesterday to the problems of turning the project into a viable economic scheme. Although the development field is potentially one of the most exciting for a research worker - a field in which he can see the results of laboratory work converted into something of practical use - I am afraid, on the basis of past experiences, I cannot view this area with a feeling other than one of frustration.

You may feel that to this stage, I have been taking a rather negative attitude. Let me correct that impression immediately. I am being quite positive when I say that I believe the future work of the Timber and Domestic Structures Group should be less oriented towards "timber" and more oriented towards "domestic structures" as such. Don't misunderstand me. I am not suggesting a major shift in our field of work should take place tomorrow. Nor am I suggesting that all work on timber should be phased out.

You will recall that I said in my opening remarks that I believed we should do our best to retain the authoritative position we have held for years, a position in which we can reasonably ensure that no timber obtains an unjustifiable advantage in terms of the risk factor in its structural use over any other. I am now suggesting that we should move into the wider field to ensure that no one material obtains an unjustifiable advantage in the same terms over any other. As the position stands at present, it would be, without a recognised authority to appeal to, perfectly feasible for a building authority to accept metal framed domestic structures based on design criteria differing markedly from those applied to timber structures. If these design criteria were more stringent, more conservative than those applied to timber frames there would be no problem from the timber industry's point of view. Actually if this happened, then sooner or later some one should ask the question on the public's behalf "are the more stringent criteria justified for steel frames?" It would however be quite fortuitous that every criterion, particularly for stiffness, would be more conservative. Then the timber industry has got a problem. By moving into this field, we should hope to minimise the problems that could arise if different materials were given, unjustifiably, different treatment in structural design.

My comments regarding metal frames apply equally to the 47 systems classified by the Federal Government's Task Force on Modern Housing Techniques as "in operation", 26 other systems considered "sound, potentially competitive but not yet in production", and 34 others classed as "sound but requiring further development", a total of 107 schemes differing from the traditional timber framed structure. Admittedly, the total number of units built in all of these schemes put together is a mere fraction of the number of timber framed units being built annually. Nevertheless, it is very likely that at least some of these schemes will continue to be viable in the long term, and the problem will not just "go away". Sooner or later, someone will ask the question "what are the design criteria for these constructions?" This question has only relatively recently been asked in the United States in relation to mobile homes. Because of the hold this type of structure has on the housing market in that country, it is likely to be quite some time before the regulatory authorities there solve all the problems that the delay in asking this question has caused. The regulatory authorities here would indeed be foolish if they did not learn from this experience and did not question the design criteria at a very early stage in the development of new systems intended to compete with the timber frame. As I said before, I believe this is a fruitful area in which our Group can operate so as not only to provide the answer to the question but also, as mentioned earlier, to try to ensure that no one material receives a more favourable treatment than any other in regard to the performance criteria applied.

Outside the areas I have discussed, another field in which I feel we can operate with advantage for some time is that of reducing much of our research knowledge and expertise into easily digestible material that will hopefully have some beneficial effect in the public's interest. As an example, I would mention the series in the Forest Products Newsletter on workmanship and the Light Timber Framing Code. This field however has little new research content.

Summing up, I would say that having regard to the inertia both in the timber industry and the building industry, an inertia that prevents both industries from taking full advantage of the sophisticated developments resulting from more than 45 years of timber research in this country, the answer to the question I originally posed is "no, a continuing major research effort in the structural timber field is not justified". Until the two industries have caught up some of the leeway, until the "Law of Diminishing Returns" no longer applies as it does at present and unless some completely unforeseen development occurs, then only a spread of the Group's endeavours into new areas that show a likelihood of significant benefit to the public interest can, I believe, be justified.

Invited Paper 4

NEW TECHNOLOGIES FOR NEW FIBRE RESOURCES

H. G. Higgins

SUMMARY

As traditional forest resources become fully committed, the newer sources of fibre increase in significance. The potential of the following forest resources is discussed in relation to paper production: hardwood plantations, coppice regeneration, bark, sawdust, dense hardwoods, mixed tropical hardwoods and wood residues. Possible alternative sources of fibre are mentioned, including plant crops such as kenaf and elephant grass, of which the fibre is seen as the principal but not the only product; agricultural residues; synthetic fibres, films and pulps; waste paper and garbage. New technological approaches are considered under four headings, which are related to the Renewable Resources programme of the Division of Chemical Technology, viz. plant fractionation, composite materials, pulping technology and forming processes. Several possible future technologies related to fibre use are also introduced.

1. GENERAL OBJECTIVES

Perhaps the dominating feature of today's world is the tempo of change. The relentless rush towards a new human condition, for better or worse, raises very serious difficulties in the fields of social, economic and industrial planning. In the formulation of research programmes, deep consideration has to be given to the trends in the material indices of our society - resource utilization, depletion and renewal; population; pollution; industrial and technological development - and on the basis of the most likely interpretation of such trends a stance or policy may be adopted. Arguments have been put forward previously (1) that, in the forest products field, as in others, this should involve recognition of the necessity for a more steady-state economy, based on a technology of material equilibrium (2).

The research needed for development under these conditions would emphasize the need for higher sustained yields of renewable resources. Studies would be made of how raw materials could be produced not only with minimum environmental deterioration but, where technically possible, with an actual improvement of the environment. Efforts would still be directed towards improving the quality of raw materials, the better use of existing resources through waste reduction, and the development of what are now regarded as lower grade resources. Ways of reducing the energy requirements in processing the raw materials, or reducing costs in other ways, will need to be investigated, and improved technologies will also be required to reduce pollution and the cost of pollution control in industrial operations. New developments in the processes of recycling secondary products could increase the raw material base of our industries without resource depletion or other deleterious effects. Research is also needed in the matching of product quality and use requirements, which should be based primarily on technical considerations. Another field of activity which is likely to increase in importance is that of adapting industrial processes to the most appropriate sources of energy.

In what follows, reference will be made to recent work in the Division of Chemical Technology related to some at least of the above objectives, and this will be interwoven into a personal view of current and possible future trends in the development of fibre resources and the technology of their utilization.

2. FOREST RESOURCES AND PAPER PRODUCTION

Paper provides the main outlet for reconstituted wood fibres. The future Australian fibre requirements were analyzed in the report of the FORWOOD Conference (3) and it was concluded that by the year 2010 in a self-sufficient pulp and paper economy it might just be possible to meet the maximum anticipated demand for hardwood pulpwood, but that there could be problems in supplying sufficient softwood. Such projections depend on the anticipated population increases, the trend in individual consumption, the proportion of imports, future plantation policy, technological changes which may for example facilitate the use of small isolated resources, and other unknown factors, but it seems likely that the uncertainties would move the date at which our forest resources become fully committed by only a few decades, at the most, and that our grandchildren will have to face up to the inevitable problem of resource depletion. In this context we shall briefly review recent work on a number of forest resources which are at present either unused or in only incipient use.

(a) Hardwood Plantations

As pulpwood, the young low-density hardwoods are to be preferred to older and denser woods on most grounds - lower chemical consumption in pulping, higher pulp yields, superior black liquors leading to easier chemical recovery, minor extractives problems, higher bonding strength, smaller vessels with less picking in off-set printing. When these advantages are considered alongside the rapid growth rates attainable, it is not surprising that pulp and paper manufacturers are showing increasing interest in hardwood plantations. A recent review by Robin Cromer (4) on the potential for *Eucalyptus* plantations in Australia brings out the following points:

(i) Nitrogen and phosphorus fertilizers at a rate of application of 202 kg/ha(N) and 90 kg/ha(P) more than quadruple the above ground biomass production of *Eucalyptus globulus* after four years,

(ii) Mechanized harvesting can reduce labour requirements to perhaps one third of those required for a normal billet operation,

(iii) The application of agricultural techniques such as those used in tree plantations overseas can improve productivity enormously; this represents a great change from the growing of a forest crop by natural silvicultural methods with as little disturbance and as little input as possible.

Work at the Gippsland Research Station of the Forest Research Institute (5) has been concerned with provenance studies, hybridization, vegetative propagation and the breeding system of *Eucalyptus regnans*.

Significant differences in wood basic density have been revealed between families (6) and we have shown that these are sufficient to have an appreciable effect on paper properties (7). In accordance with principles discussed at the last Conference, paper properties dependent on interfibre bonding are higher, and tearing strength lower, for wood of lower density.

In the selection of species for plantations, silviculturalists and forest products scientists need to work in close collaboration. This is happening in respect to the development of forest industries in Papua New Guinea, and the potential as pulpwood of a range of possible plantation species is being evaluated in this laboratory. The species include *Eucalyptus deglupta*, the results on which will be reported later by Frank Phillips and Alan Logan, *Terminalia brassii*, *Anthocephalus chinensis*, *Elaeocarpus multisectus*, *Eucalyptus tereticornis*, *Melaleuca leucodendron*, *Albizia falcataria*, *Eucalyptus grandis*, *Acacia auriculaeformis* and *Gmelina arborea*. The aim of the reforestation programmes is to attempt to provide the raw materials for integrated industries in the proportions likely to be required in the future, and the suitability for sawmilling and veneer production, as well as pulping, needs to be assessed before planning for efficient utilization of both thinnings and mature wood can be completed.

(b) Coppice Regeneration

A major advantage of pulpwood plantations is that they may be mechanically harvested at an early age. With species which coppice easily, mechanical harvesting can be particularly effective. Jack Nicholls and Frank Phillips (8) showed that coppice-regenerated *Eucalyptus viminalis* with a period of rotation of 6-8 years can provide a useful source of chip material. After removal of leaves and twigs during the harvesting operation, the remainder of the material above ground can be utilized for pulp and paper or fibre-board production.

(c) Bark

It was shown, in collaboration with the N.S.W. Forestry Commission Division of Wood Technology (Lindsay Bryant) that young trees of *Eucalyptus sieberi* could be pulped quite satisfactorily without removing the smooth inner bark (9). Similar studies have been carried out on young *E. regnans* and on branchwood from *E. diversicolor*, again with very good results. Thus the fibre supply can be substantially increased from a given area, thinning of regrowth in fire-affected areas can be made more economic, and waste can be reduced. Details of this work will be reported later in the programme.

Even the stringy bark of *Eucalyptus muellerana* can be converted into pulp, but with a rather high chemical consumption and low pulp yield.

(d) Sawdust

Interest in sawdust for pulping has increased rapidly because of the rising cost of pulpwood and its decreased availability, compared with the ready availability of huge quantities of sawdust as a waste product of the timber industry. Softwood sawdust has been found to be more suitable for pulping than that from hardwoods because of the greater fibre length of softwoods, which results in a lower proportion of very small fibre fragments after sawing. The total amount of softwood sawdust available in Australia is of the order of 100,000 tonnes (o.d.) per year (10), and there are several locations where softwood sawmills and pulp mills are in reasonably close proximity and sawdust utilization for pulping would be feasible because of low freight costs. Peter Nelson's work (11) with various types of radiata pine pulp has led to the conclusion that sawdust pulps may be added to pulps prepared from wood chips in proportions up to about 10 per cent without rendering these unsuitable for many of their present uses.

Particle size is of course an important factor in sawdust pulping, and the application of methods of reducing waste by modifying the saw to reduce the width of the kerf could lead to pulps with less satisfactory properties.

Despite the inferiority of hardwood sawdusts for pulping, a report (12) has appeared on the utilization of neutral sulphite pulp from hardwood sawdust as a component of corrugating medium in proportions up to 20 per cent. Although satisfactory in most respects, the resulting blend was reported to have poor wet-web strength, which could however be overcome by the addition of long-fibred pulp.

(e) Dense Hardwoods

The effect of wood density on pulp and paper properties was discussed at the last Conference (Topic 1/9). Although high density is an advantage for some purposes - in providing bulk, opacity and compressibility in the paper sheet, in reducing freight costs in bulk chip transport, and in increasing digester production efficiency - dense woods are not favoured as pulpwood, on account of wear on chipper knives, lower pulp yields, and inferior pulp strength. They are unsuitable for many end uses, although it has now been established by Jim Colley (13) from laboratory work that bleached kraft pulps from dense hardwoods should be acceptable as a component of papermaking furnishes for the higher grade printing and writing papers. It is most unlikely that paper made predominantly from dense woods could meet the normal specifications for these grades, but when bleached with pulps from low density hardwoods, or with softwood pulps, considerable proportions - up to about 30 per cent - could be tolerated. Such pulps could probably be used also as components of tissue papers.

The vessel picking problem in off-set printing tends to be worse with paper from dense woods than from woods of low density, even at the same vessel:fibre ratio, as has been shown (14) by comparing a very dense eucalypt (*E. tetrodonta*) with one of low density (*E. regnans*).

The greater bonding capacity of the laterally conformable fibres from the wood of low basic density results in the vessel segments being bound more firmly into the paper surface than is possible with the uncollapsed fibres from the dense wood.

Information relating basic density and other wood characteristics to pulp and paper properties has been of considerable use in resource assessment and development in Australia and Papua New Guinea, and in international assistance programmes in Asia and South America.

(f) Mixed Tropical Hardwoods

This subject was also treated at the last Conference (Topic 5/6). Since that time a great deal of further information has been accumulated and analysed by Frank Phillips and Alan Logan on the pulping and papermaking properties of Papua New Guinea species and on composite samples from particular areas, and work is well advanced in collaboration with the PNG Department of Forests on determining the most suitable species for future plantations. The following special aspects have also received attention:

(i) Vessel picking - Work initiated by Jim Colley has provided information on the vessel picking tendency of a range of PNG species and composite samples, and on the effect of beating on vessel pick number; it has also allowed the mixed tropical hardwood pulps to be compared with eucalypt pulps.

(ii) Surface smoothness - A series of 30 PNG species were used in an assessment of the effect of wood basic density on surface smoothness of the paper sheet (14). The high density woods yield papers with rougher surfaces, but the pulp fibres can be modified by beating so as to improve the smoothness of the sheet. The low density woods yield pulps which in terms of surface smoothness do not respond to beating.

(iii) Other surface properties - The scanning electron microscope has been used by Gordon Scurfield to study surface smoothness of papers from tropical hardwoods, the mode of bonding of vessel segments into the surface, and the occurrence in some species of crystals which resist alkaline pulping and appear as granular deposits located in depressions in the paper sheet.

(iv) Black liquor properties - A visiting scientist, Raysabro Oye, from Tokyo University of Agriculture and Technology, has studied the viscosity, swelling volume and other properties of black liquors from the pulping of individual species and composite samples from PNG, and compared then with the properties of eucalypt black liquors. Swelling volume of the PNG mixed species is considerably lower than even over-mature eucalypts, and much lower than regrowth or ash-type eucalypts.

(v) Ecological effects of clear felling - Arrangements have been made with the PNG Department of Forests for Len Webb, a CSIRO rain forest ecologist, to act as ecological consultant for the development of wood chip export industries, particularly in relation to acceptable procedures for clear felling.

Pulping tests on composite samples from different areas of Papua New Guinea have given rather similar results, even when the species composition of the forests has differed markedly. However it is quite invalid to conclude that all tropical forests will be equally suitable as pulpwood resources, as has sometimes been suggested. The mean basic density of potential pulpwood resources in S.E. Asia and N.E. South America, for example, may differ by as much as 40-50 per cent of the lower figure, with consequent effects on pulp yield, paper quality and processing costs. Some forests may contain a relatively high proportion of species which cannot be economically processed on account of high silica content or some other undesirable feature. In PNG, however, it seems likely that species exclusion can be kept to a very low level.

(g) Wood Residues

The question of chipping sawmill residues was introduced at the last Conference (Topic 4/8). Since that time a survey has been carried out by Bill Balodis in the East Gippsland area to assess the potential yield of pulpwood chips from offcuts. He concluded that the weight of green chips, in tonnes, which is available from the offcuts from standard sawlogs is about one third of the volume of log inputs in cubic metres. The relative chip output may be considerably increased from lower quality sawlogs. Mills have the option of accepting such logs and changing over from sawmills, from which only waste goes into chips, to integrated sawn timber and chip producing plants.

An independent estimate of chip output from offcuts based on a Tasmanian survey by F. McCallum (Bureau of Statistics, Hobart) indicated that 32 per cent of log input goes into offcuts and that the recovery of chips from offcuts is 87 per cent. From figures given by Ron Liversidge (10) for total offcuts from Australian sawmills in 1969/70, Balodis estimated that they would represent a potential source of 3.6M tonnes of green chips. This would have been sufficient to provide about twice as much pulp as was actually produced in Australia in 1972/73. In the United States the pulp produced from wood residues rose in the quarter century from 1945 to 1970 from zero to nearly a quarter of the total fibrous material used in domestic paper and paperboard mills. These figures illustrate the considerable contribution which wood residues could make to our future fibre supplies, and utilization of this material is entirely acceptable from the environmental point of view.

3. ALTERNATIVE MATERIALS FOR PAPERMAKING

As this is a Forest Products Conference I shall not dwell at length on other sources of fibre, but it may be appropriate to refer briefly to some of the more important alternative materials.

The pulping and papermaking potentialities of various plants have received attention in recent years in the Division. These include kenaf, elephant (or napier) grass, sorghum, cassava, abaca and lucerne.

The interest in all these is not solely as a raw material for the paper industry, but they have also been studied as sources of starch, protein, seed oil or stockfeed, as well as fibre for use in paper, in composite materials or for ultimate conversion to food, chemicals or energy. Such studies relate to the concept of integrated photosynthetic product industries, as described by Don Weiss (15).

One of the most promising of these fibre sources is kenaf (*Hibiscus cannabinus*), the papermaking potential of which is being intensely studied in collaboration with the Department of Northern Development and the CSIRO Divisions of Tropical Agronomy and Land Use Research. Kenaf crops grown in northern Australia reach similar levels of productivity to the best short-rotation forests (16), and they have the advantage of being able to provide a quick return on resource investment. The growing and pulping operations would have to be closely integrated to avoid any interruption in the supply of raw material to the mill. Substantial amounts of nitrogenous fertilizers are required (on present indications about 1.5 tonnes of urea/ha/year), and the possibility of alternating crops with legumes such as *Crotalaria* and *Sesbania* has been considered.

With kenaf, the properties of the bark, which comprises about 35 per cent of the dry weight of the stem, and of the wood are very different. The fibres in the bark are similar in average length to those of softwoods (about 3 mm), whereas those in the woody part of the stem are much shorter (about 0.6 mm). The pulps made from the bark resemble softwood pulps in most properties, whereas the woody fraction yields pulps with quite good bonding properties but low tearing strength. Kenaf pulps are normally subject to the disadvantage that water removal is slow, particularly in pulps from the woody stems. This is one of a number of aspects of kenaf utilization which are receiving detailed attention.

Elephant grass (*Pennisetum purpurum*) has a very high growth rate. Its pulping properties were examined by Alf Watson at the instigation of Alan Stewart of the Agro-Industrial Research Unit, who was looking for a plant which could be given a primary fractionation in the sugar mills in the off-season. When pulped by the soda process under fairly mild conditions satisfactory yields and Kappa numbers were obtained, and the pulp properties were similar to those of commercial pulps from mixed eucalypt species.

Agricultural residues such as bagasse, wheat straw and rice straw are used on a considerable scale in some countries for pulp and paper production. In Australia large quantities of bagasse and wheat straw could be made available as a source of fibre (3). A problem with material which is produced on a seasonal basis, however, is that large quantities have to be collected over a short period and stored for several months. With annual or perennial crops in some tropical or sub-tropical areas, the growing period can be spread over most of the year, thus reducing storage problems.

The production of paper-like products from synthetic polymer fibres, plastic films or synthetic pulps will probably increase, and they will supply a small but significant part of the market at present occupied

by paper and paperboard, on account of properties such as high wet strength, fold and opacity, which can be easily imparted to them for special uses. Reviewing the general question of the symbiosis of synthetic polymers and paper, Alfred Nissan (17) concluded that petro-chemical-based polymers and cellulose-based paper would increase in use over the next two or three decades, and that while competition between them would continue, their joint use will result in greater growth for both than their competition will decrease the use of either.

Waste paper is already an important resource for the paper industry, supplying about a fifth of the world demand for fibre. A large proportion of the total paper produced is theoretically recoverable, and under normal conditions up to 40 per cent of waste paper can be used in paper and board manufacture. The use of waste paper can certainly be increased, and much research effort will go into seeking better ways of recycling paper products so as more nearly to approach the properties of the virgin pulp. This will probably run parallel to attempts to develop methods of attaining desired paper properties by reversible rather than irreversible treatments. The hydrogen-bonded system is essentially reversible under mild conditions of temperature and pH, and we should consider whether we are going in the right direction in attempts to improve paper properties by incorporating the cellulose fibres into systems which are irreversible, or reversible only with considerable difficulty. Of course the proposed end use is highly relevant to this: documents for archives have very different requirements from daily newspapers or disposable packages, but in general the development of composite materials from cellulose and synthetic polymers or other materials is more appropriate to structural or engineering products than to paper.

John Coleman has been involved in investigations whereby the proportion of waste paper used in paper and board may be increased. He has developed pilot equipment (18) for a process (19) which involves addition of a starch solution between the newly formed plies at the wet end of a machine making multi-ply board, with the result that it should be possible to increase machine speed by eliminating the starch application to the partly-dried paper web. To the extent that product quality is also improved by this technique, it should be possible to increase the proportion of waste paper and still meet the previous strength specifications. For liner boards which are to be printed upon, a novel extension of this idea (20) is to incorporate suitable pigments between the outer ply and the remainder of the board, thereby whitening and opacifying the waste paper substrate and reducing the requirements of bleached virgin pulp in the outer layer.

Garbage contains a high proportion of paper (median 60 per cent in U.S., 40 to 50 per cent in some British industrial cities), and waste paper reclamation by normal methods reduces this only slightly owing to costs of collection and sorting (21). Improved methods should increase the amount of fibre available from this source. However, it has been suggested (21) that acid hydrolysis of the paper component of garbage to yield fermentable sugars for industrial alcohol production could be a profitable process.

4. NEW TECHNOLOGICAL APPROACHES

Future developments in the technology of processing both new and existing resources will be considered under the following four headings, which are related to major parts of the Renewable Resources programme in the Division of Chemical Technology:

(a) Plant fractionation
(b) Composite materials
(c) Pulping technology
(d) Forming processes

(a) Plant Fractionation

The IPPI concept (Integrated Photosynthetic Product Industries) was described by Don Weiss in his contribution to the last Conference (Introductory Paper No. 1), and its objectives have been pursued actively in the intervening time. The scheme is envisaged as applying to especially productive plant crops, particularly under conditions of sunshine and water availability which will ensure maximum yields per hectare. The plants must be capable of producing useful fibre, and their utilization is seen as being made more attractive economically by fractionating them into other products which are either of immediate use or are suitable for further economic processing into useful commodities. Thus the plant forms the raw material base for an integrated agro-industrial complex in a new type of rural community. The concept of complete plant utilization becomes attractive when it is remembered that on a world scale food shortages appear to be reaching an acute level before fibre shortages, so that tree plantations have to compete with agriculture for suitable land. As mentioned above, predominantly food-producing plants such as wheat and rice already produce very large amounts of fibre and their further use for this purpose only depends on the economic necessity for resource extension.

Geoff Gartside will deal with the subject of plant fractionation in a later contribution, and provide details of the plants studied, techniques of fractionation and economic possibilities.

(b) Composite Materials

Closely related to the IPPI concept, the composites programme of the Division is aimed at finding useful outlets in building, structural or engineering fields for composite materials based on cellulosic fibres derived from plant fractionation processes, or from residues of processing wood or other plant material. In developing such forms of reconstituted wood, the matrix may be composed of synthetic polymers or other systems, and the appropriate processing technologies can be drawn on as required, alongside fibre technology.

As will be brought out in a later paper by Geoff Irvine, Tony Michell, Janet Vaughan and Don Willis, the requirements of fibres for inclusion within synthetic polymer or other matrices differ from those of paper-making fibres. Whereas paper of high strength is composed of flexible

fibres with the capacity to collapse laterally during the papermaking process to provide a structure with a high bonded area, strong composites need stiff fibres. When the fibres are derived from wood, composites might then provide an alternative outlet for some types of fibre which are not highly regarded as a raw material for paper manufacture. Alex McKenzie has considered the properties of cellulosic fibres in relation to other reinforcing materials, and has defined certain areas in which wood fibre reinforcement of plastics appear to be immediately feasible. Bob Coutts is investigating novel methods of producing wood fibre - polymer composites.

(c) Pulping Technology

Developments in the pulping field are being increasingly dictated by environmental considerations and better resource utilization. The ideal of the effluent-free mill may never be wholly attained but great strides are being made in this direction. Already odorous emissions from kraft mills have been greatly reduced by black liquor oxidation. The amount of sulphur dioxide emitted and the BOD of liquid effluents are also falling. It has been suggested by Nils Hartler (22) that in the 1980's the most advanced mills will be operating a polysulphide process with a fully-closed system. On the other hand oxygen-alkali pulping seems to be on the threshold of commercial development, but all the associated problems do not appear to have been solved (energy consumption, carbohydrate degradation, accessibility to pulping reagents) and it is to be expected that further significant advances in oxygen pulping research will take place which may improve its relative position.

In situations where capital cost is to be small, consideration may be given to low pressure oxidative pulping, which has the following advantages: reduction of pollution, mild pulping conditions (low temperature and no pressure), possibility of small-scale installations, high pulp yield, and excellent pulp properties, with low beating requirements. As against this however no reagents have appeared which are sufficiently cheap to make the process economically attractive.

In the Australian environment, a need is arising in some areas for smaller pulping units than those at present considered economically viable, as was pointed out at the FORWOOD Conference. However, improved technology is required to overcome the scale factor. The distribution of our softwood resources, which are often insufficient, in a particular area, to support a modern large-scale chemical pulp mill is stimulating research in this direction. The Division is mounting a substantial effort with the objective of developing a pulping process which would not only be economic on a relatively small scale, but which would be capable of producing pulps of fairly high quality without much pollution. The necessity for acceptable effluents is particularly pressing where the wood resource is situated on an inland drainage system, as is often the case.

The aim of this research is a very difficult one to achieve, but the number of options available for investigating fibre separation suggests that the ideal pulping process may not be just a pipe dream. Various

lines of research in the Division are looking for a promising lead in the right direction.

High-yield pulps are continuing to attract attention, and the possible applications of a mechanical or chemi-mechanical pulp produced by the explosive defibration of wood chips will be discussed later by Heikki Mamers and Alf Watson.

(d) Forming Processes

Several new paper forming processes have been developed overseas, e.g. Wahren's high consistency process (23) and dry forming. As our available water resources become increasingly committed to industrial development or other purposes, interest in the manufacture of cellulosic products without water would be expected to increase. The amount of water available and its quality is always an important consideration in the location of paper mills, but dry forming could remove this constraint, and the reduction or elimination of liquid effluents is also an attractive aim. These factors have to be weighed against the economic advantages of the integrated pulp and paper mill, where the pulp is available in slush form. However, dry forming is already of interest for non-integrated mills making lightly-bonded absorbent products, and further research should extend the use of the process into other fields. One interesting possibility is that dry-forming might be able to use lignin-rich fibres such as those produced by mechanical and chemi-mechanical processes to give products similar in some respects to those obtained at present from chemical or semi-chemical pulps.

The conscious application of principles of material science should provide a basis for developing a field which we can designate as Web Reinforcement. This is concerned with novel types of fibre interaction in multiphase systems, and the objective is to improve the properties of the wet web and the dry paper sheet so that normally unacceptable papermaking materials can be utilized economically.

ASSOCIATED TECHNOLOGIES

Mention should be made of a number of areas of research which, while not necessarily part and parcel of the fibre utilization field, may nevertheless interact with it in such a way as to hold promise of benefits which may improve the economics of processing.

The evolutionary capacity of plants can be utilized to make photosynthesis a still more efficient means of fibre production. We may hope that tree breeding will develop to give higher wood yields and higher polysaccharide content in the wood. In the field of complete plant utilization, genetics has yet to be widely applied to produce varieties in which the yield of several constituents, rather than one, is optimized.

Advances in lignin research may be expected to lead to a fuller economic utilization of the chemical potentialities of the lignin molecule. Reductive processes will be attractive in the era of liquid

fuel shortages, but pyrolysis or partial oxidation of black liquors, in association with non-polluting pulping and recovery processes, could also provide chemicals of economic value.

The phenolic extractives of eucalypts offer another huge source of potentially useful compounds. Ellagic acid is a most interesting molecule in respect to both its structure and properties, and it might be hoped that modification by controlled pyrolysis or by other means might yield economically desirable materials, or that the intact molecule could be used as a base for special polymers.

The formulation and use of papermaking additives with special properties which will improve paper properties, fibre retention, etc. will no doubt be continued for some time, but eventually there could be a diminution in the use of some additives as prices become prohibitive as a consequence either of the depletion of the non-renewable resource on which they are based, or, in the case of edible materials such as starch, of their diversion to food. In the meantime we can expect more specific application of additives than is achieved in traditional methods such as beater addition.

Another field in which some developments may be hoped for is the biological utilization of wood wastes. Various approaches, which have recently been reviewed by Tony Michell, have been considered - microbiological, chemical and physical treatments to improve the digestibility of lignocellulosic material, direct conversion of sawdust to proteinaceous foods by mycological techniques, and yeast fermentation of acid or enzyme hydrolysates of wood to produce protein. The possibility of producing a cattle feed is receiving attention in the Division, and Chris Mardon will describe later his experiments on ways of improving the ruminant digestibility of cellulosic wastes.

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Invited Paper 5

UTILISATION OF FOREST AND SAWMILL RESIDUES

A. Krilov and C. E. Ironside

Environmental factors and the energy crisis have precipitated a major reappraisal of attitudes towards the disposal of residues. A growing awareness of the rapidly approaching gap between supply and demand for forest products has lent impetus to the search for practicable means of utilising this vast and potentially valuable source of fibre, polymers and energy. In many instances efficient debarking would provide the key to entrepreneurial activity in co-operation, marketing and transportation.

Let us consider the developments and the difficulties yet to be resolved.

1. SAWMILL RESIDUES

A. Softwood

Improved utilisation of residues in softwood mills is an excellent example of good management solving the numerous technical and economic problems in the interests of the environment and operational profitability. Initially, however, the certainty of success was far from self-evident: the industry was undercapitalised, fragmented, and many of the mills were distant from markets. Few had either the capital or throughput to justify expenditure on a debarker - the indispensable unit to fuller utilisation of softwoods. The remedy was found in reorganisation of the industry by amalgamation and acquisition.

Manufacture of local debarkers made under licence (Fulghum) together with drastic reduction in import duties for high capacity foreign models (Cambio, Morbark) has improved the situation even more. The introduction of efficient separation of bark from wood by mechanical means coincided with a rising interest in bark for orchid growing and landscaping purposes. The physical problems of sorting, milling and grading were easily surmounted. Penetration by new products, into what was then a limited market dominated by imported bark and peat, took courage, money and perseverance.

Supply now lags behind demand and saturation point for quality bark is not in sight. As might be expected an undersupply position has led to a lowering of specifications. Much cambial type juvenile bark, which would be more appropriate composted, is currently being marketed as landscaping mulch. Hopefully, such producers will anticipate a decline in their share of the raw bark market and perfect practicable and economic techniques for composting juvenile bark (11) so that the expected upsurge of supply of early thinnings (18) can be accommodated. It is noteworthy that, owing to the scarcity and soaring prices of imported peat, well rotted samples of softwood sawdust are now eagerly sought for potting mixes.

Renewed interest is being shown in extraction of polyphenols from radiata bark for use as adhesives in particleboard and plywood manufacture and at least one firm is erecting a pilot plant following successful work by CSIRO Division of Building Research. As the extracted bark is likely to be too wet for fuel and unsuitable for composting, this development may produce its own particular disposal problems.

As the sawn product generally provides the miller with the highest remuneration, any steps to increase recovery of such material are worthy of attention, simplifying the residue utilisation situation by employing the resource before it ever enters the residue pile.

It is therefore surprising to observe excessive production of sawdust by high gauge blades in the primary conversion, where a narrow kerf could be used with astonishing savings - a fact well illustrated by the following table, related to a peeler core recovery project (16) but equally applicable in softwood conversion.

POSSIBLE SAVING DUE TO CONVERSION BY THINNER SAWBLADES

(Compared with 6.35 mm kerf)

Blade gauge	Blade thickness mm	Kerf mm	Saving per cut mm	Saving per core mm	Saving per core %
13	2.41	3.61	2.74	16.44	10.6
12	2.77	3.97	2.38	14.88	9.2
11	3.05	4.25	2.10	12.60	8.0
10	3.40	4.60	1.75	10.50	6.8
9	3.76	4.96	1.39	8.34	5.2

Conversion of shorts by finger-jointing is another means of keeping residues as merchantable material in the high price bracket. Installation of completely automated finger-jointing lines is now more frequent.

Because of its technical limitations visual grading has always been extravagant, demanding a far higher average grade than is actually required. Introduction of mechanical stress-grading has resulted in much finer tolerances, with the safe acceptance of lower grade stock, which would previously have been rejected, providing a significant effect on recoveries. Work by Kloot, Rumball and Ditchburne (15) on a sample of the *Pinus radiata* tree population from all states has lifted each visual grade by one stress grade.

However, most solid residues - edgings and offcuts - are used for particleboard manufacture. The technological trend is towards transforming softwood edgings into chips during the primary conversion: chipper-canters, "beavers" and chipping headrigs of various types should gain favour in Australia as efficient tools for small log conversion. Chipping heads are usually designed to produce desired chip characteristics, which brings us to an interesting field for investigation. As similar principles could be usefully applied to sawblades, let us produce wood particles accurately dimensioned for a particular end use, instead of mere sawdust, which at best is relatively unsatisfactory in particleboard manufacture, where it is sometimes used as a recovery item in the low strength centre layer.

Renewed interest is being shown in design and development of furnaces for steam or heat generation, using by-product fuels including large quantities of moist sawdust (Bradshaw).

Shavings from the large number of post-peelers in N.S.W. are another softwood mill residue very much in demand. Good quality shavings produced by these machines are sold for manufacturing wood/cement insulating boards (2). With a little ingenuity those residues could also meet the needs of manufacturers of particleboard and light weight wood/cement building blocks.

The millers of plantation softwoods can look forward to 100% utilisation of logs in the near future. This is unfortunately not the case in cypress pine mills which suffer from all the disadvantages of fragmented small scale operations distant from the main markets.

Some millers may be able to dispose of residues locally for fuel or horticultural purposes, but the prospects are not bright.

B. Hardwood

Residue utilisation in the hardwood industry is in its infancy. The problems are similar to those previously incurred by the softwoods industry, only greatly magnified. There are many more low capacity hardwood mills and the debarking problems are more serious. As most forms of residue utilisation and minimisation benefit greatly from economies of scale it is likely that here too the problem will resolve itself in part by amalgamation of interests and accelerated closure of smaller mills. Larger concerns can devote the necessary capital and effort to the marketing of residuals. They would also have the throughput to justify investment in mechanical debarkers which would have a major bearing on any successful residue utilisation project. This factor combined with the great interest in converting offcuts to pulp chips should give impetus to the search for a better mechanical debarker for hardwood logs.

Though the scope for the designer is tremendous, really successful mechanical debarking of thick fibrous-barked hardwoods has yet to be achieved. Considerable efforts in this direction have been made by the Forest and Timber Bureau in Canberra, whose research has been centered around the design of a mobile debarking unit (4), but so far the prototype has not produced any orders for commercial machines. Some trials of prototype heads on a mobile debarker have been undertaken by CSIRO (17).

Increasing interest is also being shown by foreign manufacturers, who are negotiating a joint venture along with a local company and the Forestry Commission of N.S.W. They aim to produce a new type of mechanical debarker, specially designed and adapted to the rough working conditions in Australian forests and capable of successfully debarking the difficult stringybark species.

Mechanical debarkers offer the hardwood industry bark-free offcuts for chipping but debarking may be justified on its own merits as:

- it would stimulate faster cutting practices,
- reduce blade maintenance,
- increase sawblade life,
- improve product quality.

Invited Paper 5

At present, considerable quantities of hardwood edgings and offcuts are converted into chips and sold mainly for export. To achieve this, most of the timber is manually debarked in the forest, an operation that is labour intensive and thus expensive. An interesting development is semi-automatic debarking of larger logs by skidder, carried out when the bark is relatively loose, at about a third of the cost of manual debarking viz:

- small dia. logs: $0.11 - 0.12/m^3$
- large dia. logs: $0.08 - 0.09/m^3$

However, this technique would not be applicable on a year round basis.

To separate efficiently sawmill residue from bark, before chipping, CSIRO researchers are investigating the use on offcuts of excess steam in plant kilns. In the absence of a satisfactory debarking machine this technique, if commercially viable, will find many users among sawmillers with a buyer for chipped waste.

Utilisation of chippable residue is relatively well organised in hardwood sawmills on either side of the N.S.W. - Victorian border who are selling their chips to the Eden chip terminal. The annual production on the North Coast of N.S.W. of some 400,000 tonnes of dockings, slabs and edgings by local sawmills should make an excellent basis for establishing a similar operation somewhere north of Sydney. Investigations made by the authors (13) indicate definite benefits of replacing small, low production mills by large groupings or concerns, more capable of negotiating transport facilities which is the key to woodchip export expansion. A positive approach to this question would transform sawmill residue, now being dumped or incinerated, into approximately 300,000 tonnes of pulp chips, increasing Australian exports by over $8 million at current values.

Compared with softwood residues, the disposal of vast quantities of hardwood bark presents a problem. This is closely connected with debarking difficulties as well as the differing nature of barks from a range of species. Investigation of these problems are presently being carried out by the Forestry Commission of N.S.W. A most promising field for research would be the manufacture of building and insulating boards based on the reaction between formaldehyde and tannins (3). Erosion control, agricultural and landscaping uses are other promising outlets for large volumes.

Utilisation of hardwood sawdust remains a major unsolved problem. When "Charcoal from N.S.W. species of timber" (10) was written, no mention was made of the Nichols Herreshoff vertical hearth furnace, as at that time there was no foreseeable possibility of marketing the minimum capacity of 8,000 tonnes per annum of charcoal fines from sawdust or hogged bark. Yet such an outlet would now appear to be within the realm of practicability.

What has been said previously regarding the excessive production of softwood sawdust is also applicable to hardwood: besides partial utilisation of the latter as a boiler fuel and some recent interest in peat substitute, the problem would be substantially reduced by the use of well designed thin blades.

Utilisation of mudguts, estimated at a gross 28% of hardwood residues (12) offers a challenging line of research. An attempt to establish the technical and technological possibilities of freeing the valuable fibre from associated

dote, mud and termite galleries, is at present being actively carried out by the authors.

2. VENEER PLANT RESIDUES

Utilisable veneer plant residues can be classified as follows, in order of importance:

- Peeler cores
- Veneer offcuts and clippings
- Veneer log offcuts
- Bark

A practical approach to converting sound peeler cores into a product more valuable than boiler fuel was investigated by the Forestry Commission of N.S.W. (16) with production based on Wauchope and Grafton. Practical trials, including seasoning of the sawn product, have shown encouraging results: it would be a viable project if established on a co-operative basis, but the conversion of cores into sawn timber at each and every mill proved uneconomic.

Veneer clippings and veneer log offcuts present an interesting source of raw material for use other than as fuel. Preliminary research on quantities, volumes and marketing possibilities demonstrates that a co-operative effort of interested veneer manufacturers is indispensable, if this supplementary supply of raw material is to be profitably used.

A large percentage of veneer logs are debarked by hand or by various types of slow working homemade devices. It has been established that these units are often cutting too deep into the wood giving a disproportionate loss in valuable veneer. The mixture of bark and rough slivers from some species provides quite an attractive decorative mulch which could be remunerative if local markets, distant from pine areas, were sought. Residue could be further reduced by random width clipping and reduction of post-pressing trim.

3. FOREST RESIDUES

A. Softwood

There is only one particular softwood forest residue that is worth mentioning for the moment; the stump, together with the main root system is not recovered yet in local harvesting practice. It could represent up to 25-30% of merchantable stem dry weight (9), but a more modest estimate would appear realistic: nevertheless this offers a substantial amount of additional raw material for particleboard manufacture.

Some equipment designed for their extraction has been built and tested (Koch, Wagner-Bartlett), but the commercial application is still questionable, especially in rocky or heavy soils. The concept however deserves attention as the degree of utilisation would be improved and site preparation for the succeeding stand ameliorated.

B. Hardwood

Even to the most casual observer it is obvious that huge amounts of sound wood fibre are being left in the logging areas in the form of stumps, branchwood, damaged advance growth and culls. It is equally obvious that a separate harvesting of some of these such as branchwood or the damaged advance growth is not economically attractive, as they lie tangled in the wake of heavy logging equipment.

What is less obvious is the large quantity of overmature derelicts from earlier exploitation, and currently unmarketable poles throughout the forests, which urgently require thinning, even to waste (7), to achieve diameter growth in remaining trees.

The total volume of potentially pulpable wood is staggering. In North Coast forests the percentage of useless stems which are unmerchantable has been given as 37-68 (5). A possible loss, in 23 years of growth, of as much as 30% in value, caused by the presence of surplus poles, has been demonstrated (8).

An account of some 20 year old fire induced white stringybark regeneration (1) mentions stocking of up to 7500 stems per hectare with 2500 stems/ha as common with an estimated pulpwood volume of 70 m^3/ha.

A quick glance at Jacobs' prescriptions (14) for full stocking in eucalypt forests unveils the possibilities, bearing in mind that the dominants will be in the 15-22 cm dia. class.

DIAMETER BREAST HEIGHT in cm	TREES PER HECTARE		
Crown ratio:	12	15	18
7.6	11960	7655	5315
15.2	2990	1913	1329
22.8	1329	850	591

Hardwood forest residues can be conveniently considered under the following headings:

- Stumps
- Crownwood
- Poles
- Derelicts

Some preliminary attempts to estimate available volumes, distribution and possible degree of utilisation of forest residues have been made in several forests on the South Coast of N.S.W. by the authors.

Stumps

Whilst assessment of stumps left to degrade in the forest was not covered by the original survey, it was observed that these were frequently as high

as 1 m from the ground, i.e. about waist height - the most comfortable felling position.

It is our view that the majority of felled stems could be cut lower by some 50 cm or so with no particular inconvenience to the feller, yielding an additional 3-10 m^3/ha usable wood fibre.

We do not think that introduction of stump-extracting machines, similar to those used overseas for salvaging operations in pine, would be an adequate solution in hardwood. Even the most powerful machines would have trouble dealing with such root systems and the product would not be commensurate with the effort.

An American felling technique using a two-man light-weight powered saw could be studied with advantage, as this would permit a lower cut without fatigue.

Crownwood

It is a feature of some eucalypt species that they cast the outer bark from the younger branchwood at intervals. It was, in fact, the production by Watson, Higgins and Bryant (19) of a satisfactory pulp from branch and pole wood of this type with the thin green phloem, which provoked interest in the recovery of crown material. Samples of different age regrowth eucalypt, with bark, were subsequently evaluated in Japan and shown to be acceptable if diluted with bark-free chips.

In our study of crowns it has been established that:

- Crowns from very large trees were generally unattractive. They were often mis-shapen, with much decay. Recovery would tend to be dangerous and would require the services of highly skilled bushworkers, who are already in short supply.

- Stringybarks were mis-shapen and frequently full of dote.

- Ash and similar species from trees up to 50 cm dia. were attractive. They have usually comparatively few, reasonably straight branches which are free of rough outer bark.

On average we obtained (overbark) 0.167 m^3 green branchwood and 0.180 m^3 green branchwood and 0.180 m^3 roughbark bole per ash crown with the latter equivalent to 0.140 m^3 underbark measurement. Application of these figures to inventory data of pulpwood trees of suitable species would suggest the amounts of extra material of this kind to be expected. A recent analysis concluded that 58% of the eucalypt trees, growing in the south east of Australia, carried smooth bark on the main branches.

Investigations are now being made by CSIRO Division of Chemical Technology into the pulping qualities of the bark of stringybark and some other species, which form an important constituent of Australian forests.

In conclusion, our investigation showed that, whilst technically feasible, recovery of crowns alone would not be very attractive.

Throughout the forest, however, there are large quantities of advance growth to be found, frequently in dense pockets.

Crown recovery in association with advance growth exploitation would be a very different proposition, when a satisfactory method of large scale debarking of small diameter fibrous-barked stems is attained.

Poles

Considerable quantities of poles up to 20 cm dia. are to be found in many hardwood forests where they persist in keen competition, to the detriment of more valuable growing stock (8), and aggravate the fire hazard. Such pole stocking is related to forest type and fire history of each particular area, and therefore can vary considerably.

The small diameter of material presents in itself a major challenge to the extraction and logging equipment designer, as a fair percentage of stems are too small to be handled by conventional means.

Actual developments in mechanisation for logging the forest residues are mainly centered in primary transport, especially on forwarders for shortwood extraction. Introduction of various delimbers (Can-Car, KCL) presents an important step forward, but their application is obviously of more significance in softwood harvesting.

Recent application of hydraulic grapples particularly on feller-bunchers (Drott 40) has proved itself by reducing the labour component considerably.

Various types of roadside processors have been designed and tested, but their efficiency is usually restricted by their reach. This presents an interesting field for further research.

Present tendencies in mechanisation lean toward multi-tree felling and processing equipment, which has a promising future, particularly for small diameter material extraction.

However, even the most sophisticated processors (Koehring-Waterous, Beliot) and multi-function harvesters (Morbark Total Chiparvestor, Timberjack Treelength Harvester) present a number of serious problems, such as maintenance or the cost of repairs in the forest, which have to be solved before their ultimate acceptance. But, it will be this type of equipment, modified for local conditions, which will be used if the removal of the advance growth and other necessary thinning operations, considered to be a matter of urgency, are to be carried out at maximum profit.

A dual approach to utilisation of these forest residues is possible:

- Large scale operations based on stationary installed equipment
- Fragmented operations in selected forest areas, carried out by specialised mobile units.

(a) Large scale operations

There are two major problems to concentrate upon:

- Large volumes of available small diameter raw material.
- Considerable percentage of stringybark type species, requiring an unconventional debarking set-up.

These factors have long precluded the economical use of such wood, as processing small pieces individually can be an expensive proposition. A solution to this problem requires a different technological approach comprising new processing facilities, tailored in accordance with detailed specifications, which in their turn involve major risk capital investment based on careful examination of all known technico-economic problems.

To succeed we have to consider various aspects to obtain cumulative benefits:

- Species
- Seasonal effects
- Climatic influences
- Period and conditions of storage
- Bio-degradation of bark/wood interface.

A solution to debarking lies possibly in application of adequately modified, stationary mounted Waplan type M.C. barking drums, performing in the capacity range of some 150-180 m^3/h. High capacity chipping equipment should be provided for successful performance on very large quantities of small diameter material. For this purpose we advocate use of corresponding drum chippers.

At this point, thanks to the work of Watson et al. (19) we take a great leap forward - ash, gums and similar species with green bark branchwood and poles can go directly to the chipper to produce a top grade pulp. Such work leads us to hope that advancing paper technology will find a tolerance of greater proportions of bark in the furnish - particularly inner bark, which has such a tight grip on the underlying wood and which would appear to have so many wood-fibre like features.

Naturally auxillary problems may be expected when dealing with utilisation of forest residues on a large scale:

(i) Char

As pulp containing char cannot be bleached, even the smallest fraction of charcoal in the chipped material is unacceptable. But fire has been widespread and consequently most of the trees have some char, particularly on the lower bark, which must be removed completely prior to pulping.

(ii) Bark disposal

In the past bark has had little or no commercial value, and usually has been either dumped or burned - neither solution is environmentally satisfactory, particularly in bulk. Lately, some bark has been used for

agricultural and horticultural purposes, in landscaping, in erosion control, as bedding for livestock and to prevent puddling in the fields. However, bearing in mind that bark from pulpwood operations would supplement the existing supplies, this would represent only a limited outlet.

It is expected that with an operation of some magnitude the conversion plants will be forced to solve the bark disposal problem, as huge amounts of wet bark will be piling up around the plant equipment.

Investigation of all other possible outlets, in particular building boards, insulation batts and packing materials should be promoted and carried out with an element of urgency. We would suggest that the main effort should be directed towards investigation of the fibrous bark potential in manufacture of insulation boards or batts, whose practical application in the building industry would be large enough to constitute a definite marketing proposition.

It should be borne in mind that any bark loosening system would be of major importance as it will affect the physico-chemical condition of the bark. Non-fibrous bark and fines should probably be composted as soil improvers.

(iii) Pollution

It is obvious that large quantities of water will be needed. The sea could be regarded as an attractive source, but we do not advocate it. The presence of large quantities of tannin in the bark of some species would soon create a major pollution problem, whilst the salt content of sea water would stultify any reasonable method of use or disposal that comes to mind.

In any case, in the interests of both water conservation and pollution control, filtering operations and recycling of water will have to be an integral part of any such scheme.

(b) Fragmented mobile operations

An alternative approach to partial utilisation of forest residues would consist of a number of independent mobile chipping units, especially adapted to carry out the clean-up operations in selected forest areas.

One such unit manufactured by Isles, Forge & Engineering Pty. Ltd. of Coff's Harbour, is at present operating in the region of Batemans Bay, where it is involved in a salvage operation efficiently transforming into chips mobile sawmill waste as well as various small dimensioned forest residues. The output of this equipment is determined by the residue. However, under ideal conditions it can produce as much as 25 tonnes/hour, converting material approx. 2.5 m long and up to 0.25 m dia.

The use of mobile units largely obviates the problems of pollution, but the enterprise has to carry the extra costs of mobilised equipment and fragmented operation. Mobiles offer great opportunities as a back up to silvicultural operations, in salvage and in handling isolated pockets of trees not suitable for sawing.

Derelicts

Once the surplus poles had been removed, visibility and access throughout the forest would be greatly improved. It would then be possible to undertake

a regular removal of a proportion of derelicts and no-hopers to favour development of select stems. In most virgin Blackbutt forest at least 70% of the basal area is useless for saw logs; in nearly every assessment done in any of the eucalypt forests, at least 50% of the basal area is useless (6). The techniques for exploitation of such material would be little different from those currently employed in sawlog and pulpwood production except that much greater care would be required to minimise damage in felling and extraction - a normal requirement of intensive forestry.

Conclusion

We would advocate the large scale use of hardwood forest residues, as a means to:

- augment available resources,
- provide a growth point for rural industries,
- regenerate and rejuvenate our forests,
- safeguard the forests for wild life, for man and his environment against the ravages of fire.

Such activities would finance and necessitate an adequate road network, and thus:

- add to the recreational value of the forests,
- make the forest healthier and fully productive through regular thinning operations,
- provide access for fire protection.

This paper does not attempt to be encyclopaedic: we have confined our attention to commercially interesting issues with their respective problems and developments.

The various residues accumulated in industry or in the forest present a major source of raw material and yet most are wasted.

The potential is tremendous. Residues offer a superb opportunity for investigation and research. The volumes are so immense that great efforts will be justified. Social and economic pressures are such that even if no development takes place now, the identical problems must arise, greatly magnified, in the near future.

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TOPIC 1

Mechanical Processing and Applications

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1/2 Chip/Bark Separation
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1/5 Treatment of reconditioner effluent
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1/8 Computer simulation of sawing
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Topic 1/1

STEAM DEBARKING OF PINE AND HARDWOOD ROUNDS AND EDGINGS

H. Greaves and R. M. Liversidge

Previous work at the Division (Greaves 1968) indicated that the bark could be removed readily from such species as *Pinus radiata*, *Eucalyptus regnans*, *E. obliqua* and *E. dives* by steaming small logs at atmospheric pressure. The process required between one and 2½ hours at 100°C. More recently attention has been focused on the problem of debarking edgings and other mill residues with a view to utilising this material in the form of chips. Steaming was considered as a possible technique. This report presents some of the initial experimentation to determine the feasibility of steam debarking such edgings. At the same time short logs were included in the tests to re-examine the broader potential of the technique.

Some 18 different species of commercial timbers from Victoria, New South Wales and Queensland have so far been examined. These include radiata pine, slash pine, hoop pine, mountain ash, messmate, brush box, blue gum and tulip oak. Material has ranged from freshly felled to 10 weeks old (the period has varied with different species), and steaming has been applied from periods of 30 minutes to 3 hours. In the case of radiata pine, logs as well as edgings were steamed, otherwise the material consisted of various lengths and thicknesses of slabs and edgings. Bark thickness was also variable, especially in *P. radiata*.

The results showed that steaming edgings as soon as possible after felling for 1-1½ hours was sufficient for easy bark removal (Figure 1). Steam temperature was approximately 100°C. The technique proved satisfactory for both hardwoods and softwoods, and thickness of bark made little difference. In a separate study using slabs of *P. radiata* with various bark thicknesses, thermocouples were inserted at different depths to ascertain whether heat transfer was a critical factor in the steaming process, and whether thicker barks caused any significant increase in the time of steaming. Initial assessment appeared to indicate that the thickness factor was only critical with regards heat transfer in the outer 2-3 cm. After this depth, temperature in the wood rose at similar rates whether the slabs were thick or thinly barked; it took between 3 and 3.5 hours for the wood c.5.5-7.0 cm below the slab surface to reach 100°C.

The earlier work undertaken at the Division suggested that the hot steam might cause bark-wood interface breakdown by hydrolysing cell wall pectin in the vascular cambium zone or by causing differential expansion of the flexible cambium and the relatively rigid wood cells. In either case there is a dependence on water content. This became noticeable when material not freshly cut was placed in the steaming chamber. Bark removal was more difficult and steaming times were longer. When samples of this type of material were soaked in water overnight and subsequently steamed a marked improvement was observed. Apparently it is somewhat critical that the process be applied to relatively freshly felled material. If this is impractical, then soaking or possibly longer steaming, perhaps with superheated steam, may give a satisfactory clean removal of bark.

Logs present a different problem to the edgings, since even after steaming a starting cut for initial release of the bark has to be made.

However, our trials to date show that the technique has considerable potential for log debarking (Figure 2). We are examining the possibility of cutting a longitudinal groove to the depth of the wood in a log prior to steaming. It is also possible that initial loosening of the bark by steaming could improve the debarking of logs in conventional debarkers.

In a review on debarking of eucalypts, Woodhead (1969) has discussed the use of steam, and although it has many merits, he suggests that the technique could only be used as an adjunct to conventional removal techniques, and that a substantial outlay on equipment is required. In our experience it should be possible to remove the loosened bark simply and cheaply from slabs and conceivably also from logs (for example, the bark fell cleanly from slabs of *P. radiata* when they were dropped from the steamer trolley to the laboratory floor - a distance of c.1m). Furthermore, construction of a steaming chamber along the lines, say, of our sketch in Figure 3, would again be simple and relatively cheap. It is worth noting at this point that one Tasmanian sawmiller is currently constructing a chamber approximately 12m long x 6.5m wide x 1.2m high, since his initial trials on hardwood and softwood logs 3.6m long and up to 0.5m diameter were so successful.

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CHIP/BARK SEPARATION

R. M. Liversidge

Since only a limited proportion of bark is acceptable with wood chips for some uses, the question of bark removal becomes a matter of importance where solid sawmill residues are to be chipped. If the bark cannot be accepted with the wood chips, the following appear to be the possible alternatives.

(a) Debarking of all logs prior to sawing.

(b) Debarking of slabs and edgings prior to chipping.

(c) Separation of bark from the chips where the residues have been chipped with the bark on.

In some mills, for various reasons, logs are sawn with the bark on and, if the slabs and edgings from these mills are to be chipped, alternatives (b) or (c) above would have to be adopted.

Some work on one method of removing the bark from slabs and edgings by steaming is reported in a paper to be presented at this Conference.

Alternative (c), i.e. separation of the bark from the chips following the chipping operation, is also under investigation at the Division of Building Research and a number of possibilities are being considered. These include air aspiration and flotation methods, one of which employs a vacuum technique and has been used in an overseas plant.

As part of this study, solid residue from a number of species considered important to proposed chipping schemes will be chipped and an examination made of such factors as:

(i) Degree of separation of bark and wood occurring during chipping.

(ii) Characteristics and size of bark particles formed.

(iii) Relative densities of the bark and wood.

WATER POLLUTION IN THE SAWMILLING INDUSTRY

R. S. Johnstone

Summary

A system of reducing water pollution in the sawmilling industry is presented based on a method of treatment applied to a sawmill in New South Wales. A considerable improvement in effluent quality was obtained.

Introduction

Sawmilling and preservation plants will undoubtedly come under a closer scrutiny in the next few years with regard to the effects of their liquid effluents on the environment.

Water pollution is a part of environmental contamination that is of special significance because of its predictable mobility along a set path and because of this, the relative ease of tracing the pollution back to its source.

Apart from their moral obligations to minimise the quantity and improve the quality of liquid effluents, N.S.W. sawmillers now need to comply with legislation under the Clean Waters Act, 1970, gazetted in November, 1972.

This Act sets limits on any liquid outflow at the point where that liquid leaves the property of the sawmiller.

This paper reports a case history of attempts to improve the quality of a sawmill effluent in order to comply with this Act.

Method

The original investigation was initiated in September, 1971 following a complaint from a local government authority that surface liquid from the sawmill was contaminating a creek.

Effluent within the sawmill boundaries was carried by a natural watercourse into which also flowed general run-off from the property and some storm-water drainage.

The sources of contamination of the effluent stream appeared to be:

(1) Liquid from the reconditioner

(2) Borax spillover from the immunisation tank

(3) Boiler blow-down effluent

(4) Leachate from stacks of timber immunised with boron.

The quantity of effluent from each source was estimated at:

(1) 2,500 litres per day)

(2) variable) total 3,200 litres per day

(3) 560 litres per day)

(4) dependent on rainfall

The contaminating substances contributing towards the composition of the effluent appeared to be primarily wood extractives and boron.

Samples were taken at several positions between the effluent sources and the creek outside the company boundary in November, 1971. Determinations of pH, boron, non-filterable residues and total solids were made. Results for the sampling positions 1 and 2 are reported in Table 1.

As a result of this sampling operation, a settling pond was constructed to retain the effluents for treatment, and the immunising tank run-off diverted into it.

Slaked lime was added at a tank prior to discharge into the pond and a retaining wall of permeable soil constructed to filter off precipitated solid material. A catchment drain trapped the treated effluent which then flowed into a natural watercourse. A diagrammatic layout is shown in Figure 1.

For a three months' period (March-May, 1974) samples were taken weekly at several points along the effluent stream and tested for pH, boron, biochemical oxygen demand, non-filterable residues and total solids.

	pH		boron (mg/l)		biochemical oxygen demand (mg/l)		non-filterable residues (mg/l)		total solids (mg/l)	
	1	2	1	2	1	2	1	2	1	2
November 1971	6.5	5.0	5.1	0.0	-	-	100	400	1000	3600
May 1974	8.0	8.2	0.88	5.5	1.0	5.5	44	274	292	924

TABLE 1. Effluent quality at November, 1971 and May, 1974.

Flow rates, temperature, and pH measurements were recorded daily over this period by a mill operative.

Results have been graphed (Figure 2) to show the difference between the effluent samples at two positions before treatment (November, 1971) and after the installation of a treatment system (May, 1974). A comparison has been made with the regulations under the Clean Waters Act, 1970.

Discussion

The addition of slaked lime at the settling pond produced the following results:

(1) Increased the pH to an acceptable level

(2) Reduced the boron content by precipitation, presumably as calcium borate

(3) Precipitated some of the polyphenolic extractives

(4) Partially decolourised the solution.

The effect of repetitive condensation of steam on stripped hardwood boards is to produce a dark-coloured leachate of low pH. The reconditioner effluent would consist of a varying percentage of hot-water extractives - primarily polyphenolic substances - and including tannins, carbohydrates and organic acids.

Residual liquid from the boiler would include mainly flocculated particles (or possibly flocculating agents) and would tend to contain a fairly high filterable residue.

The area surrounding the immunising plant (in this case a 'hot and cold' bath operation) contained a high boron concentration plus organic extractives leached out at the elevated temperatures of the treating solution.

The drying yard was a source of leached boron (no stack covers being provided), the amount of leachate being directly dependent upon rainfall.

A dosage rate of about 1 kg slaked lime per 100 litres of effluent produced the results contained in this paper. A more refined technique would be to monitor the pH and adjust the lime dosage accordingly.

The solution to problems of water pollution in the sawmilling industry require individual assessment since the problems depend on species, throughput, the type of processing plants, terrain, and location of the sawmill or preservation plant. Rainfall may also be a contributory factor.

A relatively simple procedure, however, along the lines suggested here should enable the sawmiller to maintain the quality of his effluent to within the statutory requirements.

WOOD WASTE COMBUSTION

P. Y. H. Fung, E. P. Lhuede and R. M. Liversidge

Part I - Incineration of sawmill residues - the changing scene
Part II - Current methods of heat recovery
Part III - Value of timber mill residues as fuel

PART I - INCINERATION OF SAWMILL RESIDUES - THE CHANGING SCENE

Obviously utilization of sawmill residue should be the ultimate aim of the industry with incineration regarded purely as a last resort. However, despite increased outlets for previously unusable material, particularly where solids can be converted and sold in chip form, there is still likely to remain in most mills some residue which cannot be used and must be either dumped or burnt. In view of proposed chip outlets based on the use of solid sawmill residue, certain aspects relating to sawmill waste disposal need to be considered.

At present many sawmills are satisfactorily disposing of their total mill waste (solids and sawdust) in "teepee" type burners but, if the proposed chipping outlets come to fruition, then the waste disposal task at the participating mills will be markedly changed. From general comments made recently by sawmillers, the impression is gained that the burning of fine waste in a "teepee" type burner, without the addition of solid waste, could result in excessive smoking. A further complication is that if the burner was sized correctly initially to handle the total mill waste, then it may be grossly underloaded when handling sawdust and chipper waste only. Such underloading could again contribute to poor performance.

While it might be possible to modify an existing "total mill waste" teepee burner to handle fine wastes only, this seems unlikely and it is probable that some form of refractory lined unit could be required, possibly together with a hopper to control the feed rate.

The CSIRO prototype burner in Hobart (based on the McCashney incinerator) is handling this type of waste satisfactorily and there may be other refractory lined units suitable for the purpose. The CSIRO burner was originally designed in response to a requirement for a total mill waste burner but, in the light of changing conditions in the industry, this raises an important question as to the most pressing need in the wood waste disposal area.

A rapidly decreasing number of mills have to dispose of their total mill waste and the disposal of sawdust and chipper waste is a more likely requirement to be met.

Further, with the need to debark material which is to be chipped and the possible installation of mechanical debarkers in the larger mills, the problem of efficient bark disposal is becoming increasingly important. Little work has been done to date in Australia on the disposal of barks, particularly those of a stringy nature which present special handling problems.

Work is being carried out by the Division of Building Research on the problem of bark disposal (and, of course, utilization).

Additionally, a new concept of burner intended for incineration and/or heat generation is currently in the design stage and it is hoped that a prototype of this unit might be built. This is principally intended to handle small particle wastes.

PART II - CURRENT METHODS OF HEAT RECOVERY

Wood is a suitable fuel for heat generation, particularly if it is a waste product produced in saw mills with large heat requirements. Table 1 shows the heat requirements of various seasoning operations and the corresponding amount of wood (at approx. 70% moisture content) required to supply the heat.

There are a number of wood fired heat generators currently being used or available to the industry. The most common is the traditional steam boiler using a step grate furnace, although other systems with a flat grate, or centrifugal (McCashney type) combustion chamber have been employed. The actual steam boilers (i.e. the primary heat exchanger) range from discarded locomotive boilers to dry back return tube types.

Generally, it is conceded that pressure fired boilers are expensive to operate since they require certificated boiler attendants; hence there is an incentive to move away from direct steam raising.

Hot water, hot oil and hot air are the other types of heating media currently used to transfer the heat from the combustor to the area of use, (e.g. the seasoning kiln). A number of commercial furnaces designed for these heating media are now available, some of which are highly automated being directly controlled by the plant demand and nominally require no attendants. However, it should be pointed out that such automated plants may have high capital costs.

With the four different types of heating media; steam, hot water, hot oil and hot air, the choice of the working fluid depends on:

(a) The fluid properties, e.g. the maximum working temperatures, and whether a gas or liquid.

(b) Capital cost and depreciation of equipment such as boilers, heat exchangers, pumps, blowers and ducting.

(c) Operating costs, such as labour and electrical power.

Table 2 lists the working properties of the different heating media that determine their suitability for a particular application.

These properties also influence the capital and operating costs of heat exchangers, pumps and blowers.

There would appear to be a requirement to develop a rational basis for selecting the most suitable system for a particular requirement.

TABLE 1. Wood fuel requirements for seasoning operations

Installation	Capacity (cu.metres)	Heat Required*	Quantity of Wood Req'd (tonnes/hr) (60% effic.)
Predryer	850	4.2 mill kJ/hr	0.41
Hardwood Kiln	140	4 mill kJ/hr (heating up)	0.39
		1.1 mill kJ/hr (mid-cycle)	0.10
Softwood Kiln	140	21 mill kJ/hr (heating up)	2.04
		5.3 mill kJ/hr (mid-cycle)	0.51
Reconditioner	28	1100 Kg steam/hr (heating up)	0.26
		500 Kg/hr (mid-cycle)	0.18

TABLE 2. Comparison of different heating media

	Steam	Water	Oil	Air
Operating Temps.	170°C (800 KPa)	100°C	290°C	320°C
Heat Transfer Coefficient (KJ/hr m^2 °C)	31,000	14,300	1600	100
Heat Capacity (KJ/Kg °C)	5000	4.2	2.4	1.4
Specific Volume (m^3/Kg)	0.25 (800 KPa) 1.25 (140 KPa)	0.001	0.0012	1.68

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PART III - VALUE OF TIMBER MILL RESIDUES AS FUEL

As a strong and developing market exists for wood chip the main interest under this heading is to establish some scale of value for using saw dust as a fuel. The case of a mill producing 47 m^3 per day of sawn timber with an accompanying production of 14 tonne/day of sawdust has been considered.

When used as a fuel, in the mill, conveying to a hopper, provision of the hopper, and feeding from the hopper may incur costs over and above those which would exist if the sawdust was incinerated directly with no heat recovery; the steam raising plant itself may also prove more costly than either a conventional oil or coal fired installation.

The minimum cost of using sawdust as a fuel with no transport charges, and no extra cost for the boiler has been assessed as $1.00/tonne, and for a recoverable heat value of 6100 kJ/kg (2700 BTU/lb) the cost per megajoule (mJ) is 0.016 cents. (The costing is based on a capital outlay of $10,000, interest charges of 12% on a decreasing capital repayable over 10 years ($0.485/tonne), and maintenance/operating costs of $2000/year ($0.57/tonne)).

The figure of 0.016 cents/mJ, for particular installations could (conceivably) be doubled so that a general level of cost for burning in the mill of 0.02 to 0.04¢/mJ may be reasonable.

Where the miller sells the sawdust he will make a charge to cover his internal and capital costs and his selling price may be 0.032¢/mJ or about $2/tonne (15% on capital).

Transport charges have been assumed as 5¢/tonne kilometer or 0.0008¢/mJ.kM.

Using these values a comparison can be made with some conventional fuels or energy systems used simply as a source of heat at relevant combustion efficiencies (C.E.'s). The comparisons have been based on transport to two centres (viz. Armidale, N.S.W., Bairnsdale, Vic.) where the bulk cartage of timber mill residues would be over moderate distances and where a case might be made for using the fuel in a large scale (e.g. district heating) scheme.

TABLE 3. A Comparison of Fuel Costs

Fuel	Basis for Cost	Cost of Energy ¢/megajoule (¢/mJ)
Distillate Fuel Oil	Delivered to Bairnsdale $78.3/tonne ($69 ex Melb) Dec 1974 C.E.* 0.85	0.22
	Delivered to Armidale $82.7/tonne ($69 ex Sydney) Dec 1974	0.23
Black Coal	Delivered to Tamworth $13/tonne 12% ash, Oct 1974 C.E.* 0.80	0.05
Briquettes	Delivered to Bairnsdale $13/tonne (ex Latrobe Valley) C.E. 0.80 (Values estimated)	0.074
Electricity	2.5¢/kW.Hr. (Utilization at 0.95)	0.72
Natural Gas	Min. Victorian Rates, C.E. 0.90	0.093- 0.11
Saw Dust	Use on Site C.E. 0.60	0.02 - 0.04
	50 kM cartage @ 5¢/tonne kM	0.08 (i.e. 0.04+0.04)
	100 kM cartage	0.12
	200 kM cartage	0.20
	Deliver to Armidale (Av. 200 kM)	0.20
	Deliver to Bairnsdale (Av. 70 kM)	0.096
Chip	At $12/tonne (150 kM cartage)	0.20

* C.E. is the efficiency of combustion or utilization.

For cartage distances between 50 and 100 kM, sawdust, when burnt in a simple existing boiler installation, has a competitive value as a base fuel. The comparison with existing fuels should be continually under review and the resource availability in various States needs to be established.

TREATMENT OF RECONDITIONER EFFLUENT

P. Y. H. Fung

Introduction

Most timber mills producing seasoned timber have reconditioners which discharge a black effluent particularly when eucalypt timbers are reconditioned. During the reconditioning the combined effect of heat and steam extracts volatile oils, organic acids, polysaccharides and tannins from the timber and when this condensate comes in contact with iron objects such as rails and door fittings, the acidic solution corrodes the metal. The dissolved iron is oxidized by air to ferric ions which react with the tannins to form an intensely coloured blue-black iron tanning complex. Often, a creek running near a mill is blackened by the effluent and it is because of this disposal problem, studies were undertaken to find a method of treatment.

Treatment Techniques

Since the tannins are the compounds responsible for the formation of the black complex, treatment would involve their removal. The tannins can be precipitated by a number of reagents such as gelatine, bromine water, acetates of lead and copper, stannous chloride, tartar emetic and mineral acids. However, the compound found to be the most practical and effective was calcium hydroxide. This neutralizes the acidic effluent, decomposes the iron tannate and precipitates out calcium tannate and ferric hydroxide. The precipitate formed is gelatinous and requires genetic agitation for a period of about 15 minutes or longer to floculate into a precipitate of reasonable separating properties. Mean sedimentation rate was measured and above the critical settling point it was found to be 0.37 m/hr. Specific filtration resistance of the precipitate was 34000 hr^2/kg.

Treatment of the effluent can be carried out either batchwise or continuously. In the batchwise operation, the effluent is collected over one or more reconditioning cycles, slake lime is added and the mixture is stirred for a period of more than 15 min. The precipitate is then allowed to settle overnight and the slurry filtered in a sand bed filter. The filters can be cleaned by allowing the cake to dry whereby it shrinks and cracks, thus allowing the solids to be easily shovelled off the sand.

Commercial Plants

Since a large filter would be required to handle the quantity of slurry in one batch before the next cycle of operations, a continuous operation can alternatively be used where a compact treatment plant is desired. The effluent discharges into a stirred tank, slake lime is continuously added and the slurry then overflows into a fabric bag filter which collects the precipitate. The filter can be cleaned by turning out the bag.

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The sizes of the various units for a typical size mill with a reconditioner capacity of 25 m^3 is shown in the Table.

Treatment Plant Sizes

Reconditioner Capacity = 25 m^3

Effluent Volume = 1.5 m^3

Wt. of slake lime required per charge = 2 Kg

	Batch System	Continuous System
Mixing Tank Size	3.5 m^3 1.5 m dia. x 2 m high	0.1 m^3
Type of Filter	0.5 mm sand, 0.3 m depth, supported on graded gravel bed laid over agricultural drains	Fabric bag filter with Air Permeability 0.33 m^3/ min/m^2 at 125 Pa
Filter Size	12 m^2 Area x 0.7 m deep	1.5 m dia x 1.5 m deep
Cleaning Cycle	After 5 charges	After 3 charges

Thus treatment of reconditioner effluent by neutralization of the organic acids and precipitation of the tannins with slake lime followed by filtration is an effective method of overcoming the effluent disposal problem.

SAWMILL NOISE AND OPERATOR PROTECTION

E. P. Lhuede

1. Noise levels in saw mills

High sound pressure levels have been common in a number of manufacturing industries and are recognized as an industrial hazard; the Australian timber milling industry is no exception and data relating to specific items of conversion equipment is available.

While the tabulation of such data may point to the existence of a hazardous situation, it is of limited value without reference to a number of additional related factors; these need to be specified in order to determine either a risk of damage to the hearing of operators or permissible times of exposure. The more important factors may be listed as follows:-

(a) The actual "on time" for which the noise level exists.
(b) The background, or continuous noise level in the mill.
(c) The position of the operator relative to the noise source.
(d) The sound pressure level spectrum associated with the noise.

To obtain information that would enable an assessment of the significance of noise levels in saw mills to be made, a series of measurements of dBA levels and sound level spectra were taken in timber mills in N.S.W., Victoria and Tasmania on a variety of conversion plant and a tabulation (Table 1) for some typical situations has been prepared. The figures for exposure times have been obtained from other work.

Some comments on the data presented in Table 1 warrant comment:

(a) The duration of the noise levels associated with the primary conversion processes (breaking down and resawing) vary between 20% and 30% of the total operating time.

(b) Some band saws produce a "no-cutting" noise level of the same value as produced when cutting. Such saws tend to increase the mill background noise level.

(c) Operating enclosures have been built adjacent to breaking down saws primarily for the physical (i.e. other than hearing) protection of the operator. They can provide a significant attenuation of the noise level at the operator.

(d) The industry has developed machine enclosures for isolating planers and moulders but the success of the designs has been variable.

(e) One of the highest noise levels produced in a mill is due to the exhausting of air from a number of pneumatically actuated cylinders used in the conveying and handling of timber.

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2. Significance of Noise Levels in Saw Mills

There appear to be two criteria for assessing the significance of a given combination of noise levels and exposure times and while it is not proposed to discuss the rationale of either system a typical situation is postulated and is assessed by the two methods.

The "typical" situation based on Table 1 is taken as:

(i) A circular resaw with a cutting time of 20 secs/min
(ii) Noise level adjacent to an operator while cutting 100 dBA
(iii) Air exhaust noise 3 secs/min
(iv) Noise level of exhaust air 105 dBA
(v) Continuous mill background 88 dBA

The first method of assessing these conditions is according to the I.S.O. Recommendation R1999 of May, 1971 and establishes a continuous equivalent sound level of 97 dBA. For this level a risk of impairment for conversational speech of 9%, 23% and 30% (approx.) is quoted for 5, 10 and 15 years of exposure respectively. The method does not deal directly with permissible time of exposure but defines impairment in terms of a loss in hearing capability at stated frequencies.

The second method of assessment uses the U.S. Department of Labour's revised "O.S.H.A." noise regulations (1973) which enables a figure for a "daily dose" to be determined. This figure should not exceed unity, and the value obtained of 2.6 indicates that a daily exposure time of about 3.0 hours is permissible. The purpose of this standard is said to be to minimize the risk of permanent hearing damage, presumably, to all people exposed.

It is apparent that using either basis of assessment the environment around saw machinery can represent a hazardous situation as regards the possibility of loss of hearing. However, it should be pointed out that neither system predicts a given (or any) loss of hearing for a particular individual or situation; there may be some significance in the comments of particular sawmillers, with years of exposure, that their hearing is satisfactory. Local legislation, which is still generally in the formulative stage, may not accord directly with either of the two methods of assessment discussed.

3. Operator Protection

The use of ear muffs or ear plugs is probably the simplest and most effective method of protecting the hearing of operators in high noise level situations.

These devices are neither widely used nor readily accepted by saw mill workers and the reasons for their rejection requires future consideration.

There are alternative methods of protection which have been documented in relevant texts and appear to be applicable to many situations in the sawmill; screening of operators appears very appropriate. Enclosures adjacent to breaking down saws have provided reductions of 10 to 25 dBA depending on the degree of enclosure.

There are a large number of sawmill operators throughout the industry working at fixed control consoles, who, after due consideration to their necessary freedom of movements could be given effective acoustic shielding by partial enclosures.

The greatest problem that presents itself is the protection of operators of circular saw breast benches which are still widely used; screening of the operators adjacent to the bench might be considered and the possibility needs to be studied. Overseas workers have investigated the slotting of circular saws, the use of wide collars and the insulation of the saw bench as possible methods of attenuating the noise produced by these saws; the proposal to insulate the saw bench may be the most likely to be accepted by saw operators.

The enclosure of saws and dressing machines is a method of protecting operators by controlling the sound as its source. This technique has been adopted by a number of sawmillers with varying success for reducing the noise levels associated with planers, moulders, etc., and overseas designs for these enclosures are available. Such finishing machines produce noise levels from 105-114 dBA and good designs can reduce the level by 20 dBA; with less satisfactory designs the reduction may be 10-12 dBA.

The efficiency of a boxing-in arrangement will be largely dependent on the percentage of area left un-enclosed for working the machine; for this reason the enclosure of bandsaws and multi-saw board edgers may be only marginally successful, but nonetheless useful. For instance, a poorly fitted 18 mm thick particle board cover can reduce the noise level at the rear of a 183 cm dia. band saw by 8 dBA.

4. Machine Design

The high noise levels associated with some band saws is a subject requiring investigation and the design of a reliable low pressure drop air exhaust muffler may be considered.

5. Conclusion

Noise levels existing around machinery in timber mills may result in loss of hearing for conversational speech for some operators. The incidence of this damage should be identified for the local industry.

Apart from supplying and encouraging the wearing of ear muffs, there are a number of methods open to the sawmiller, at apparently reasonable cost, for protecting operators at fixed controls.

A need exists to rationalize the designs of machine enclosures currently being installed by Australian sawmillers.

Acknowledgement

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TABLE 1. TYPICAL NOISE LEVELS FOR SAW MILL CONVERSION EQUIPMENT, MILL BACKGROUND NOISE LEVELS AND EXPOSURE TIMES

Saw or Equipment with Hardwoods		Background in Mill (dBA)	Distance of Operator from Source (metres)	Adjacent to Operator in an unprotected area		Noise level at Normal Operator Position (cutting) (dBA)	Number of Cuts (Times) per minute	Cutting or "On Time" secs/min
				Noise Level Cutting (dBA)	Noise Level Idle (dBA)			
Band Saw Head Rig	A	92-94	2.0	93.5	94	84-85 (protected)	--	20 (assumed)
	B	92-96	2.0	101	101.5-102	94-96 (semi-protected)	1.5-2.0	18-24
	C	90-93	2.0	94-96	90	90 (open)	0.9	15
Circular Saw Head Rig	A	94-96	7.0	94	93-94	88-92 (semi-protected)	--	20 (assumed)
	B	85-94	1.5	98-100	90-94	98-100 (open)	1.8	27
	C	84	2.0-3.0	100-102	84-90	100-102 (open)	1.4	25
Circular Saw & Pony Carriage		88	5.0	94-96	88-90	94-96	2.0	18
Band ReSaw, 4-Man		85-90	1.5	98-100	94-95	94-95	5-7	20-30
Circular Re Saw, 4-Man		85-92	1.0	102-105	94	102-105	3.6	15
		85-87	1.0	96-103	88	96-103	3.3	16
Planer (Open)		95	2.0	104-108	96	102	-	30 (assumed)
Moulder (Enclosed)		80-81	Outside Enclosure	107-108	-	86	-	40 (assumed)
Planer-Moulder (Enclosed)		85-87	Outside Enclosure	104-106	96	89-92	-	40 (assumed)
Air Exhausts		-	3.0-5.0	-	-	102-112	2.0 (approx.)	2

RECOMMENDATIONS FOR FUTURE RESEARCH IN WOOD CUTTING

W. M. McKenzie

Importance of wood cutting research in the Australian context

1. Costs of buying, operating and maintaining mechanical processing machinery, and of wasted raw material, comprise a large fraction of total processing costs, and even a small increase in efficiency of cutting operations spread over the wood-using industry would be valuable.

2. Residues comprise about half of the sawmill log, and could be much more valuable if reduced to a particle of convenient size and shape, by efficient machinery.

3. Cutting technology is important in the above areas, and research in Australia and elsewhere has provided a base for improvement throughout the wood-using industries.

4. However, I believe that, currently in Australia, the greatest scope for improvement in wood cutting efficiency lies in the management area. More professional expertise is required to direct the purchase, installation, operation, maintenance and retirement of processing machinery, to approach optimum economy. Much more attention should be given to selection and training of operatives and maintenance personnel, particularly in relation to sawing.

5. A scheme for technical training of saw doctors is urgently required, especially if excessive costs of introducing band saws is to be avoided

6. It has been asserted for agriculture, and can be equally strongly asserted for wood industries, that the low level of prosperity can be traced to the generally low levels of education of people working in these industries.

7. Considering technical research, the most promising approach for increasing sawing efficiency appears to be to increase saw stability, and hence accuracy, kerf efficiency, and power efficiency. Temperature sensing equipment now available in DBR would be of great value in this area.

8. Another economically valuable line of work would be to investigate the use of a thin (1 μm) hard coating on the clearance faces of cutting edges, which produces a self-sharpening effect, and hence increases sharpening life. The key problem is the bonding of such a film strongly to the body material of the tooth or cutter.

9. In the area of residue utilization, the need is for a machine capable of economically removing a roughly match-shaped particle of unspecified size from the outside of a log ahead of sawing or from sawing residues I believe that such particles could be orientated in a block or slab of great potential value.

10. The research mentioned above should only be undertaken as a cooperative venture in conjunction with industry, which must have a stake in the work and be involved at all stages. Only then is there a prospect of smooth and rapid application of results.

COMPUTER SIMULATION OF SAWING

Jack E. Opie

The aim of this work is to develop a computer-based model for simulating the conversion of stems into sawn timber. Such a model would greatly facilitate the valuation of timber stands and the definition of economically efficient silvicultural regimes and sawing patterns. The simulation of sawn conversion promises several advantages over the traditional method which is based directly on sawmill studies, and which is costly, time-consuming, and very restrictive for the examination of alternative sawing patterns.

The technique of computer simulation of sawing requires detailed mapping of stem shape and all stem defects. This information is used to prepare maps of the board surfaces yielded by a given sawing pattern. From these maps the simulated boards are then graded into product classes by reference to any specified set of grading rules.

Models developed elsewhere (and principally in the U.S.A.) have been based on the sawing of sample stems into boards, followed by the recording of defects on the board faces by means of cartesian co-ordinates. This technique appears to be inadequate for eucalypt sawlogs where small defects (e.g. kino veins one to four mm wide, and located around the growth rings) may be important determinants of log grade.

An alternative technique developed at the School of Forestry, University of Melbourne, by Mr. H. Dowden for an anatomical study of kino veins has been extended to deal with this situation. The technique is based on peeling. In our work to date, described below, we have confined our attention to *Pinus radiata*, which offers few complications.

In order to define its shape accurately, the standing tree is measured and marked conspicuously at various heights, and is photographed from several points. The tree is then felled and cut into bolts one metre long. Each bolt is peeled into thin (2.54 mm) rotary veneer. The veneer sheets are photographed, and the photographs are mapped by means of a digitizer, which records the shape and size of each sheet and the position, shape, size and type of each defect on the sheet. The core remaining after peeling (diameter about 152 mm) is dissected by cross-cutting, usually with three to four cuts at each node. The core sections are also photographed and mapped. The digital records of the shape and defects of the veneer sheets are then converted (i.e. "rolled up") to form, together with the digital records of the core, a three-dimensional map of the bolt. The maps of all bolts are then assembled by reference to the specifications of tree shape to form a map of the entire stem.

The model has been developed to the stage of "rolling-up" the digital records of the veneer sheets. The three most challenging problems that remain are as follows:

1. To develop an efficient method for grading the results of the simulated sawing. Such a method should be flexible, to cope with changes in grading rules.

2. To extend the model to hardwoods, which are complicated by (among other things) the marked effects of growth stresses. Our preliminary investigations into the simulation of distortions such as spring suggest that it would be inefficient to approach this by manipulating the map arrays. The dual approach, of transforming real-world straight cuts to curves, is currently favoured.

3. To determine the form of the trade-off between accuracy in defect mapping and accuracy in simulation. The highly detailed mapping of defect described above is very costly, and could not be justified for some types of study such as the valuation of extensive timber stands. It may be that for such studies a few cross-sections of each sample tree would suffice. The trade-off between input and output could be defined by operating the simulation model with progressive deletion of input data.

Acknowledgement

The main worker on this project has been Mr. I. S. Thompson, formerly of the Research Branch, Forests Commission, Victoria, and now with Australian Newsprint Mills Ltd., Boyer, Tasmania.

WEIGHT AND BARK FACTORS FOR THE MEASUREMENT OF PULPWOOD

J. P. Wright and G. Waugh

Weighbridge weighing is a common method of measurement of pulpwood. However, it is often necessary to convert the weight so determined to volume for accounting purposes or to relate actual production to estimated forest yield, which is nearly always expressed in volumetric terms. It is therefore necessary to establish relationships between the weight of pulpwood as delivered and the true volume of the wood.

Recent work in Victoria has examined volume/weight factors for various types of pulpwood. This work has involved studies of billet pulpwood of several different species, both hardwood (ash and mixed species eucalypts) and softwood (radiata pine), delivered to a number of different pulp or board mills. It has also involved studies of sawmill residue, delivered as either chips or slabs. In situations where wood is delivered in an unbarked condition, bark quantities have also been estimated.

Studies have involved the following types of wood:

radiata pine	-	unbarked billets
	-	sawmill slabs (barked)
ash eucalypts	-	barked billets
	-	sawmill chips (barked)
mixed species eucalypts	-	unbarked billets
	-	barked billets
	-	sawmill slabs (unbarked)

Average volume/weight (V/W) and bark relationships for these various types of wood are summarised in Table 1. These relationships were determined on wood as it is delivered at the mill, and represent the condition of the wood at the point of sale. General trends emerging from these studies are as follows:

Radiata pine

Radiata pine billet wood averaged about 0.95 m^3/tonne. Although the two studies examining this factor varied somewhat, both indicated that this V/W factor is not significantly affected by locality. This is surprising in view of a generally accepted trend for higher wood density on poorer sites. The increased wood density on poorer sites appears to be compensated for by lower moisture content of the wood and a higher proportion of bark, resulting in a V/W factor for green unbarked wood which is similar for wood from different localities and with differing growth conditions. Likewise the age of trees and position within the tree has little effect on this V/W factor.

Bark weight averaged about 13% of total overbark weight, but this factor showed considerable variation, with values of up to 16% on poorer sites.

Sawmill slabs averaged just under 1.0 m^3/tonne. This factor showed a high level of variability, probably associated with differences in the intervals between tree felling, sawing of the log, and delivery of slabs. Surprisingly, seasonal differences were not great, summer values being about 10% higher than winter values.

Ash eucalypts

Billet pulpwood of ash eucalypts, mainly *E. regnans*, averaged just under 1.0 m^3/tonne. Seasonal differences were surprisingly small, average values for summer and winter differing by less than 5%. Likewise age of the trees (i.e. whether from regrowth or mature stands) had little effect on the V/W relationship. The lack of seasonal effect in particular is of major significance, since it means that one V/W conversion factor can be used throughout the year.

Sawmill chips were lighter than billets, averaging just over 1.1 m^3/ tonne. As for radiata pine sawmill residue, variability is high, but again seasonal trends are not important.

Mixed species eucalypts

Two separate studies on mixed species billet pulpwood were made, on wood from two different localities. V/W factors were similar in each case and averaged a little over 0.9 m^3/tonne. Mixed species pulpwood was therefore about 10% heavier than that of ash eucalypts. Once again, seasonal differences were found to be unimportant.

In one of these studies (involving wood from the Daylesford-Trentham area) separate V/W estimates were made for three distinct species groups - stringybarks, peppermints and gums. No differences in the V/W factor were apparent, but the weight of bark was slightly lower for the stringybark wood. Overall, bark averaged about 17% of the total over-bark weight.

Sawmill slabs also averaged a little over 0.9 m^3/tonne, again with high variability but with little seasonal trend. Sawmill slabs delivered in an unbarked condition contained a high proportion of bark, averaging nearly one quarter of the overbark weight.

Discussion

These studies of weight and bark relationships provide objective and unbiased estimates of conversion factors for the determination of wood volume from weighbridge weights for a number of different categories of pulpwood. They indicate that, for both billet wood and sawmill residue, single conversion factors are feasible for each of the main species groups utilized as pulpwood in Victoria, irrespective of the source of the wood or the season. Further work is required to:

(i) confirm the V/W relationship for radiata pine billet wood, where results to date are somewhat variable,

(ii) provide a V/W factor for radiata pine sawmill residue in chip form,

(iii) provide V/W factors for wood delivered in log form.

This latter factor will be required as harvesting methods change in response to increasing mechanization in the forest and greater integration of conversion plants.

TABLE 1. Volume/weight and bark relationships for pulpwood in Victoria

Species	Type of wood	Location	Volume/weight (m^3/tonne)	Percent bark (overbark weight basis)
Radiata pine	Unbarked billets (Study No. 1)	Ballarat	.992*	
" "	Unbarked billets (Study No. 2)	Ballarat	.900*	13
" "	Sawmill slabs (barked)	Ballarat	.986	
Ash eucalypts	Barked billets	Central Highlands Gippsland	.988	
" "	Sawmill chips	" "	1.121	
Mixed species eucalypts	Unbarked billets	Daylesford-Trentham	.928	17
	Barked billets	Gippsland	.898	
" "	Sawmill slabs (unbarked)	Daylesford-Trentham	.922	24

* The V/W relationship in these studies is determined on the basis of the weight of wood plus bark. In all other cases V/W is based on weight of wood only.

MEASUREMENT OF FOREST PRODUCE

J. P. Wright

Measurement of wood is an essential basis for sales, for the payment of royalty, logging and transport, and for inventory control. However, it can be a costly operation and adds nothing to the value of the product. For this reason the method of measurement used in any particular situation should be carefully evaluated, and based on the requirements of both the seller and the buyer, the value of the product, and a predetermined level of accuracy and precision. The method chosen must also integrate closely with the method of harvesting and conversion.

Many methods of wood measurement are currently employed in the Australian forest industries, and there are a number of developments which could in future markedly alter the current measurement procedures. This paper lists the possible measurement procedures which could be employed, indicates those methods currently in use, and outlines possible future developments. A list of criteria is presented which can be used in evaluating any particular measurement system for any particular situation.

METHODS OF WOOD MEASUREMENT

Measurement must define the quantity of wood, and may also be required to define its size and quality characteristics. As a general rule, the higher the intrinsic value of the product, the more precise and comprehensive is the measurement required. Thus, for pulpwood, total fibre quantity is the main requirement, whereas for sawlogs, log dimensions and quality characteristics are also important.

Quantity is usually expressed in terms of volume, but may also be expressed in terms of mass or number of pieces of a given size. With respect to determination of volume, methods of wood measurement can be divided into two broad classes, direct and indirect.

1. Direct Measurement

This involves actual measurement of the volume of wood or its dimensions. Measurement or assessment of quality characteristics may be included if required.

(i) Volume. The only way to directly measure wood volumes is by displacement. However, this is generally not practicable for commercial use.

(ii) Dimensions. Measurement of dimensions and subsequent calculation of volume is the most common method used for sawlogs, peeler logs and poles; in fact for most forest products apart from industrial wood (pulpwood), firewood and bush sawn or split timbers sold on a piece basis. Measurements include length and girth or diameter at one or both ends or at midlog. Measurement of dimensions is simple and straightforward, but can be very costly, especially if piece size is small.

Measurement of dimensions can be made at the stump, at log landings, on truck or in the mill yard, depending largely on the method of harvesting. Measurement in the forest or on truck is usually done manually, while measurement in the mill may be done manually or automatically. Recent development of electronic measuring equipment promises to bring major changes in log measurement. The approach is based on optical/electronic techniques for measuring both diameter and length of a log, combined with electronic computation of log volume. Facilities for data sorting and storage, printing, and control of log sorting or sawmill set-works may be integrated with the measurement equipment.

2. Indirect Measurement

This involves measurement of certain characteristics of logs or trees which are then related to wood volume by some form of conversion factor.

(i) Mass. Measurement of mass using a weighbridge is commonly used for pulpwood, but is less commonly used to measure sawlogs or veneer logs, where size and quality are important, and where the quantity of wood is often not sufficient to warrant the capital cost of a weighbridge.

Weighing is quick and simple, but may be costly if throughput of the weighbridge is low.

Conversion of mass to volume is influenced by a number of different but often inter-related properties of the wood, the most important of which are moisture content, basic density and the presence of extractives. These properties may vary with the species and age of trees, and with growth rate, locality, season of felling and time between felling and weighing.

(ii) Stack Volume. This method is often used for pulpwood or firewood where information on size and dimension is not particularly important. It is a quick and simple method, but is usually only employed when wood is cut to more or less uniform size, e.g., billets or chips, which can be stacked in a regular way so that the dimensions of the stack can be measured. The stack volume/true volume relationship may vary very widely depending on the size and shape of wood pieces (e.g., length of billets, size of chips) or the method or preparation.

Measurement of stack dimensions may be made manually or indirectly, by means of photographic or electronic images.

(iii) Measurement of Standing Trees. The measurement of standing trees is the basis of forest inventory, but is sometimes also used as a basis of sales. Its use depends on the accuracy required in the determination of volume, and the accuracy with which the product mix and the amount of internal defect can be assessed.

(iv) Estimation From Product Yields. The quantity of the converted product can be used to estimate log volume. However this method tends to encourage wasteful conversion practices and is not commonly used.

THE FUTURE

The current methods of measurement have evolved over many years and in most cases are well suited to the product and to the method of harvesting. However, because of changes in the methods of harvesting and the need to reduce costs there is a need to critically evaluate current and possible new methods with a view to cheaper and more efficient measurement. One important aspect is a need to reduce the labour involved in measurement. Labour, particularly labour employed in the forest, is becoming scarcer and more costly and future methods must look increasingly to automation of measuring procedures, combined where possible with automatic accounting procedures.

In evaluating measuring procedures the following criteria require examination. Any proposed measurement system must be

1. uniform - capable of consistent application
2. economic - related to value of the product
3. simple - readily understood, particularly by the measurer
4. objective - subjective judgements replaced by objective measurement wherever possible
5. accurate
6. precise - capable of reproduction within specified limits
7. stable - not subject to frequent change
8. complete - including all size or quality parameters required for the particular product
9. additive - measurement of different products in the same units wherever possible.

The most promising techniques available at this stage for improving measurement and lowering costs appear to be:

1. The use of mass for determining the volume of sawlogs

Weighting is not generally used for sawlogs because of the need to determine log size and quality. Several methods for estimating log size and quality in conjunction with weighing are being investigated, and used in some instances. These include the detailed measurement and quality assessment of selected sample loads, and the estimation of easily determined load parameters, such as total length of logs on a load, for the determination of average piece size.

2. Automatic measurement of sawlogs

There are a number of automatic measuring devices available overseas, but none are yet operating in Australia. Although the capital cost is high (commissioned costs range from about $30,000 to over $60,000) this approach has the advantage of low labour cost, accuracy, reliability, automatic volume calculation and accounting, and possible integration with sawmill equipment. This method is likely to become common in future, particularly in the large, highly mechanized mills of the softwood sawmilling industry.

One important aspect concerning the possible use of automatic measurement, identified during recent evaluation of this approach for a large integrated sawmill/pulpmill in Victoria, is the requirement of the seller that all logs suitable for the production of sawn timber are sold as sawlogs. With a device measuring actual mill input there could be a tendency for smaller or lower grade sawlogs to be diverted to the pulpmill, and brought to account as pulpwood. In such situations some form of check measurement may be required by the seller to ensure that all logs made available as sawlogs are actually brought to account as sawlogs.

SAWN TIMBER LOSSES ASSOCIATED WITH THE USE OF TREE FELLING SHEARS

R. McCormack and G. Waugh

Introduction

Due to rapid increases in the cost of labour, and the desire to create a safer and more pleasant environment for the forest worker, forest industries in Australia can be expected to follow a similar trend to what has occurred in the Northern Hemisphere, where forest harvesting operations tend to be much more highly mechanised. Then the felling of trees by shears, initially for pulp wood, but now also for sawn timber, is gaining wide acceptance. This is giving rise to a major problem as damage to the wood in the way of end splits, butt pull and fibre compression, while not considered serious in pulpwood, could cause direct losses in sawn timber.

This trial was carried out in order to assess the extent of damage to the butt section of *Pinus radiata* saw logs from trees felled by shearing, and to compare such damage to that of similar trees felled by a chain saw.

Experimental

The mechanical shear unit employed was a double action Drott shear with the two shears working against each other and activated by hydraulic arms. The shears were 1.27 cm thick and sharpened to give a cutting edge of 30°. The shear was mounted on a Caterpillar 955 Traxcavator and fitted with grapple arms to hold the tree during felling. The grapple arms were modified to prevent them placing a side stress on the tree during felling. The shear and grapple arms were so designed to allow them to be tilted forward, sideways, and aft, to align with the tree trunk. The maximum stem diameter over bark which could be handled by the unit was 45.6 cm.

For the trial, 40 butt logs were obtained from eight trees in each of five, 5 cm diameter classes covering the range from 20 to 45 cm (breast height over bark). Of these selected trees, four in each diameter class were felled by chainsaw and four felled using the shears. The butt logs were then converted into sawn timber, cut for a final board thickness of 19 mm, and later seasoned. Conversion was carried out using a log gang saw and board multisaw edger, thus eliminating differences between logs due to different sawing patterns. Following seasoning, the boards were inspected and the length of docking required for each board to conform to Australian Standard AS 1489-1973 was recorded. This standard for sawn boards from radiata pine does not allow checks which extend through the board.

From board cross-sectional dimensions, and docking lengths, the volume and value of sawn timber lost through butt damage for each tree was obtained. The results were then weighted to remove the effect of diameter and analysed to determine if there was any difference between treatments.

TABLE 1. SAWN TIMBER LOSSES FOR SHEAR FELLED AND CHAINSAW FELLED TREES

Log Large End Diameter (cm) Under Bark	Average Monetary Loss (cents)		Average Relative Loss (Weighted for Log Size)	
	Chainsawn	Sheared	Chainsawn	Sheared
20-24	1.15	2.00	0.242	0.422
25-29	0.00	3.62	0.000	0.690
30-34	4.08	4.18	0.716	0.733
35-39	21.47	18.90	3.306	3.086
40-44	4.93	35.30	0.756	5.414

The transformed relative loss data produced the following statistical parameters.

	chainsawn	sheared
sample size (n)	20	20
mean ($\bar{x}$)	0.922	1.538
variance (S^2)	3.656	5.147

An "F" test indicated no significant difference between treatment variances, and a "t" test indicated no significant difference between treatment means. However, in both cases for chainsawn and shear felled trees, the transformed data showed that losses were significantly higher for logs of 35 cm large end diameter (under bark) or greater than for smaller logs.

Discussion

The degree of damage to sawlog due to shear felling has been well documented (Conway, 1973, Johnston, 1966; Johnston *et al.*, 1973). The force required on the shear appears to be a function of wood density, tree diameter and shear thickness, with temperature becoming a critical factor at temperatures below 0°C. The greater the force required for shearing, the greater is the amount of energy dissipated to the stem, thus increasing the potential for more butt damage.

Butt damage due to shear felling appears to be of three distinct types.

1. Fibre compression

As the shear passes through the wood, the fibres are crushed and displaced, resulting in numerous minute fractures for a distance of about 2 to 3 cm from the cut surface.

2. Splitting

3. Butt Pull

In many cases it is difficult to separate fibre compression damage from splitting, as often minute fractures may appear for up to 5 cm from the cut surface. However under certain circumstances, severe splitting may occur up to 30 cm from the butt, particularly when an attempt has been made to shear a tree beyond the design capacity of the shears. In such cases, end splitting is usually accompanied by butt pull, due to the failure of the shears to cut across the complete stem cross-section, so when the stem is lifted away, the uncut section of the stem will pull away resulting in butt pull, and often side forces applied at this time will result in splits developing.

Both these forms of damage are also evident in trees felled by chainsaw, often resulting from poor felling techniques or from felling leaning trees. It could be expected that when handling trees within the design capacity of the shears, end splits and butt pull should be greatly reduced, as the grapple arms reduce the possibility of high stresses being imposed on uncut fibres at the butt during felling. Also as the grapple arms in fact lower the tree rather than fell it, impact damage should be much reduced.

Conclusions

The results of this trial showed no significant difference in the degree of butt damage to sawlogs whether the tree was felled by mechanical shears or by chainsaw.

It would appear that as long as the operator of mechanical shears only handled trees of a size within the design capability of the shears, butt damage to sheared sawlogs should be kept to a minimum. Under such conditions damage should be no greater, in fact may be less than that already accepted in butt logs from trees felled with a chainsaw.

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SUITABILITY OF 1939 REGROWTH MOUNTAIN ASH FOR VENEER AND PLYWOOD MANUFACTURE

B. McCombe

1939 regrowth Mountain Ash occurs mainly in a regenerated forest of some 300,000 acres in the central and eastern highlands of Victoria. Growth originated from devastating bush fires in the area in 1939. Exploitation is at present limited to thinning operations and some clear felling of sparsely stocked stands with logs being used for pulp and to a lesser extent sawmilling.

At times in the past large diameter old-growth of the species has been used with at least moderate success for utility and finish grades of plywood. However in recent years peeler quality logs have become virtually unobtainable.

The following assessment of young-growth Mountain Ash was undertaken at the request of the Victorian Forests Commission, who manage the stand, and with the support of local plywood manufacturers who have shown interest in using material of this type as a base for a structural product.

Three log samples were investigated. The first two from low altitude at Neerim South were evaluated at the CSIRO Forest Products Laboratory using the Laboratory's peeling, drying and testing facilities. The third and largest sample, from relatively high altitude near Toolangi, was evaluated in commercial trials at the plywood factory of Hancock Bros., Keon Park, Victoria.

LABORATORY TRIALS

The main objectives of laboratory work was to assess the performance of non-graded material and at the same time obtain an appreciation of range of defect. This information could be used, if necessary,to devise log grading criteria for selecting further log samples.

Log Selection

Sixteen 12 ft. logs, two from each of eight trees, were used in each trial. The only restrictions in tree selection were that the stem be free from resin bleed and that girth breast height be at least 45 inches. There was no difficulty in finding trees meeting this specification. The two 12 ft. logs were cut at random positions along the length of the stem to a top diameter of 10 inches.

Conversion

After preheating for 16 hours at 150°F two 39 inch billets were cut 12 inches from one end of each log. The billets were peeled into 1/10 inch veneer which was then clipped into 42 inch wide sheets and dried between trays in the laboratory screen drier at a dry bulb temperature of 80°C.

Grading

Sheets were graded to a structural veneer specification which would allow the plywood product to be made to the requirements of the Australian Standard "Hardwood Structural Plywood" and also to an Industry Standard for concrete formwork. The grading rules used are given in Table 1. Grades 4 and 5 are for classification purposes only. Grade 4 denotes veneer sheets containing unacceptable faults but from which useable veneer could be recovered. Grade 5 veneers would be totally unacceptable and therefore constitute waste.

Yields of veneer in the various grades for each trial are shown below. The data applies for 6 x 3 conversion.

	Percent Yield in Grade				
	Grade 1 cover	Grade 2 underlay	Grade 3 centre	Grade 4	Grade 5 reject
Site 1 Mean dia. U/B 13.2 inches Mean Knotty core dia. 9.2 inches	3	17	56	22	2
Site 2 Mean dia. U/B 12.4 inches Mean knotty core dia. 9.6 inches	0	6	47	35	12

Yields of cover and underlay veneer were well short of the minimum requirements for 7/10 inch concrete formwork which are 29% (2/7th) of each grade. The prospect of up-grading Grade 3 veneer by patching out faults was considered but it was found that most faults were too irregular or expansive to be effectively covered with the maximum permissible size of patch (3 inches).

The further possibility that quality yield could have been improved sufficiently by careful log selection was also investigated, but again results were not encouraging. Selection on a billet rather than a log basis would be more effective, however this would not be feasible as it is essential with free-splitting ash-type eucalypts that preheating be carried out in long lengths.

It was concluded that the most suitable end product would be low-grade 3-ply structural sheathing using Grade 3 veneer throughout.

Analysis of defect

Veneers were down-graded by gum, end splits and knots. The influence of each fault on quality yield is shown in Table 2.

Gum was the most prevalent fault appearing as a first order defect in 30% of Grade 2 and lower grade veneer. As such it was mainly responsible for the low yield of cover and underlay veneer. In Grade 3 and better veneer it was usually in the form of veins but in Grades 4 and 5 massive pockets were common.

End-splits caused almost as much fall down to Grades 4 and 5 as gum, however they were much less significant in the better grades. Most end splits originated from billet end shakes. In the worst form, Grade 5, they led to disintegration of the sheet into narrow pieces.

Knots were generally dead and loose. In the presence of gum and end-splits, they were relatively unimportant.

Origin of Gum

In view of the critical effect that gum had on quality, its presence was subjected to further analysis.

Results given in Table 3 show that gum associated with knots was the sole cause of fall down in at least 15% of sheets. It appeared as margins, sometimes broad and expansive, to all dead knots. In most cases it was a higher order defect than the knot itself.

Gum also appeared to originate from grub holes and insect traces. Gum of this type was a first order down-grading fault in at least 17% of sheets and, together with knot-associated gum was the most common fault in Grades 4 and 5 apart from end splits. The grub was identified as *Lepidoptera*.

Most gum encountered had no obvious association with knots or grub holes. In logs, this type of gum was usually in the form of thin veins 10 inches long and 2 to 3 inches broad.

COMMERCIAL TRIALS

This phase of work was essentially an evaluation of efforts to secure better quality logs. It was also intended to provide information on volumetric yield.

The results of the laboratory trials were far from favourable, however, there was still hope that better quality material might be obtained at other sites, if necessary, by resorting to careful log selection.

On advice of the Victorian Forests Commission, the area around Toolangi was chosen for a further log sample. Three logging sites were visited before suitable material could be obtained. At the first two sites, both at low altitude, tree stems often showed evidence of *Lepidoptera* attack and cross-cut ends indicated an incidence of gum similar to that for the Neerim South material.

The third and chosen site was at relatively high altitude (3000 ft. approx.). Tests for gum were more favourable and seven trees, the four largest in an area of about 2/3 acre, and three

smaller ones of superior form, were cut down for test material. A 28 ft butt length was taken from each tree.

An evaluation of log form and extent of end-splitting is given in Table 4 together with data on quality yield from individual logs.

Tracings were taken of gum deposits evident on log ends. These are reproduced in Figure 2a, 2b, 2c and 2d to provide an indication of the prevalence of gum.

Full information on the performance of the test material through individual processes is set out in flow chart form in Figure 1. Production parameters are listed in Table 5.

As shown in the flow chart yield of Grade 1 veneer was 21% but if necessary could be increased to a maximum of 30% when veneer eligible for patching (Grade 1 patch) was repaired. Thus the minimum cover veneer yield for producing 7-ply with Grade 1 faces and backs could just be satisfied. The flow chart shows veneer being used for this purpose, although in fact only a portion of the output was converted into this product.

Yields of reject sheets (Grades 4 and 5) was still high (28%). Recovery in salvaging useable veneer from this material was 56% but would have been higher, perhaps 80%, if selective clipping had been adopted.

Overall volumetric yield (41.6%) was relatively low, mainly because of abnormally high losses from shrinkage and in repair operations. Volumetric shrinkage in drying to approximately 5% moisture content was 13.6% with width and thickness components of shrinkage 9% and 5% respectively.

The finished product, 7/10 inch plywood, both plain finished and overlaid with phenolic film for use as concrete formwork, was of faultless quality.

CONCLUSION

The performances of the three log samples in the trials, variable as they were, indicated that with a minimum of log selection the material would most likely satisfy minimum quality yield requirements for the lowest grade of plywood in the structural range. The type of product envisaged is C-D 3-ply structural sheathing as used extensively in house construction in the U.S.A. but not as yet to any extent in Australia. Whether production of such a product would be economically feasible is doubtful since the need to preheat logs, the prevalence of end splits and relatively low recovery would tend to make production relatively costly as compared with, say, production of a similar product from a plantation-grown conifer.

The most serious shortcoming of the material was a high incidence of gum defect. Gum was consistently associated with dead branches and grub or insect damage but was often without hint of origin. In

two of the samples a critically high porportion of veneer was totally unusable. A relatively low incidence of gum found in one sample from a high altitude site confirmed a common belief that gum is less a problem at high altitude.

The main hope in utilizing 1939 regrowth mountain ash for plywood seems to be in improving quality yield by careful selection of logs on the basis of relative freedom from gum and growth stresses. If a yield of clear veneer of around 20% could be maintained, then a premium quality thick structural product suitable for flooring or concrete formwork could be made. This strategy was applied in selecting material for the commercial trial and proved effective. However, the consistently poor performance of logs from low altitude material give little hope that it would work on such material.

Assuming that some sites will yield logs of suitable quality, the feasibility of making plywood will then depend on the proportion and location of eligible sites and on the degree of log selection that has to be applied. Further sampling will be needed to obtain this information. However, it should not be necessary to test all samples in peeling trials. Visual evaluation of log quality, as applied in selecting logs for the commercial trial, should be sufficient. Should the results of further tests prove negative there would still be prospects that quality will improve in successive years of growth and in some future time meet requirements.

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TABLE 1. IMPROVISED VENEER GRADE SPECIFICATION

(Permissible defects in 3 x 6 or 6 x 3 sheets)

Defect	Grade 1 cover	Grade 2 underlay, back	Grade 3 centre (Maximum permissible defect)	REJECT Grade 4 re-clip	Grade 5 discard
Knots	Occasional small intergrown knot, small sound galls	Intergrown to 2" in dia. loose knots or knot holes to 3/4" dia.	Intergrown to 3" dia. loose knots and knot holes to 2" dia.	Maximum permissible defects exceeded but Grade 3 or better veneer recoverable between defects	Maximum permissible defect exceeded, little or no Grade 3 or better veneer recoverable between defects
End splits	Closed splits, occasional open splits up to 1/16" wide and 8" long	Up to ½" wide and one half the sheet dimension along the grain in length	As for Grade 2		
Gum pockets and gum veins	Up to two small sound veins per sheet	Up to 1" wide	Up to 2" wide		

"1" patch - upgradable to grade "1" using no more than five 3-inch patches

TABLE 2. INCIDENCE OF KNOTS, SPLITS AND GUM AS FIRST ORDER DOWNGRADING DEFECTS IN 3 x 6 SHEETS

	Cause of fall-down from higher grade and per cent of sheets affected			
	Knots and knot holes only	Splits only	Gum pockets and veins only	Gums solely or in combination with knots and splits
Grade 2 (112 sheets)	2%	10%	71%	88%
Grade 3 (316 sheets)	10	-	56	90
Grade 4 (147 sheets)	3	36	61	61
Grade 5 (28 sheets)	0	54	46	46
All Grades (603 sheets)	7	13	60	80

TABLE 3. INCIDENCE OF GUM AS A FIRST ORDER DOWN-GRADING DEFECT IN 3 x 6 SHEETS ACCORDING TO TYPE

(% of total veneer in Grades 1 to 5)

	As the only first order defect	Occurring solely or in combination with other first order defects
Gum associated with dead knots	10%	More than 15%
Gum associated with grub holes and insect traces	9	More than 17
Gum having no obvious association with knots and grub holes and traces	30	More than 39
Types of gum in combination	60	80

TABLE 4. LOG QUALITY VERSUS QUALITY YIELD

Log No.	Length (ft.)	Mean dia. mid-length (in.)	Condition of bole	Condition of billet ends with regard to end splits (4 x 6.5 ft billets)	Quality yield green full width sheets*			Principal veneer downgrading fault(s)
					Clear with and without splits (%)	Clear without splits ('1') (%)	'3' and lower grade (%)	
1	28	17.1	Free of branches; swelling on one end, otherwise straight and smooth	Extending to within 3" or less of periphery on all billets	27	17	38	Gum veins and pockets generally not associated with knots
2	"	19.4	Branch stubs and just occluded branches affecting 1 billet only otherwise smooth and straight	Diametral split on one billet; to within 3" of periphery on others	26	3	85	Loose knots; end splits
3	"	19.7	1 x 3/4" branch stub affecting one billet, others smooth and no clear evidence of occluded branches	Diametral split on one billet; to within 1½" of periphery on others	33	9	68	Loose knots; end splits
4	"	23.1	Numerous small dimples and evidence of Lepidoptera attack; 3 x 2½" branch stubs on one billet; one small branch stub on another	Diametral splits on 3 billets; to within 3" of periphery on one billet	7	2	61	Loose knots; gum veins associated with Lepidoptera attack
5	"	14.1	Free of branch stubs. No swellings but evidence of occluded branches; numerous small dimples at one end	Diametral splits on all billets	0	0	90	Gum veins and pockets generally not associated with knots
6	"	20.6	1 x 1" branch stub affecting one billet; slight swellings on another indicating occluded branches	Diametral splits on two billets	23	15	52	Loose knots; gum veins generally not associated with knots
7	"	14.0	Free of branch stubs, smooth	Diametral splits on 3 billets, mostly open at periphery	40	0	84	End splits

* Recovered from reeled veneer. Full width sheets were clipped regardless of defect present. Unreelable and round-up veneer in narrow form not included.

TABLE 5. PRODUCTION PARAMETERS

PRETREATMENT	
Heating medium	- Air-steam mixture
Temperature	- 160°F
Nominal heating time	- 16 hours
CROSS CUTTING	
Log length	- 28 ft (predetermined)
Allowance for offcuts	- 2 ft "
Net length for peeling	- 26 ft
Billet length	- 78 inches
PEELING	
Veneer lathe	- Merrett without telescopic chucks and back roll. Chuck design modified to minimize splitting.
Peeled thickness	- 0.100 inches
Scribed length	- 77 inches
Minimum width of narrows recovered	- 12 inches (approx.)
Type of reeling device	- Torque control
CLIPPING PRACTICE	
Reeled veneer	- Clip to full sheet widths regardless of defect.
Round-up and unreelable veneer	- Clip to max. available width
Minimum acceptable width	- 12 inches approx.
Clipped width (sheets)	- 42.5 inches
DRYING	
Drier	- Steam heated Schilde roller, jet ventilation
Steam pressure	- 150 psi
Dry bulb temperature	- 300°F (approx.)
Final moisture content	- Around 5 per cent
Drying time	- 12½ minutes
Shrinkage (Av.)	- Width, 9 per cent Thickness, 5 per cent Volume, 13.6 per cent
Dried veneer thickness (Av.)	- 0.095 inches
Dried sheet width (Av.)	- 38.6 inches
GRADING	
Grading rules	- See Table 4

ANALYSIS OF YIELD IN VENEER AND PLYWOOD MANUFACTURE

B. McCombe

In the veneer industry veneer recovery is routinely calculated by dividing the volume of veneer produced in a month by the volume of logs consumed in that month and expressing the result as a percentage. Overall recovery in converting logs to finished plywood can be calculated in a similar way.

The information obtained is useful to the factory Accountant for determining cost of wood in unit finished product and, on occasions, as a double check on log and veneer inventories for the month. It also tells how much recovery deviates from an accepted norm.

Unless the result is most favourable it has only limited value as an indicator of efficiency of recovery practice for the factory. For example, a veneer recovery of, say, 43% could conceivably reflect very good or very poor production practice depending on the quality of the raw material and the quality specification to which the product is made.

Similarly, the result may be misleading if used as a measure of the performance of a particular species or log quality since it may have been biased by unsuitable production procedures used at the factory.

In any critical enquiry into recovery obviously a technique is required which separates out the effects of raw material and practice and does this process by process so that specific shortcomings in either can be pinpointed.

Basic Technique

A technique which largely satisfies these requirements has been developed by the Laboratory in the course of a series of field studies of veneer and plywood recovery. It is best described by referring to the results of one such study. These are shown in flow chart form in Figure 1.

Total log input for the study was 12,000 sup.ft. but for convenience an input of 1,000 sup.ft. true measure is shown. The successive processes, shown as blocks in the flow chart, are crosscutting, peeling, green clipping, drying, jointing/splicing and grading. The fractional figure shown inside each block represents recovery for the process. With the decimal point removed, this recovery factor becomes recovery in per cent for the particular process. The output from the process is obtained by multiplying the input by the recovery factor. For example, the input to the crosscut saw is 1,000 sup.ft. and the output 1000 x .95 or 950 sup.ft. The loss of wood in crosscutting of 500 sup.ft. is shown directed to a common waste line.

Losses in peeling are shown as only cores and scribings, and this is in accordance with convention in recovery work. Round-up waste, such as fishtails etc., although normally associated with the peeling operation, are allocated to green clipping.

After peeling, material branches into two lines - the upper line for reeled veneer and the lower line for round-up veneer including round-up waste. Reeled and round-up veneer may not in fact be separated in production

but nevertheless are accounted for separately in setting up the recovery flow chart.

After clipping the flow chart expands into three lines - the top and bottom lines for sheets and the central line for narrows produced at the clipper.

After drying and some loss in volume due to shrinkage, sheets that have developed bad splits in the drier are diverted to the central narrows line. This in turn passes through jointing/splicing where all narrows are composed into sheets with wastage in the form of jointer offcuts. The three lines then converge and pass through grading where sheets are graded into face and back without loss of raw material.

The flow chart is for a run of cedar logs of mean diameter 23 inches converted in 8 ft. lengths. Veneer grade specification required face veneer to be virtually flawless and allowed only minor defects in back veneer. There is little reason to question the recoveries obtained for cross-cutting, peeling and drying. Log yard losses of 5 per cent represent only a 12 in. offcut in 20 ft. of log length, and in peeling core diameter is small considering that billets were peeled without the advantage of telescopic chucks and a back roll. The scribing loss of 3 per cent of the total log input corresponds to a scribing allowance of a little over 3 inches per billet. Again this is minimal. Recovery in drying of 94 per cent indicates that average shrinkage in drying was 6 per cent, this being quite normal for a veneer species. On the other hand, high losses recorded for green clipping and jointing-splicing and the relatively high proportion of sheets seemingly downgraded in drying through drying splits, all need explanation.

Recovery in green clipping is shown to be influenced to a large extent by the high proportion of round-up veneer in the input to the clippers (40 per cent). This in turn could mean that gross errors had been made in centering the billets or that log form and quality had been especially bad.

Further investigation of clipping losses was in fact not needed as it became evident in the course of the study that while centering errors and over-generous margins in clipping out defects had contributed to wastage, the low quality of logs in respect to form and internal defects was the main reasons for the low recovery.

The high losses for jointing (23 per cent of the input finished up as jointer off-cuts) was due in part to jointing of pieces to prescribed widths rather than random widths, a practice which was dictated by the Company not having a cross-feed splicer. Another factor contributing to loss in jointing was handling damage in the veneer which had the effect of almost doubling the number of pieces before the veneer was received as the jointer. Conclusions on losses in clipping and jointing were checked out in an examination of samples of offcuts at the respective processes.

The fall-down in grade of 15 per cent of sheets out of the drier was observed to be due mainly to handling splits, not so much because of rough handling into the drier but because of poor facilities for loading veneer into the drier.

The overall conclusions of the study was that the yield of 43 per cent was relatively good considering the quality of the raw material. A gain in yield to perhaps 47 per cent would be possible through improvements in centering, clipping and grading practice and through greater care in handling sheets into the drier. A further gain of about 30% would result if a crossfeed splicer was used in place of the existing end feed splicer.

Mathematical Representation

The outcome of passing raw material into the production scheme depicted in the model is determined entirely by the values of a set of network parameters. As depicted in Figure 2 there are 12 parameters, 7 are recovery factors and 5 are branching factors. The latter apply at circled points in the network and determine how much material continues in the main stream and how much is diverted. For example, the branching factor 0.7 after green clipping indicates that 70 per cent of the output of green clipped veneer from the reel "continues on" as dimensioned sheets. The balance, 30 per cent, is random width narrow pieces left after faults had been clipped out and this is diverted to the common narrows line.

The network could be more complex than shown and could account for several lathes and driers and a continuous instead of piece drier as in the example.

Overall recovery for this 12-parameter network is as follows:-

$$P_1.P_2.P_8.P_{12}.\left(P_3.P_4.\left(P_6.P_9\ (1-P_{11})+P_{11}\right)+P_5.(1-P_3)\left(P_7.P_{10}.\ (1-P_{11})+P_{11}\right)\right)100\%$$

Individual parameters are derived as follows:-

CG = Mean centre girth of billets)
RU = Mean round-up diameter of billets) Root-mean-square averages
CD = Mean core diameter)
t = Veneer thickness
W = Nominal sheet width (green veneer)

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P_1 (recovery factor, crosscutting)

$$= \frac{\text{No. of billets peeled x nominal billet length}}{\text{Total length of logs}} \text{ (approx)}$$

P_2 (recovery factor peeling)

$$= \left(1 - \frac{\pi^2 . (CD)^2}{(CG)^2}\right) \times \frac{\text{nominal scribed length}}{\text{nominal billet length}}$$

P_3 (branching factor, yield or reeled veneer from lathe)

$$= \frac{\pi^2 (RU^2 - CD^2)}{(CG)^2 - \pi^2 (CD)^2}$$

P_4 (recovery factor, clipping of reeled veneer)

$$= \frac{4.t \times (\text{total width of narrows} + \text{No.of sheets} \times W)}{\pi ((RU)^2 - (CD)^2)}$$

P_5 (recovery factor, clipping of round-up veneer)

$$= \frac{4 \pi t \times (\text{total width narrows} + \text{No.of sheets} \times W)}{(CG)^2 - \pi^2 (CD)^2}$$

P_6 (branching factor, yield of sheets reeled veneer ex clipper)

$$= \frac{\text{Total No. sheets xW}}{\text{Total No. sheets xW + total width of narrows}}$$

P_7 (branching factor, yield of sheets, round-up veneer ex clipper)

$$= \frac{\text{Total No. of sheets xW}}{\text{Total No. sheets xW + total width of narrows}}$$

P_8 (recovery factor, drying)

$$= 1 - \frac{\text{Per cent shrinkage}}{100}$$

P_9 (branching factor, yield of sheets, reeled veneer ex drier)

$$= \frac{\text{No. of sheets downgraded in drying}}{\text{Total No. of sheets}}$$

P_{10} (branching factor, yield of sheets, roundup veneer ex drier)

$$= \frac{\text{No. of sheets downgraded in drying}}{\text{Total No. of sheets}}$$

P_{11} (recovery factor, jointing splicing)

$$= \frac{\text{Total No. of spliced sheets xW}}{\text{Total green width of narrows}}$$

$$P_{12} \text{ (recovery factor, grading)} = \frac{\text{Total No. sheets after grading}}{\text{Total No. sheets before grading}}$$

Ideally, all recovery factors should be unity since then overall recovery would be 100 per cent. Branching factors mainly decide the output of narrow veneers in production and hence the volume of material channelled through jointing and splicing. They only become significant if wastage occurs in processing narrow veneers. This is usually the case and so branching factors should also preferably be unity.

In practice veneer recovery can never be 100 per cent and, in fact, rarely exceeds 60 per cent. The over-riding limitation is the raw material itself, in particular in respect to its size and form, shrinkage and drying properties and to what extent logs are affected by end splits and internal faults. Obviously quality specification to which the product is made must also influence recovery. When veneer grading rules are not very restrictive, such as with veneer for structural plywood, recovery can be relatively high. Other important influences on recovery are performance and working order of equipment, production procedures used and, of course, the work performance of factory personnel.

Extended Analysis

If the results of a recovery study are to be of fullest value, effects on recovery attributable to species and log quality, equipment, production procedure and work performance should be separated out. In the case study in the previous section factors in these categories that had unduly influenced recovery were identified but their effects were not quantified. It was deduced that lack of telescopic chucks and backroll on peeling equipment, the procedure of jointing veneer to set widths and work performance of operators in centering billets and in clipping had all contributed to losses, but the most significant influence of all was log quality.

The ultimate approach in analysing losses would be to consider that each of the P parameters to be compounded as follows:-

$$P = (P_o)\ P_e . P_p . Pw$$

where (P_o) represents the absolute contribution of the raw material to the parameter and P_e, P_p, P_w, are discounting factors or penalties accounting for deficiencies in equipment, procedure and work performance of personnel respectively.

For example, the recovery factors P5 for green clipping of narrow veneers may have actually been compounded as follows:-

$$P_5 = .50 = (.58) \times (.97_e) \times (.93)_p \times (.95)_w$$

The discounting factor .97 for equipment could have, for example, been due to shortcomings of veneer handling facilities at the outfeed of the lathe which had resulted in wastage of 3 per cent of the total round-up volume from breakage.

The factor .93 assigned to "procedure" may have been a penalty for recovering round-up veneer in 8 ft lengths. Centre scribing into 4 ft lengths would have been the optimum procedure and in this hypothetical case would have allowed 7 per cent more veneer to be recovered from round-up veneer. The factor .95 for "work performance" may have meant that 5 per cent of round-up veneer was lost through the lathe operator over-shooting round-up and through the clipper operator clipping unnecessarily wide margins from round-up pieces.

If required the P-parameter can be expanded still further until all discreet elements have been accounted for:-

$$P = (P_o) \times \left(P_{e,1} x P_{e,2} \times \ldots P_{e,n}\right) \times \left(P_{p,1} x P_{p,2} \times \ldots P_{p,n}\right) \times \left(P_{w,1} \times P_{w,2} \times \ldots P_{w,n}\right)$$

For some parameters, e.g. the recovery factors in green clipping, there may be five or more sub-parameters in each category while for others, mostly branching factors, there may be only one in each category. Thus recovery for the particular veneer line will become a function of twelve species or log quality parameters ($P_{q's}$) and a large number of production parameters. If the mill had modern and well-maintained equipment, uses production procedures giving maximum recovery and had a well-trained workforce, then most of the production parameters would be unity or close to unity. Under these conditions recovery would be close to optimum for the given species and log quality and veneer grade specification. It should be noted, however, that efforts to seek optimum recovery sometimes conflict with other interests of production. Centre-scribing of round-up veneers and jointing of narrows to random widths already cited as optimum procedures may be unacceptable for certain types of end product. Furthermore, work performance suffers if production demands are great and so, in some cases, the optimum solution is a compromise between production rate and recovery.

Much of the information needed to calculate sub-parameters can be obtained in a post mortem analysis of residues.

Analysis of losses in such detail is not proposed for general use in recovery work. Quite often the result would only be of academic interest and could have been predicted with sufficient accuracy by careful examination of residues. The technique is especially applicable when the origin of a large block of losses cannot be identified with certainty.

Topic 1/17

PEELING TECHNIQUE IMPROVED BY INTRODUCTION OF RING DEBARKER

A. Atanackovic

Demand for small round softwood timber used as fence posts, vineyard stakes and structural components in park furniture has reached an impressive level but, surprisingly, development in production technology has not followed the same pattern.

This paper sets out to discuss the performance of two types of debarking machine, analysing the possibility of improvement, using an actual industrial situation for illustration.

A plant whose potential market is far higher than its capacity processes 2614 m^3 of true under bark volume of timber, annually, of predominantly moderate sizes as shown in the table below.

Length m	Diameter ranges in mm								Total
	50-75	75-100	100-125	125-150	150-175	175-200	200-225	225-250	
	Volume in m^3								
1.80	23	156	202	175	141	11			708
2.10	1	19	34	43	50	-			147
2.25	5	37	72	101	91	26	2	1	335
2.40	2	36	55	66	59	16			234
2.70	9	57	93	92	67	16			334
3.00	22	83	109	92	56	5			367
3.30	2	25	32	29	29	-			117
3.60	8	60	101	98	92	13			372
Total	72	473	698	696	585	87	2	1	2614

This production is achieved by five men, a fork lift and a post peeler as basic equipment for debarking, working a single eight hour shift. The post peeler works on the principles of the planer where the knives of the cutter head take the bark and a certain quantity of wood from the rotating post while it travels through the machine (1).

Regarding these working principles and sizes of timber it should be interesting to assess the volume of residues and their percentages to the total true volume of underbark timber.

	Diameter ranges in mm								Total
	50-75	75-100	100-125	125-150	150-175	175-200	200-225	225-250	
	True volume in m^3 of:								
Timber	72	473	698	696	585	87	2	1	2614
Bark	14	77	101	102	88	12	-	-	394
Wood chips	13	62	71	63	41	5	-	-	255
	Percentage of residues to true under bark volume of timber in %								
Bark	19.62	16.34	14.52	14.68	14.98	14.07	13.32	13.66	15.03
Wood chips	17.87	13.03	10.24	9.09	7.10	6.18	5.46	4.90	9.84

Quantity of wood residue in form of chips depends on depth of cut. It is presumed that only 3 mm is an average depth of cut in the table above. Even such modest estimation represents almost 60% of the total volume of residue.

The waste residue which consists of 394 m^3 of bark plus 255 m^3 of wood chips, creates rather serious and costly disposal problem. This volume as presently formed can find only a limited market as low grade ground cover although they are sometimes actually preferred for use in children's play areas. Because the residue in such form has minimal merchantable value, the choice frequently lies between burning or dumping.

If the plant has to invest money purchasing a burner, which is the case in this example, the cost of burning this material will be $5.63 per m^3, without the use of burner's full capacity (2).

Disposal of this material by dumping for land fill under the best favourable conditions, at say 10 km distance, would be about $2.30 per m^3 (2). But are such expenses really necessary?

If bark and wood were produced as separate residues this volume would be considerably enhanced with adequate demand for the bark compost, as soil improver, and wood for particleboard, or better still, in its original form as an integral part of the major product.

To achieve such separation a reappraisal of processing is required. The bark would have to be removed as such, followed by peeling of the posts, if required.

In the attached sketch the present layout of machinery would be altered by introducing a ring debarker. By the proposed layout the production will be divided in two flows.

All over barked material will be put through the ring debarker as the basic machine. In the outfeed debarker line round timber will go in two directions.

Posts for structural components in park furniture and pieces which need peeling for a better surface will be sent to the post peeler. For all other debarked posts processing through the ring debarker will be final (3).

Such production flow would provide higher throughput, utilisation of residues, better wood recovery and not only savings but also a profit which would justify the extra cost of an additional machine.

From the annual throughput of the post peeler very fair estimation of the infeed speed will be 5 m/min (4) a mere quarter of that of a ring debarker under similar conditions (5). This greater volume of debarked posts should decrease the cost of debarking operation per m^3 processed.

Debarking posts by two machines will offer savings on cost of burning or dumping and profit by selling the residue in separate form as valuable items.

To get some indication of such saving and profit, assuming that the throughput by ring debarker will increase production four times, and that 25% of this throughput will be processed in the post peeler, the quantity of residue will be:-

bark:	394 m^3 x 4	= 1576 m^3
wood fibres:	255 x 1	= 255 m^3
		1831 m^3

Saving by avoiding the annual running cost of the burner is $3660 or alternatively, of dumping 1831 m^3 x $2.30 is $4211 and by selling the bark residue for use as a soil conditioner (6) (1572 m^3 of bark at $8.98 per m^3 = $14198) the total saving will be in the vicinity of $17874 and $18409 per annum excluding the benefit of selling wood chips and wood recovery.

It is difficult to estimate nett gain of chips but one figure quoted is one quarter of sawn timber value - a not inconsiderable sum (7).

Wood recovery will appear in two ways, through selling chips or remaining in its original form, increasing the average diameter of debarked material by reduced depth of cut.

The introduction of the ring debarker and splitting of production flow would result in higher throughput and better utilisation of wood and waste residue. Moreover this will present an opportunity to convert profitably residue from waste into more valuable products.

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STRUCTURAL TIMBER LAMINATED FROM THICK VENEER - APPRAISAL OF ALTERNATIVE PRODUCTION CONCEPTS

B. McCombe and P. G. Simpfendorfer

Laminating is a recognized answer to a shortcoming of solid wood in construction, i.e. the difficulty of obtaining very large sections of long length and reliable strength and dimensional stability. As such and because with laminating curved beams can be made with relative ease, it has made wood competitive in heavy engineering applications.

At some lesser scale, for example when the structural member required is a beam, say, 25 ft. long and 12 in. deep, it often becomes just practicable to meet performance specifications with carefully selected solid timber. In Australia the source of solid product of around this size is often relatively costly imported Douglas fir. As size reduces down to the common stud size acceptable material becomes increasingly available.

In the range of light framing timber, the competitiveness of a laminated product depends firstly on any cost advantages it offers over a solid product. In favour of laminating is the fact that by grading laminates and using less defective material in the outer layers the product can be made stronger than a solid product converted from the same raw material. Even if this measure is not taken the end product will be more uniform in strength and hence higher working stresses can be assigned. With laminating therefore there is the prospect of using lower quality and cheaper raw material for a given end result, or, alternatively, making a superior and hence higher value product from a given raw material. A further cost advantage for laminating stems from the fact that the relatively thin laminates dry faster than an equivalent volume of solid stock.

However, on the debit side for laminating there are substantial additional costs, notably glue, labour for fabrication and, when laminates have to be dimensioned before gluing, the cost of labour and wastage incurred. In Australia laminating of sawn and dressed boards is well established as a means for producing "difficult to obtain" sizes and custom-made products but needless to say has yet to prove viable for producing a broad range of light framing timber.

Advantages of using a veneer laminate

Recent development of the idea of using peeled veneer instead of sawn and dressed boards for laminates has improved the competitive position of the laminated product. Partly through elimination of kerf losses associated with sawing and with no need to dimension stock before laminating, there would, according to some research workers, be a 30-50% gain in volumetric yield.

Other research, notably that of Peter Koch (1) confirmed the superior quality of a veneer product produced from average quality

southern pine saw logs. Vertically laminated beams* fabricated from ¼ in. veneer and solid stock sawn from matched material were found to have comparable, average strength moduli. However, in view of reduced variability in strength of the veneer product Koch calculated that a working stress more than double that for the solid stock could be applied to it making it equivalent to the strongest structural grade of southern pine lumber. This good performance of the veneer product was despite the use of butt joints throughout. Acceptability of the butt joint with thin lamina had already been predicted in the research of Leicester and Bunker (2).

Koch's findings with southern pine suggest that the entire vertically laminated product from typical logs of our radiata pine might qualify for a 1600 f or at least 1250 f stress grade. Obviously intensive testing is needed to establish the quality of veneer product from radiata pine.

Considering the thinness of the veneer laminate (¼ to ½ inch) and the relatively high cost of waterproof glue, it can be expected that glue will be a major cost item in the manufacture of the veneer product. Therefore, it is of interest to calculate to what extent the saving from the promised increase in volumetric yield will cancel out the added cost of glue.

When ¼ in. veneers are used, phenol-formaldehyde glue at the current cost of about 15¢/lb and spread at the rate of 4 lb/100 sq. ft. of single glue line will add $2 to the cost of producing 100 su. ft. of veneer product. Further calculations show that if yield is 40% higher for the veneer product then raw material costs break even when the mill-door cost of logs is around $2.20 per 100 su. ft., that is, at this log price cost of wood and glue in unit finished veneer product will then be the same as cost of wood in unit solid product. When logs cost more than $2.20 per 100 su. ft., as is often the case, a comparison of raw material costs favours the veneer product.

A veneer-based operation therefore promises a superior product and possibly marginally reduced raw material costs. The product will be consistent in strength, thus eliminating the need for grading and the cost incurred. Also, conversion costs up to and including drying would most likely be less for the veneer product than the solid product. In any event the difference would not be great.

This sums up the advantages of a veneer-based operation and at the same time indicates that a main issue affecting its viability will be to what extent the gain in product quality, or value added, compensates for labour and capital investment costs for the additional operations of laminating and conversion.

* Gluelines arranged in the direction of the depth of the beam.

The objective now is to compare various concepts that have been proposed for the mass production of a veneer product and comment on their merits or otherwise, especially with regard to equipment and labour costs for laminating and reconversion and technological development, if any, that is still needed.

J. C. Bohlen - Laminating in a continuous hot press

Bohlen (3) envisages production of an endless plank 4 ft. wide and 1½ in. thick from sheets of 8 ft. x 4 ft., ¼ in. thick peeled veneer. Butt joints every 8 ft. would be systematically staggered through the assembly. The plank would be subsequently sawn into dimension lumber of 1½ in. thickness.

Because of the poor heat conductivity of wood conventional hot pressing of thick assemblies is inherently inefficient. For example, Bohlen reports that whereas pressing time for a 3/4 in. thick assembly may be only 5 minutes, a 1½ in. thick assembly will require 20 minutes. Considering 20 minutes to be too long for the operation to be economically feasible, Bohlen proposed a pressing scheme which he maintained would allow curing time to be effectively reduced to 6 minutes or less. Three continuous presses would be coupled in series with each press applying two veneers. In this way heat from the platens would have to penetrate no more than ¼ in. compared with the maximum of 3/4 in. for a single pressing operation. The two central veneers in the assembly would be bonded in the first press, a further two veneers, one on each side, would be applied in the second press and the other two veneers in the third press.

For an outfeed speed of 8 ft./min. three 16 ft. long and 4 ft. wide continuous presses and six glue spreading and veneer feeding stations would be required. Production would be at the rate of 2900 su. ft./hour. If in practice more than 2 minutes curing time is required at each stage, then presses would have to be made proportionately longer to maintain the given production rate.

It is difficult to estimate the cost of equipment for the Bohlen scheme because both press and the veneer spreading and feeding gear has yet to be developed.

Bohlen proposes "rotary presses" employing endless stainless steel belts between which the veneer assembly is transported and through which heat and pressure are applied. While such a press has been developed for particle board manufacture, there is no certainty that it could be modified for a high pressure veneer operation. Considering the high degree of sophistication in engineering design required for the coupled press system and the veneer spreading and feeding systems, costs would be considerably in excess of that for an equivalent plywood fabrication line and probably more than $½ million.

Assuming that the operation could be automated beyond fabrication to the bundling of finished product we estimate that a crew of six, mainly engaged in process monitoring, would be required. Unit direct labour requirements would then be of the order of 0.2 man-hours/100 su. ft. of finished product.

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FPL Press-Lam Team - Press drying and continuous press-laminating of preheated veneer

This production concept (4) originated from the U.S. Forest Products Laboratory in Madison, Wisconsin.

Key features are the drying of veneer between platens in a multi-daylight hot press, retention of heat from drying in the veneer until fabrication and the fabrication of the hot veneers in a continuous press using residual heat to accelerate the curing of a cold setting resorcinol-based adhesive.

The advantages claimed are a saving in drying costs over conventional drying methods (drying time is much shorter) and, as a result of using preheated veneers in fabrication, shorter pressing time (2-4 minutes) and hence greatly reduced and simplified pressing needs.

The main disadvantage is the relatively high cost of the adhesive which in Australia is about three times the price of phenolformaldehyde. If the product is based on ¼ inch veneer then unit glue costs will be about $6 per 100 su. ft., $4 more than if phenolformaldehyde was used. However, the FPL Press-Lam Team indicated that they were hopeful that a cheaper cold setting glue at US$0.15¢ per lb. could be developed.

Comparison with the Bohlen process on the basis of production rate of 2900 su. ft./hour and 4 ft. width of plank shows that pressing equipment could be reduced in length by one-third or more, and without need to supply heat to the press, its construction could be greatly simplified. There is the further advantage that the product could be completely pre-assembled and fed in from the front of the press instead of being assembled in stages using six feeding stations as with the Bohlen process.

The FPL Press-Lam Process, as proven so far in laboratory evaluation, offers the prospect of a reasonable cost for laminating equipment. Both laminating press and lay-up system are available which, with some modification, could be used but a press-drier with loading and unloading facilities would have to be developed. It would then remain to be shown that the innovations of high temperature press drying and gluing of hot veneers can be integrated and made workable on a commercial scale and, if so, at what cost for auxiliary equipment and control systems. There also seems to be a need for further product evaluation, testing exhaustively for any harmful effects the novel drying and gluing methods may have on the bond quality and serviceability of the product.

Dr. Peter Koch - Laminating Using Conventional Pressing Equipment

In the first stage of the Koch process (1), 8 x 4, ¼ inch thick veneer sheets are fabricated into 32 x 4 ft. slabs in a 32 ft. long multi-daylight hot press using phenol-formaldehyde adhesive. After hot pressing and cooling, pairs of panels are bonded together in a cold press to make 32 ft. x 4 ft. x 1½ inch slabs which are then sawn into scantling sizes as required. A resorcinol-based adhesive is proposed for the second gluing operation.

The combination of hot pressing and cold pressing is Koch's solution to the problem of low hot press productivity when pressing thick panels. With the addition of a bank of cold presses of relatively low cost, production of the expensive hot pressing unit can be more than doubled.

Koch gave details of the basic equipment required for a fabrication line yielding 3800 su. ft. of products per hour. The hot press would be 32 ft. x 4 ft. and have 8 openings. Four single-opening cold presses would be required to match hot press production. The hot press would operate on a 12-minute cycle and the cold presses on an 8-hour cycle.

The Koch approach, being a variation of the process making plywood presents no special development challenge. Lay-up, handling and pressing equipment already proven in the plywood and particleboard industry should be easily adapted to suit requirements.

While the Koch process is equatable in many respects with plywood manufacture, capital investment for setting it up can be expected to be considerably more than for a conventional plywood operation of the same capacity and may, in fact, be prohibitive.

Much of the excess in cost would be associated with the exceptionally large size of panel. For example, the 32 ft. long 8-opening hot press, although having the same capacity as an 8 x 4, 32-opening standard plywood press is in effect equivalent to four 8 x 4 presses, each differing from the standard plywood press only in respect of number of platens and stroke of pressure rams. Cost of the large press could easily be twice that of an 8 x 4 press of the same capacity.

The greatest impact of panel size may be on the cost of handling equipment. Because of the awkward size and weightiness of the product, handling through processes will have to be completely mechanized using over-size equipment. With handling functions requiring at least 32 ft. to execute, we estimate that the length of 5 ft. wide or wider production line up to unloading of the cold presses will be of the order of 900 ft. as compared with about 150 ft. of 8 ft. wide line common for structural plywood production. Total length of production line including re-conversion may exceed 1500 ft.

It was estimated that 12 men would be required for the complete operation. Unit labour imput would then be 0.3 man-hours per 100 sup. ft. of product.

Laminating in a Continuous Press Using Radio Frequency Heating

The authors of the three production concepts described have recognized a need, or even a necessity, for accelerating glue cure and reducing pressing time. Each proposed a different approach for achieving this end.

A further approach is to cure glue by radio frequency heating. In the normal application of R.F. heating gluelines are arranged parallel to the electric field. The field then acts preferentially on the

glue-lines curing all parts at more or less the same rate and with minimal heating of the wood. Provided the path of the electric field through the work piece is relatively short, preferably less than 6 inches, and sufficient power is available, then glue cure can be completed in 2 minutes or less.

While R.F. heating is ideal in principle, it has some notable practical shortcomings. R.F. power is expensive and because the cheap phenol formaldehyde adhesive is not compatible with the process, a more expensive adhesive, usually one based on resorcinol, has to be used. Also the limitation on depth of glueline practically necessitates manufacture of a horizontally laminated product although the stronger vertically laminated product would be preferred.

High unit glue cost has been the main objection to using R.F. heating in the manufacture of a veneer product, but now research at this laboratory (5) promises that a low-cost tannin formaldehyde adhesive suitable for use with R.F. heating can be developed. In anticipation that this adhesive will ultimately become commercially available an appraisal is being made at this laboratory of the feasibility of incorporating R.F. heating in the laminating process. This followed production trials starting with peeling and taken through to the fabrication of 20 ft. long beams in a commercial continuous R.F. laminating press, and finally the strength testing of the product with favourable results. The beams were made from three species including radiata pine using 0.4 and 0.5 inch thick peeled veneers.

The use of R.F. heating to cure glue in thick assemblies in one minute or less would permit considerable simplification and scaling down in size of pressing and auxiliary equipment. For example, a 3000 su. ft./hr. output of endless product 24 x 6 inches in section could be achieved in a 10 ft. x 6 inch single-opening continuous press as compared with the 32 ft. x 4 ft. 8-opening press proposed by Koch for producing 3800 su. ft./hour. Under these circumstances there are good prospects for low-cost automation. Indeed, our current studies show that integration and automation of the processes veneer clipping through to packaging on an uninterrupted flow basis would be feasible using almost entirely commercial equipment and proven control techniques. Innovation would be needed in the design of a "flexible" coupling between veneer drying and fabrication and in the design of a mechanism for feeding glue-spread laminates to the press.

Subject to the successful development of this auxiliary equipment, an operation with capacity 2400 su. ft./hour would require a direct labour work force of twelve, occupied mainly in process monitoring. Total unit labour input would then be 0.5 man hours/100 su. ft. of product, half of which would apply to fabrication and reconversion.

Electric power requirements for R.F. heating calculated on the basis of 1 kW minute energy input per 60 square inches of glueline would be 350 kW R.F. Unit energy cost, assuming 55% efficiency in generating R.F. power and a special electricity tariff of 1.8 cents/ kW hour, would amount to 48 cents per 100 su. ft. of product.

Conclusion

The introductory sections of this paper arrived at the conclusion that framing timber laminated from veneer would almost certainly be superior in quality to an equivalent solid product. Also, since conversion and raw material costs would be about the same for both products, the viability of a veneer based operation would be assured if there was a favourable balance between value added and the costs associated with labour and investment in equipment for the additional processes of laminating and reconversion. This basis for evaluation would be valid for present day conditions in Australia. Future changes in the raw material situation such as a relative increase in log costs over glue costs would favour a veneer based operation and would necessitate evaluation on different terms.

Unfortunately information on the performance of a veneer product from Australian species is still very limited and it is not as yet possible to estimate with any precision the value added by laminating. This made the task of appraising the various production concepts difficult. However, it became clear that most production schemes would require heavy investment in laminating and auxiliary equipment. With the exception perhaps of the concept employing R.F. heating overall manufacturing costs would be greater than for making plywood. Also with all but one of the concepts, that proposed by Koch, further research and development will be needed to show that they would in fact be commercially feasible.

When full information is available on the performance of the product and the processes are fully proven it may be decided that conditions are not yet right for a veneer product. Nevertheless the concept of making framing timbers from veneers is still evolving and new and better approaches are likely to be found.

From the conservation viewpoint the idea is well worth persevering with since, in the words of one authority, it offers at least a 50% higher yield of house frames from logs. This estimate takes into account the increase in yield in conversion and the saving from diminution in frame sections that becomes possible when a higher grade of timber and longer lengths are used.

Acknowledgement

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BUCKLING STRENGTH OF PLYWOOD WEBS

R. H. Leicester

1. INTRODUCTION

In AS 1720, the metric version of the SAA Timber Engineering Code (Ref. 1), a design procedure is presented for the buckling strength of slender plywood webs. The following is an outline of the concepts on which this procedure is based. These concepts relate to small deformation theory which usually leads to conservative estimates of strength in the case of plate structures. At present there is inadequate information for the formulation of a design procedure based on the true ultimate strength of plywood webs.

2. THE EULER BUCKLING LOAD

The design procedure based on small deformation theory involves the use of the Euler buckling load. Good approximations for this load may be obtained from the use of simple variational methods such as those described by Timoshenko (Ref. 2). These methods have been applied by Lekhnitskii (Ref. 3) and March *et al.* (Ref. 4) to many useful problems of plywood diaphragms.

The following discussion is concerned with a simply supported rectangular plywood plate such as that shown in Figure 1, of side lengths "a" and "b", thickness "h", and with the grain of the plies running parallel to the sides of the plate. The Euler buckling load of these diaphragms is specified in terms of plate bending stiffness parameters defined as follows,

$$\lambda = 1 - \mu_{TL}\,\mu_{LT} \qquad \text{——— (1a)}$$

$$D_1 \equiv E_1 h^3/12 = \int_{-h/2}^{h/2} (E_x/\lambda)\, z^2.dz \qquad \text{——— (1b)}$$

$$D_2 \equiv E_2 h^3/12 = \int_{-h/2}^{h/2} (E_y/\lambda)\, z^2.dz \qquad \text{——— (1c)}$$

$$C = G_{LT} h^3/6 \qquad \text{——— (1d)}$$

$$\alpha = (E_L\, \mu_{TL}\, h^3)/(12\lambda) \qquad \text{——— (1e)}$$

$$D_3 = \alpha + C \qquad \text{——— (1f)}$$

$$\beta = D_3/\sqrt{D_1 D_2} \qquad \text{——— (1g)}$$

where z refers to the distance along the coordinate perpendicular to the plane of the plywood sheet, E_L and E_T are the Young's moduli of elasticity

parallel and perpendicular to the grain of the plies respectively, E_x and E_y are the Young's moduli of elasticity of the appropriate plies in the x and y directions respectively, E_1 and E_2 are defined by equations (1b) and (1c), G_{LT} is the shear modulus in the plane of the plies, and μ_{TL} and μ_{LT} are Poisson's ratios for the plies relative to the grain direction and defined such that

$$E_T \mu_{LT} = E_L \mu_{TL} \quad .$$

For the case of edge loads applied in the plane of the plywood plate as shown in Figure 1, the theoretical mode shape for Euler buckling of a plate infinitely long in the x-direction consists of a half wave in the y-direction and a uniform train of waves in the x-direction with a characteristic half wave length that will be denoted by a_{ch}. This limiting value of the Euler buckling load will be denoted by $N_{E(\infty)}$ and may be written in the form

$$N_{E(\infty)} = \frac{\pi^2 \sqrt{D_1 D_2}}{b^2} \, k \qquad \text{——— (2)}$$

where k is a function of the plate stiffness parameters.

The following are based on good approximate derivations by Lekhnitskii (Ref. 3) of $N_{E(\infty)}$ for the membrane forces shown in Fig. 1;

(a) For loading by end compression membrane force N_C,

$$k = 2(1 + \beta) \qquad \text{——— (3a)}$$

$$a_{ch} = b \sqrt[4]{D_1/D_2} \qquad \text{——— (3b)}$$

(b) For loading by edgewise bending force N_B,

$$k = (9/32)\, \pi^2 \sqrt{25 + 40\beta + 16\beta^2} \qquad \text{——— (4a)}$$

$$a_{ch} = b \sqrt[4]{D_1/4D_2} \qquad \text{——— (4b)}$$

(c) For loading by edge shear N_S,

$$k = \sqrt[4]{D_2/D_1}\, [3.66 + 2.00\beta] \qquad \text{——— (5a)}$$

$$a_{ch} = b[1.00 + 2.00\beta] \sqrt[4]{D_1/D_2} \qquad \text{——— (5b)}$$

The limiting Euler load $N_{E(\infty)}$ is a good approximation to the Euler load N_E for panels with side lengths longer than the characteristic value a_{ch}. For shorter panels N_E can be considerably greater than $N_{E(\infty)}$

and Figure 2 illustrates the assumptions on which are based the appropriate modification factors in AS 1720.

Lekhnitskii (Ref. 3) and March *et al.* (Ref. 4) have also computed the Euler buckling loads for many practical cases other than those illustrated in Figure 1. In particular the results of the numerical analysis indicate that a suitable criterion for the combined actions of the membrane stresses shown in Figure 1 is

$$(N_C/N_{EC}) + (N_B/N_{EB})^2 + (N_S/N_{ES})^2 = 1 \qquad \text{——— (6)}$$

where N_{EC}, N_{EB} and N_{ES} are the Euler buckling values of N_C, N_B and N_S respectively when one of these is acting alone.

3. DESIGN BUCKLING STRENGTH (SMALL DEFORMATION THEORY)

In AS 1720, the effect of slenderness on strength is denoted by a stability factor K_{12} defined by

$$K_{12} = f_a/F \qquad \text{——— (7)}$$

where f_a is the allowable design stress and F is the value of f_a if the member were completely stable. The stability factor K_{12} is given as a function of the material used and the slenderness coefficient S defined by

$$S = \Omega \sqrt{F/F_E} \qquad \text{——— (8)}$$

where Ω is a specified constant and F_E is the Euler buckling value of F.

The rationale for this definition of slenderness is illustrated in Figure 3. It is based on the fact that according to small deformation theory the graph of the stability factor is asymptotic to the line $f_a = F$ for small values of slenderness, and asymptotic to the curve $f_a = F_E/3$ for large values of slenderness when a safety factor of 3 is applied to the estimated Euler load. With the slenderness coefficient S defined by equation (8), these two asymptotic lines graph the same for all structural members and consequently the curves of stability factors plotted in this way are normalised and very similar to one another.

In AS 1720, the specified constant Ω used in equation (8) is taken to be given by

$$\Omega = 0.822\ (E_L/F'_c) \qquad \text{——— (9)}$$

where F'_c is the specified basic design stress in compression. The reason for this choice of constant Ω is that it leads to the familiar S = L/D for solid rectangular pin-ended columns of length L and depth D.

For the case of a plywood membrane, equations (8) and (9) may be combined and rewritten

$$S = 0.822\ (E_L/F'_c)(N/N_E) \qquad \text{——— (10)}$$

where N is the allowable design membrane force per unit length for stable membranes and may be written

$$N = j.F'_c\, h \qquad \text{——— (11)}$$

in which j is a constant that can be determined directly from the design rules of AS 1720. Equations (1), (2), (10) and (11) then lead to the following definition of slenderness coefficient for a plywood diaphragm,

$$S = q(b/h) \qquad \text{——— (12)}$$

where

$$q = (E_L/\sqrt{E_1 E_2})(j/k) \qquad \text{——— (13)}$$

In AS 1720 the constant q has been evaluated and tabulated for various plywood lay-ups and edge loads. The slenderness coefficient obtained according to equation (12) is then used to obtain a stability factor corresponding to dry solid timber columns of Class A straightness. For the case of combined edge loads, AS 1720 recommends the use of an interaction formula similar to that of equation (6), as this form of interaction appears applicable to both Euler buckling and the strength of stable diaphragms.

4. ULTIMATE BUCKLING STRENGTH

The available published test data indicate that for slender webs the ultimate buckling strength may considerably exceed the Euler buckling load, a fact which is at variance with the predictions of the small deformation theory. One example of this is illustrated in Figure 4 with data taken from Reference 4 for plywoods subjected to an end compression force such as that denoted by N_C in Figure 1. The notation N_{ult} used in Figure 4 refers to the ultimate strength of the plywood panel; the notation N_{stable} is the value of N_{ult} that would be obtained if the panel were perfectly stable.

The small deformation concepts used for the design procedure in AS 1720 may be represented approximately by the Rankine equation

$$(N_{ult}/N_{stable}) + (N_{ult}/N_E) = 1 \qquad \text{——— (14)}$$

The idealised large deformation strength theory proposed by von Karman (Ref. 2) may be written

$$(N_{ult}/N_{stable})(N_{ult}/N_E) = 1 \qquad \text{——— (15)}$$

It is seen from Figure 4 that AS 1720 and the Rankine equation (14) considerably underestimate the strength of slender webs, and equation (15) is unsafe for stocky webs.

A useful fit to the test data with the Rankine formula is obtained if the slenderness coefficient is taken to be only 70% of the value given by equation (8). This leads to

$$(N_{ult}/N_{stable}) + (N_{ult}/0.49\, N_E) = 1 \qquad \text{——— (16)}$$

Similarly the large deformation equation of von Karman may be modified as follows to produce a reasonable fit to the test data,

$$(N_{ult}/N_{stable})(N_{ult}/N_E) = 0.5 \qquad \text{——— (17)}$$

Equations (16) and (17) are plotted in Figure 4.

This example illustrates the fact that for slender webs it may be necessary to consider large deformation theory to derive realistic design procedures.

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a number of the outer laminations must either be of continuous length or contain structural joints. Therefore the fabricator must have some equipment to make structural joints in the laminations.

Design Procedures

In the Timber Engineering Code, the theory of linear elastic fracture mechanics has been used to provide formulae to estimate the effect of tension and shear stresses acting at a joint. The formula contained in the metric draft for the calculation of stress at an inner butt jointed lamination is given by

$$\frac{f_t \sqrt{t}}{10} + \frac{f_s \sqrt{t}}{1.7} \leq K.F_{sj} \qquad \ldots\ldots\ldots\ldots\ldots (1)$$

where f_t = nominal tensile stress at the butt joint (MPa)

f_s = nominal shear stress at the butt joint (MPa)

t = lamination thickness (mm)

F_{sj} = the lesser of 2.3 MPa or the basic shear stress

K = modification factors.

For a simply supported beam subject to a uniformly distributed load, the maximum bending moment occurs at the point of zero shear force, and zero bending moment occurs at the point of maximum shear force. Therefore equation (1) should be calculated firstly for the cross-section subject to maximum bending moment, then checked at the cross-section having maximum shear, and also at a cross-section estimated to have the worst combination of tension and shear.

Likewise, considering the distribution of stresses across a given plane in the beam, maximum tensile stress due to bending occurs at the position of zero shear and maximum shear occurs at the point of zero moment. Therefore equation (1) should be calculated for the butt joint subject to the highest tensile stress, and whatever shear stress may be present; and also for the butt joint subject to the highest shear stress, and the amount of tension stress present.

For beams manufactured in accordance with AS 1328 "Glued Laminated Structural Timber", which specifies a minimum spacing and also forbids clusters of joints, there is no reduction necessary in the calculation of moment of inertia to be used to estimate bending deflection. That is, a glulam beam containing butt joints is as stiff as one containing structurally jointed laminations which, in turn, is as stiff as a solid beam.

Optimum Location of Butt Joints

Glulam beams are generally used over relatively long spans. In such cases, tensile stresses due to bending are more critical than are shear stresses. Therefore, if butt joints are to be used, the best place to locate them would be in the laminations near to the mid-depth of the beam, where the tensile stresses are a minimum. A convenient rule of thumb that may be used is that butt joints may be located in the central third of the beam depth.

GLULAM - TO BUTT OR NOT TO BUTT

G. F. Reardon

Introduction

Over the last five or more years there has been a renewal of interest in glued laminated construction. During that period, the Timber Engineering Code, AS CA65, was first issued, and this code contained revised recommendations for the design of laminated members. In particular, a definite procedure was specified for the design of members containing butt joints, that is joints formed when two laminations have square cut ends and are butted against each other. With this type of joint there is no continuity within the lamination and any axial force must be transferred across the butt via adjacent laminations.

Whilst the Timber Engineering Design Handbook acknowledged the deleterious effect of butt joints on strength, it offered only an empirical procedure to be followed when using them. This method specified a reduction in moment of inertia to be used when calculating the section modulus of a beam, or the cross-sectional area of a compression member. Because of this empirical approach to the design, the use of butt joints in glulam construction was not encouraged.

Types of Joint

One of the main reasons for laminating timber is to provide structural members that are of a greater cross-section or length than is available from sawn timber. Also, one of the benefits in fabricating glulam is to be able to upgrade the timber by cutting out defects in the laminations. In order to do this, laminations must be jointed along their length. Two different methods of end jointing laminations are currently being used in the Australian glulam industry, namely finger jointing and scarf jointing. Both these methods require special machinery to make the joints. Whilst the machinery for making finger joints is more expensive it results in a minimal wastage of timber in forming the joint, whereas for a scarf joint the wastage of timber is in the order of 3%. These two methods of jointing both provide structural joints capable of carrying axial loads. As the strength of the joints is greater than that of the worst defect on which the material is graded, the laminations can be considered equivalent to continuous laminations. Therefore in the context of this paper the term "continuous laminations" shall include both laminations of continuous length and structurally jointed laminations.

A third alternative is to make no structural joint at all in the longitudinal members, thus the butt joint. A butt jointed lamination relies solely on its adjacent laminations to transfer axial forces across the butt. Therefore the shear strength of the timber, as well as of the glue bond in the vicinity of the butt, becomes critical.

The advantage of butt jointing laminations is that there is no need for special preparation of timber. Thus there is a saving in equipment cost and a saving in manpower cost as well as the elimination of timber wastage. It should be noted that for butt jointed glulam to be efficient

Test results have shown that for the range of lamination thicknesses normally used for glulam, butt joints in the compression zone of a beam have no effect on the beam's fracture strength. Therefore butt joints may be used in the compression zone as well as in the central core of the beam depth. Thus a beam ten laminations deep may have a lay-up of one continuous top lamination, say four continuous bottom laminations and the remainder may be butt jointed. From the design aspect, the top lamination does not have to be continuous, but in order to withstand handling stresses, it is preferable to have it so.

While this approach may sound simple in theory, it does have one basic disadvantage. It means that the beam in question now has a top side and a bottom side, with significantly different strengths in each direction. A beam used incorrectly would have only approximately one third of the anticipated strength. It is therefore essential that the beam be used correct side up. To ensure this, it should be marked clearly and frequently.

Another concern about introducing butt joints into the top zone of a beam is that in some instances this zone may be subject to tension stresses rather than compression. Such is the case over the supports of a continuous beam or for a cantilever. In a situation such as this, the glulam beam should be fabricated with only the central zone butt jointed, and with the top and bottom zones continuous.

When to Use Butt Joints

The introduction of butt joints results in a saving in fabrication cost of each structural joint that was replaced by a butt joint, without a compensating cost outlay. When the limiting criterion for design is stiffness rather than strength, a large proportion of the laminations can be butt jointed. Such is the case with floor beams where, for reasons of human comfort, the limiting deflection is kept relatively low. The following example demonstrates this principle.

A glulam floor beam, 50 x 325 mm, of stress grade F8, can support a combination of 1.5 kN/m live load and 0.5 kN/m dead load over a 5.7 m span, using a design criterion of span/360 for live load deflection. The beam, consisting of 13 laminations, 25 mm thick, would still be strong enough if only the four bottom laminations were continuous. Conversely, if there is no deflection limitation, a beam of 11 laminations would be strong enough provided that the bottom four laminations were continuous.

The above example demonstrates an optimum solution to a particular problem. It can be envisaged that for a different set of parameters, the optimum solution may be to use a different number of butt jointed laminations. However, from the manufacturer's viewpoint it would be impracticable to tailor the lay-up of each beam to suit the optimum design. The usual practical solution to this problem is for the manufacturer to specify a minimum percentage of continuous laminations to be used in the lower zone of the beam. Thus for a beam of given depth, the lay-up of laminations would be the same irrespective of its end use. This solution may occasionally result in the use of one more continuous lamination than is necessary.

Cost Savings

Obviously, if the introduction of butt joints into a beam does not mean an increase in cross-sectional area, the saving involved is directly proportional to the number of structural joints eliminated. Based on relatively rough estimates of costs, it appears that the cost of structural joints in a beam varies from 10 to 15% of the total cost of the beam. Thus if 50% of the structural joints were eliminated there should be a saving in excess of 5% of the total cost. Presumably there would be a slight cost involved in marking the beam so that it would be used right side up, but this should be negligible compared to the saving.

Conclusions

Butt jointed laminations may be used in glulam members provided they have been taken into account in the design theory. The inclusion of butt joints should reduce the fabrication cost of glulam. If butt joints are used in the top zone of a beam, special precautions must be taken to ensure that the beam is used the correct way up. If such a beam is used incorrectly its strength would be reduced by approximately 67%. It is not recommended that beams continuous over two or more spans be fabricated with butt joints in their top zone.

CSIRO CONTINUOUS KILN

Keith Fricke

INTRODUCTION

The continuous kiln was evolved about two years ago to provide an opportunity to improve commercial drying practice following successful laboratory tests on high temperature drying of radiata pine. It had been shown earlier that short sample boards 25 mm thick could be dried from green at temperatures up to 180°C in the order of three hours in a small tunnel kiln.

By using 3 m long boards of various widths and thicknesses and by being able to vary temperature, air velocity and drying time, considerable information on drying characteristics could be obtained with the prototype continuous kiln. Later variables included presteaming and differing types of racks. Methods of restraint were indeed to prove one of the most important factors of the project.

KILN DESCRIPTION

The continuous kiln prototype was designed so that boards could be dried in a unique transport system (see Fig. 1). This system consisted of loading individual pre-thicknessed boards into fixed finger racks which were attached to slowly moving, endless chains which pulled the racks through the 4 m long kiln. After a short cooling section, the racks travelled through a 1 m long steaming chamber thus receiving a HHT (high humidity treatment) of just under a quarter of the drying time. The boards were then unloaded and the empty racks returned beneath the kiln to the loading end.

Air was heated to the control temperature by a direct heating natural gas burner mounted upstream of the two air circulating fans. The air was blown down between the boards at the loading end and then redirected up and down towards the unloading end so that the boards received seven reversals of air flow during their drying. The effective air path was eight times the height of the boards on edge in the racks.

Separate racks were built for 25, 42 and 51 mm thick boards although all racks occupied 0.6 m of chain length and all were fitted with 25 mm fingers.

Pairs of small inlet and outlet vents were provided but there was no provision for any other humidity control.

EXPERIMENTAL RESULTS (See Table 1)

Runs 7, 8 and 9 using 42 mm material and Runs 10, 11 and 12 using 51 mm material were made to compare the effects of fitting locking bars across the top of the fingers to restrain spring compared to their non use, as well as to compare their compliance to twist and spring standards after drying to differing final m c (moisture content). The locking bars were found to be of little importance on spring restraint. Both twist and

spring seemed to be more dependent on a higher final m c. Although the best runs, 8 and 12, showed only 83 and 74 per cent compliance after drying, they showed 97 and 91 per cent after holding and machining. However, when these boards were visually inspected after machining by the timber suppliers' inspectors, all boards except those with "heart in" were passed.

Following further laboratory drying at 180°C, drying times were so reduced that runs 13 and 14 were made in the continuous kiln to again test the locking bars at this higher temperature and to also compare the effects of HHT's in the kiln steaming chamber with a separate steaming chamber known to run at higher temperatures and humidities. Again there was no improvement in spring with the locking bars fitted but a slight improvement occurred in twist and spring with the 95°C HHT. Similar improved conditions are expected in larger steaming chambers that would be used in commercial installations.

A series of smaller runs, 15 to 18, were made to check the effects of presteaming on both radiata pine and slash pine. For both species the major effect of presteaming was the decrease in final m c which indicated that subsequent drying times could be reduced to reach the same final m c. However, there seems little advantage in saving on drying time at the expense of additional presteaming time for no apparent gain in compliance to distortion standards. Presteaming may well be of benefit where a high proportion of "heart in" material is dried.

The comparatively poor results for slash pine prompted further tests and runs 20 to 24 and 27 and 28 were made using various sizes of boards, and high and conventional drying schedules as well as new racks incorporating improved restraint devices. The low compliance percentages that resulted from these runs, including that intended to simulate present commercial drying schedules at 120°C, clearly showed that more severe, continuous restraint must be applied to this material than our racks could do at the time.

Runs 25 and 26 were made with "heart in" radiata pine in the most difficult size to restrain, 51 by 80 mm. These were the only runs with radiata that did not use "run of the mill" material - that is only a small proportion of "heart in" boards. The racks with continuously applied restraint gave a much better result than the conventional racks but were still below the results of earlier "run of the mill" runs.

Run 29 was made with conventional racks using radiata pine to determine the effects of one shift operation - that is stopping the kiln when full, allowing it to cool down and then start up from cold. There was found to be little difference in either final m c or compliance to standards for boards dried continuously (29 b) compared to those held in the kiln for one night (29 c and d) or those held in the kiln for three nights (29 a).

DRYING TIMES

Compared to the estimated 54 hours to kiln dry 42 mm radiata pine at 88°C and 14 hours at 120°C, the continuous kiln provided drying times of the order of 5 3/4 hours at 150°C and 3½ hours at 180°C.

HEAT USAGE

Compared to the estimated heat requirement of conventional drying of radiata pine at 88°C, the gas readings for the continuous kiln indicated heat usage at about 50 per cent at 150°C and about 45 per cent at 180°C (these estimates do not include steam for HHT).

STRENGTH

Strength tests (compression parallel to grain) have been carried out for samples dried at 150°C and compared to control samples have shown no significant difference. Similar tests on samples have shown no significant difference. Similar tests on samples dried at 180°C have been tested but the results are not to hand at this time.

GLUABILITY

Doubts have been raised on the gluability of material after having been subjected to temperatures above about 150°C. Samples or radiata and slash pine dried at 180°C are undergoing standard gluing tests at this time.

C.S.I.R.O. DIVISION OF BUILDING RESEARCH
FOREST CONVERSION ENGINEERING GROUP
CONTINUOUS KILN TESTS - 1974

TABLE 1

RUN	SPECIES	CROSS SECTION mm x mm	NO. OF BOARDS	FAN REVS rpm	AIR FLOW m/sec	PRESTEAM TEMP °C	PRESTEAM TIME hr. min.	DRYING TEMP °C	DRYING TIME hr.min.	H.H.T. TEMP °C	H.H.T. TIME hr.min.	INITIAL M.C. %	FINAL M.C. %	FINAL M.C. (M.METER) %	GAS FLOW ft^3/hr	GAS RATE ft^3/m^3	RESTRAINT SPRING	RESTRAINT TWIST	RESTRAINT BOW	F7, AS1490 or STD AS0107 SPRING %	F7, AS1490 or STD AS0107 TWIST %	F7, AS1490 or STD AS0107 SPRING & TWIST %
7	Radiata	42 x 102	268	960	6	-	-	155	6.30	85.90	1.30	50	6	-	426	1834	0	/	/	81	81	68
8	Radiata	42 x 102	268	960	6	-	-	152	5.45	85.95	1.20	68	10	-	500	1904	/	/	/	91	90	83
9	Radiata	42 x 102	268	960	6	-	-	150	6.20	80.90	1.25	72	8	-	492	2063	/	/	/	97	74	72
10	Radiata	51 x 102	238	960	7	-	-	148	8.05	75.85	1.50	60	6	-	486	2424	0	/	/	92	65	61
11	Radiata	51 x 102	238	960	7	-	-	150	7.27	80.90	1.45	72	7	-	494	2272	/	/	/	95	76	71
12	Radiata	51 x 102	238	960	7	-	-	142	8.08	75.85	1.40	65	9	-	513	2575	/	/	/	94	78	74
13a	Radiata	42 x 102	4	960	6	-	-	184	3.36	-	-	?	8	-	667	1590	0	/	/	100	100	100
b	"	"	32	"	"	-	-	"	"	95	1.00	73	14	17	"	"	0	/	/	88	94	88
c	"	"	106	"	"	-	-	"	"	82	0.55	51	7	13	"	"	0	/	/	73	86	65
14a	Radiata	42 x 102	4	960	6	-	-	184	3.36	-	-	?	6	-	667	1590	/	/	/	50	100	50
b	"	"	32	"	"	-	-	"	"	95	1.00	51	11	13	"	"	/	/	/	71	89	64
c	"	"	90	"	"	-	-	"	"	82	0.55	54	14	17	"	"	/	/	/	75	80	61
15	Radiata	42 x 102	32	2160	10	100	1.00	171	3.16	95	1.05	72	7	13	-	-	0	/	/	100	94	94
16	Radiata	42 x 102	32	2160	10	-	-	171	3.16	95	1.05	85	13	19	-	-	0	/	/	100	97	97
17	Slash	51 x 80	28	2160	12	100	1.00	178	4.29	95	1.00	106	9	12	-	-	0	/	/	100	7	7
18	Slash	51 x 80	28	2160	12	-	-	178	4.29	95	1.00	106	11	15	-	-	0	/	/	89	21	21
20	Slash	42 x 80	16	2160	10	-	-	177	4.15	83	1.22	106	6	9	-	-	0	/	/	75	12	12
21	Slash	51 x 80	14	2160	12	-	-	180	4.37	75	1.05	107	-	10	-	-	0	/	/	93	0	0
22	Slash	51 x 80	14	2160	12	-	-	180	4.37	75	1.05	107	-	9	-	-	SWING RACK			106	7	7

CSIRO DIVISION OF BUILDING RESEARCH

FOREST CONVERSION ENGINEERING GROUP

CONTINUOUS KILN TESTS – 1974

TABLE 1 (cont'd).

RUN	SPECIES	CROSS SECTION mm x mm	NO. OF BOARDS	FAN REVS rpm	AIR FLOW m/sec	PRESTEAM TEMP °C	PRESTEAM TIME hr. min.	DRYING TEMP °C	DRYING TIME hr.min.	H.H.T. TEMP °C	H.H.T. TIME hr.min.	INITIAL M.C. %	FINAL M.C. %	FINAL M.C. (M. METER) %	GAS FLOW ft^3/hr	GAS RATE ft^3/m^3	RESTRAINT SPRING TWIST BOW	F7,AS1490 or STD AS0107 SPRING %	TWIST %	SPRING & TWIST %
23	Slash	51 x 80	14	960	7	–	–	124	14.00	95	4.00	91			–	–	SWING RACK	100	29	29
24	Slash	51 x 80	14	960	7	–	–	124	14.00	95	4.00	91	10	11	–	–	CONVENTIONAL RACK	93	21	21
25a	Radiata	51 x 80	14	2160	12	–	–	177	2.46	70	0.38	38	9	15	–	–	SWING RACK	100	43	43
b	"	"	"	"	"	–	–	"	"	"	"	"	"	"	–	–	CONVENTIONAL RACK	93	14	14
26a	Radiata	51 x 80	14	2160	12	–	–	177	2.46	70	0.38	38	9	15	–	–	TRANSVERSE RACK	100	64	64
b	"	"	"	"	"	–	–	"	"	"	"	"	"	"	–	–	CONVENTIONAL RACK	86	7	7
27	Slash	51 x 80	14	2160	12	–	–	177	4.25	95	2.00	136		12	–	–	CONVENTIONAL RACK	93	0	0
28	Slash	51 x 80	14	2160	12	–	–	177	4.25	95	2.00	136		10	–	–	TRANSVERSE RACK	93	7	7
29	Radiata	42 x 102	318	2160	10	–	–	177	3.38	75	0.50	61	7	12			CONVENTONAL RACK	92	85	77
a	3 night break		90	"	"	–	–	"	"	"	"	64	9	16			" "	88	91	80
b	No break		88	"	"	–	–	"	"	"	"	58	6	11	800	1932	" "	98	84	81
c	1 night break		88	"	"	–	–	"	"	"	"	59	6	10			" "	90	78	69
d	1 night break		52	"	"	–	–	"	"	"	"	64	7	12			" "	91	89	80

ASPECTS OF THE HIGH TEMPERATURE DRYING OF DISTORTION-PRONE JUVENILE SOFTWOOD

J. Hartley

High temperature drying is becoming increasingly accepted as a commercial method of drying plantation softwoods in Australia, particularly *Pinus radiata* D. Don, *P. elliottii* Engelm. var. *elliottii* and *Araucaria cunninghamii* Ait. ex D. Don. It is used both as a method for accelerating drying in general, and also, in conjunction with substantial restraint, as a means of controlling warp in distortion-prone core-wood. This latter aspect has been the main stimulus for the commercial adoption of high-temperature drying in Australia, which has rapidly followed relatively recent research work (3, 4, 6, 7, 8, 13, 15, 16, 19).

We have assisted the industry in planning and establishing high-temperature drying operations, and have become aware of a number of aspects that are still far from fully resolved. This paper discusses some of these aspects that are particularly relevant to the high-temperature drying of core-wood under restraint in compartment kilns, but some will also be relevant to more general applications of this drying method.

1. Moisture content control

There is general agreement that to obtain a satisfactorily narrow range in final moisture content (m.c.) charges should be overdried then given a final conditioning treatment (3, 5, 8). The final mean m.c.'s generally recommended in Australia are in the range of 9 to 11% (6, 8, 19), which is consistent with recommendations to dry to about the minimum service equilibrium moisture content (e.m.c.) to achieve maximum stability (3, 4, 14). High-temperature dried wood has a lower e.m.c. than wood dried at conventional temperatures (1, 18, 22), and this will be accentuated by the hysteresis effect in wood that is overdried and then conditioned.

This indicates that the desirable m.c. specification for high-temperature dried material should be somewhat lower than for conventionally dried - probably by about 2%. This may cause practical problems for specifiers and users as high-temperature dried material cannot be readily identified after planing. Another problem is that relatively low m.c.'s in *P. radiata* cannot be measured with the electrical resistance moisture meters normally used.

2. Monitoring drying

Determining when the charge has reached the desired final m.c. is a problem that has not been fully solved. Electrodes embedded in the timber connected to a moisture meter and potentiometer outside the kiln (21) have been used in research (6, 20) and are used in commercial drying in Queensland. This method has the disadvantage of the time taken to prepare and embed the electrodes, and the problem of assessing the rather "wild" m.c. readings that can occur, although this can be eased by measuring the temperature difference between the wood and the circulating air (6). Also little information is available about the corrections to be made to meter readings in the range of temperatures used in high-temperature drying. A relationship has been found for *P. elliottii* (6), and has been referred to, but not published, for *P. radiata* (20). Further work is required to improve the convenience of this method and the reliability of the readings, and to determine the corrections for temperature to be applied for the commercially important species.

For routine drying it should be possible to establish time schedules in each plant. This will require a considerable amount of practical testing and routine production quality control of final m.c.'s, with appropriate feedback to the kiln operators. Drying time for southern pines in the U.S.A. varies approximately linearly with material thickness and increases with increasing material width (15, 16). This aspect should be checked for the commercial Australian species - particularly *P. radiata*. In commercial practice using constant sticker thickness for all timber sizes the drying times will also be affected by the different air velocities resulting from different material thicknesses.

Another indicator of when the charge is dried is the temperature drop across the stack (6, 17). This is used in at least one commercial plant, but has to be established for each type of charge in each plant, similar to establishing time schedules. The mean difference between a number of points on each side of the charge should be used to minimise errors caused by localised variations in air velocity.

It is likely that the last two methods used in combination will be most satisfactory for routine commercial operations, with the embedded electrode technique used while the drying parameters are being determined, and for any non-routine drying.

3. Effect of stack construction on drying rate

Most of the research has been done with relatively narrow restrained stacks. However the radiata pine industry is applying the technique to normal commercial sized stacks, generally about 1.8 m wide. Little has been published that can provide practical guidance about the interaction between drying conditions, material size, sticker thickness and air velocity with drying rate and final m.c. uniformity in stacks of this width. More work is needed in this area, but there are practical difficulties as few, if any, research facilities can accommodate stacks this wide, and commercial plants generally have only limited capacity for varying drying conditions - particularly air velocity.

4. Factors involved in the control of warp

There are many factors involved, with many probable interactions between them. Some have been explored in research projects, but the effect of many remains quantitatively virtually unknown. Some of the factors are -

(a) The influence of pre-steaming

This gave the best results with *P. radiata* "heart-in" studs (19), and gave a lower torque required to straighten unrestrained studs during drying in laboratory experiments (20). Live steam injected into the kiln was used to accelerate heating during research on *P. elliottii* and *A. cunninghamii*, and gave initial wet bulb temperatures higher than those used subsequently during drying (6). Koch (13, 15, 16) did not heat with high-humidity conditions, but his restraint is not directly comparable with

that used in Australian research. Torque developed in drying *P. radiata* studs was reduced by increasing air velocity, and the torque required to straighten previously dried studs was found to be influenced by temperature with a minimum at 127 to 146°C (20).

It appears that there is probably an interaction between the use of pre-steaming, drying temperature and drying rate as influenced by air velocity and the level of restraint required to achieve a particular reduction in warp. This has not been quantified in a manner directly applicable to commercial drying, and present commercial practices regarding pre-steaming and the level of restraint used vary widely from plant to plant.

(b) Reverse twisting of stacks

This was used in research on *P. elliottii* and *A. cunninghamii* and has been adopted commercially in Queensland (6, 7). With the reducing average size of *P. radiata* sawlogs, the mean grain spirality is increasing, with a corresponding tendency for twist to become more severe and predominantly anti-clockwise (9). It is likely that clockwise twisting of stacks will reduce the mean twist and increase the proportion of the end product with twist within acceptable limits.

(c) Effect of material size

The restraining effect of different levels of weighting on 100 x 38 mm and 25 mm boards in *P. radiata* and 75 x 50 mm and 100 x 38 mm *P. elliottii* and *A. cunninghamii* has been examined (4, 6, 8, 19). More work is required to determine optimum levels of restraint on the other important framing sizes in *P. radiata*.

5. Post-drying cooling period under restraint

Insufficient is known about the improvement in product quality gained from maintaining restraint during the cooling period or longer, and whether this is related to the drying conditions used. Recommendations range from removing the weights from 25 mm *P. radiata* as soon as it is cool (4), to the 24 h (6, 8, 19) and 48 h (13) used in experimental trials. The effect of this possible requirement on the design of continuous driers has also been recognised (12, 13, 14). A subjective report from one producer indicated appreciably improved product quality in framing that had been stored under restraint over the New Year close-down period before the stacks were broken down.

6. Other effects of high-temperature drying

(a) A reduction in shrinkage has been reported (1, 15). This could be partly offset by drying to lower final mean m.c.'s than by conventional drying, but it may be enhanced by the lower shrinkage of low density immature wood (2, 11). This could lead to the adoption of lower shrinkage allowances in sawing juvenile wood to be dried under restraint at high temperature.

(b) Effects on strength properties have been widely investigated for a number of species and will not be discussed in detail. Generally effects are only small except in a few cases, or after much longer

exposure to elevated temperatures than occurs in normal H-T drying. Any effect is certainly a function of both temperature and duration of exposure.

(c) An upper limit to the severity of drying conditions could be set by the effect on gluing properties (10).

(d) It is possible that high-temperature drying could alter the susceptibility of wood to attack by insects. Resin migration and volatilisation occurs, and the proportions and compositions of sugars and starches could be altered.

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EFFECT OF VARYING STICKER THICKNESS IN HIGH TEMPERATURE DRYING

D. K. Gough

Introduction

In any seasoning operation and in particular with high temperature drying, the nature of the temperature drop across the stack is important in achieving optimum production of uniformly dried timber.

As hot air passes through a stack of green timber, its evaporation potential is greatly reduced. Three factors determine the location of this area of low evaporation:-

1. Fan capacity
2. Width of stack
3. Sticker thickness

In combination they amount to the volume of air, per unit time, per unit width of stack, and slow and non-uniform drying occurs when this value is low.

A study was undertaken at Wilkinsons' Pine, Caboolture, where fan capacity in the 10 m long kilns is fixed at five x 915 mm diameter reversible cross shaft fans running at 1440 rpm. Stack width is fixed at 1.35 m. To optimise drying time consistent with uniform drying, different sticker thicknesses: 32 mm, 28.5 mm and 25 mm were investigated for slash pine 40 mm thick, green off saw.

Experimental method

Final moisture content, uniformity of final moisture content, and time of drying were the criteria on which the judgement of optimum sticker thickness could be made.

Twelve kiln charges of 40 x 100 mm pine were investigated, the three treatments being repeated four times each. Final moisture content was sampled on the systematic basis illustrated in the diagram. Values were obtained using a moisture meter and nails driven in to the core. One reading was taken per piece. The average moisture content value for each charge, and averages of the readings for each of five board positions across the stack were examined.

Termination of the drying of a kiln charge was a decision made by the kiln operator, based on readings of a number of moisture content electrodes embedded in selected boards in the charge. In some charges unfortunately, the electrodes were not embedded deep enough and there was some variation in average final moisture content.

Other variables influencing drying time were:-

1. possible variation in initial moisture content between charges,
2. inconsistent steam pressure and hence kiln temperature.

In view of this the assessment of results had to be made on a more subjective basis.

Results

Christensen and Gough (1975)* showed that 11 per cent moisture content was about the maximum desirable for high temperature dried material. In this project charges with higher average values were considered to be insufficiently dried.

Within group 1, (25 mm stickers), two runs had average moisture content values of 9.75% and 9.8% respectively. In group 2, (28.5 mm stickers) only one run had a desirable moisture content condition of 10.45% and in the 32 mm group there was only one run with a suitable average moisture content of 10.81%.

Moisture Content values across the stack for these runs have been plotted (Figure 1) with an average being taken for the two 25 mm runs.

As indicated in Figure 1, there was some variation in average final moisture content between the three sticker thickness groups, and some indication is gained of variation in M/C range across the stack. Direct evaluation of drying times to a standard moisture content was not possible. However it has been estimated that, in this particular kiln and with other conditions being comparable, drying times to 10% average M/C for charges of 40 mm slash pine, having the sticker sizes under investigation, would be of the order of -

25 mm	23.25 hrs
28.5 mm	22.5 hrs
32 mm	21.25 hrs

Table 1 is a summary of the situation. Kiln capacity increases with smaller sticker thickness and this is recorded as "number of rows".

Based on the 32 mm stickers, kiln capacity for the 28.5 mm stickers would be increased by 4% and for 25 mm by 8%. There would however be a corresponding increase in drying time of 5.9% and 9.4% respectively.

The 32 mm stickers gave the shortest drying time but when working within a 24 hour drying cycle this is not of great importance.

Drying time for charges with 25 mm stickers is estimated at 23.25 hours and allowing for some variability in drying time, this size could result in some charges taking more than 24 hours to dry. Also variation in M/C across the stack was unfavourable for the 25 mm stickers.

Charges with the 28.5 mm stickers should dry well within the 24 hour period, with a satisfactory moisture distribution also. For slightly increased kiln capacity this size would be preferred over the 32 mm stickers.

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* Christensen, F. J. and D. K. Gough, 1975, Control of drying distortion in framing from young plantation slash pine (*Pinus elliottii*), CSIRO Div. of Building Research Tech. Paper (in preparation).

Air circulation rates also listed in Table 1 were taken for each sticker size. The increase in circulation from the 28.5 mm to 25 mm stickers is almost twice that observed from 32 mm to 28.5 mm stickers. It is likely that with the thinner sticker spacing, air flow is more laminar rather than turbulent, and although a faster rate would be obtained, turbulent air flow is more desirable.

The volume of air per second passing through each sticker spacing per metre of stack length has also been recorded. The optimum value for this figure is not known, but to maintain uniformity of drying it would have to increase as stack width increased.

Included in this project was a trial to assess the suitability of timbers other than slash pine for use as stickers. Certain hardwoods could be readily obtained as a recovery exercise from hardwood mills, where shorts and small sizes are usually of low value.

The hardwoods had been kiln dried and dressed prior to use and dried slash pine stickers were used as controls. All species were examined for deterioration after each run and comments after four runs of each size are as follows:-

1. White gum (*E. dunnii*) abnormal shrinkage and some checking was evident after the first run. The checking increased with further use.

2. Stringybark (*E. eugenioides*) developed some abnormal shrinkage and some checking but not as bad as white gum.

3. Forest Red Gum (*E. tereticornis*) there was some surface checking but general condition was good.

4. Tulip Oak (*Argyrodendron trifoliolatum*) some checking but general condition was good.

5. Brush Box (*Tristania conferta*) some light checking and a tendency to spring.

The white gum is considered unsuitable, stringybark marginally suitable while the remaining species appeared to be comparable in performance with slash pine. Some indentation was observed but this was no worse than with slash.

Important points are that the hardwoods must be well dried before use and timber close to knots should be excluded.

TABLE 1

Sticker Thickness mm	25	28.5	32
Estimated average time to dry to 10%, hrs	23.25	22.5	21.25
M/C variation across the stack	fair	good	good
Number of rows of boards in Wilkinsons kiln	27	26	25
Air circulation rate, m/sec	5.9	5.4	5.1
Volume of air per metre of stack length, through each sticker space m^3/sec	.148	1.54	1.63

DESIGN FOR A HIGH TEMPERATURE KILN

H. C. Wickett

As with most other Forest Authorities the Forests Department of W.A. has considerable and rapidly increasing volumes of pine timber requiring to be removed from plantations as thinnings. The wood has the usual spiral grain combined with knot whorls giving a marked tendency to twist and distortion. High temperature drying under restraint is therefore indicated to give a straight product with a minimum kiln occupation time. As our rate of production in any particular geographic area is fairly small at present we do not have the large parcels of particular length x thickness groups which would seem to be the prime requirement to justify a chain and pocket type of progressive kiln. A more or less conventional compartment type of kiln therefore seems to be indicated.

We looked at what pine producers were doing in other States and quickly decided that there were more problems than successes particularly in the following fields:-

(a) high heat usage to steady temperature state
(b) high heat losses from radiation and leaks
(c) expansion/contraction problems
(d) corrosion, materials, fastenings problems
(e) electric motor and supply wiring failure when these are in the kiln chamber.

We therefore came to the following conclusions:-

1. the fabric had to have a low mass to have a low heat requirement
2. the structure had to be well insulated to control radiation losses
3. thermal changes must not promote destruction of the fabric
4. electric motors should not be inside the chamber.

In regard to item 4 there is no difficulty in finding motors with insulation, bearing grease etc. to withstand the temperature but bearings properly designed and built with clearances to accommodate the expansions and distortions are almost impossible to find in Australia (in spite of many rash assurances to the contrary) and certainly cannot be relied upon to be available from overseas (Japan and U.S.A.) in small quantities when required. The risks here are just too great to be commercially tolerated.

Some hard thinking influenced by some yacht designing and building experience lurking in the subconscious brought a ray of light in the form of ferro-cement as a fabric. An experimental trough about 4' x 2' x 1'6" x 3/4" wall, with radiused arrises was made by the local ferro boat specialist and, after curing in a plastic cover for seven days, was heated and cooled daily for four weeks in a concrete block autoclave at 150 p.s.i.g. (367°F). It showed no sign of distress and in fact it would be certain that the strength of the trough would have been considerably improved by the steam curing. From this it was decided to proceed with a design and working drawings, which are now available as microfilm or normal dyeline, were prepared.

Preliminary consideration seemed to show that a screen type of kiln was likely to be appreciably more costly to build than a conventional overhead multiple cross-shaft type but for a thorough comparison of capital and operating costs a detailed design of each would be required. It was decided to detail a conventional type first.

For the seasoning aspects and practice a procedure set down by Leo Brennan was used as a guide. For the heat transfer, fluid flow and general thermodynamics the stalwarts Reynold, Prandtl, Nusselt and Grashof gave the necessary assistance.

As regards insulation, polyurethane foam had some attraction but even varieties claimed by their makers to withstand 250°F were too badly degraded by short term tests at this temperature to be acceptable. We therefore settled for A.C.I. Lightweight Fibreglass weighing 1 3/4 p.c.f.

When four or more chambers are operating in parallel it is probably better from the point of view of throughput, heat economy and corrosion control to conduct heating-up and M.C. equalisation in a separate chamber but, when only one or two chambers are proposed, there are considerable construction cost and heat economies in performing all processes in each chamber. Experience will be necessary to evaluate this and particularly to assess corrosion hazard.

An opportunity arose to buy a second-hand High Temperature Oil generator rated at 5.4 million Btu/hr which has the great advantage of working at say 500°F at almost atmospheric pressure, requiring no certificated attendance and avoiding the very serious feed-water quality problems we have in W.A. The need to supply steam for heat-up and equalising would seem to be fairly simply met by running hot oil pipes through a water trough as is done in some sand-lime brick autoclaves. Of course there will be scale deposits in such a trough but I think these can be readily enough dealt with.

A set of dyeline prints or micro-film slides and calculation sheets can be readily made available to interested parties. The details shown are based on oil at 400°F which has some advantages in regard to oil flow rate through the generator when using only one kiln but with two or more kilns 500°F would be more economical and would still leave a good margin of safety on oil longevity.

Some of the more important quantities in the design calculations are shown below.

Chamber = 35' x 12'w x 16'-3"h.	
Charge = Nom. 32' x 4'w x 8'-6"h	= 6 650 sup.ft. of 2" stock
Weight, including concrete blocks	= 60 000 lb.
Schedule	= 260°/160°F
Air velocity, mean through stack	= 1 030 fpm.
Static head total, excluding fan, at Imp. S.T.P.	= 0.44" S.W.G.
Weight of wall structure	= 13.75 p.s.f.
Heat to raise building 200°	= 1.6 mil. Btu.

Insulation, ACI fibreglass, 1 3/4 p.c.f.	=	4"
Conductivity of walls	U =	0.06 Btu/sq.ft/hr ^{o}F
Radiation, total loss per hour	=	48 000 Btu.
Heat transfer, Oil/Air 400^{o}/250^{o}	U =	5.5 Btu/sq.ft/hr ^{o}F
Oil/Water 400^{o}/212^{o}	U =	200 Btu/sq.ft/hr ^{o}F

"CREEP" OF PARTIALLY SEASONED TIMBER

L. D. Armstrong

1. Introduction

An extremely important phenomenon occurring in wood and wood products is that of greatly enhanced deformation that arises during the simultaneous action of applied load and moisture content change. This mechano-sorptive deformation is usually responsible for the excessive and unsightly sag that is sometimes observed in the rafters, battens, ceiling joists, hanging beams and lintels of timber-framed houses. The amount of the deflection in such beams is dependent upon the size of the change in moisture content occurring after the service loads are applied to the members and is highest in collapsible species loaded at very high moisture contents. With these latter materials, increases in the deflections of beams may amount to as much as five or six times the deflections that result from the application of the loads.

In the Timber Engineering Code and the Light Timber Framing Code, factors of 2 and 3 have been adopted in stiffness calculations for timber beams to allow for the total effects of sustained loading, i.e. both creep and mechano-sorptive deformations, in dry and initially green wood, respectively. In accepting the factor of 3 for initially green wood, account was taken of the fact that a substantial amount of drying occurs in green timber between the time of processing of a log and the time at which service loads are applied to the sawn timber in a structure.

With the introduction of so-called "stabilised" timber, which is timber given a rapid case drying treatment to reduce shrinkage and warping in service, it became of interest to determine if the mechano-sorptive deformations would be significantly reduced in the partially dried timber because of the lesser amounts of moisture content change that would occur, at least in the case material, after installation in a structure.

2. Experimental

Twelve beams, 3 m x 100 mm x 50 mm, were cut from each of a log of mountain ash (*Eucalyptus regnans* F. Muell.) and a log of messmate (*Eucalyptus obliqua* L'Herit.).

Four beams of each species were kept at their high moisture content after sawing and until testing commenced, while the remaining eight beams of each species were treated in a seasoning kiln. The conditions in the kiln were chosen to simulate commercial practice in the production of "stabilised" timber and consisted of a run of 4 days at 50°C followed by a further 4 days at 60°C, with the vents of the kiln closed and no control over relative humidity during the total treatment.

The average moisture contents of the beams on cutting from the logs were 120% for mountain ash and 75% for messmate. After treatment in the kiln, the moisture contents, averaged over the cross-section, were 60 and 45% in the respective species. Examination of typical beams showed that the cross-sections consisted of case material of about 4 mm

thickness at about 22% moisture content and the remainder was of core material at high moisture contents in the green range. Substantial collapse was evident, especially in the beams of mountain ash.

The tests were carried out inside a large, unlined shed. The beams were erected over a span of 2.74 m and loaded at the centre points to the allowable stress values for each species. Deflection measurements and moisture content measurements were made, at frequent intervals, over 8 months.

3. Results and Discussion

The relative-deflection versus time graphs for the four groups of beams are shown in Figure 1. Relative deflection is the deflection at any time, subsequent to loading, expressed as a multiple of the initial deflection measured on loading.

The deflections of the initially green beams increased by about 350% in the case of mountain ash, and by about 200% in the case of messmate, over a period of 100 days and little change in the deflections occurred after that time. The average moisture contents of the beams of mountain ash decreased from 120% to 13% during the initial period of 100 days and remained fairly steady thereafter. The beams of messmate followed a similar pattern with the moisture contents decreasing from 75 to 13%.

The large relative deflections in the mountain ash beams would be due to large mechano-sorptive deflections occurring with moisture movement and extensive collapse during the period under load. The incidence of collapse was highest in the mountain ash during the period under load and may have been influenced by the high moisture content at the start of the test.

The relative deflections of the beams of "stabilised" timber were considerably lower in magnitude than those of the initially green beams of the respective species. In mountain ash, the initial deflections increased by 125% and in messmate the increases were about 100%. These values were between about one-third and one-half of those present in the initially green material.

In these investigations, it has been shown that the "stabilising" treatment of at least two collapsible hardwoods has significantly reduced the magnitudes of the mechano-sorptive deformations that occur in beams drying under load. On the other hand, it may also be observed in Figure 1 that the major part of the increase in the deflection of the initially green beams tested here occurred within the first month after loading when extensive initial drying in the materials of high moisture content would be present. In practice, similar extensive drying usually occurs in the period between sawing of timber and the application of service loads, with a resultant substantial reduction in mechano-sorptive effects. Wherever this latter condition occurs in practice with building scantling, little advantage may be attached to the use of "stabilised" timber in reducing mechano-sorptive deformations.

Although benefits in the use of "stabilised" timber may accrue from reduction of shrinkage and warping that accompany drying of green timber in service, it should be brought to attention that when rapid drying treatments are used with some species of hardwood checking may be present

to such an extent that important mechanical properties such as shear strength and nail holding-power may be seriously affected.

4. Conclusions

A rapid case-drying treatment of hardwood scantling is being practised commercially to produce so-called "stabilised" timber in order to assist in reducing shrinkage and warping that occur in house frames of initially green timber.

The behaviour of "stabilised" timber under sustained bending loads was compared with that of initially green timber of high moisture content to determine if the mechano-sorptive deflections, that are due to the interaction of applied load and moisture content change, were significantly less in the case-dry material.

It was determined for the species of mountain ash and messmate that the relative deflections of loaded beams of "stabilised" timber were less than about half those present in the beams of initially green timber.

Further, the results of the experiments indicated that the relative behaviour of initially green and "stabilised" beams would not be greatly different if a delay of about 1 month were ensured between the sawing of green timber and the application of service loads. The amount of drying during this period would be sufficient to avoid the substantial mechano-sorptive effects that may be attributed to moisture movement in the presence of cell wall collapse in green wood drying under applied load.

DEFLECTION OF WOOD UNDER INTERRUPTED LOADING

P. U. A. Grossman

1. Need for Experiments

This laboratory has played an important role in evaluating creep of wood, i.e. increase in deformation of wooden members under continuous load. Design codes make allowance for the duration of loading, and published results of investigations provide an estimate of expected increase in deformation for given situations.

Much of the information available refers to constant load, a condition often but not always fulfilled in practice. The deformation due to load sequences other than constant load is readily derived from known creep data if it can be assumed that effects are additive. Work done here and elsewhere has confirmed that such superposition of effects is valid to a fair approximation when loads do not greatly exceed prescribed design loads.

However, designers are cautious and require more direct assurances that periods without load reduce the overall deformation. Repeated loads of extended duration are often considered as continuous over the total time under load as if recovery had no effect. Sometimes, more conservatively, they are treated as permanent loads. It has even been suggested that periodic loading and unloading might in some circumstances cause more severe deformations than a permanent load would.

While the periodic application of loads of a duration of weeks or more is thus treated conservatively, live loads of very short duration are permitted to be reapplied without change in allowances. Should fatigue be of concern, then it would certainly have to be considered for short live loads. Even in the absence of any fatigue effects the question remains: when can short repeated loads be considered to be without cumulative effects?

We conducted a comprehensive experiment in order to clarify the situation. We were fortunate in having had with us, on a fellowship from the Japanese government, Mr. T. Nakai who was responsible for conducting the bulk of the experiment.

2. Experimental Program

Deflections of continuously loaded beams were compared with those of beams unloaded and reloaded periodically. In one series of tests, loads were reapplied every 2 weeks for a total of 6 months; in another every 2 days for 1 month; in yet another series every 14 minutes for over 7 hours. One half of the periodically loaded beams was allowed to recover without load for as long as they were loaded in each cycle, the recovery period for the other half was six times as long as the loading period. Four different load levels were used, 67%, 50%, 33% and 17% of the estimated short term strength of the beams. The two highest loads greatly exceed design load but they were included to indicate the trends and reinforce the conclusions. Three species were tested, mountain ash (*Euc. regnans*), jarrah (*Euc. marginata*) and hoop pine (*Araucaria*

cunninghamii), but it was not intended nor attempted to determine differences between species or specific properties of any one species.

All tests were conducted at strictly controlled temperature and humidity in order that features studied should not be obscured by random fluctuations.

3. Results and Discussion

The study provided a wealth of results which will be published elsewhere. Only the main findings can be summarized in this paper. The deflection of beams allowed to recover periodically was lower at any time than that of beams loaded continuously. It was also lower than that corresponding to continuous creep over a period equal to the cumulative time under load. The differences were more pronounced when recovery lasted longer than loading. Only at the highest loads were departures from these trends occasionally observed. Many of the beams loaded to 67% of short time strength failed during the test and the surviving ones did not provide a consistent picture.

If any fatigue were occurring the changes in deflection measured immediately on application or removal of load would tend to rise with increasing number of cycles. A small rise was observed at the highest loads but any small trends observed at lower loads went in the opposite direction indicating a stiffening.

Deflections were compared quantitatively to check on the validity of the superposition principle. This could certainly not be applied at the 67% load level and the departures from superposition at the 50% load level were appreciable, but for loads not exceeding permissible design values, the deflections observed during interrupted loading agreed well with those that were derived on the basis of superposition for such a loading sequence from the continuous creep curve. This corroborates earlier observations and strengthens confidence in the predictions of expected deflections after any known sequence of loadings. It also permits us to give some rough guidelines for creep allowances during specific loading programs such as regularly repeated loading and unloading. It can, for example, be accepted that a beam periodically loaded for one time unit in ten will after the end of the first loading period deflect further by less than a tenth the amount the permanently loaded beam would.

During short loading cycles, deflections at the end of the loading periods increased with continuing cycling and approached a limiting value. The 30 consecutive load cycles applied were too few to allow this limit to be reached by many of the specimens, in particular those allowed no more recovery than loading time. On the basis of superposition it may be concluded that a load repeatedly applied over comparatively short periods may be considered to cause no deflections much in excess of the immediate deflection - provided the intervals between loads are appreciably larger than the duration of each load. In practice, say that for every minute of loading there should be at least five minutes of recovery if no allowance for duration of loading is to be made. Wind gusts with periods of lull or changing directions would have no cumulative effect nor would light traffic on a bridge, but traffic with little interruption would have the effect of a load of longer duration.

4. Extension and Application

The experiments described were conducted under strictly controlled conditions of temperature and humidity and showed therefore no influence of moisture changes. Moisture fluctuations would occur in practice even in dry timber and would cause greater deflections, if each loading period exceeded the time necessary for a significant moisture change. However, it would seem justifiable to apply the main conclusions from the tests to the general case: periods during which the material is not loaded reduce the maximum deformation reached.

The timber engineering code must be a concise guide and cannot contain precise recommendations for all conceivable sets of conditions. In view of the range of uncertainty which the designer must allow for, it would be futile to try pinpointing the expected long-term deformations to within a few per cent. But conclusions from the tests described will have to be included in the next revision of the Timber Engineering Design Code.

MECHANICAL GRADING OF TIMBER IN AUSTRALIA

A. Anton and D. J. Grant

Summary

This brief paper details the present state of the mechanical grading of timber in Australia and outlines the role of the Forestry Commission of N.S.W. in the Australia-wide adoption of the new concept.

Introduction

Because of the Commission's interest in the more efficient utilization of our timber resources its Wood Technology Division in close co-operation with the timber industry has been involved in applied research since 1962 into mechanical timber grading. This resulted in the development of the Computermatic Timber Grading Machine which has been accepted by the timber industry throughout the world. Up until July 1974 Plessey Australia had manufactured 50 machines and total exports of them stood at 35.

Present State of Mechanical Grading in Australia

Fifteen timber grading machines are located in the three eastern states, South Australia and the Australian Capital Territory. Table I gives detailed information about the machines located in Australia. Seven of the machines commenced operation during the year and as a result 1974 will be remembered as the year that the Australian softwood sawmilling industry mechanically graded a significant proportion of its output of structural timber.

Forestry Commission Involvement

The Wood Technology Division provides an advisory service on all aspects of the mechanical grading of timber and has been actively involved in the formation of the Association of Mechanical Timber Graders. The members of this Association have agreed to pool all quality control data and the Division, for the benefit of the operators, is using these data to assess the various operations and to revise and amend existing programs.

A system that ensures the integrity of the mechanically graded timber has been developed from the Division's direct research into the practical aspects of mechanical grading. This system provides for the following:

1. The training of machine operators.

2. Specifications for the programming of the grading machine to produce required stress grades.

3. Specifications for a quality control scheme the purpose of which is to provide evidence of the quality of the graded timber.

4. Specifications for the testing of quality control samples. This ensures that the Modulus of Elasticity and the Modulus of Rupture are determined under identical conditions no matter who does the testing.

5. The verification of the machine by the operator during normal grading operations. This is achieved by passing at frequent intervals calibrated lengths of timber called Verification Sticks. These sticks are prepared by the Wood Technology Division.

The training of operators is one aspect which needs to be discussed in detail as the success of any operation depends on the skills of the operator. Hence this course has been designed to introduce actual operators to all facets of the grading of timber. There has been however a great interest in the course and personnel of high administrative and technical level have been attending them.

The main topics of the course include:

1. Intensive practical training in machine operation.

2. Familiarization with the basic theory of mechanical grading.

3. Appreciation of the theoretical and practical importance of quality control.

4. Training in record keeping to provide evidence of the quality of the graded timber and the efficiency of the operation.

5. Training in the use of Verification Sticks, with special emphasis on the practical importance of securing the correct operation of the machine.

6. A broad introduction into timber engineering and the reasons why timber has to be graded.

TABLE I. Details of Mechanical Stress Grading Operations in Australia

Operator	Location	Species Graded	No. of W.T.D. Trained Personnel	No. of Machine Verification Sticks in Use	Approximate No. of Q.C. Samples Taken up Until Sept. 1974	Remarks
A.P.M. Wood Products Pty. Ltd.	Tumut (N.S.W.)	Radiata pine	2	22	100	In full operation
Timber Industries Ltd.	Oberon (N.S.W.)	Radiata pine	2	23	500	In full operation
Hudsons Timber Pty. Ltd.	Dural (N.S.W.)	Oregon and Western hemlock	4	-	-	Operation to commence early 1975
Forestry Commission of N.S.W.	W. Pennant Hills (N.S.W.)	Oregon Ladder Stiles & Research	2	20	900	In full operation
Integrated Forest Products Pty.Ltd.	Manuka (A.C.T.)	Radiata pine	3	19	200	In full operation
Lloyds Australia Ltd.	Port Adelaide (S.A.)	Oregon and Western hemlock	2	10	200	In full operation
Timber Merchants Association of S.A.	Port Adelaide (S.A.)	Oregon and Western hemlock	1	10	150	In full operation
Woods & Forests Department	Mt. Gambier (S.A.)	Radiata pine	1	15	600	In full operation

TABLE I (cont'd)

Operator	Location	Species Graded	No. of W.T.D. Trained Personnel	No. of Machine Verification Sticks in Use	Approximate No. of Q.C. Samples Taken up Until Sept. 1974	Remarks
A.P.M. Wood Products Pty. Ltd.	Waygara (Vic.)	Victorian Mixed Hardwoods	2	8	350	In full operation
Australian Forest Industries Pty. Ltd.	Myrtleford (Vic.)	Radiata pine	2	11	150	In full operation
Beecham-Wright Pty. Ltd.	Altona North (Vic.)	Oregon and Radiata pine	1	2	Unknown	In full operation
Wilkinsons Timber Industries Pty. Ltd.	Mt. Gravatt (Qld.)	Slash pine Loblolly pine	1	10	600	In full operation
Hyne & Son Pty. Ltd.	Maryborough (Qld.)	-	0	-	-	-
Robb & Brown Pty. Ltd.	Brisbane (Qld.)	-	0	-	-	-

SOME ASPECTS OF MECHANICAL STRESS-GRADING

W. J. Smith and D. M. Greve

In destructive testing of mechanically stress-graded slash, loblolly and hoop pines in Queensland, it has been found that about 5% of the check samples fall below the mechanically indicated stress-rating. This is apparently within acceptable quality control limits set out in AS CO1-1972 - Australian Standard Rules for Mechanical Stress Grading of Timber.

At least one major lending and constructional Authority in this State has also expressed concern that some branded, mechanically stress-rated timber in trusses is evidently not of satisfactory quality. Investigation has shown this concern to be justified in some instances, including bottom chord members.

The reliability of MSG material and the application of the relationships on which the system is based have also been questioned in the United Kingdom.

It is suggested that perhaps there may be too much complacency in the beliefs that the relationships between modulii of rupture and elasticity are as good as they could and should be for performance predictive purposes and that the commercial operational procedures for the commonly used stress-grading machines provide a completely reliable product with stress values true to brand.

It is understood from an authoritative source (1) that:-

(a) the relationships established predominantly on *P. radiata* in that instance were based on determination of M/E on one randomly selected flat face and M/R on edge, with any obvious defect on the tension side in the latter case;

(b) the correlation coefficient so determined is usually of the order of 0.7 to 0.8, and

(c) that, whereas the "Microstress" grader required stressing for both wide faces in grade determination, the later "Computermatic" machine grades in a single pass by an inbuilt correction for initial curvature in the piece.

From a comparison of regression lines for seasoned radiata pine, mixed slash and loblolly pine (mostly slash pine), and hoop pine, all of comparable cross-sectional dimensions (see Figure 1), the question arises as to possible explanations for the observed apparent higher strength per unit stiffness at the lower end of the scale for radiata pine compared with the other species, despite the latters' higher Strength Classifications. (SD5 and 6 compared with SD7). Comment would be welcomed on the following and any other possibilities:-

(i) If, as seems likely, the populations came from normal framing production, the radiata pine could well have been relatively free from

pith, heart and associated high sloping grain values, as required for light framing by the relevant Standard, whereas the Queensland grown slash, loblolly and hoop pines did comprise a larger proportion of pith-in material, in accordance with local practice and Australian Standard provisions. Thus, there may have been a poorer numerical representation at the lower end of the scale in the *P. radiata*, due to lower incidence of juvenile corewood property effects, with a possible effect on the slope of an assumed linear regression.

(ii) High-temperature drying, which predominated in the slash, loblolly and hoop pine material, could possibly have affected the normal relationship between M/R and M/E. The earlier-processed radiata pine was unlikely to have been dried in this manner.

(iii) In N.S.W. work in developing the *P. radiata* regression, determination of M/E on one random wide face could have given a different relationship with M/R than in Queensland work on the other species, where M/E for opposite wide faces was averaged. This could be emphasised by a likely lower incidence of pith and heart in the *P. radiata*. At best, the effective sample size for the *P. radiata* population would seem to have been half that of the other species, even if a random dispersion of defects effect in the test specimens can be reliably assumed.

The magnitudes of the correlation coefficients are also not as high as one would like for predictive purposes in a rather critical application purporting to give engineered precision. From quite large samples of populations, the variation in M/R accounted for by variation in the measured parameter, M/E, apparently rarely exceeds 50% and is often less (see r^2 values on Figure 1).

The effect of the presence of defects on similar higher-level relationships for clear timber and of intrinsic species differences has been demonstrated by Pearson (2).

In view of the known variable effect of individual defects when tensilely or compressively stressed (as in a grading machine), and the trend towards "one-pass" "Computermatic" type machines, it is suggested more care in their commercial application is necessary or at least highly desirable. These machines, apparently designed to compensate for initial curvature in a piece, evidently cannot cope in a single pass with the problem of differences in the effect of individual defects, stressed sometimes in compression and sometimes in tension. Knots machine-stressed in compression could give misleadingly high strength ratings, as could pith-associated wood stressed in tension.

It is suggested that:

(a) work should be intensified to attempt to improve the predictive value of the M/R and M/E relationship, through fundamental studies on some of the more important species; and

(b) checks be made on the effect (if any) of production practices, particularly high-temperature drying and preservative treatment on, established relationships, especially those in commercial application.

In the meantime, it may be desirable to re-evaluate the modification factors used in deriving and adjusting regression lines for use in MSG, with a possible interim increase in the safety factor and some reconsideration of the quality control provisions of the relevant Standards to ensure increased consumer confidence.

There seems no doubt that improved quality control in commercial operation is essential. If "Computermatic" machines are not to be required to provide for double-face grading, it is evident more care must be exercised in either (a) ensuring that operators with a knowledge of the variable effects of defects in compressive and tensile stressing have pieces passed with the limiting defect stressed to record minimum grade, or (b) all material be visually checked and suspect pieces be re-passed for stressing on the opposite face. The latter would be more feasible and probably more effective in practice and is understood to have been introduced in one Queensland installation.

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DESIGN OF BRACING SYSTEMS FOR TIMBER STRUCTURES

R. H. Leicester

1. INTRODUCTION

Timber structures are usually fabricated from slender members in such a way that the strength of these structures is considerably influenced by the use of bracing restraints against buckling. The traditional method for the design of buckling restraints is to require that they be sufficiently stiff so as to act affectively as rigid restraints, and to require that they be sufficiently strong so as to be able to safely carry specified semi-empirical design forces. In a previous paper, (Ref. 1) a more flexible design approach is described. This design method is applicable not only to single structural elements such as beams and columns, but also to total structures of complex configuration. For this method it is assumed that bracing members are chosen from prior considerations. For example this usually applies to purlins when they act as bracing for their support rafters. The design procedure then provides an estimate of the design load capacity of the primary structure when assisted by the bracing, and also the forces on the bracing when this design load is applied to the structure. This method is used to provide the design rules for the bracing of beams and columns given in Appendix D of AS:1720, the metric version of the SAA Timber Engineering Code (Ref. 2).

2. OUTLINE OF THE DESIGN PROCEDURE

(a) Design Strength of the Primary Structural System

In AS:1720 (Ref. 2), the effect of slenderness on strength is specified in terms of a stability factor K_{12} defined as follows,

$$W_{all} = K_{12} W_{st} \qquad \text{——— (1)}$$

where W_{all} is the allowable design load and W_{st} is the value of W_{all} if the primary structure were completely stable. In AS:1720, the stability factor K_{12} is given as a function of material used and the slenderness coefficient S defined by

$$S^2 = 0.822 \ (E_L/F'_c) \ (W_{st}/W_E) \qquad \text{——— (2)}$$

where E_L is Youngs modulus of elasticity, F'_c is the allowable basic stress in compression, W_{st} is the allowable design load in the primary structure if it were completely stable and W_E is the Euler buckling load of the primary structure when assisted by the bracing system. The rationale for this definition of slenderness coefficient has been described elsewhere (Refs. 1, 3).

The quantities E_L, F'_c and W_{st} may be obtained directly from the design rules of AS:1720. The Euler buckling load W_E may be obtained with sufficient accuracy for practical purposes from the use of simple variational methods such as those described by Timoshenko (Ref. 4).

(b) Forces on Buckling Restraints

Buckling restraints are considered to act as simple springs attached to the primary structure. Consequently the force in the springs are known once the displacements of the primary structure at the points to which the buckling restraints are attached have been determined. The displacement at a specific point on the primary structure can be obtained with reasonable approximation from the equation

$$\Delta = \Delta_o/(W_{EO}/W_{app}-1) \qquad \text{——— (3)}$$

where Δ_o is the initial displacement due to initial crookedness of the structure, W_{app} is the applied load to the primary system and W_{EO} is the pseudo Euler buckling load computed by strain energy methods (Ref. 3), with the assumption (in general untrue) that the buckling mode shape is similar to that of the initial specified crookedness. Numerical investigations indicate that equation (3) predicts displacements that are usually within 20% of the correct value (Ref. 1), an accuracy considerably in excess of that with which the initial imperfections of the structure can be estimated.

3. BRACING SPECIFICATIONS IN AS:1720

(a) General

The design procedure outlined in the previous section was used to derive design rules in AS:1720 for the bracing of simple beams and columns. The three cases considered to derive the design equations are illustrated in Figure 1. These are a column subjected to an axial load P, having N lateral intermediate restraints, and a beam loaded by end moments M, and braced with either N lateral or N torsional intermediate restraints. The intermediate restraints are equally spaced along the column or beam which is of length L and depth D. The stiffness of the lateral and torsional restraints are denoted by K_A and K_B respectively. The notations EA, EI_y, GJ, and EΓ will be used to denote axial, bending, torsional and warping stiffness respectively of the primary structural element.

(b) Slenderness Coefficient of Columns

For the case of axially loaded columns, equation (2) becomes

$$S^2 = 0.822\ (EA/P_E) \qquad \text{——— (4)}$$

where P_E is the Euler buckling value of P.

For the cases of no lateral restraints and effectively rigid lateral restraints we have $P_E = P_o$ and $P_E = (N+1)^2 P_o$ respectively where

$$P_o = \pi^2 EI_y/L^2 \qquad \text{——— (5)}$$

It only remains to find an estimate of P_E for intermediate conditions. It is assumed that during Euler buckling the displacement u in the y-direction is given by $u = a \sin(n\pi z/L)$ where a is arbitrary constant and $n \leq N$ is an integer,

then the strain energy method of approximate analysis (Refs. 4,5,6) leads to the eigen values

$$P_n = P_o\left[n^2 + \frac{\alpha_1}{n^2} \right] \qquad \text{——— (6)}$$

where

$$\alpha_1 = \frac{K_A L(N+1)}{\pi^2 P_o} \qquad \text{——— (7)}$$

The Euler load P_E is the smallest eigenvalue P_n. Hence a conservative approximation is obtained from the condition $\frac{\partial P_n}{\partial n} = o$, which leads to

$$P_E = P_o \sqrt{4\alpha_1} \qquad \text{——— (8)}$$

Substitution of equation (4) into (7) and leads to

$$S = S_o/(\beta_1)^{\frac{1}{4}} \qquad \text{——— (9)}$$

where

$$\beta_1 = \frac{0.492\ K_A(N+1)L\ S_o^2}{EA} \qquad \text{——— (10)}$$

and where $S_o = \sqrt{0.822\ (EA/P_o)}$ is the slenderness coefficient corresponding to the case of no restraints.

(c) Slenderness Coefficient of Beams

For beams, AS:1720 specifies F_b', the allowable stress in bending, to be $(4/3)F_c'$ and hence equation (2) can be written

$$S^2 = 1.1\ EZ_x/M_E \qquad \text{——— (11)}$$

where M_E is the Euler buckling value of the moment M and $Z_x = I_y/(D/2)$. For the case of no bracing restraints the Euler load is given by $M_E = M_o$ (Refs. 4, 5,6) where

$$M_o = (\Pi/L)\ \sqrt{EI_y\ [GJ + E\Gamma\ (\Pi/L)^2]} \qquad \text{——— (12)}$$

and for effectively rigid restraints a conservative approximation to the Euler load is given by $M_E = (N+1)M_o$. For intermediate cases the Euler load is obtained approximately by strain energy methods in which the buckling mode shape is taken to be given by $u = a \sin(n\pi z/L)$ and $\phi = b \sin(n\pi z/L)$, where a and b are arbitrary constants, ϕ is the twist and $n \leq N$ is an integer. These asseumptions lead to the eigen values (Ref. 1) for the system shown in Figure 1 as follows

$$M_n = (L/n\pi)^2 (K_A D/2L)(N+1) + (L/n\pi)^2 \{EI_y (n\pi/L)^4 + (K_A/L)(N+1)\}^{\frac{1}{2}} \{GJ\ (n\pi/L)^2 + EI'(n\pi/L)^4 + (K_B/L)(N+1) + (K_A D/2L)(N+1)\}^{\frac{1}{2}} \quad \text{——— (13)}$$

The minimum eigenvalue M_n is taken to be the Euler buckling load M_E. For the case of lateral restraints only, K_B = o and a conservative approximation of equation (13) is

$$M_n = M_o \left[(\alpha_2/n^2) + n \right] \quad \text{——— (14)}$$

where

$$\alpha_2 = (K_A/L)(D/2)(N+1)(L/\pi)^2/M_o \quad \text{——— (15)}$$

The condition $\frac{\partial M_n}{\partial n}$ = o to obtain an approximation for M_E and use of equation (11) leads to

$$S = S_o (\beta_2)^{1/6} \quad \text{——— (16)}$$

where

$$\beta_2 = 0.736 K_A D L S_o^2 (N+1)/(EZ_x) \quad \text{——— (17)}$$

and where $S_o = \sqrt{1.1\ EZ_x/M_o}$ is the slenderness coefficient for the case of no laterial restraints.

Similarly for the case of torsional restraints only, K_A = o and a conservative approximation of equation (13) is

$$M_n = M_o \sqrt{n^2 + \alpha_3} \quad \text{——— (18)}$$

where

$$\alpha_3 = EI_y K_B (N+1)/(LM_o^2) \quad \text{——— (19)}$$

The minimum eigenvalue, given by the condition n = 1, is the Euler load M_E. Substitution n = 1 into equation (18) then leads to

$$S^2 = S_o^2 (1+\beta_3)^{\frac{1}{4}} \quad \text{——— (20)}$$

where

$$\beta_3 = 0.826\ K_B I_y S_o^4 (N+1)/(ELZ_x^2) \quad \text{——— (21)}$$

(d) Forces on Buckling Restraints

The design restraint forces specified in AS:1720 are based on computations for very slender rectangular members by use of equation (3) and spot checks by exact analyses. The initial imperfections for bow and twist were assumed to be $u_o = a_o \sin(\pi z/L)$ and $\phi_o = b_o \sin(\pi z/L)$ where the constants a_o and b_o for the case of sawn timber were taken to be given by $a_o = L^2/(6400B)$ and $b_o = L/(300B)$. The notation B refers to the thickness dimension.

These values of a_o and b_o are related to the maximum grading imperfections specified in Appendix G of AS:1720. As indicated by measurements on Radiata pine (Ref. 7), these assumptions of crookedness can be too conservative, particularly as a considerable amount of straightening is done in locating a structural member in place. However, some degree of conservation is necessary to allow for the amplification of the effects of variability and creep due to the nonlinear relationship between applied load and restraint force as indicated in equation (3). Furthermore some allowance must be made for the fact that the contribution of joint slip to restraint stiffness is likely to be overlooked in practice.

Typical characteristics of a restraint force are shown in Figure 3. This figure shows the maximum restraint force computed for the case of an axially loaded column 50 mm x 100 mm in cross-section and 3000 mm long when subjected to the allowable design load. Except for low values of restraint stiffness, usually well below the stiffness at which the restraint becomes effectively rigid, the restraint force is directly proportional to the applied load. Another characteristic of restraint forces, illustrated in Figure 4 for the same example, is that the ratio of peak restraint force to applied load is inversely proportional to (N+1). Both these characteristics were utilised in the formulation of the design rules in AS:1720.

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SERVICEABILITY OF LOWER DURABILITY TIMBERS IN CONSTRUCTIONAL FRAMING

D. M. Greve

At the 1971 Forest Products Research Conference, discussion included certain aspects associated with the rapidly increasing availability of softwood timbers for use by the building industry, and the extent to which protective treatment was necessary for such timbers for use in various exposed or partially protected situations. It was agreed that major benefits would accrue from surveys of performance records in the various states, particularly from softwood framed houses imported from Europe in the early 1950's.

Since then, surveys have been undertaken in conjunction with the Queensland Housing Commission covering over one hundred of the imported houses mentioned above and over fifty rainforest timber framed houses in North Queensland. A final report on these surveys is not yet available but in the following paragraphs a general outline of the procedure, results and discussion, and recommendations is provided.

Procedure

Generally, only the south east corner on all houses was inspected as it is this corner which is exposed to the prevailing winds in both south and north Queensland coastal areas.

It was assumed that by so doing the worst possible decay situations would be uncovered.

The majority of the houses inspected were timber clad but a small number were sheeted externally with asbestos cement. The normal procedure was to remove one or two weatherboards at window sill and wall bottom plate levels on two adjacent walls at the south east corner of the house, or close to it where windows did not extend to the corner. This was generally sufficient to expose stud/sill junctions, stud/bottom plate junctions and corner studs for close inspection. With asbestos cement clad houses it was usually necessary to remove three or four sheets to expose the necessary framing members.

The type of information recorded included location of house, age, type of construction, species of timber used, condition of paintwork, whether or not sarking was present, type and amount of ventilation provided in the building cavities and the condition of all timber members inspected.

Results and Discussion

Table 1 summarises the results by showing the numbers of houses where decay was found in various positions for each area surveyed.

It will be noted that in the imported softwood framed houses (all of them in South Queensland), decay was found mainly under the ends of window sills and to a lesser extent in the corners. Timbers involved were of *Abies*, *Picea* and *Pinus* species. The decay under the window sills

usually affected window studs and in many cases extended to the wall bottom plate, although rarely affecting the wall cladding. The cause was invariably poor design in the window sill area in some cases, combined with inadequate maintenance i.e. painting.

In the corners, poor fitting of weatherboard ends against corner stops again combined with inadequate maintenance, was apparently the cause. Members affected here were usually corner studs, wall bottom plates and occasionally joists and bearers.

In North Queensland, a variety of timber species ranging in durability rating from two to four has been used in house framing, and all of these were found to be affected by decay to some extent in different situations. Treatment against decay or insect attack was rare.

From Table 1 it can be seen that the number of houses with decay under the ends of window sills is considerably reduced even though many of the houses were as much as twenty seven years old and had not been repainted for more than ten years. This result as compared with the results in South Queensland, could be attributed partly to the higher durability of the timber species involved, but also to the better design in the window sill area in the local houses.

The high incidence of decay in the corners of houses inspected in North Queensland, as shown in Table 1, needs further clarification as there are at least two causes involved here.

Firstly, and this would account for a major proportion of the house numbers shown in Table 1, a considerable amount of decay was found in bearers as a result of the bottom weatherboard being fixed flush against this member, thus allowing water to flow under the weatherboard and seep up between the cladding and the bearer. This also accounts for those instances where decay was found other than at corners or under the ends of window sills.

The secondary cause is similar to that found to be causing decay in corner studs and bottom plates of the softwood framed houses in South Queensland viz. faulty fitting of cladding ends at the corners.

Sarking was found under window sills in only three of the European houses and in all three cases there was no evidence of fungal attack in the framing members.

Other factors not mentioned above which were found to have an effect on the incidence of decay in external wall framing timber include: the use of window sills joined in the centre, the practice of checking mullions into window sills, springout of nails fastening A.C. sheeting and climatic factors such as high relative humidity and quantity and duration of rainfall.

Recommendations

As a result of these surveys, recommendations have been formulated regarding the use of conifers and other low durability species as external wall framing with horizontally fixed timber or asbestos cement cladding.

Recommendations along these lines are currently being made by the Queensland Department of Forestry to all enquiries concerning the suitability of these species.

These are as follows:-

1. That all window and door openings should be effectively flashed and framing below window openings sarked down over the bottom plate.

2. That all corner studs should be effectively sarked for the full height of the wall.

3. That bottom plates should be flashed so that any water falling on to stumps or foundations can not seep in under the bottom plate, and

4. That all nogging should be fixed on edge where possible to improve ventilation of the wall cavity.

Where vertically fixed timber cladding is used it is recommended that sarking be used throughout.

It is not claimed that these recommendations provide the ideal compromise between economy and decay prevention when using softwoods in external wall framing situations, but until further information becomes available it is considered that they are practicable and reasonable precautions to be followed.

TABLE 1. Summary of Results (Numbers of houses in categories shown)

Location	Number of houses inspected	Bad decay found (affecting strength of member)				Slight decay found (not significantly affecting strength)				No decay found
		Under window end	S.E. corner	Under window	Along wall	Under window end	S.E. corner	Under window	Along wall	
SOUTH QUEENSLAND										
Inala	15	1				1				13
Ipswich	15	6	1			2				7
Carina-Mt.Gravatt	16	2				2	1			11
Zillmere (Timber)	24	12	3			5	4			3
" (A.C.clad)	6	2	1			3				-
Toowoomba	10*	8	7			2	3			-
Totals	86*	31	12			15	8			34
NORTH QUEENSLAND										
Cairns	30	4	17	1	1	3	8			6
Innisfail	16	2	5				3	2	1	9
Atherton	3		1							2
Milla Milla	2		1				2			-
Totals	51	6	24	1	1	3	13	2	1	17

* Information was obtained on a further 20 houses but not included here because it is incomplete.

THE BEHAVIOUR OF PARTICLEBOARD AS FLOORING

K. R. Bootle and P. R. Chapman

Particleboard has been used for flooring, at least on an experimental scale, for perhaps 15 years in Europe and New Zealand; in the latter country about 75% of new dwellings currently incorporate a particleboard floor but in Australia promotion and acceptance have been slow, with current use less than 2% of new floors.

Alleged advantages stem from the large sheet size and reduced waste on site, with potential for faster and safer building, less loss from theft and a draught-free dwelling.

The urea board produced here for many years for internal use is a very hygroscopic material which is rapidly degraded by exposure to dampness so there has been a natural reluctance to accept this type of material for flooring because of the likelihood of high humidity conditions in the underfloor area. This latter problem can be tackled by insistence on much better standards of ventilation, but there remains the problem of weather exposure involved in platform construction, when the floor, laid as soon as joist level is reached, may remain exposed to the elements for months before the building is enclosed. Greater care by the householder in ensuring the continuance of good ventilation during the life of the building is also involved.

The criterion of suitability of any product surely must be that it maintains its integrity when exposed to the most severe conditions likely to arise in that particular end-use. For flooring, one also expects a reasonably smooth finished surface, dimensional stability not too different from established materials, good nail holding power and resistance to impact loads.

The most significant of these properties to particleboard is dimensional stability, for any large moisture content change will cause a thickness increment. When the board is first exposed to moisture there occurs not only the normal swelling of wood particles but also the recovery from the compression set developed by the pressing operation (1). This is more noticeable with urea-bonded boards.

The magnitude of the stresses caused by continued cycles of shrinking and swelling and their effect on board properties depends on the binder's ability to resist stress and the ability of the wood to creep; the latter will reduce the amount of stress on the binder because of plastic flow in the wood. Even at the quite common moisture content of 18% creep has been found to be very considerable: in urea bonded material it can be ten times as great at that figure as at 6% (2). Both urea and phenolic boards undergo much greater creep than solid timber (3). Creep in material subject to continued adsorption and desorption is much greater than in that at a constant moisture content. The phenolic binder has reasonable resistance to the stresses arising from moisture and temperature fluctuations when fully exposed but urea boards undergo continuous degradation (1).

The moisture content of particleboard used as flooring will be higher than in previous interior uses and will have a significant effect on strength. Boards of higher density can be made but increased density means more compressive set resulting in greater thickness swelling, though this can be restrained by increased resin content (4). Strength in bending falls away very rapidly with increasing moisture content and may be halved at 20% (3).

Monitoring moisture content changes in particleboard presents problems. Though the e.m.c. of particleboard may be the same as that of natural wood at 30% relative humidity (5), at more common levels it is appreciably less. This is believed to be due to the effect of the heat used to dry the particles before the formation of the mat and to cure the resin. Moisture meters give erratic readings in particleboard and at present cannot be used to monitor moisture content changes.

The use of particleboard as platform flooring will necessarily involve repeated cycling under potentially very severe conditions of heat and moisture: such repetition can have a severe effect on strength. With phenolic bonds the strength loss is always accompanied by increase in thickness but this is not necessarily so in urea boards (1). In an overseas test mechanical failure from such repeated stressing was not noticeable in phenolic boards but urea boards suffered continual deterioration, attributed to deterioration of the resin. Urea resins are sensitive to temperatures below 71°C (1) unlike phenolics and melamine; surface temperatures in excess of this figure can be expected in Australian cities.

Wax, to the extent of 1%, is commonly incorporated in flooring grade board to act as moisture repellent. It is claimed (6) that 1% is as effective as 2% or 4%. However, after 14 days soaking in water the swelling of waxed boards approaches those without wax (7).

The use of tempering oil does not seem practicable because of interference with the adhesive bond (7).

Paint primers are sometimes used for extra edge protection, with reports of effectiveness for several weeks (8).

New Zealand experience (9) suggests further points worthy of investigation - depth of sanding required to remove edge swell and stains; extent and effect of possible core exposure in sanding; effect of ponding of warm water on strength; puncture resistance to dropped building materials; degree of seasonal cycling of moisture conditions.

The above assembly of potential hazards has led us at Pennant Hills to lay down some practical trials, hopefully to gain some insight into the best ways of using particleboard. The various Australian manufacturers differ in their recommendations for nailing, edge sealing, surface protection with water repellent solutions, expected movement etc., so four products (one urea bond, 1 tannin, 1 hardwood phenolic and 1 softwood phenolic) were chosen for initial study.

A simulated building 10.8 m x 3.6 m was constructed with brick piers, unseasoned hardwood bearers (at 1.8 m c/c) and joists (at approx. 450 mm c/c), with each board type covering a quarter of the area. All edges were fully supported and boards extended under the plates to their full width. The plates were weighted to simulate the full effect of a conventional timber

wall and roof frame. Bearer height varied from 300 to 650 mm and slotted hardboard was placed around the perimeter to monitor the ventilation level.

The floor is being exposed for 3 months; this period was selected because it is the maximum exposure time nominated in the current SAA draft code. After that period the structure will be covered and when at equilibrium the floor will be sanded. Testing of the physical properties of the boards, both before and after exposure, is being undertaken to determine the degree of deterioration and also, if possible, the effectiveness of short term laboratory tests in indicating the likely results of exposure to the weather.

At the time of writing (late November) the three months' period is not quite up so it is not proposed to comment on board behaviour but full details will be provided at the Conference.

The following measurements are being taken on samples from exposed sheets and from the exposed sheets at the conclusion of the test period, before and after sanding. Where tests are made using mechanical fasteners they are intended to comply with AS A188-1972 (Determination of basic working loads for metal fasteners for timber).

Test	Source of Method
1. Soak-dry Cycling	F.C. N.S.W.
2. Surface Water Absorption	SAA draft
3. Swelling in Water (Thickness Stability)	SAA draft
4. Janka hardness	ASTM
5. Shear in Plane of Board	F.C. N.S.W. & ASTM (modified)
6. Screw Withdrawal	ASTM and ASO115-1968 (modified)
7. Tension Parallel to Surface	ASTM (modified)
8. Compression Parallel to Surface	ASTM
9. Lateral Nail Resistance	ASTM (modified)
10. Nail Withdrawal	ASTM (modified)
11. Nail Head Pull-Through	ASTM (modified)
12. Impact Strength	BS1811-1969
13. Modulus of Rupture	SAA draft
14. Modulus of Elasticity	F.C. N.S.W.
15. Density	SAA draft
16. Tension perpendicular to surface	SAA draft
17. Glue Bond Durability	SAA draft & F.C. N.S.W.
18. Glue Bond Quality	SAA draft & F.C. N.S.W.
19. Dimensional Changes	F.C. N.S.W.

Regular measurements during the weathering period are being taken of edge swelling under the plate, at junction of sheets and at open gap between sheets.

Nail and eucalypt hardwood stain areas have been installed on each sheet.

Moisture content levels just under the sheets are being monitored with samples of solid radiata pine to ensure that the moisture content does not reach excessive levels. Already, additional ventilation well beyond current practices has been found necessary.

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AGEING OF PARTICLE BOARDS UNDER SIMULATED SERVICE CONDITIONS

A. M. Stashevski

Introduction

Accelerated ageing tests are being conducted in DBR with the aim of determining the behaviour in service of commercially produced flooring boards bonded with UF, TF and PF resin adhesives. Two sets of test parameters are being used to define the limits of bond durability.

In one study specimens of flooring grade boards are being subjected to humidity cycling conditions at 40°C. Each cycle consists of one week's exposure to 25% R.H. and one week's exposure to 86% R.H. The selection of these test conditions attempts to simulate two moisture content levels which a flooring board is likely to reach following average seasonal changes. A temperature of 40°C was selected because on past experience it does not appear to have a harmful effect on urea resins and on the other hand produces a reasonably fast rate of moisture content change. It is suggested that each cycle reproduces the moisture content changes to which a flooring board may be exposed each year under average climatic conditions in South-East Australia.

In the second study boards were submerged in water for 24 hours and subsequently redried at 25% R.H. All work was again carried out at 40°C. This study attempts to simulate flooding conditions to which flooring boards may be exposed occasionally, as was the case during the recent Brisbane floods.

The graphs included show board behaviour only in respect of two mechanical properties, MOR and IB, for five types of commercially produced flooring grade particle boards bonded with UF, PF and TF adhesives. The results are compared with the lowest acceptable value of lot mean (LAVLM) of the proposed AS 0115 Standard under revision.

Conclusions

The results of both ageing studies are an indication that flooring boards bonded with PF and TF resin adhesives are likely to fulfill the requirements set out by building codes even if subjected to occasional flooding conditions.

There is an indication that UF bonded flooring boards may give a satisfactory service life only if placed in relatively dry situations. The selection of UF resin and glue addition level appear to be critical under test conditions.

TANNIN ADHESIVES FOR GLUED-LAMINATED STRUCTURAL TIMBER

K. F. Plomley and P. J. Collins

The results of some laboratory tests of tannin-formaldehyde adhesives for laminating timber, when using radio-frequency heating to cure the adhesive, were reported in 1973 (1). Since then studies have been made of other tannin adhesive formulations and of the effect of repeated vacuum-pressure cycling on the bond. The effect of rate of cure on the development of bond strength has also been examined.

Assemblies of 5 pieces of *Pinus radiata* 610 mm long x 50 mm wide x 21 mm thick were bonded with adhesives based on commercial wattle tannin and a laboratory-prepared extract of *P. radiata* bark with/without addition of phenol-resorcinol-formaldehyde (PRF) resin. The glue spread was 340-365 g m^{-2} single glue line, pressure 1.30 MPa. Cure was effected at a power input of 7 kW for 32 sec or 6 kW for 38 to 42 sec. Dry tests and vacuum-pressure cycling were conducted under the conditions specified in AS 1328-1972, except that up to 6 vacuum-pressure and drying cycles were used.

The results of dry bond and cycling tests are given in Table 1.

High failing loads and wood failures were obtained for all tannin-paraformaldehyde formulations, but differences between formulations were revealed as the result of repeated cycling. After a single cycle the results were uniformly good, but after cycling 6 times there was a small increase in delamination for assemblies bonded with the *P. radiata* adhesive and extensive delamination of those bonded with the wattle tannin - *P. radiata* blend. The formulations cured with hexamine - NH_4Cl% showed lower failing loads and wood failures in the dry test and the results of repeated cycling were unsatisfactory.

In a study of the effect of rate of cure on bonding, assemblies of 6 pieces of *P. radiata* 914 mm long x 90 mm wide x 26 mm thick were glued with three wattle tannin and wattle tannin - PRF formulations. The assemblies were cured for 2.0, 2.5 and 3.0 minutes at a pressure of 1.03 MPa and a total power input of 10.7 kW min. When subjected to a single vacuum-pressure cycle the maximum delamination for all formulations was less than 1%.

In limited tests conducted under factory condition *P. radiata* glued with wattle tannin - PRF satisfied the requirements of AS 1328 when tested by vacuum pressure cycling.

Over-all tannin-based adhesives have shown considerable potential as low cost substitutes for resorcinol-formaldehyde adhesives, which are in short supply at the present time. Further factory trials are planned.

Reference

1. CSIRO Forest Products Newsletter, No. 391, May 1973.

TABLE 1

Adhesive	Curing agent	Block shear test* (failing load, MPa and wood failure %)	Delamination (%) after vacuum-pressure cycling**			No. of specimens completely delaminated
			No. of specimens	No. of cycles		
				1	6	
Wattle tannin	Paraform-aldehyde	10.43 - 86	7	1	6	0
Wattle tannin PRF	"	10.12 - 95	7	0	0	0
Wattle tannin PRF	"	10.66 - 95	5	0	0	0
P. radiata tannin	"	10.43 - 86	6	0	6	0
Wattle tannin - *P. radiata tannin* 50:50	"	10.52 - 94	7	0	4+	2
Wattle tannin	Hexamine NH_4Cl	9.38 - 73	6	11	4+	4
Wattle tannin	"	9.17 - 62	5	6	38+	3

* Means of 30 specimens, tested dry

** AS 1329-1972 specified one vacuum-pressure and drying cycle

\+ Specimens which delaminated completely in one or more glue lines during cycling were removed from the test. The values reported after 6 cycles represent percentage delamination of the remaining specimens.

TOPIC 1 COMMENTS

1/1c The effect of heat on wood quality
W.E. Hillis

1/2c Measurement and effect of moisture in building cavities
D.M. Greve

1/3c Use of floor sealants in platform type construction
D.M. Greve and N.R. Keating

1/4c Use of microwave ovens for the rapid determination of moisture content in timber
R. Davis and A. Zosars

1/5c Timber for cross-arms
W.J. Smith

1/6c Factors affecting the utilization of timber in pallets
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1/7c Veneer recovery from radiata pine in the A.C.T.
N.M. Rowan, R.G. Buick and K.W. Groves

1/8c Withdrawn

1/9c Densification or resin impregnation of timber as a means of improving wear resistance
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1/10c End splitting and checking in round timber - what is the problem?
J.E. Barnacle

1/11c Conversion studies on fast grown small diameter eucalypts
E.P. Lhuede, D.J. McKittrick and G. Waugh

Topic 1/1c

THE EFFECT OF HEAT ON WOOD QUALITY

W. E. Hillis

High temperature wood processing procedures are being introduced increasingly to reduce production times in drying and gluing operations, to reduce the extent of defects resulting from normal processing procedures, to improve the surface finish of products etc.

Overseas workers have reported that above certain temperatures, these processes as applied to softwoods can yield products with unsatisfactory quality for certain uses, and that they have ascertained the basic causes. Similar data on local timbers is limited. Neither is there much data on the amount and nature of the volatile materials produced and their effect on equipment. Indications of the behaviour of pines can be obtained from overseas studies but eucalypts would be expected to behave differently and few studies have been made on these woods.

In order to provide reference data to aid industrial design of high-temperature processes, information on the chemical, anatomical and fine structural changes of wood, in particular eucalypt wood, during different heating conditions will be obtained.

Topic 1/2c

MEASUREMENT AND EFFECT OF MOISTURE IN BUILDING CAVITIES

D. M. Greve

Simulated external wall panels are being used to determine the rate of change in moisture content of initially green framing timber and the effects of moisture release on mould development and staining of the internal wall sheeting. The effect on decay occurrence in the framing members is also being determined. Results of this work should be available early in 1975.

With this type of experiment it is not difficult to accurately monitor moisture conditions in the framing timber and in the panel cavity by using weighed timber samples. Whether such panels accurately represent the normal building situations, however, is open to question.

Ideally, this work should be carried out in real building situations but here, monitoring of the moisture conditions becomes much more difficult. For example, access to the wall cavity requires either entry to the building whenever readings are required and a situation where part of the internal lining can be readily removed, or an opening in the exterior cladding which would necessarily require an air tight seal when not in use.

It is believed that various types of electrodes used embedded in the framing members and in conjunction with an electrical resistance type moisture meter have been tried as a means of monitoring moisture content but without a great deal of success.

Another method, which is described in the United States Forest Service Research note FPL-0142, uses small pieces of wood with opposite sides coated with conductive silver paint as electrodes. The reliability of these is unknown as yet but if they do prove to be satisfactory they could be invaluable in any work where it is necessary to monitor moisture content of timber or building cavities.

USE OF FLOOR SEALANTS IN PLATFORM TYPE CONSTRUCTION

D. M. Greve and N. R. Keating

Platform type construction of dwellings is used extensively in Queensland at present and, if anything, is increasing in popularity with builders, partly as a result of the economy to be obtained from this practice and partly because it provides a safe working platform.

With this method, flooring is laid prior to the erection of wall and roof framing and so can be exposed to the weather for periods of up to several weeks before protection is provided.

Inspection of buildings constructed in this way, after completion of the building and allowing the moisture content of the floor to reach equilibrium, has shown that the effect of leaving seasoned timber floors exposed to the weather for such periods is quite variable and apparently not necessarily related to the amount of rainfall during the period of exposure.

As a result of this apparent variability in performance, it was decided to run trials on a number of different strip flooring species and one sheet flooring type particleboard with three different types of sealer. The Queensland Department of Forestry and T.R.A.D.A.C. cooperated on this.

Twenty panels, 1.8 m x 0.9 m, were constructed to take five different flooring types with four treatments. These were supported on a timber frame in an open area, with subfloor ventilation provided in accordance with AS CA38, for a period of eight weeks, twenty days of which will be wet. If rainfall was insufficient the panels were hosed at regular intervals to provide an equivalent wet period. Strips of timber around the edges of the panels were used to simulate the bottom wall plate on a house, thus ensuring that all water was not immediately shed by the floor surface.

During this period, moisture content of the flooring timber was monitored as also was moisture conditions in the subfloor cavity.

After the exposure period, the panels were to be allowed to dry for four weeks then sanded and given a coat of Estapol and observed for a further four weeks.

Actual results from the trials should be available in time for presentation at this Conference.

USE OF MICROWAVE OVENS FOR THE RAPID DETERMINATION OF MOISTURE CONTENT IN TIMBER

R. Davis and A. Zosars

Further investigations to those initiated eight years ago at the advent of the microwave oven have been carried out by this laboratory, revealing certain necessary techniques for obtaining correct moisture results of timber and veneer with these ovens. Available alternative methods all suffer from some disadvantages, viz.

Normal oven drying is time consuming, requiring at least twenty four hours, whereas drying by microwave excitation need only take fifteen minutes or so in most cases. After kiln drying, the microwave method can provide a quick accurate cross-check on production standards, provided the operator is trained in the correct procedure.

Apart from the normal oven drying technique, there are the infra-red method and the moisture meter. The latter falls down as an accurate system because it requires frequent calibration, relying on a mean curve for correction, and is affected by timber thickness and preservative used. It is also inaccurate at low moisture content and at moisture contents greater than twenty-five percentum.

Infra-red drying must be carried out on chipped samples, inhibiting its use in the field. The thermocouple device devised by P. Marshall of Wood Technology Division is the most effective and rapid means of controlling and determining moisture content in a kiln.

The microwave technique investigation revealed that after the water has evaporated, the rate of temperature increase can be so great as to produce darkening and even charring, unless the following precautions are taken by the operator.

(1) A large beaker of water placed in the microwave oven to maintain constant relative humidity.

(2) A number of short bursts rather than a few long bursts of radiation.

(3) Oven must have a ventilation fan.

(4) Thin wood sections (within balance sensitivity).

(5) Wood grain vertical (parallel to microwave propagation).

(6) Wood must be placed above oven floor (e.g. glass rods).

Note: The rate of drying is a function of distance from the principal axis of the microwave generator.

(The microwave oven used in these investigations was a standard "Radarange" unit operating at a frequency of 2,450 mega Hertz, a current, rating of 7.5 Amperes and a ventilating fan).

Employing these precautions it was found that satisfactory results could be achieved for practical application.

TIMBER FOR CROSS-ARMS

W. J. Smith

Following reported difficulties by consumers in obtaining adequate supplies of cross-arms in Queensland, considerable success has been achieved in gaining acceptance by Electricity Supply Authorities of an appreciably extended range of species and, more importantly, of a multi-grade quality specification capable of being met by low-level selection from normal mill-run hardwood framing production.

Whereas only nine timbers (ten species) were acceptable previously, the revised specification contains forty-three timbers (fifty species).

It was established that the stress-rating stated to be generally applied in cross-arm design in Queensland was F17, with some requirement for F22 material by one Board on a general Regional basis and by others for higher-stressed high-voltage lines. These stress-grades could be met from Strength Group S1-S3 species graded to Standard or Select Grade (and, in three species, even by Building Grade) under AS. 0.82, Sawn Eastern Australian Hardwoods.

A revised specification prepared on this basis but with special limitations on some defects where considered necessary or desirable (particularly in the central 300 mm of length) is apparently easing local supply problems and replacing the many Regional quality specifications with a State-wide uniform one.

Producers formerly reluctant to supply to rigid quality requirements in a restricted species range can now tender in anticipation of supply by selection from normal production. This should, theoretically, reduce production costs.

It is suggested this same principle could and should be adopted to re-frame other special-purpose specifications, using basic production Standards as far as practicable.

FACTORS AFFECTING THE UTILISATION OF TIMBER IN PALLETS

D. M. Greve

Demand for timber pallets in South East Queensland appears to be for a low cost product with very little emphasis placed on quality.

For this reason, hardwoods, which can be obtained relatively cheaply in short lengths, but often with a considerable amount of defect, are used almost exclusively. Softwoods, it is claimed, are too expensive and too easily damaged.

However, the supply of hardwoods for this purpose is, if anything decreasing, partly as a result of an increasing use of sawmill residue in hardboard manufacture and partly because short lengths are being used more frequently in end-matched flooring.

Australian Standard AS E41, Flat Pallets for Materials Handling, does not appear to be adhered to by pallet manufacturers, certainly not those manufacturing disposable pallets, which differ in size from the standard pallet. Defects are often greater in size than is specified in the standard but to offset this, it is claimed that the average load is considerably lower than what is required in AS E41.

There are also problems in the assembly of hardwood pallets. End splitting of deckboards is quite common while it is claimed that pre-drilling is uneconomic. The nett result of all these factors is that the hardwood pallet may have little or any strength advantage over softwood.

There appears to be a need to re-assess the suitability of AS E41 as it relates to present practices, especially with regard to load requirements and the sizes of allowable defects.

Should this standard also cover disposable pallets?

The increasing difficulties in obtaining hardwoods points to the inevitable increase in the use of softwood timber for pallets. Should we be doing more research in this area?

Topic 1/7c

VENEER RECOVERY FROM RADIATA PINE IN THE A.C.T.

N. M. Ronan, R. G. Buick and K. W. Groves

A study of 325 radiata pine peeler billets was undertaken to provide a breakdown of component losses and graded veneer recovery. The logs came from 4 sample plots within the A.C.T. forests and were run-of-the-forest material from average quality stands. All logs were identified by tree and log position within the tree.

Average production of A-grade veneer was more than sufficient for the manufacture of the most commonly demanded grades and sizes of *Pinus* structural plywood. From a log input volume of 82 m^3, 39% was recovered in panel sized equivalent of 0.25 cm thick graded, clipped veneer sheets. Average grade distribution was 18% A, 28% B and 54% C grade.

Rounding-up losses (average 27.9%) and clipping losses (average 11.2%) were the largest and most variable. Centreing inaccuracy was shown to be a major cause of excessive rounding-up losses. A theoretical analysis indicated that at least an 8% increase in veneer volume recovery would result from modifying the centreing system from a 3-armed to a 4-armed system.

Grade recovery was found to be unrelated to simple log quality parameters such as maximum knot size and the presence of dead knots. Veneer splitting was a major source of high clipper losses. The causes of splitting are complex and appear to show little relation to log characteristics.

Recovery information is available by 2 cm diameter classes and log position within tree classes.

DENSIFICATION OR RESIN IMPREGNATION OF TIMBER AS A MEANS OF IMPROVING WEAR RESISTANCE

K. Cokley

The technique of densification and/or resin impregnation for improving the hardness of timber and timber products has been known and partly applied for many years. For example impregnation with methyl methyacrylate is practiced e.g. in parquetry tiles and articles such as tool handles. Even surface coatings such as butylated ureas, polyurethanes have been found effective.

Trials by the author using synthetic resins such as urea or phenolic formaldehyde using heat polymerisation have given promise.

Four factors merit further examination:

(i) Abrasion resistance on soft species such as the exotic pines and low density rain forest species will widen their application.

(ii) It has been found that moisture absorption is significantly reduced and hence the product is more dimensionally stable. This is important in tropical areas.

(iii) Surface texture as a substrate for paints and finishes is significantly improved.

(iv) The abrasion resistance can be improved to a degree where severe mechanical uses e.g. rail sleepers are feasible with presently unsuitable species.

Facilities exist locally in the form of either kilns where the thermosetting resins may be polymerised after impregnation in conventional plant or in the case of thermoplastic resins impregnation of the softwood material with the resin dissolved in an organic solvent. This is then heat treated and allowed to cool alternatively irradiated by such as a Cobalt 60 or Caesium 137.

Facilities for these exist in Sydney and Melbourne and are proposed for Brisbane.

At present most promise has been given by softwoods and veneers but the low density species such as White Cheesewood also appear promising.

A major field will be the packaging industry. It is considered, but yet remains to be proven, that such applications may also:

(i) Prevent attack by insects such as Lyctus and termites

(ii) Because of the inert surface and resistance to moisture absorption will also significantly reduce the susceptibility to fungal attack.

In summary I postulate that these techniques will in practice not only increase the wear resistance of the product but also could be regarded as an alternative to conventional preservative practices.

END SPLITTING AND CHECKING IN ROUND TIMBER - WHAT IS THE PROBLEM?

J. E. Barnacle

End splits and checks have often been claimed to be a costly problem to the industry in Australia and elsewhere.

Much time and effort has been expended in studies of end splitting and, in some instances, such as the installation of water spray systems for log storage piles, research results have been put to good use. However, it is not uncommon to see logs or poles, split at the ends, but with no evidence of any measures to control or limit splitting.

This poses the question - "when, and under what conditions, does splitting in rounds become a problem"? If that question could be answered definitively with some quantification of the value loss due to splitting, it should not be difficult to consider what control measures might be applied and whether they could be economic. But apparently definition and hence solution, of the end splitting problem is not simple.

This subject is raised, primarily, for two reasons. First, the "problem" of end splitting has periodically, been raised at the Division by industry (not always the same part of industry) and, at least, partial answers have been obtained following problem-oriented studies. Yet, rarely it seems, has the nature, extent, or frequency of the end-splitting problem or the value of the corrective measures ever been determined.

Secondly, it could be said that the sum total of research effort - not only in this Division - but elsewhere - has only resulted in the delineation of numerous factors which, under certain circumstances, can influence end splitting. However, the extent to which each factor <u>contributes</u> to the overall problem, or the conditions under which a given factor can virtually determine the degree of splitting in a round timber has not been defined.

As a result, examples can be found where unusually severe end splits have been attributed to high levels (assumed) of growth stress; high levels of starch in the sapwood; high differential shrinkage of some species; impact in felling, (or rough handling in the forest or dumping from trucks). These and many other factors are suggested in the literature as 'causes' of end splits, and if shake is taken into account a whole host of other causes can be added.

In some cases a particular contributing factor may be postulated as the cause or a major cause of end splitting but the conclusions drawn from the evidence are, in some cases at least, questionable.

All this is of little concern if end splitting in rounds really doesn't matter. But if it is important then some serious rational thinking and experimenting needs to be done in order to ascertain causes of end splitting with a view to determining what are the <u>major</u> factors contributing to end splitting (particularly the more economically important types) and whether, under certain conditions at least, it is economically feasible to eliminate or reduce their effects.

It is suggested that such determinations might well reduce (i) needless waste of natural resources which indirectly derive from our lack of understanding of real or major causes of end splitting and (ii) direct waste of financial resources which result from using 'the right tool for the wrong job' in what are sometimes ill-informed attempts to combat end splitting. But first, it is essential to determine whether end splitting in rounds is a real problem, or just a nuisance we would prefer to do without.

Topic 1/11c

CONVERSION STUDIES ON FAST GROWN SMALL DIAMETER EUCALYPTS

E. P. Lhuede, D. J. McKittrick and G. Waugh

This is a cooperative study incorporating the Victorian Forests Commission, sawmillers and CSIRO. The study is being carried out on thirty-five year old regrowth *Eucalyptus regnans* growing in the Central Highlands area of Victoria.

The objective of this work is to investigate the influence which sawmilling procedures, when applied to small regrowth logs, may have on production rate, along with grade output and recovery of sawn products.

Trees will be selected so as to encompass a wide range of log characteristics including size, growth stresses and surface characteristics. Five sawmilling procedures will be evaluated; they will include grade sawing, where primary conversion will be by a breast bench, a conventional twin head rig (in two mills) or by a twin edger, and by gang sawing which offers a minimum opportunity for grade sawing. All sawn output will be measured and visually graded to Australian standards AS 081 and AS 083 or their metric equivalent(s). The data will be collated by computer which will assemble grade outputs, recoveries, monetary value of products and sawing times for individual sawlogs. Further statistical analyses will be carried out to determine which tree or log characteristics may influence sawmill outputs.

It is hoped that field work will be completed prior to the Forest Products Conference, and analysis of the results will be under way.

TOPIC 2

Wood Biology and Preservation

Sub-topic 2A Wood Biology

2/1 Fast grown eucalypts for wood
W.E. Hillis

2/2 Why heartwood forms
R.K. Bamber

2/3 Juvenile/mature relationships in some coniferous wood properties
W.J. Smith and D.B. Eccles

2/4 Tree to tree variation in the occurrence of kino veins
H. Dowden

2/5 Variation in selected growth and wood characteristics of plantation grown Eucalyptus regnans
G. Waugh

2/6 Branch characteristics and their influence on log characteristics in P. radiata
J.P. Wright

2/7 Incidence and effect of resin pockets in Pinus patula
D.B. Eccles, J. Alcock and W.J. Smith

2/8 Preliminary anatomical studies of the weathering of radiata pine sapwood
R.K. Bamber

2/9 The prediction of heartwood diameter in radiata pine trees
W.E. Hillis and Nell Ditchburne

2/10 Polyphenol distribution in Pinus radiata bark
R.E. Palmer

2/11 The role of calcium and magnesium in the development of marine organisms
K. Cokley

2/12 Possible causes of durability under marine conditions of Syncarpia laurifolia (turpentine)
D. de Silva, W.E. Hillis and K.W. Groves

Sub-topic 2B Wood Preservation

2/13 Organic solvent preservatives
N. Tamblyn

2/14 A new type of incising machine
F.A. Dale

2/15 Systematic collection and collation of service data
E.W.B. Da Costa and J.E. Barnacle

2/16 Centre rot problem in poles
J.E. Barnacle

2/17 Developments in the formulation of organic solvent preservatives for milled radiata pine
R.S. Johnstone and W.D. Gardner

2/18 Evaluation of soft rot field test sites in N.S.W.
D.W. Edwards, R.S. Johnstone and W. Pitt

2/19 Two developments in protection and use of wood
R. Johanson

2/20 Microdistribution of preservative in wood using electron probe X-ray analysis
H. Greaves

2/21 Techniques for early evaluation of *in situ* treatments for poles
E.W.B. Da Costa

2/22 Improved method for detection of internal decay in poles and in building timbers
E.W.B. Da Costa

2/23 Health hazards associated with treatment and disposal of CCA treated timber
F.A. Dale

2/24 Decay control in plywood by glue-line additives
D. McCarthy and E.W.B. Da Costa

2/25 Termiticidal effects of insecticidal glue-line additives
C.D. Howick, N. Tamblyn and J. Creffield

2/26 The effects of insect growth regulators on wood-destroying insects
J.R.J. French and R. Robinson

2/27 Comparative tests of superficial coatings and dip-diffusion treatments for Lyctus-immunization of Victorian eucalypt framing timbers
N. Tamblyn and A. Rosel

2/28 Dutch elm disease beetle in Australia
J.R.J. French and A. Rosel

2/29 Behaviour of currently available external finishes for wood
K.R. Bootle

2/30 Water repellent coatings for platform flooring
K.R. Bootle

FAST-GROWN EUCALYPTS FOR WOOD

W. E. Hillis

Australia will need increasing amounts of materials for building, furniture, pallets, packages, fibre etc. The use of wood and wood-based products for many of these purposes will continue to expand although the predictions of the amount needed vary. The demand for wood may be greater than the predictions if there is restriction of the use of materials derived from non-renewable resources and those which cause pollution.

The areas of man-made forests being established in Australia to meet projected needs may be inadequate. Little allowance has been made for the possible occurrence of catastrophes such as fire, disease and insect attack which could (as in the past) destroy large areas of forest. In addition, some of the most productive forest land will be taken over for agricultural purposes, roads, housing, recreation, water catchment etc. Accordingly, to meet community needs greater attention must be given to increasing site productivity, to the influence of forest practices on wood quality and to the maximum production of forest products from available forests and in particular those products obtained with the minimum consumption of water, energy and adhesives. Furthermore, the products must be used in the most efficient manner and properly protected.

The choice of species and their varieties for establishment in future forests will depend on many inter-connected aspects such as land use policy, climatic factors, nutrition requirements, ease of establishment, disease and insect resistance, end use requirements, socio-economic conditions, etc. Some eucalypt species could satisfy many of these requirements better than most other tree species. Eucalypts grow rapidly for at least 10 years in some overseas countries and under ideal conditions are reputedly the world's fastest wood producers. Plantation areas are being enlarged rapidly overseas but even so, eucalypts form less than 10% of the world's plantation area at this time. More attention should be given in this country to the cultivation of seedling, and particularly coppice, fast-grown eucalypts as a source of wood. They will produce even-sized small logs with wood quality different from that of mature trees of the same species. An integrated approach of a project team with specialists of many disciplines is needed to ensure the establishment of the most suitable species and forest practices to produce logs and wood of the required quality and characteristics that will be converted in maximum yield to the most highly valued end-products.

What will be the commercial eucalypts of the future? Those of major importance in Australia at present are *E. delegatensis*, *E. diversicolor*, *E. globulus*, *E. grandis*, *E. marginata*, *E. obliqua*, *E. pilularis*, *E. regnans*, *E. sieberi*. Other species are *E. amydalina*, *E. calophylla*, *E. camaldulensis*, *E. maculata*, *E. microcorys*, *E. muelleriana*, *E. nitens*, *E. patens*, *E. resinifera* and *E. viminalis*. Those species with greatest volume production in overseas countries are *E. grandis*, *E. globulus*, *E. camaldulensis*,

E. viminalis, E. maculata, E. maidenii, E. microcorys, E. diversicolor, E. cloeziana, E. tereticornis, E. dunnii, E. deglupta, E. alba, E. citriodora, E. fastigata, E. muelleriana, E. obliqua, E. resinifera, E. fraxinoides, E. andreana, E. stjohnii. Eucalypt wood of the future will come very largely from these species. Provenance studies and tree improvement programmes have been started in this country on *E. regnans, E. obliqua, E. grandis, E. globulus, E. pilularis* and *E. nitens* and in Papua New Guinea on *E. deglupta*. Some studies on coppice growth have been commenced. Future attention could be given to the production of trees with shorter but wider boles, relative production rates of wood from seedling and coppice sources and supply of nitrogen requirements by mixed planting with *Acacia* spp.

Wood quality and end-use requirements will partly determine the selection of the species and provenances for planting. The characteristics of the wood from regrowth specimens of some of the above species have been determined here and overseas. They differ from those of wood from mature specimens. To varying extents, regrowth woods show significant variations from normal wood properties and these may sometimes be severe. The variations include properties associated with growth stresses, such as end splitting of logs, broken fibres and brittle heart, also kino veins, discoloration and decay, collapse on drying and interlocked grain. The severity of these variations differs according to the country and locality.

Information on wood and log quality of fast-grown eucalypts is of importance at 3 different stages. It is needed (a) for those trees which will yield seed or cuttings for future forests, (b) for trees at different ages and the effect of different silvicultural treatments on them, (c) for those trees which have reached harvesting age.

To permit maximum utilisation of the wood from fast-grown eucalypts, further studies are required to define those factors causing departures from normal wood properties and how they may be alleviated by breeding, silvicultural practices or treatment of trees, logs or sawn product.

Economic and other considerations will result in increasingly larger numbers of small diameter logs of uniform size, but possibly of different quality, becoming available for conversion. The cost of all logs will continue to increase so that errors in judgement of the quality of the material entering conversion plants will become more costly. Consequently, the development of rapid non-destructive assessment methods is required. These will indicate the wood quality present in standing trees (to enable the classification of a stand or compartment) or in a log so that the optional use of a forest can be achieved and products of uniform quality can be produced. Because the biggest shortfall in the next 15 years will be of saw and peeler logs, the production of solid wood products and veneer must take priority. The assessment methods will assist the raw material to be channelled to the most appropriate conversion procedure in an integrated operation.

As the local industry has been developed for the utilisation of large sized eucalypt logs, it is probable that different mechanical procedures will be required to process many small logs. After the wood quality in a log has been assessed, rapid sorting and adaptable handling procedures will

be needed at all stages of conversion to obtain maximum recovery at lowest cost. Improvement in cutting techniques will be required for this material. Because of their size, these logs will probably be more costly per unit of board produced than the presently used larger diameter logs. Consequently mechanical aids will need development to assist rapid decisions at various stages to be made accurately.

A larger proportion of juvenile wood will be present in logs from short rotation forests. Its properties differ from mature wood so that examination of the effects of seasoning, determination of strength properties, assessment of protection methods and improvement of stabilisation need to be undertaken. As some of the properties of juvenile wood may affect its application in some products, a re-examination of product specifications for end use is needed to ascertain whether they are appropriate for modern needs.

At present there are difficulties in the utilisation of wood from some fast-grown eucalypts. It should be remembered however that not long ago, the use of wood from mature eucalypts as a source of pulp was discouraged and that most of the nation's timber needs for building, furniture and industrial wood were imported. Research and development has lead to the widespread use of mature eucalypt wood for these purposes and their advantages exploited. Re-examination of the above aspects as they apply to a different type of wood, namely that from fast-grown eucalypts, will lead to improved efficiency in their use.

WHY HEARTWOOD FORMS

R. K. Bamber

The presence of heartwood in trees is somewhat of an enigma. As inert material it can only contribute mechanical support to the tree. However as the sapwood adequately performs this role, for example in *Pinus radiata* heartwood is not formed until after the trees are about twelve years or more old, then it would appear that heartwood is not essential for support of the tree.

The widespread occurrence of heartwood in trees* however indicates that it is essential for trees, at least over a long period of time, to develop heartwood. It is suggested that heartwood formation is concerned with the physiology of the tree and is a mechanism for regulating the amount of sapwood to an optimum level.

In support of this hypothesis can be cited the strong relationship between rate of growth and the amount of sapwood. In 20-year old plantation-grown trees of *Eucalyptus grandis*** we have obtained a correlation coefficient of 0.84 between rate of growth (as indicated by tree diameter) and sapwood width. In 39-year old plantation grown trees of *Pinus radiata* a correlation coefficient of 0.93 was obtained between rate of growth (tree diameter) and sapwood width.*** This relationship between sapwood amount and rate of growth indicates that within a species there is a requirement for a specific amount of sapwood perhaps determined by the capacity of the sapwood to supply the crown with water and nutrients.

However as growth of new wood continues and the amount of sapwood exceeds the trees' requirements it is suggested that it is advantageous for the excess sapwood to be rendered inert and separated from the physiologically active sapwood by conversion into heartwood. It is argued that because the sapwood contains living tissue, (principally parenchyma), which requires nutrients such as phosphorus, potassium and nitrogen to nourish it, that surplus sapwood constitutes a drain on the nutrient balance of the tree. It is well known that these nutrients are resorbed from the sapwood when heartwood forms (Daube, 1883; Ziegler, 1967; Beadle and White, 1968). The significant nature of this resorption in eucalypts is demonstrated in the following table:

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* Krzynik (1954) considers heartwood to be produced by all tree species.

** The data for *E. grandis* and *P. radiata* was analysed with the assistance of Mr. N. Omar, Statistician, Forestry Commission of New South Wales.

*** Carrodus (1972) also reports a close relationship between rate of growth and sapwood width of *P. radiata*.

Species	Phosphorus (p.p.m.)		Potassium (p.p.m.)	
	Sapwood	Heartwood	Sapwood	Heartwood
*Eucalyptus campanulata**	53	3	160	32
*E. corymbosa***	53	12	514	230
*E. grandis***	103	7	1087	238
*E. microcorys***	80	8	545	37
*E. pilularis***	43	5	494	7
*E. saligna**	110	3	1000	35

* Beadle and White (1968).

** Marcia J. Lambert, Forestry Commission of New South Wales, unpublished data.

The amount of nutrients held in the sapwood can be quite large in terms of the total amount in the tree, for example Forrest (1969) has shown that in *Pinus radiata* the sapwood phosphorus can be one third of the tree phosphorus. If heartwood was not formed the sapwood would constitute an ever increasing drain on the nutrient resources of the tree.

The question then arises as to the mechanism of heartwood formation. It is postulated that the pattern of heartwood formation indicates that the parenchyma cells remain dormant until triggered by a heartwood inducing substance (hormone) to undergo the heartwood conversion. This substance is considered to move centripetally along the rays, probably originating in the phloem, until it reaches the cells adjacent to the impermeable core or existing heartwood. As further centripetal movement is not possible the concentration of heartwood inducing substance (HIS) increases in the parenchyma cells adjacent to the impermeable core until the threshhold level for heartwood formation is reached. This model is illustrated in Figure 1.

Examination of the cells in the intermediate wood or transition zone shows that the initial stage of heartwood formation is the blocking of the water-conducting cells and that this change is fairly rapid (Figs. 2 and 3). It can also be seen in Figure 3 that the transition occurs in cells of the same axial strand or in cells connected to the same axial strand more or less simultaneously which means that the HIS must reach the threshhold level in these cells at virtually the same time.

The possibility of heartwood formation being triggered by a HIS is supported by the well known phenomenon of included sapwood (Erdtman, 1958; Hillis, 1962; Jane, 1970) in which injury to the cambium results in the segment of sapwood between the injured cambium and the heartwood not undergoing the normal transformation to heartwood and finally being

incorporated into the heartwood as included sapwood. This is considered to demonstrate that injury to the cambium interrupts the centripetal movement of HIS along the rays and as a consequence the heartwood transformation is not activated.

The burst of cellular activity associated with the heartwood transformation noted by Chattaway (1952) and the increase in respiration observed in the intermediate wood (Höll and Londzian, 1973; Nekrasova, 1973; Shain and Mackay, 1973) demonstrate that the transition from sapwood to heartwood is an active growth process comparable with other growth processes such as leaf abscission, fruit ripening and the initiation of cambial division.

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Topic 2/3

JUVENILE/MATURE RELATIONSHIPS IN SOME CONIFEROUS WOOD PROPERTIES

W. J. Smith and D. B. Eccles

Summary

Correlations of generally excellent predictive value have been established between the first five- and ten-year incremental core basic density and percentage latewood values and those for whole-core values at later-age rotational intervals in Queensland-grown *Pinus taeda*, *P. elliottii* var. *elliottii*, *P. caribaea* var. *hondurensis* and *P. patula*. These are considered reliably applicable to tree ages ranging from at least 17 years in *P. caribaea* to at least 37 years in *P. taeda*.

Predicted estimates based on the earlier five-year core would be somewhat less reliable than for the older core but still very useful, except for percentage latewood in *P. patula*, in which this feature apparently cannot be reliably predicted from the five-year core. The applicability of these results in tree improvement programmes is briefly considered.

Introduction

In tree improvement work, the primary emphasis is generally on superior volume productivity, whether selection be on the basis of comparative species, variety or provenance trials, progeny tests or individual tree evaluation for seed orchards.

While this priority is justifiably accorded, due care has to be exercised to ensure that the wood from extensive areas reforested at considerable cost will be capable of fulfilling its intended end-uses at the prescribed harvesting intervals, whether this be as thinned or clear-felled material.

The advantages of establishing even reasonably reliable correlations between early and later rotational-stage performance are obvious in any comparative evaluations of alternative stock under consideration, whether the parameters are volume increment, environmental tolerance or type of wood produced.

In tree-breeding work, useful predictive correlations would be invaluable in enabling earlier screening of progeny tests and selection of breeding stock from them, to reduce the age interval between generations in a long-term crop.

The results of work reported on juvenile/mature correlations for volume and wood quality parameters have been very variable but, in many cases, quite encouraging (possibly more so for the latter than the former) and recent investigations in Queensland are considered to have been particularly fruitful.

Topic 2/3

Wood quality assessment in this State is based on diametral cores extracted from about 1 m above ground in single-level sampling. Two of the more important of several wood properties determined are basic density and, in the exotic conifers, percentage latewood. Values for these features are determined for cumulative 5-ring incremental pith-to-bark segments as well as individual rings at 5-ring intervals. The use of cumulative segments has the practical advantage of providing density and dry wood weight yield data directly relatable to commercial harvesting intervals.

The present study is aimed at determining the reliability of "juvenile" core-wood basic density and percentage latewood values in predicting these properties at later rotational stages.

This is particularly important because of the predominant emphasis placed on the first 10-year incremental core data in the comparative evaluation of exotic conifers for wood quality. This was rather arbitrarily set, but determined to a considerable extent by the age of the first *P. elliottii* progeny tests on which wood studies were done and the age of the earlier *P. caribaea* seed orchard candidates. The usefulness of observations on this core in this type of work needed checking.

Materials and Procedure

Applicable data was used from a number of other studies on four exotic conifers, *Pinus taeda*, *P. elliottii* var. *elliottii*, *P. caribaea* var. *hondurensis*, and *P. patula*.

The largest number of trees represented was in *P. taeda* for basic density. This was not because of scarcity of data for the other species, particularly *P. elliottii* and *P. caribaea*, but only because a study on *P. taeda* was in progress when it was decided to test the relationship. Results were so promising that a smaller sample of the other species was also checked to evaluate its general applicability.

Further refinement is now being undertaken, pooling all available data from previous work.

The *P. taeda* and *P. elliottii* data used was quite broadly based, geographically, over the major areas planted to these species. The *P. patula* came from three locations quite close geographically, but the species has, in any case, a limited planting range in this State, so the data could be reasonably representational.

However, the *P. caribaea* came from only one location in south-east Queensland and, particularly because of its extremely wide planting range, must be regarded as a locational relationship for the time being.

Age ranged from a minimum of 18 years in *P. caribaea* to a maximum of 40 years in nine of the 140 *P. taeda* trees, with sample sizes for the various ring-age limits tested in the relationship as shown in Table 1.

Tree age has been found to be generally one to two years older than indicated by ring number from pith at one metre above ground.

For each species the relationship of (a) the first 5-years and (b) the first 10-years incremental core values with those for progressively older whole-core values were tested by regression analysis, assuming a linear relationship. Five-year intervals were used.

Results and Discussion

The results of the analyses for basic density and percentage latewood data for each species are presented as correlation matrices in Table 1.

(a) Basic Density

Generally very highly significant high-order correlations were established between basic density of both the first five-year and the first ten-year incremental cores and later-age whole-core values in trees ranging in age from 18 years in *P. caribaea* to 40 years in *P. taeda*.

The ten-year core was generally the more reliable for predictive purposes, as would be expected ($r = 0.892$ *** to 0.985 ***), with variation in its density accounting for from 80% to 97% of the variation in whole-core density, depending on species and age for which prediction was required.

However, the five-year core is also very useful for earlier evaluation of comparative performance, especially in progeny and provenance trials, with a more variable degree of correlation ($r = 0.721$ * to 0.952 ***), indicating an association of from 52% to 91% of the variability in this younger core density with that of older whole cores. Correlation coefficients at the lower limits of the observed range are seen as being more applicable in family, provenance, variety or species evaluation rather than in single-tree comparisons. The consistency of the relationships with increasing tree age for both stages of juvenile core was good for the southern yellow pine group, but there was an indication of reducing predictive value with age for the 5-year core in *P. patula*.

Although not shown in Table 1, extending core age beyond ten years gave no great improvement in predicting whole-core values in those species with material old enough for this test to be meaningful.

(b) Percentage Latewood

For both early incremental cores in *P. elliottii* and *P. caribaea* and the ten-year core in *P. patula*, very highly significant linear relationships of a very useful order were also established with older core values ($r = 0.824$*** to 0.989***; $r^2 = .68$ to $.98$). However, in *P. patula*, although percentage latewood in the five-year core was significantly correlated with the ten-year and 15 year values, the magnitude of the coefficients was too low to be considered useful for predictive purposes and became non-significant for later ages. The

relationship has not yet been tested for this feature in *P. taeda*, but from established relationships with basic density and similarities shown for the basic density relationships common to the two species in Table 1, can reasonably be expected to be similar to that for basic density in this species.

Three closely situated locations were represented in the *P. patula* material, from a species with characteristically low latewood content, and the possibility must be considered that the apparently much better predictive value of the same core in the usually low percentage latewood *P. caribaea* may be due to its having come from a single location.

Conclusions

It is concluded that:

(a) Basic density and percentage latewood values from single-level sampling determined at age 11-12 years can be quite reliably used to predict what these properties will be at later rotational stages to at least 37 years in *P. taeda* (for basic density), 27 years in *P. elliottii* var. *elliottii* and *P. patula*, and 17 years in *P. caribaea* var. *hondurensis* grown in Queensland.

(b) Sampling at the age of 6-7 years can be expected to give extremely useful if somewhat less reliable estimates for even earlier evaluation, except in the case of percentage latewood in *P. patula*, in which species evaluation of this feature at the earlier age cannot be considered sufficiently reliable.

(c) Use of the first 10-year incremental core values in earlier tree improvement work in Queensland is considered to have been validated and their continued application justified;

(d) Checks of locality variational effects on the relationships established are considered desirable; and

(e) The results are seen as an important development for application in tree improvement programmes to expedite progress in the evaluation and improvement of wood quality and wood weight yields.

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Procs. IUFRO Joint Meeting of Working Parties in Population and Ecological Genetics, Breeding Theory and Progeny Testing, Stockholm, 1974: pp. 217-251 (and other references quoted therein).

TABLE 1. Correlation Matrices Showing Relationships Between "Juvenile" and Later-Age Values for Basic Density and Percentage Latewood in Four Queensland-Grown Conifers

CORE AGE (YEARS)	AVERAGE BASIC DENSITY						AVERAGE PERCENTAGE LATEWOOD					
	10	15	20	25	30	35	10	15	20	25	30	35
	Pinus taeda											
5	876***	.784***	.820***	.770***	.724**	.846**			NOT DETERMINED			
n	140	140	55	35	15	9						
10		.971***	.940***	.921***	.919***	.955***						
n		140	55	35	15	9						
	P. elliottii var. *elliottii*											
5	.938***	.896***	.835***	.924***			.871***	.845***	.851***	.854***		
n	45	45	25	10			45	45	25	10		
10		.984***	.957***	.982***				.966***	.876***	.904***		
n		45	25	10				45	25	10		
	P. caribaea var. *hondurensis*											
5	.952***	.928***					.895***	.857***				
n	20	20					20	20				
10		.983***						.989***				
n		20						20				
	P. patula											
5	.946***	.900***	.842***	.721*			.638**	.532*	$.425^{ns}$	$.499^{ns}$		
n	15	15	14	7			15	15	14	7		
10		.985***	.952***	.892***				.861***	.824***	.904***		
n		15	14	7				15	14	7		

*** Significant at the 0.001 level ** Significant at the 0.01 level * Significant at the 0.05 level

ns non significant at the 0.05 level. n = number of trees in the sample.

Topic 2/4

TREE TO TREE VARIATION IN THE OCCURRENCE OF KINO VEINS

H. Dowden

Despite the importance of kino veins, or 'gum veins' as they are commonly but incorrectly called (Dadswell and Hillis, 1962), in the grading of eucalypt timbers there is little information on their occurrence in Australian forests or timbers. More than 30 Australian standards cite 'gum veins' as a source of degrade or rejection in timber yet in Australia only Irvine (1936) and Jacobs (undated) appear to have studied kino veins as they occur in trees, while their significance in converted timber was last considered in some detail by Turnbull et al. (1938). This situation is like that relating to studies on the anatomy of kino veins as noted by Dowden and Foster (1973).

An examination of the distribution of kino veins within and between trees in crops could indicate whether environmental or genetic factors had a greater influence on the occurrence and extent of veins, and this knowledge could lead to more effective management of eucalypt forests. Vein distribution associated with such factors as topography, compass direction or growth periods, with little tree to tree variation could suggest that external environmental factors were influential. On the other hand random distribution of veins with marked tree to tree variability might imply that internal genetic factors had significant effects. Assessment of environmental factors might lead to the development of methods for controlling them, while genetic factors might be amenable to selection and breeding procedures. In addition, information on the distribution of veins within trees should give indications of the degrade and loss likely to occur following conversion.

In an introductory study, two transverse sections from each of 52 trees of mature *Eucalyptus obliqua* were obtained from plots maintained for many years by the Melbourne University School of Forestry in Broadford State Forest, Victoria. At least five sections per tree from each of 12 *Eucalyptus regnans* aged 13 years were obtained from plots in A.P.M. plantations near Traralgon, Victoria.

Numbers and a range of parameters were assessed for all sections after the surface had been smoothed.

The data was subjected to analysis by Chi-squared tests, regression methods and analysis of variance.

Nearly 2500 kino veins were examined in the *E. obliqua* sections and over 300 in the *E. regnans* sections.

The analyses for vein numbers and dimensions showed that the main source of variation was that from tree to tree. There were differences between sections within trees and within sections, but this variation was generally less than that between trees. Differences between plots were not found to be significant. Table 1 shows the range of variation in numbers of veins between sections from different trees and between tree totals.

TABLE 1. Variation in numbers of kino veins.

Species		Section	Tree
E. obliqua	Minimum	1	7
	Maximum	72	116
E. regnans	Minimum	0	13
	Maximum	31	46

The differences between trees were statistically significant at above the 0.1% probability level.

TABLE 2. Variation in kino vein measurements, mm.

Species	Source of measurement	Tangential length		Radial thickness	
		Minimum	Maximum	Minimum	Maximum
E. obliqua	Veins	1	1033	0.2	4.9
	Trees	3	172	0.7	2.1
E. regnans	Veins	1	244	-	-
	Trees	17	56	-	-

Table 2 shows that the difference in tangential length of veins (i.e. the length measured round the curve of the growth rings in a transverse section) was more variable, both for veins and trees, than the radial thickness, although the latter was markedly variable. The tables show that numbers of veins and some of their measurable dimensions were thus very variable from tree to tree.

Hand plotting and regression analyses indicated that there was no significant preferential orientation of veins, nor were they significantly associated with growth periods or radial distance from the centre of the tree. However, veins were often grouped, and these groups were significantly associated with knots or insect damage, as had already been observed by Irvine (1936) and Jacobs (undated).

In the samples examined the main differences were those between trees, and no obvious relationship was detected between internal features and external factors. It is therefore likely that differences in vein numbers and dimensions were related to individual genetic characteristics of the trees, rather than general environmental factors. A limited amount of work (Dowden, in preparation) indicated that there were also differences between young small trees in their response to vein inducing agents.

Future work

Since individual trees vary in their liability to produce kino veins it should be possible to select trees for low kino vein production, and joint work between CSIRO and the Forestry Commission of N.S.W. is already under way, using the techniques described by Dowden and Foster (1973). A set of progenies of *E. grandis* has been obtained from the Forestry Commission's breeding stocks, and work is in progress both at the Division of Soils in

Glen Osmond and the Wood Technology Division at Pennant Hills. It is intended to estimate the response of young small trees in glasshouse conditions, followed by field plantings to assess the reactions of treated trees at greater ages.

This work may thus enable plants to be obtained which have in addition to other desirable characters resistance to the production of kino veins, which should increase the value of the crop for whatever purpose it may be grown.

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Topic 2/5

VARIATION IN SELECTED GROWTH AND WOOD CHARACTERISTICS OF PLANTATION GROWN *EUCALYPTUS REGNANS*

Gary Waugh

Introduction

At the last Forest Products Conference in May 1973, I made mention of the fact that a study was underway to examine the variation in selected tree and growth characteristics in a population of young fast grown *Eucalyptus regnans* trees. Characteristics under study included -

(a) growth stress (G.S.)
(b) specific gravity (S.G.)
(c) tree girth, breast height over bark (GBHOB)
(d) kino vein intensity

Measurements were carried out on trees growing in replicated half sibling (only maternal parent known) family plots established in the south Gippsland hills in Victoria, in 1960 and 1962 by Dr. K. G. Eldridge of the Forest Research Institute, Canberra.

Material and Method

A technique developed by Nicholson (1971) enables the measurement of strain associated with growth stress release in small wood samples when they are removed from the stem periphery. The small wood samples were also used for specific gravity determination and for sampling for the presence of kino veins.

The experimental design encompassed measurements on 25 half sibling families with two replications on each of two localities, bringing the total number of family plots to 100. The total of 25 families represented families chosen from five parent trees from each of five altitudes from the side of Mt. Erica. The actual intensity of measurement was determined following a comprehensive pilot study. This resulted in four measurements being made on each tree at a height of 1.5 metres above ground level on four trees in each family plot. The pilot study also assessed the affect of seasonal variation in the above mentioned factors, in order to determine what effect this may have over the three months of actual measurements for this study.

Results

The data obtained from the field measurements was subjected to a four way orthogonal analysis of variance for a random plot design. A summary of the results of the analysis can be found in Table 1.

(a) GBHOB

The analysis showed a significant difference at the 95% confidence level in GBHOB between families within elevations.

(b) KINO

A highly significant interaction (at the 99% confidence level) between blocks and families within elevations was detected in the analysis, with no significant difference between families within elevations or between elevations.

TABLE 1

ANALYSIS OF VARIANCE - WOOD AND TREE GROWTH CHARACTERISTICS

Source	df	Mean Square			
		GEHOB	Kino	S.G.x1000	GS
Block	1	231313**	28.09**	6839	96.78
Replications	2	5660	5.14	2377	67.78
Elevations	4	12400	4.037	3305	182.0**
Families within elevations	20	24760*	1.679	3730***	52.90
Block x elevation	4	19711	1.909	1966	40.02
Block x families within elevations	20	12210	2.9915**	1886	39.55
Rep x families	48	15176	1.145	1692	46.44
Trees within families	300	14235	1.235	1162	41.17
Total	399				

* significant at the 95% confidence level

** significant at the 99% confidence level

*** significant at the 99.9% confidence level

(c) SPECIFIC GRAVITY

The analysis showed a very highly significant difference (at the 99.9% confidence level) in specific gravity between families within elevations.

(d) GROWTH STRESS

For strain associated with peripheral longitudinal stress release, the analysis detected no significant difference between families within elevations, but there was a highly significant (at the 99% confidence level) difference between elevations.

An analysis of covariance was also carried out between the various factors, and at no time was any significant correlation detected between any of these properties.

Discussion

The fact that no phenotypic correlation was detected between these properties, including between growth stress and tree girth, indicate that the results of this work do not support the long standing belief that the fastest grown trees will be the most highly stressed trees.

For both GBHOB and specific gravity, there was significant phenotypic variation between families. This is a further indication that both factors could possibly be modified through tree selection. Rudman et al. (1960) have reported that both of these factors have a moderately high heritability in eucalypts.

A highly significant growth stress difference between elevations can be rather confusing to interpret. The progeny from parent trees selected at one elevation recorded consistently higher growth stress levels than for all the other elevations which remained consistently uniform. Although the parent trees chosen at that altitude apparently were spread out over a few hundred metres, they may have been close enough to make up the one family group, all having the one common highly stressed ancestor. Another possibility is that the general locality from where the parent trees were selected may be a site which is exposed to severe environmental conditions, such as wind and drought. Over the generations natural selection in that area could have tended towards a more highly stressed tree. However, this is purely conjecture and has been raised to highlight the fact that much is still unknown regarding what genetic and environmental factors may influence growth stress levels.

There has been no attempt to make any estimate of environmental or genetic variance components nor any heritability estimates from the results of this work, as the original parent trees were not randomly selected. The plots were originally established to study the altitudinal variation of various tree growth characteristics. Also it is doubtful whether 25 families would be a large enough sample on which to base meaningful results. Although many more families were established on both blocks, the 25 families used represented the largest possible sample which would allow an orthogonal experimental design to be employed.

Conclusions

Although this work fell a long way short of answering the question of what contribution tree selection can play in modifying growth stress levels, significant differences between families indicate that the question is worthy of further investigation. Many years of work would be involved in the establishment of a well replicated field trial encompassing a suitable number of randomly chosen families, and then allowing the progeny to reach an age where wood fibre characteristics approach that of a mature tree.

Acknowledgements

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Topic 2/6

BRANCH CHARACTERISTICS OF RADIATA PINE AND THEIR INFLUENCE ON LOG QUALITY

J. P. Wright

Supply of logs of a constant or predictable quality mix is of major importance to the wood using industries, not the least the sawmilling industry. In radiata pine, the quality of the timber is determined largely by knot characteristics, and thus is influenced greatly by the branching characteristics of the tree. Branching characteristics determine the number, size, distribution and condition of knots; all important characteristics influencing the grade of sawn timber.

In view of the importance of knots in sawn timber there is surprisingly little information available on knot characteristics in radiata pine sawn timber, or on the branching characteristics of tree. A study in Victorian radiata pine plantations involving examination of the variability of branch characteristics of the lower stem over a range of sites and stand densities has attempted to improve our knowledge of branch characteristics and their influence on the quality of sawn timber.

A broad range of characteristics related to the number, size, distribution and condition of branches was studied. These characteristics varied in differing ways and to differing degrees with changes in site quality, locality, and stand density. However, they can be conveniently grouped into two broad classes; characteristics that determine the number and distribution of knots, and characteristics that determine the size and condition of knots.

Branch Characteristics that determine the number and distribution of knots

Characteristics examined included the number of whorls in the annual shoot, internode length and number of branches per foot of stem. They all show high levels of variability, but this variability is not closely associated with site or stand conditions, tree size, or growth rate. There is no discernible trend in any of these characteristics with changes in stand density, while only slight trends are found with changes in site quality. On better sites the number of whorls and internode length increase slightly, whereas the number of branches per foot of stem decreases slightly. It is evident that genetic rather than environmental factors are the major causes of variability, since differences appear to be determined at the stage of formation of the branches, rather than during subsequent growth.

Branch Characteristics that determine the condition and size of knots

Characteristics examined included green level (i.e. the height above ground of the lowest live branches), branch diameter, branch angle and nodal swellings. These characteristics are significantly influenced by the environment in which the tree is growing, since their values are determined both at the bud primordia stage and during subsequent growth of the branches.

These characteristics are very variable, the variability being associated with both site quality and stand density. In stands of similar age it is found that green level, branch diameter and nodal swelling increase on higher quality sites, while branch angle decreases. In widely spaced stands, green level is significantly lower and branch diameter is significantly larger than in dense stands. The more important of these relationships are illustrated in Figures 1 and 2. Figure 1 also indicates that the earlier death of branches on better sites leads to earlier and more extensive rotting of dead branches, resulting in earlier and greater incidence of rotten knots.

Green level, branch diameter, nodal swelling and to a lesser extent branch angle are also associated with tree size. However, removal of the effect of tree size by covariance analysis does not significantly influence the relationships between most of these branch characteristics and either site quality or stand density. The exception to this rule is branch diameter; in this case tree size accounts for practically all of the variation associated with stand density, and for much of that due to site quality. This association between tree size (and therefore tree growth rate) and branch size indicates that the possibilities for manipulating branch size by silvicultural techniques are somewhat limited, since situations which will result in small branches, such as poor sites or dense stocking, will also reduce tree growth rate.

Implications of variations in branch characteristics for the production of sawn timber

Of the many branch characteristics examined, it was found that for only two, green level and branch diameter, do the variations associated with site quality, locality and stand density have important implications in relation to sawn timber.

For structural timber, where the frequency, distribution and size of knots are important, the grade yield is expected to decrease with better sites and wider spacings, because of larger knots. A compromise is therefore necessary between the requirements for rapid tree growth and small branches. The option of increasing grade yield by closer initial spacing or planting of poorer sites must be evaluated against other options, such as silvicultural practices aimed at rapid tree growth, perhaps in conjunction with pruning, or upgrading processes after sawing.

For board timber, where the condition of knots (i.e., whether intergrown or incased, sound or rotten) is also important, the grade yield is expected to decrease with better sites and closer spacings, mainly because of the higher incidence of bark-encased knots. One promising option is to maintain green level as low as possible, by the adoption of low initial stocking and heavy early thinnings, even though this increases branch size. For the higher grades of boards, however, it would appear that large scale production will only be achieved by pruning or by upgrading processes after sawing.

Based on the results of this study, general guidelines for minimum initial stocking levels for unpruned radiata stands have been determined as follows:

structural timber

good sites	-	900 trees per acre
poor sites	-	500 trees per acre

board timber

good sites	-	500 trees per acre
poor sites	-	300 trees per acre

It should be noted that these stocking levels are suggested minimum levels based on considerations of the quality of sawn timber. They are not necessarily the optimum stocking levels, which will depend on considerations of total production and economic return as well as on quality.

Topic 2/7

INCIDENCE AND EFFECT OF RESIN POCKETS IN *PINUS PATULA*

D. B. Eccles, J. Alcock and W. J. Smith

Introduction

Resin pockets are known to occur in many coniferous woods throughout the world. In Queensland they have been observed in most *Pinus* spp., to a variable extent, but are particularly prevalent in *Pinus patula*, planted over an area of just over 1,600 hectares, comprising about 3% of the total area in exotic conifers and concentrated predominantly in the Yarraman District in south-east Queensland. This species suffers considerable degrade in sawn boards due to this defect, and assumes appreciable economic importance in a timber which constituted 13% of the State's total exotic coniferous plantation harvest in 1973/74. A recent sawing study on this species presented an opportunity to check the incidence of these defects and possible evidence for causal factors.

Materials and Procedures

A total of 156 trees had been selected for the sawing study from 3 localities, 55 each from Yarraman and Benarkin and 46 from Pechey. These ranged in age from 22 to 46 years (see Table 1). The Pechey material averaged about 14 years older than that from the other two locations. This base sample had been stratified to provide equivalent representation of size classes throughout the range in each stand.

For detailed examination, a total of 37 5-cm thick discs were cut from 13 trees from the sawing study (three at random from Yarraman and five each from Benarkin and Pechey). The discs were taken from the butt, approximate mid-section and top of the merchantable bole of each tree. Two discs (a butt sample from Benarkin and a top sample from Yarraman) were, unfortunately, lost in transit.

The smoothly-surfaced end-sections of the discs were examined macroscopically and stereo-microscopically for morphological and chronological occurrence of resin pockets, and indications of possible relationships with environmental factors determined from meteorological records and other sources.

The sawing study logs were sawn to 25 mm and 16 mm thick boards as wide as possible and graded green-off-saw to the grade provisions of the relevant Australian Standard AS. 0.108-1969 - Sawn Boards from Australian-grown Conifers. These allow resin pockets in only the lowest two of five grades (Building and Utility grades).

From the seasoned sawn recovery, a 10% sample was taken and the number and individual length of all resin pockets on both faces of each piece recorded and related by districts to a unit surface area for comparative purposes.

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Results and Discussion

Of the 37 discs examined, 10 showed the typical lens-shaped defect on at least one end-section. These occurred on at least one of the three sampling levels in 8 of the 13 trees sampled. All five trees from Pechey contained the defects in discs from at least one level, two of the three from Yarraman, and only one of the five from Benarkin, suggesting possibly highest incidence at Pechey, lowest at Benarkin and intermediate occurrence at Yarraman if a random distribution of the defects in the vicinity of the three sampling levels is assumed.

TABLE 1. Incidence and Occurrence of Resin Pockets in Discs from *P. patula* at Three Locations

Data	District		
	Yarraman	Benarkin	Pechey
Tree age (yrs)	25-26	22-26	34-43
No. of trees in sawing study	55	55	46
Total Mech. Volume (m^3)	26.6	28.8	28.0
No. of trees sampled for detailed study	3	5	5
No. of trees with disc defects	2	1	5

There was also some indication of a possibly higher incidence in the mid-section of the merchantable bole, with six of the 13 trees showing a total of 11 defects in mid-section discs, while only two trees of the 13 showed defects in butt and top discs (6 and 3 defects, respectively).

Period of Occurrence

By chronological dating on the radial strip it was determined that defects had occurred in at least 12 of the last 24 rings. However, in view of the small number of discs and from observations on the sawn boards, it is apparent they may have occurred in some trees in any year at one or more locations.

From examination of the discs and a large proportion of the sawn boards, it was established that, under growing conditions in these three localities, resin pockets were invariably initiated during the early stages of earlywood production. In about 60% of the cases it was associated with a growth flush following true or false latewood deposition and the remainder were all initiated within the first half of the earlywood production period. None of the hundreds of defects examined was initiated during a period of latewood or false latewood

production despite a deliberate search to locate this. Whilst the precise time of earlywood initiation in this species is not known, it is estimated, from observations made by local field staff and general patterns of incremental growth for other exotic conifers, to be in September to October.

There is also some indirect evidence that latewood production commences in about March, so that it seems possible resin pocket initiation here could be associated with factors occurring in about the period September to December.

Causal Factors

It has been suggested in the literature that resin pockets could arise in association with frost cracks. Meteorological data for the locations precludes frost as a possible causal agent here.

The view has been expressed by Brown *et al.* (1) that they are formed as a result of cambial activity in which contigous cambial derivations over a considerable area suddenly cease differentiating as tracheids in order to develop resin epithelia.

This tends to support the hypothesis presented by Cown (2) that, in *P. radiata* in New Zealand, the pocket initiation results from the rupture of cells along a line of weakness, perhaps enhanced by a proliferation of resin canals, along the false latewood/earlywood boundary immediately after relief of water stress. However, no such evidence of tangential series of resin canals as potential zones of weakness has been observed in the Queensland-grown material.

Since the defects here were all formed in the earlywood, many immediately adjacent to the last-formed latewood or, in a few instances, just after false latewood, it seems quite conclusive that the onset of rapid growth, or the factors that contribute to it are in some manner the causal factors of these defects. The possibility of water stress during a period of higher moisture requirement is an obvious consideration. Precipitation data for the 3 months preceding the estimated time of earlywood initiation at these three locations reveals that, for the years of occurrence for 7 out of 8 recently formed defects, rainfall exceeded the 44-year average for the areas. However, this could mean that the average precipitation may itself be limiting in generating water stress here and that this accounts for the extremely common occurrence and large size of the defect in Queensland-grown *P. patula*.

It is significant that other exotics, including *P. elliottii*, *P. taeda*, *P. caribaea* and *P. radiata*, in all of which it occurs to a variable degree, are far less affected. Slash, loblolly and radiata from the same areas as patula pine in Queensland are relatively little affected, indicating the latter's probably higher sensitivity to factors affecting moisture availability, if, as seems likely, moisture stress is a major factor in resin pocket development.

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In the 10% sample taken from the sawing study, the incidence and length of resin pockets were measured and recorded for both faces of each piece.

If differences in resin pocket occurrence between the three areas were shown to be evident, then it could be inferred that these were associated with any environmental differences between the three areas and/or between-locality age effects.

The effects of size-class differences were also tested.

TABLE 2. The size and incidence of resin pockets in *P. patula* sawn boards from three locations

Locality	No. of Resin Pockets	Board Surface Area (sq.ft)	Res. Pcts per Sq.ft. Surface Area	Average Length of Pocket
Yarraman	1113	1079.3	1.03	48 mm
Benarkin	1786	1307.4	1.37	46 mm
Pechey	1473	1265.1	1.16	46 mm

From Table 2, there was an apparently larger number of resin pockets per unit board area in the Benarkin material, followed by Pechey and Yarraman in that order. To see if tree age had any possible effect on pocket occurrence, the data from Yarraman and Benarkin were combined as these trees ranged in age from 22 to 26 years whilst the trees from Pechey were between 34 and 43 years of age when felled.

TABLE 3. The effect of age on Resin Pocket incidence

Locality	No. of Resin Pockets	Board Surface Area (Sq.ft.)	Resin Pockets per Sq. ft. Surface Area
Yarraman and Benarkin (22-26 years)	2899	2386.7	1.21
Pechey (34-43 yrs)	1473	1265.1	1.16

From Table 3, there appears to be no reason to believe that older trees have an appreciably greater incidence of resin pocket occurrence, in terms of number of defects per unit area, because of age alone.

The average length of resin pocket for each area was remarkably similar, 48 mm for Yarraman, 46 mm for Benarkin and 46 mm for Pechey. From the 10% board sample, it seems that any differences in resin pocket incidence between the three areas are of little or no practical significance, since, on the basis of a 4 m length of 100 x 25 mm sawn material, the difference in average number of 46 mm - 48 mm long pockets would vary only from 4.1 to 5.5 per board. While the differences in number per unit area (Table 2) seem appreciable, they would have virtually no real effect on resale value or utility.

To test the effect of G.B.H. and volume on resin pocket average length, maximum length and the number of pockets per square foot of board surface area, the three areas were examined separately first and then in combination.

The results of this analysis are presented in Table 4 and show a tendency for larger trees to have a larger number of resin pockets of greater average and maximum length at Pechey. The relationships did not show up in the younger and appreciably smaller trees from the other two areas, except for a very low-level correlation between girth and average defect length at Yarraman.

The implications of this between-locality difference in the relationships tested require further consideration.

TABLE 4. Relationships between Log and Resin Pocket Parameters for the three Locations

	Yarraman	Benarkin	Pechey
Av. Lth. v. G.B.H.	0.287*	-0.042 NS	0.399**
Av. Lth. v. Vol.	0.186 NS	-0.063 NS	0.420**
Mx.Lth. v. G.B.H.	0.273 NS	0.029 NS	0.521**
Mx.Lth. v. Vol.	0.204 NS	0.072 NS	0.500**
No./Sq.ft. v. G.B.H.	-0.003 NS	-0.140 NS	0.359*
No./Sq.ft. v. Vol.	-0.009 NS	-0.098 NS	0.296 NS

* = Significant at .05 level

** = Significant at .01 level

NS = non-significant at .05 level.

Sawing Study

From the results of the sawing study, the percentage of unseasoned sawn recovery downgraded by the presence of resin pockets differed between areas of origin. At Benarkin the percentage affected was

44.7, at Yarraman it was 48.9 and at Pechey 54.0. Thus, about 50% of the board volume had no resin pockets on at least one face. This follows the same relative order of incidence indicated by the check made on the small sample of discs checked (Table 1).

A good positive relationship between stem volume and percentage material downgraded due to resin pockets was established for Pechey, with much lower-level ones at Yarraman and Benarkin in that descending order. This supports the 10% sample data in Table 4.

While percentage sawn recovery degrade due to resin pockets showed Pechey as worst affected and Benarkin least affected and this is indicative of their economic effect under present grading rules, it is not a reliable indication of the relative incidence of resin pockets in the areas studied in terms of size or number per unit area. The present grading rules make no differentiation for number of pockets; for example, a single board of 4 m length with only 1 pocket would fall into the same grade as another board of equal length but containing perhaps 30 pockets, the difference between the two not manifesting itself in recovery figures.

The between-locality differences in number per unit area in Table 2 could be a more useful guide to possible causal factors.

Summary

The relative incidence and effects of and possible causal factors for resin pockets in *Pinus patula* from three locations in South-East Queensland have been investigated.

They occur on at least one face of about 50% of the sawn board volume, with slight variation about this figure between locations.

It has been established that the defects are initiated during the first half of the earlywood production period. They are located exclusively in this tissue. Resin pockets can apparently be produced in some stems in any year.

It is inferred that they probably arise as a response to factors causing moisture stress during these periods of terminal growth and high moisture requirement. Also, from the high general incidence of the defects over the localities studied and reference to meteorological data, that average climatic conditions in the area, such as precipitation, could possibly be limiting in generating such moisture stress. From a 10% sample of the sawn product, the three districts examined proved to be very similar in size of defect produced, which averaged nearly 50 mm long.

The older, larger stems from Pechey had a higher percentage of its sawn volume recovery degraded due to the presence of resin pockets, but this economic effect gives no indication of relative incidence of the defect, because of the framing of the grading rules. Actually the Benarkin locality showed a higher incidence of resin pockets per unit surface area of sawn board than the other areas. Even on this

basis, between-locality differences in terms of economic effects were not considered to be of any practical significance.

Percentage degrade due to the defect was found to increase directly with log volume in the older Pechey material. An inference could be drawn that this effect could become more evident at the other two localities as those stands age and the size range there extends. This probable trend could well affect management decisions in those areas.

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Topic 2/8

PRELIMINARY ANATOMICAL STUDIES OF THE WEATHERING OF RADIATA PINE SAPWOOD

R. K. Bamber

A preliminary study of the pattern of surface breakdown of radiata pine sapwood when exposed to the weather has been undertaken.

The weathered sample was a dressed, air-dried board of radiata pine. The board was exposed at an angle of 45°, facing due north in the Wood Technology Division exposure site at West Pennant Hills for a period of six months. Samples approximately 3 x 3 x 1 mm were taken from the exposed side and dried in a dessicator. Control samples of the same size were taken from a microtomed block of green radiata pine. The control samples were dehydrated in a graded series of acetone, followed by sulphuric ether and allowed to dry in air. Both weathered and control samples were fixed to aluminium specimen stubs with silver adhesive, coated with gold and examined by means of scanning electron microscopy.

Comparison of the control surface (Figure 1) with the weathered surface (Figures 2-4) indicates that the surface characteristics of the sapwood are considerably altered by the six months exposure. Weathering appears to have had two main effects, firstly the cells of the wood show considerable breakdown and secondly the surface is extensively colonized by fungi.

The surface breakdown is of three types, (a) loss of cell wall, (b) intra-cellular splitting, (c) inter-cellular splitting.

(a) Loss of cell wall. In Figure 2 it can be observed that the parenchymatous tissue of the radial resin canal has disappeared leaving a large radial fissure extending into the interior of the wood. This is most evident when comparison is made with the radial resin canal in the control specimen shown in Figure 1. Loss also occurred of the tori of the bordered pits of the axial tracheids (Figure 3).

(b) Intra-cellular splitting. In Figures 3 and 4 intra-cellular splitting is occurring in the walls of the axial tracheids. This splitting is either splitting across the wall layers (Figure 4) or between the wall layers resulting in delamination of wall (Figure 3). Some splitting of the wall from the aperture of the bordered pit is also taking place (Figure 3).

The splitting across the wall (Figure 4) appears to be controlled by dimensional changes occurring in the middle secondary wall (S_2 layer) as the splits describe a steep helix.

(c) Inter-cellular splitting. This splitting is due to separation of the tracheids along the primary wall/middle lamella zone (Figures 2 and 4). In a number of cases these inter-cellular splits were initiated at the ends of the radial resin canals where the tracheids enclose the canals (Figure 2).

The wood surface was extensively colonized by fungi (Figure 2). The fungi was of the sap stain type and did not appear to be contributing to the surface deterioration.

In these preliminary studies the wood cells most significantly affected by the weathering were the parenchyma cells of the radial resin canals. These cells are in the main mostly without secondary walls and lignin. While it was not observed here it could be expected that the ray parenchyma cells, which are also mostly unthickened and unlignified, would likewise be rapidly broken down. The loss of the resin canal and ray tissue may contribute to the deterioration of the wood as such loss would provide radial fissures facilitating the ingress and egress of water.

Scanning electron microscopy has been shown to be a most useful tool for the study of the surface characteristics of weathered radiata pine sapwood.

The micrographs Figures 1-4 were taken by Miss Mary Warren, Applications Engineer of Cambridge Scientific Instruments Ltd., on Cambridge Scanning Electron Microscopes. Her assistance is gratefully acknowledged.

Topic 2/9

THE PREDICTION OF HEARTWOOD DIAMETER IN RADIATA PINE TREES

W. E. Hillis and N. Ditchburne

After a certain stage of growth, the sapwood of many trees is transformed into heartwood. This change is accompanied in varying degrees by a decrease in water content, an increase in extractives content, a decrease in amount or elimination of secondary metabolites such as starch, a decrease in permeability, etc. The differences in properties between sapwood and heartwood affect the utilisation of wood in different ways and according to the end-use the presence of heartwood may or may not be an advantage. The volume of heartwood in a tree at a certain age can vary widely between species and within species, and although it may be under some genetic control, it appears to be affected by environmental conditions and silvicultural practices. Accordingly, heartwood is a factor affecting the uniformity of wood and a contributor to the uncertainty between forest inventory and the quality of wood available for utilisation.

We have derived a regression relating heartwood diameter of *Pinus radiata* to the stem diameter at the proposed time of felling and the recorded diameter at some earlier period. The relationship could be used to obtain estimates of heartwood volumes, and thus aid in the selection of the most suitable group of trees for a particular purpose. Moreover, it may indicate the most suitable silvicultural practices to achieve the type of material required.

To obtain the data we examined trees from Tumut, N.S.W., Mt. Gambier, S.A. and Creswick, Vic. of 20-47 years of age, of different crown classes, and from sites of different qualities. As core sample could give unreliable data because of the irregularly shaped heartwood, the average of the maximum and minimum heartwood diameters were obtained from discs cut from the tree.

The most useful measure of heartwood is the volume expressed as a percentage of the total volume (under bark) of a tree or stand. Using measurements made at or near the base of the tree, a regression of mean heartwood area percentage on heartwood volume percentage was derived. It had a residual standard deviation of individual trees about the regression line of 1.3, and the percentage variation in the dependent variable accounted for by variation in independent variables (R^2) = 98. The regression equation is:

$$\text{Heartwood area (\%)} = \text{Heartwood volume (\%)} + 1.33 \qquad \text{(I)}$$

Satisfactory estimates of heartwood diameter could be obtained using the regression on d.b.h.o.b. and the product of age of tree and its diameter under bark at 5 years of age (D5). The regression equation is:

$$\text{Heartwood diameter} = 0.1055\ \text{d.b.h.o.b.} + 0.03114\ \text{Age} \times \text{D5} - 2.83 \qquad \text{(II)}$$

Each of the regression co-efficients is highly significant, standard errors being 0.0397 and 0.00345 respectively. The residual standard deviation about the regression line is 1.9, and R^2 = 88%.

The multiple regression relationships between percentage heartwood area or heartwood rings and the various combinations of independent

variables considered were not sufficiently close to be of any practical use for prediction purposes.

The prediction of the amount of heartwood in radiata pine (or other trees) has not been proposed previously in the form of regression II. Part of the value of this type of regression is that the necessary information can be obtained without felling or damaging the tree if suitable records have been kept, and for this reason its applicability to further samples of *P. radiata* and to other species warrants examination.

There is a high degree of correspondence between predicted and observed heartwood diameter. The correlation is unexpectedly high as the heartwood periphery is frequently an erratic boundary over several growth rings. Moreover, the regression applies for samples obtained from a wide variety of environmental and soil conditions.

The heartwood area relative to disc area was found to be greater at breast than at zero height and this has been observed to occur usually but not always, in other species. In this work the average of heartwood area at zero and 2.4 m heights is more closely related to heartwood volume (regression I) than either area separately.

Heartwood diameter was found to have a highly significant trend with crown class, which is a relative assessment for trees within a particular stand. It would directly influence bole size, bark thickness and growth rate. The regression II gave a high degree of correspondence between predicted and observed heartwood diameter. We measured growth rates for multiples of 5 years because these time spans were the most suitable for the age of the trees studied, and those trees with the most rapid growth in the first 5 years had the greatest diameter of heartwood. When a regression of the form of (II), but with the diameter at 10 years was used, a lower degree of accuracy of prediction was obtained. It may be worthwhile to examine the growth rate at other ages to ascertain whether a more sensitive age than 5 years exists.

The apparent dependence of the diameter of heartwood on the growth rate in the early years of growth of *P. radiata* has not been considered with other species. This importance of early growth rate may explain at least some of the contradictions in the literature regarding the effect of different variables. Also it is worth noting that greater genetic variation appeared to exist in the Mt. Gambier samples than in those from Tumut.

POLYPHENOL DISTRIBUTION IN *PINUS RADIATA* BARK

R. E. Palmer

In order to be able to estimate the potential of available bark as a source of raw material for tannin formaldehyde adhesives and to facilitate the design of extraction equipment work has been started on examining the distribution of polyphenols in *Pinus radiata* bark.

From an adhesives point of view the interesting constituents in bark are the water soluble polyphenols that will react with formaldehyde to form a three-dimensional polymer network. Some polyphenols are capable of tanning hides and so the general terms tannin and tannin-formaldehyde precipitate are used. Bark is analysed by preparing a boiling water extract and reacting part of the extract with formaldehyde under acid conditions. The weight of precipitate formed when expressed as a percentage of the initial oven-dry weight of extract is termed Stiasny polyphenols which can be regarded as an indication of extract purity in formulating adhesives.

The analytical results for butt bark from a 45-year old tree from Mt. Burr, South Australia, are given in Table 1. The inner bark (phloem) is rich in extractives, a large part of which are the metabolites associated with the living tree. The grey exposed layer of the outer bark (rhytidome) is lower in extractives and tannin than the more protected red-brown inner layers. Extraction of the exposed layers in the presence of 2% sodium sulphite (on dry bark weight) produces a much larger increase in extractives and tannin yields than for the protected layers. Since sodium sulphite has the effect of solubilising the higher molecular tannins, then some of the loss in tannin from the exposed layers in aqueous extraction is probably due to polymerization brought about by weathering. Presumably some loss is also due to leaching and degradation.

It can be seen from Table 2 that the analytical data for green bark from the top of the tree is similar to that for inner bark. This is to be expected since green bark consists mostly of inner bark. The smooth bark from the middle of the tree is a clearly defined intermediate stage between green bark and butt bark.

These three types of bark are readily identifiable and the transition is fairly clear cut. It would appear that for a given bark type the extractives and tannin contents are largely independent of age and that site and genetic factors could be of importance.

The few available figures suggest that butt bark represents about 50% of total bark dry-weight and smooth bark about 30%. Although the variability in extractives and tannin contents is fairly large the Stiasny polyphenol values for a given bark type are somewhat less variable. Thus by segregating bark into its three types as it comes from the debarker it should be possible to produce an extract with a predictable Stiasny polyphenol value and therefore of predictable adhesive properties.

Topic 2/10

TABLE 1.

DISTRIBUTION OF EXTRACTIVES AND TANNIN IN BUTT BARK OF TREE 1928/2

Fraction	Aqueous Extraction			2% Sulphite Extraction		
	Extractives (%)	Tannin Formaldehyde Precipitate (%)	Stiasny Polyphenols (%)	Extractives (%)	Tannin Formaldehyde Precipitate (%)	Stiasny Polyphenols (%)
Inner bark	47.7	28.3	59	60.5	32.8	54
Outer bark						
Inner quarter	40.5	40.8	101	45.2	44.2	98
Second "	38.7	38.1	98	43.3	40.4	93
Third "	39.5	37.5	95	45.9	44.6	97
Outer "	21.0	17.5	83	33.2	30.4	92
Whole bark sample	34.5	33.0	96	41.9	39.4	94

TABLE 2.

Origin	Bark type (No. of samples)	Extractives content Range (Mean) %	Tannin-formaldehyde Precipitate Range (Mean) %	Stiasny polyphenols Range (Mean) %
S.E. South Australia	Butt (5)	20.8-34.5 (29.4)	18.3-33.0 (26.9)	86-96 (91)
5 trees 17-45 years old	Smooth (14)	19.8-25.1 (23.8)	14.2-19.7 (17.2)	64-82 (72)
	Green (9)	27.0-36.2 (31.9)	17.0-20.1 (18.7)	52-68 (59)
Northern Tasmania	Butt (3)	37.3-40.2 (39.1)	38.5-40.7 (39.9)	101-103 (102)
Samples from mech. debarker	Smooth (2)	30.7-31.5 (31.1)	27.6-28.2 (28.2)	90-91 (91)
trees 14-17 years old	Green (2)	37.5-41.8 (39.7)	24.1-25.2 (24.7)	60-64 (62)

Topic 2/11

THE ROLE OF CALCIUM AND MAGNESIUM IN THE DEVELOPMENT OF MARINE ORGANISMS

K. Cokley

As part of studies into factors which influence attack by marine organisms, particularly the *Teredinidae*, this department has carried out studies on factors which may be significant in determination of susceptibility of timbers e.g. occurrence of silica is claimed to be responsible for the resistance of Turpentine (*S. laurifolia*) but anomalous results occur in Brush Box (*Tristania conferta*) where attack has been recorded.

In addition there have been other studies, e.g. Watson studied salinities in the Brisbane River and correlated attack sites for different organisms. Temperatures, tidal flow rates, light depth penetration of surrounding water conditions have also been examined. These individually have not been completely adequate in definition of habitat conditions.

A further anomaly occurs in CCA treated timber where sapwood even though heavily impregnated with salts, is nevertheless destroyed in 4 years. Preservative distribution and initial surface softening by fungal organisms such as soft rots and even the influence of solubilising bacteria in marine waters are all significant here.

As part of the study, the question arose as to the mechanism and source for the formation of the calciferous tubes necessary for teredine survival. Chemical analysis showed that:

(a) such tubes were primarily compared (98%+) of calcium with a low percentage of magnesium,

(b) the wood content of these metals was inadequate to supply the amounts necessary - in tropical areas calciferous tubes over 2 metres in length fifty millimetres in diameter and of wall thickness up to 5+ mm with weights of 5-10 kg have been examined by the author. Typical tubes are of the order of 1 metre long, 25 mm diameter and weights of 2-3 kg.

The source of these has been shown to be the sea water and in particular from calciferous deposits e.g. reefs and in one case transported sources related to cement manufacture.

Whilst this is reported as preliminary findings only, there is an apparent correlation between soluble calcium, and magnesium in salt water and severity of teredine attack.

I have tentatively postulated that:

(i) Teredines utilise enzymic degradation of the cellulose for nutrient.

(ii) The enzymes are activated by calcium and magnesium which may be termed co-factors and these are extracted and soluble Ca^{++} and Mg^{++} during imbibation of sea water and excess excreted to form the protective sheath.

(iii) Reduction of the availability of sea water results in a reduction of available Ca^{++} etc. and hence deactivation of the gut enzymes.

(iv) If these postulates are confirmed, then

(a) the Canadian practice of use of arsenite salts as protection does in fact insolubilise these metals which are non-available as co-factors to the gut enzymes. This results in non-development from the larval stage.

(b) As the CCA timber is ingested, the residual soluble arsenic in CCA is precipitated in the gut and hence detoxified in terms of the enzyme and is excreted as the insoluble inactive salt.

(c) To some degree this could explain the apparent reduction and redistribution of the arsenic component reported by the author at the 1969 Forest Products Conference.

Further work

To clarify the function of these metals, it is hoped to have further work done along the lines of:-

1. Breed teredines under laboratory control condition - assistance of the Queensland University is proposed using saline water without Ca^{++} and Mg^{++}.

2. Incorporate radio-active Calcium and magnesium in the synthetic salt water and follow the metabolism.

3. Extract the enzymes from adult teredines and examine the degradation of cellulose with radio Ca^{++} and Mg^{++} using synthetic salt water (free of these metals) as control.

4. Using similar techniques to examine the passage of radio tagged arsenic through the organism and correlate with the presence or absence of the alkaline earths.

5. Using extracted enzymes to examine the metabolic significance of radio tagged copper. I believe at present the copper cellulose complex is sufficiently insoluble to pass through the organism without toxic effects.

POSSIBLE CAUSES OF DURABILITY UNDER MARINE CONDITIONS OF *SYNCARPIA GLOMULIFERA* (TERPENTINE)

D. de Silva, W. E. Hillis and K. W. Groves

The demand for materials durable in semi-tropical and tropical waters is increasing. Turpentine *(Syncarpia glomulifera)* has a high reputation as a marine timber but the supplies with a high durability are decreasing. Plantation grown turpentine is less durable than that from the original forests. The composition of the wood is being examined to ascertain the factors responsible for durability.

For some time, silica has been considered as the component responsible for marine durability. The silica contents of the sapwood and heartwood of a mature *Syncarpia glomulifera* collected from a native forest have been found to be similar (about 0.5%). However the durability of the sapwood to a number of marine organisms is reputed to be less than that of the heartwood.

As the amount of silica present in the wood is not strongly related to durability, the nature, location and composition of the silica in the wood has been examined by the scanning electron microscope and by EDAX.

The silica was found to be present as globules in the parenchyma of all the samples examined. These globules will be illustrated and the form is very similar to that found by other workers in other species. Some workers have considered that the form or shape of silica is important for durability but the current evidence available does not support this view. Individual globules or deposits have been analysed by energy dispersive analysis of X-ray spectra (EDAX) and found to be very largely silica.

The information from the examination of the present material, and the known behaviour of other species with a high silica content indicates that silica is not the major factor for marine durability.

An examination of the methanol soluble extractives of turpentine wood has been commenced to ascertain whether they are responsible for the durability. So far, the composition has been found to be similar to that of the pale coloured eucalypts.

ORGANIC SOLVENT PRESERVATIVES

N. Tamblyn

1. Treating Methods

Clean paintable preservatives carried in a volatile organic solvent have been increasingly accepted over the last 30 years as offering an ideal, though not always successful, approach to the treatment of exterior joinery, cladding, fascia and other timbers used in dry dressed condition.

The simplest method of application by dipping cannot be expected to give long protection unless the timber is fully prefabricated before treatment and the species is readily permeable. In the U.K. the difficulty in achieving sufficient penetration by dipping has led to the wide-spread use of a double vacuum or low pressure treatment (1) which can be "modulated" to give 2-3 times the depth of treatment obtainable in a 3-minute dip. By this method an end grain penetration of well over 30 mm is generally achieved in pine sapwood with an analysable amount of preservative in the side grain at a depth of at least 3-4 mm (1,2). Depending on climate, timber species and the life required, this may be judged satisfactory for painted exterior joinery but overseas records are as yet inadequate to predict a life even approaching the 50 years or more desirable for house building timbers in Australia. Certainly, by Australian standards such treatment, in which complete sapwood penetration is not mandatory, would be unacceptable for most timbers likely to be cut after treatment.

A more sophisticated organic solvent treatment is the "Cellon" process (called "Drilon" process in U.K.) developed by Koppers Co. Inc. in U.S.A. (3,4). This process uses pentachlorphenol (PCP) or tributyltin oxide (TBTO) with or without contact insecticide and water repellent, dissolved in liquified petroleum gas plus cosolvent if necessary, applied at pressures up to about 1033 kPa (150 psi). It achieves excellent penetration in treatable timbers and recovers more than 95% of the solvent but requires elaborate and costly plant and needs extreme care to avoid fire or explosion. A recent variation of this type of solvent recovery treatment is the "Dow" process (5) which uses dichloromethane (methylene chloride) as the preservative carrier. This has the advantage of eliminating altogether the fire hazard but the disadvantage that the solvent is costly and despite good recovery its loss in treatment is a significant cost.

In Australia, the process now coming into commercial use is an improvement on the English double vacuum treatment both in the penetration obtained and in the amount of solvent (e.g. white spirit, mineral turpentine) left in the treated wood. It is a Rueping pressure treatment - initial air pressure before flooding, then solution pressures up to about 1378 kPa (200 psi), followed by final vacuum to eject most of the solution from the wood. Although a Rueping treatment is commonly used to reduce loadings of heavy oil preservatives in permeable timbers, I believe this Division was the first to conceive and demonstrate its adaption to light oil solvent preservatives to give complete penetration in pine sapwood at very low solvent retentions - generally within the range 4-6 kg/m^3 (about

2.5-3.5 lb/ft^3). This is approximately half of that left in the treated wood by the double vacuum process - or in other terms the same amount of preservative solution can be used to obtain more than twice the depth of penetration. Also, with the much higher pressures used, far better penetration is obtained in pine heartwood than in treatments which rely on partial atmospheric pressure. For this reason the timber can be treated in random lengths for subsequent cutting.

Development of this improved treating method should not be regarded as the only requirement. There is need for much future research on all aspects which may affect the quality and permanence of the treatment. Some of these are briefly discussed below.

2. Fungicides

Although various fungicides (metallic naphthenates, copper-8-quinolinolate, rosin amine D pentachlorphenate, lauryl pentachlorphenol etc.) have found some use in dipping preservatives, the main ones used for this purpose and in double vacuum and solvent recovery treatments have been PCP and TBTO. An interesting development in the double vacuum treatment has been the use by Protim Ltd. in England of a mixture (17:4) of PCP and TBTO and the claim that in these proportions the fungicides are synergistic. The evidence for synergism is not substantial and is not upheld in recent tests made by Hof (6) in Holland. More work is necessary with a wide range of fungi to determine the relative merits of PCP, TBTO and other fungicides used alone and in mixture.

In common with most organic preservatives, PCP and TBTO are slowly volatile (vapour pressures respectively 1.1×10^{-4} mm at 20°C and 1.1×10^{-5} mm at 25°C) and it must now be accepted (2) that when applied in volatile solvents they are quite rapidly depleted from the surface layers (to about 2 mm in depth) of wood by volatilization at ambient temperatures. While depletion at greater depth is much slower, the effect of wax, resin, cosolvent or other additives on the initial gradient in the wood and on the rate of volatilization requires thorough investigation to ensure the permanence necessary (50 years or more) in treatments of joinery, cladding etc. Other factors likely to be important include type and retention of fungicide and its reaction with the wood substrate, timber species, depth of treatment, paint system etc.

At present for above ground use in southern Australia we have tentatively recommended a minimum retention in the treated wood of 0.96 kg/m^3 (0.06 lb/ft^3) of TBTO and 4.8 kg/m^3 (0.30 lb/ft^3) of PCP, or of PCP equivalent, for mixtures of the two, calculated by summing PCP content + 5 times the TBTO content. The factor of 5 for TBTO derives from laboratory tests by Da Costa and Bezemer (7) and takes more account of TBTO-tolerant fungi than overseas tests from which a factor of 10 is often adduced. These are rather low loadings and further work may well indicate that a substantial increase is necessary for a life expectancy of 50 years.

3. Insecticides

Although PCP and TBTO are highly effective as fungicides they are less so as insecticides (8,9,10). For this reason it is usual practice in the European area to add a contact insecticide to control borer attack. Lindane

is commonly used because of its low dermal toxicity and relatively low vapour pressure (3.0×10^{-5} mm at 20°C). However work by Becker (11) and more particularly by Morgan and Purslow (2) has shown that lindane is quite rapidly depleted from the surface layers of the wood (over 60% in 2 years) and that this loss was not greatly reduced by addition of trixylenol phosphate or resin to the preservative solution. Even with dieldrin (vapour pressure 1.8×10^{-7} mm at 25°C), applied in volatile carrier by a 3 minute dip, a loss of 47% occurred in 2 years. We must therefore examine the possibility that the low retentions of these insecticides which are initially effective against termites may be inadequate to protect woodwork over the long life of a house even with the deepest penetration obtainable. Other insecticides, such as the organic arsenical compound developed by Johanson (12) which appears to react and become fixed in the wood through the arsenic-oxygen linkage may be preferable where maximum permanence is required.

4. Water repellents

Most organic solvent preservatives contain water repellents - usually a wax, with or without addition of resin. Although various waxes and resins have been tested (13) most dipping formulations today contain paraffin wax (about 1%) and an alkyd resin (up to about 5%), sometimes with addition of a small amount of a stearate. The function of the wax is to cause the wood to shed water during rain wetting particularly at joints and end grain surfaces which are usually unprotected by painting. At the low concentration used the resin contributes little to water repellency but is generally regarded as improving the paintability of the waxy surface. These water repellents also have some effect in reducing the rate of adsorption and desorption of water vapour by the wood simply by the barrier effect of the coating in retarding the rate of vapour diffusion.

When applied by dipping, organic solvent preservatives form a shallow layer of treated wood in which the preservative components are present in relatively high concentration. Thus absorption of 5 kg (11 lb.) of solution over an area of 10 m^2 (108 ft^2) to a depth of 3 mm (almost 1/8 inch) would give a solution retention of 167 kg/m^3 (10.4 lb/ft^3) in the shallow layer of treated wood. By comparison the Australian Rueping treatment would give complete penetration of pine sapwood at a solution retention of about 48 kg/m^3 (3 lb/ft^3). Our treatment therefore may not give the same initial degree of water repellence or retardance to vapour diffusion as the shallower dip or double vacuum treatment but in the long term it may be superior because deep treatments are protected from the break down of wax and resin which occurs when shallower treatments are exposed to weathering. A great deal of work is necessary to determine the type and concentration of water repellents which will give best results in a Rueping pressure treatment at low solution retentions.

5. Solvents

The main solvent in most dipping preservatives and in the double vacuum and Australian Rueping treatment is a petroleum distillate such as white spirit or mineral turpentine. Both of these have a flash point of about 38-40°C and a boiling range of about 150-195°C, the main difference being the much higher aromatic content of mineral turpentine which is of particular advantage in obtaining solubility of PCP without excessive use

of cosolvent. This flash point is barely acceptable for Australian conditions and the boiling range is higher than we would like for rapid volatilization and early paintability of deeply penetrated wood. However with petroleum distillates, a combination of high flash point and low boiling range is not possible so a choice must be made somewhere between the more dangerous solvents (i.e. an aromatic paint solvent with flash point about 20°C and boiling range about 95-130°C) and a non-aromatic mineral spirit of flash point about 50°C and boiling range about 180-200°C.

Suitable solvents have a present (December 1974) bulk price of around 50¢/gallon so that a final retention of 48 kg/m^3 (3 lb/ft^3) would use about 13 gallons/m^3 at a solvent cost of about $7.50 (or about $1.50 per 100 super feet). This cost is sufficient to warrant careful consideration of the economics of solvent recovery. Recovery would ensure that the timber was safe for transport and would avoid the possibility of air pollution in the vicinity of the treating plant. It is possible that a drying room with refrigerated condenser would remove and recover most of the solvent in an overnight period.

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A NEW TYPE OF INCISING MACHINE

F. A. Dale

When the Division of Forest Products commenced its program of high-pressure treatment of hardwood rail sleepers in 1952 it was found that the overall preservative oil retention could be improved, by about 1.5 pcf, and more uniform penetration obtained in the treated case or envelope, by incising the surfaces to a regular pattern. Because penetration, even at high pressure, is confined to the vessels it was decided that the incisions should be inclined at an angle to the grain in order to cut as many vessels as possible and so allow maximum penetration of preservative oil.

As a result of this a machine was designed and built in the Division. This consisted of a reciprocating 30 ton hydraulic press with a head carrying two rows of "oyster blade" knives, 2" apart along the grain, with the knives set 1" apart across the grain. The knives in one row were staggered by ½" relative to those in the other and could be rotated in their screwed sockets at any angle relative to the grain. For our tests they were set at 30° in order to cut as many vessels as possible without excessive surface damage or strain on the knives. The knife and pattern obtained is shown in Figure 1.

About 2000 sleepers were incised with this machine and a rate of about one every 10 minutes, but it could not be developed into a commercial proposition for several reasons. The knives were expensive and could not be set on the surface of a rotating drum to cut at any reasonable angle to the grain without tearing the surface and causing excessive load on the knives. The use of a rotating drum to carry the knives is the only feasible means of incising sleepers at a reasonable speed. Moreover, none of the rotating drum machines available from overseas were sufficiently robust to incise our heavy hardwoods continuously, even though the knives only incised parallel to the grain.

When we began our experiments with the boultonizing of green hardwood sleepers in 1969 it soon became apparent that incising beforehand would improve the process by increasing the rate of heat transfer from below the wood surface, reducing the amount of gross surface checking and increasing the number of paths open to penetration. Conventional machines incising parallel to the grain can be used but very little cutting of vessels occurs and the penetration away from the incisions in some timbers, such as jarrah, is very limited.

We have known for a long time that an improved incising machine giving maximum uniformity of penetration was essential for the full benefits of treatment to be realised, using either high-pressure treatment or the boultonizing process. In the paper "Steps towards Better Rail Sleepers" presented to the International Rail Sleeper Conference in August 1973, I stated "Incising, by opening more vessels to penetration, by local crushing and lateral stress relief, is an obvious improvement but further work may be needed to find the ideal pattern".

About the same time my colleague, Ron Johanson, produced his concept of "brucising", a combination of bruising and incising, and asked if it was possible to make a machine using rollers with teeth which would penetrate

the surface to a depth of ¼" - ½", thus enabling the wood to take up large quantities of oil or arsenic in a diffusible form.

The obvious answer to our common problems seemed to be by the use of a wheel with relatively blunt teeth. Such a wheel was available in the form of a transmission chain sprocket (Figure 2). Trials with a workshop milling machine showed that the teeth of a small chain sprocket could be easily rolled into the surface of a piece of green karri (*E. diversicolor*). It was then decided to build a prototype machine, using a roll crusher built up from a 30 ton hydraulic workshop press and intended to test the effect of pre-compression of the surface of green timber on subsequent drying and impregnation (Figure 3). A brucising roll was made consisting of 22 chain sprockets specially cut from heat treatable steel (Duraflex). Each sprocket, of 9¼" diameter, has 33 teeth of 3/4" pitch of the form shown in Figure 4. The sprockets are clamped together on a 5" high-tensile steel shaft mounted on roller bearings. The flame hardened teeth can be buried in the wood to a depth of ½" and each sprocket is staggered by half the tooth pitch with respect to its neighbour to give a spiral incising pattern. The sprockets were cheap ($9 each) and the complete roller cost about $600. The shape of the tooth can be varied within limits to give the desired amount of crushing or cutting, but a sophisticated shape would be much more expensive. A tooth that is too slender will break easily, if too sharp it will lose its edge very quickly. Too squat or too blunt a tooth will need excessive pressure to embed it, use too much power and cause gross damage to the wood. The most important advantage of the pyramidal tooth is that the roller can be made wide enough to allow sleepers to be passed over it at an angle to the grain (Figure 5), so that the incising pattern is skewed across the surface, thus eliminating the occurrence of long untreated strips of wood between the longitudinal lines of incisions.

The roller is driven by a 10 H.P. motor through a worm gear box/chain drive at a surface speed of 16 ft/min. Pressure is applied to force the sleeper onto the toothed roller by an idler roll under the top crosshead. The machine is shown in operation in Figs. 6 and 7.

The machine has been thoroughly tested using 42 jarrah and 42 karri sleepers 8'6" x 9" x 6". With a little practice it was possible to produce surfaces incised to ½" depth using 5-8 tons load on the top roll, requiring less than half the rated H.P. of the motor. The only other thing found necessary was to bevel the corners of each sleeper with a power saw, to prevent them shearing off in the second pass when the sides of the sleeper were incised. There was very little surface tearing or shearing of wood between the incisions which tended to close up afterwards. The sleepers were thoroughly wet before treatment and such a good result could not be expected on dry surfaces. No wear was visible on the teeth afterwards. The 84 sleepers were returned to W.A. for treatment by boultonizing and by high pressure before putting them in service test in the Pilbara iron ore lines.

Only limited preservative treatment has been done on sleepers passed through the machine but overall retentions of over 7 pcf were obtained in a jarrah and a karri sleeper after boultonizing in creosote for 12 hours at 215-220°F with 25" Hg vacuum, followed by 1 hour's pressure of 200 psi. Case penetration was uniformly good in karri and a considerable improvement over that obtained with ordinary incising in jarrah.

The incising pattern used in the prototype can certainly be improved upon, probably by increasing the radial depth of tooth to 3/4" and the pitch of the teeth, i.e. the distance along the grain between incisions, to 1¼" or even 1½".

A major firm of structural engineers, well versed in the design of rolling machines for steel, has seen the machine in operation and see no problems in designing and building a machine with 4 pneumatically loaded rolls requiring no more than 20 H.P., for considerably less cost than an imported machine.

Work is in progress to determine optimum tooth dimensions and spacing on preservative penetration and the effect of the process on the strength of the sleeper. On theoretical considerations this effect is likely to be only minor and would be more than offset in our heavy hardwoods by the improved penetration and retention obtained.

SYSTEMATIC COLLECTION AND COLLATION OF SERVICE DATA

E. W. B. Da Costa and J. E. Barnacle

One of the most difficult tasks in research, and particularly in applied or industrial research, is the accurate definition of problems. In past research on wood technology, in this Laboratory and elsewhere, a great deal of research time has been devalued, if not wasted, by working on specific questions which were either not fully relevant at the time, or which became obsolete before full application could take place. Many of these mistakes were unavoidable, but many could have been prevented by provision of adequate and accurate service data from industry. In wood preservation, in particular, data on the service performance of different timbers, preservatives, treatment methods, in relation to location and method of use, treatment parameters etc., has in the past been difficult to obtain.

In some applications, e.g. farm fence posts, data are inherently difficult to collect, as shown by the Laboratory's fence post questionnaire (Wymond 1954). However, for timber used by large organizations (railways, electricity supply authorities, Housing Commissions) the collection of systematic data is possible. Data collection had previously been laborious, (though in some instances, fortunately, not impossible) but modern computerized methods of data storage, collation, analysis and rapid retrieval have transformed the picture or at least made transformation a practical possibility. In view of diminishing resources and rising costs of timber, of rapid increase in costs of maintenance and repair of failed or failing timbers, and of increasing complexity of treatments and uses, it is vital for the large user, as well as the research worker, to know more about timber performance. Such knowledge can reasonably be said to be within our grasp but, for the most part, is not accessible for research planning.

If data on total populations or of representative samples of utility items (selected on a "vintage" basis) were maintained, preferably on punched cards, it could be retrieved readily for analysis or for the addition of new data. The cardinal principle involved here is that information buried in the memory, or the field books, of maintenance personnel or inspectors has no permanent value and, in fact, has only limited local use even temporarily. If transferred to punched cards, however, it could be of great value in further inspection and maintenance, and its analysis could give invaluable guides to future installation and maintenance practice, and to recognition and definition of research problems. In all cases, it is essential that careful statistical and ergonomic planning should be carried out before any system is put into operation. The labour cost of transferring data from a field book or sheet to punched cards is relatively cheap and, with a little thought in design of field sheets and treatment sheets and of timber identification, the work of the man in the field will not be any greater or more difficult. (For example, it would be of considerable saving in the long run for a pole using concern to have a good record of the pre-treatment history, treatment parameters, installation data and inspection data including cause of failure of <u>each</u> pole or of properly selected poles readily available in a computer memory.) The establishment and maintenance of such data banks would allow the performance of total or sample

populations to be "metered" during their service lives, a feature that is of extreme importance if trends in, and reasons for, failure are to be determined together with the distribution of service life. We therefore suggest that - especially in the case of large-use items such as poles and rail sleepers - such data is essential if real problem areas are to be ascertained without guesswork and impending problems anticipated. (The corollary of course is that if these data are not obtained and stored in retrievable form, precise definition of problems will not be possible, research effort will be inefficiently used and results may be of little use.)

Although these points may already be recognised and understood we urge all large timber using authorities and firms to consider seriously the potential commercial value, as well as the benefits to research and development, of improved data storage and the making of programmes for selective data retrieval. We in this Division would be interested to hear of any plans to set up such systems and, if we can, to assist in any way open to us.

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Topic 2/16

CENTRE ROT PROBLEM IN POLES

J. E. Barnacle

Summary

Poles of class 3 durability species treated with vertical retort creosote have been used in Victorian power distribution lines for 17 years.

Some early pole failures due mostly to centre rot is causing some concern to pole using authorities.

Comprehensive and precise data on pole service life distribution is, however, not available although some estimates of percentage pole failures in relation to period of service have recently been made.

In this paper, an assessment is made of what is, and what is not known about the performance of class 3 durability poles in Victoria. Some suggestions are made regarding what data is needed if reliable estimates of pole performance to date, and in the future, are to be obtained. Problems associated with insufficient data are also commented on.

Field assessments of the rate of spread of centre rot in infected poles in the Melbourne area and a trial of diffusion preservatives against centre rots are referred to.

1. INTRODUCTION

The pole preservation industry began in Victoria in 1957 when poles of class 3 durability eucalypt species were impregnated at 200 psi with vertical retort tar creosote. To those accustomed to using "royal" species such as ironbarks and boxes, the development must have been viewed with some misgivings.

Such a view possibly derived from, or was influenced by, the fear of decay of the low durability heartwood inside the relatively narrow sapwood of the most commonly used species, i.e. messmate (*E. obliqua*) and mountain grey gum (*E. cypellocarpa*). Such fears possibly would have been reinforced by the tendency of some poles of these species to split and expose susceptible, and untreated, heartwood.

The evidence considered sufficient to justify a pole treating industry was obtained from graveyard tests set up in the 1932-34 period by the Division of Forest Products. Data collected from these tests over approximately 22 years pointed to the likelihood of very satisfactory service performance by a class 3 durability species namely messmate (*E. obliqua*). In fact, a life expectancy of 30 years for adequately treated poles seemed, on the evidence then available, to be a reasonable prediction. That the test poles easily achieved this life can be seen from the fact that the first failures of pole stubs at the Benalla site occurred only after 39 years (Beesley, 1971).

So much for the predictions, what has been the performance of pressure treated class 3 durability poles since commercial treatment began 17 years ago? What information is, and of equal importance, what information is not, currently available?

2. INCIDENCE OF POLE FAILURE IN PRESSURE TREATED SERVICE POLES# OF CLASS 3 DURABILITY

(a) Information not currently available.

First, as far as I am aware, no comprehensive record of pole failures since the inception of treatment in Victoria (1957) exists. This simply means that no precise statement can be made regarding either total failures to the present time of poles of any given service life age, i.e. installed 1958, 1959, 1960 etc. or of the distribution of service lives of poles treated in any particular year. Neither can the effect of pole class (diameter and length variation) or area of use on pole life be determined at this stage. Thus there is really no firm basis at present upon which to accurately forecast annual failure rates of any class of power pole from all or any cause in Victoria. It is however quite possible that localized failure rates could be determined with some degree of precision - see next section.

(b) Evidence of early pole failures and data available on performance of pressure treated poles.

Three to four years after commencing commercial treatment of class 3 durability poles in Victoria, some failures (about 30 pressure treated poles) were reported from the Mildura area due to termite attack mainly in the untreated heartwood. However, the subsequent use of an insecticide in the back-fill apparently overcame that problem. Between 1967 and 1969 there were incidences of poles, notably in the Eastern Metropolitan Area, being replaced due to centre rot*.

Soon after this, Lines Department of the S.E.C.V. initiated an examination of pressure treated class 3 durability poles in each branch in order to obtain an estimate of failure throughout Victoria. Results were widely variable and subsequently more data pertaining to the performance of a total of about 2000 poles, in both the Mildura and Melbourne areas, was summarised and issued as part of a report on power poles in Victoria, (Casserly and Murray, 1974). The data, collected to 1972, indicated an actual failure rate determined from one line of 219 poles, (55 foot poles) installed in 1960 between Merbein and Redcliffs and in which the date of replacement of every

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For reasons of simplicity, the remarks that follow will relate mainly to poles used for power distribution by one authority only, namely the State Electricity Commission of Victoria.

* The term centre rot is used to indicate decay deriving apparently from secondary infection occurring after felling of the tree and either before or after treatment. Very few isolates taken from decaying poles have been found to be "heart rots", i.e. decay organisms found in living trees.

pole was known. The percentage failure in this line was 5.1 per cent in less than 15 years and from the anticipated life of failing poles a further 2.7 per cent was expected to fail during the next 5 years. These figures however relate only to a very localized area and to one class of pole and may not be representative of the whole of Victoria. Nevertheless, another sample of 630 poles in the Melbourne area indicated that 5.9 per cent failed in less than 15 years with a further 5.2 per cent likely to fail in less than 20 years.

Note: In general terms, poles with centre rot are condemned when only a 2 inch annulus of wood remains in the critical strength zone.

In another sample of nearly 1100 poles in the Melbourne area about 8.5 per cent were considered likely to fail in less than 20 years.

Late in 1972, Lines Branch assigned 9 inspectors to systematically inspect every pole in the Metropolitan E.S. Branch. The condition of each pole together with an estimate of future life (if still serviceable) is being recorded in a manual card system set up at the Darling Pole Depot where poles can be identified via street names and areas (suburbs).

It is anticipated that all poles in the Metropolitan E.S. Branch (about 140,000) will be inspected on this program once every 3 to 4 years. The data contained in such a record will be significant as it will provide an opportunity to establish trends in pole failure and the distribution of pole service lives at least for this branch.

In April, 1974, when 40,150 poles of the most common size used in Metropolitan E.S. Branch, i.e. 30-45 foot poles, had been inspected and the data recorded, a random sample of 5,600 poles was obtained from the record cards, (Herd and Barnacle, 1974). This sample included untreated class 1 durability (royal) species, and pressure treated poles of 16 other species, most of which were class 3 durability species with service life ages of from 1 to 17 years. Unfortunately however, the sample necessarily was exclusive of all poles removed prior to the latter part of 1972. Of the total sample, 3400 were of messmate and mountain grey gum and from these the data concerning the performance of pressure treated class 3 durability poles were obtained. These data indicated that approximately 94 per cent of the class 3 durability poles used to April 1974 was made up of messmate and mountain grey gum, but the former was clearly the most frequently used species by a factor of about 8 to 1. It was also found that pressure treated class 3 durability poles made up about 63 per cent of the then existing pole population, the remainder being class 1 durability ('royal') species (cf. 100 per cent of the latter in 1956).

A further sample consisting of the total number of poles rated as failed or as being likely to fail within the next 4 years were obtained from the data bank and related to the total number of poles inspected to that time, i.e. 40,150 poles.

Analysis of the data (Herd and Barnacle, 1974) indicated:-

(i) Poles of all species.

Total poles condemned from all causes - all species whether treated or untreated, all service life ages - as a % of total poles inspected from late 1972 to April 1974 (40,150) 1.96%

As above but including those with an estimated further life of only 1 to 4 years. 3.94%

(ii) Pressure treated poles - class 3 durability.

Percentage failure rates (estimated) from all causes for three service life age groups of treated messmate and mountain grey gum poles were as follows:-

1958-1962 poles - 1.1% of poles remaining in April, 1974 will have a total service life of 15 years or less.

2.1% of poles remaining in April, 1974 will have a total service life of 19 years or less.

1963-1967 poles - 0.17% of poles remaining in April 1974 will have a total service life of 10 years or less.

0.36% of poles remaining in April 1974 will have a total service life of 14 years or less.

1968-1972 poles - None of the poles of this service age group that were inspected had been condemned.

Note: No precise estimate was obtained, from these data, of the percentages of poles that have failed or are failing specifically from centre rot (since at the time of sampling these data were not shown on the record cards). Nevertheless, it certainly appeared - from the inspectors' field books that centre rot was, generally, the principal cause of failure.

These data cannot in any strict sense be compared with those from the earlier study - since the two sets of data, in fact, refer to different populations. The latter estimates of pole failure do however seem surprisingly low in relation to the Casserly and Murray figures, i.e. if the distribution of service lives can be assumed to be normal or, what is more likely, log normal.

The foregoing data are of interest but they obviously are of limited value, their chief weaknesses being that (i) the data contained in the two reports quoted cannot be compared in any strict sense and (ii) despite the two assessments of pole performance referred to it is still not possible to determine any trends in pole failures. It is however important to note that the data used in the latter report are retrievable; the poles from which those data were obtained can, and will, be re-inspected; and particularly for the 1963-67 and 1968-72

poles meaningful service life distribution curves will begin to take shape within a few years time, at least for 30 to 45 foot poles in the Metropolitan E.S. Branch.

Note: If a separate record was required for each 'vintage' year of poles, however, it would probably be necessary to increase the size of the sample.

What could be done at this stage to determine pole service life distribution?

If a situation is to be established where it is possible to determine trends in pole performance and to make accurate forecasts of future trends then either one of two courses of action are essential at this stage.

1. If the same sample of any given population of poles could be re-inspected over a number of years it would eliminate the difficulty of trying to compare results for two entirely different samples and it could be a simple matter to chart the trends in pole failures of any given species, size, area of use, or year of treatment. Any gross differences in performance could then be related to source of supply, changes in plant conditions, quality control procedures etc. This sort of feed-back could only serve to improve the quality and uniformity of treatment and, in time, the effect of planned changes in plant procedures on service life performance could be measured. In addition, specific problems, could be identified and be more accurately defined than is possible at present, thereby facilitating research efforts to find answers. Further it should eventually be possible to determine when it was most economic to use maintenance treatments - for either sapwood or heartwood or both - to increase the life of service poles (Anon, 1973). Such a course of action - although it will maximise the data that could be obtained from existing service pole lines and the precision of predicted pole performance - will yield most benefits only in the medium to long term.

2. If the processing of data from repetitive inspections of a large number of poles in one, or in each, branch of the S.E.C.V. is considered to be too large an assignment, it is still possible to get some measure of performance, if pole lines can be found in each branch which were erected in a given year using poles of the same vintage. If enough of these can be found the history of replacement and causes of failure of individual poles can be recorded in a systematized way to permit extraction of data at any time. In fact, this is the only method open to any investigator trying to determine pole performance where no comprehensive data exists, and has been used in the Mildura area (Casserly and Murray, 1974) and elsewhere (Barnacle and Ampong, 1973).

If data such as those suggested are not obtained, no progress will be made from the existing situation, and there will still be a lack of definitive information regarding whether the failures that are occurring are excessive, i.e. relative to that which could be considered 'normal'. Also, it will not be possible either to predict pole performance in any population or to obtain overall performance data that could provide feed-back to assist in identifying ways of improving treatment or of

reducing the incidence of early failures. It will also always be difficult to establish the economics of any maintenance treatment or the optimum time at which to apply it.

Despite the lack of cumulative failure data on the performance of pressure treated class 3 durability poles it can be anticipated - on the basis of the likely form of the service life distribution curve - that failures in any pole population will increase as the median life is approached. This factor, could justify on economic grounds the treatment, at this stage, of poles with centre rots to extend their service lives.

Field observations of centre rots and initial trials of diffusion preservatives

In the Metropolitan E.S. Branch of the S.E.C.V. some hundreds of poles, that had been found to have a small amount of centre rot, have been kept under observation since 1971. This has been done by use of sonic testing equipment and by side boring of the pole, while it is still in service and these assessments are finally checked by cross-cutting and examining each of these poles at ground line after they are removed from service, (K. Herd, private communication).

A graveyard and in-service trial of various preservatives for the heartwood of poles has been initiated by the Lines Department, S.E.C.V. The preservatives used are:

Sodium fluoborate
1:1 Sodium fluoride : sodium nitrite
1:1 Boric acid : sodium borate
Copper acetate
Dip diffusion salts (B-F-Cr-As)
Disodium ethylene bis dithiocarbamate (Vapam) - solid and liquid
Johanson's Blue No. 7 (ammoniacal Cu-F-B)
Basilit BFB
SECV Cu-F-B preservative

These preservatives are being used in poles butt-bored before, or side-bored after erection. They will be left *in situ* for 2 years after which time the performance of the respective chemicals will be evaluated primarily be metering their spread in the heartwood, (K. Herd, private communication).

A problem of attitudes

There are some points concerning centre rots and early failures of pressure treated class 3 durability poles (PT poles) from any or all causes that need consideration at this stage. These points are concerned not so much with facts of PT pole performance as they are with what persons concerned with poles may think about that performance.

1. The first point is that, irrespective of the number of early failures occurring in PT poles, the fact of their occurrence has rightly or wrongly led to the development of attitudes or opinions such as, for example, that these poles are unsatisfactory, i.e. they are not reliable or that they won't give an average life of 25 or 30 years. It is suggested that attitudes such as these develop due to the absence of 'hard' data on the longevity of the better performing ('good') PT poles, the oldest of which have only been erected for 17½ years.

Note: When such attitudes exist, the data deriving from the relatively few poles in controlled graveyard tests tend to be discounted as pertaining to special cases, whereas the performance of the test poles could conceivably indicate some weakness in commercial treatment that needs to be identified and corrected.

These attitudes will be reinforced by the fact that the poles with which the PT poles are most frequently compared, namely those of durable species such as ironbarks, have been used for over 60 years, and in the three eastern states have given lives of the order of 30-50 years with some poles at least, lasting even longer, both in Queensland (Keating, 1961) and in Victoria, (Herd and Barnacle, 1974). Thus, on the basis of this long term evidence poles of ironbark and other similar species, are quite reasonably considered to be 'durable', 'reliable', 'good' etc. And the early failures that do occur in these durable species - numerous instances can be quoted of ironbark poles having been replaced in less than 2 years - do not cause the generally excellent reputation of ironbarks, etc., to suffer.

Although referring to smaller telephone poles, Keating (1961) provided further and substantial evidence of the fact of early and progressive failure in untreated poles of predominantly class 1 durable species in New South Wales. The frequency distribution of 22,816 pole replacements indicated (i) an average life of just under 25 years; (ii) 47 percent required replacement before the average life was attained, (iii) 11 percent of all replacements had occurred within 15 years, but (iv) 9 percent had lives in excess of 35 years.

It can be seen that some poles of any species or type (treated or untreated) do suffer early failures possibly for a variety of reasons but this fact alone cannot and should not be used as the index of the efficacy or otherwise of any species or type of pole: much more data is needed before a rational decision can be reached.

And it must be recognised that if adequate data is not available at the time when early failures occur it is not possible to rationally determine the median life of any pole population. Nevertheless, at that time it is still possible for persons to form attitudes and it is suggested that once they are established they will remain at least until hard data is obtained and used to demonstrate the real situation - in this case - concerning the performance of pressure treated class 3 durability poles. On the other hand it is also possible that attitudes or opinions can come to be thought of as'facts' and mitigate against action to elucidate the real situation.

2. The second point concerns the 'attitude consequences' of using heart treatments - whether as prophylactic treatments or as treatments to stop or retard centre rots - for PT poles at a time when hard data on their long term performance is not yet available. Although these heart treatments could improve the economics of poles in service, it must be recognised that their use could also serve to reinforce already established attitudes viz. that PT poles *per se* cannot be relied upon. This view may or may not be right but in fairness to PT poles and to the industry that produces them it is suggested that pressure treated poles ought to be finally appraised on fact rather than opinion.

It is therefore suggested that where supplementary heart treatments are used, action needs to be taken to ensure that those who handle and work on the poles understand that these heart treatments are used for example, not because the evidence shows that PT poles *per se* are unsatisfactory but rather because such supplementary treatments are themselves being tested (i) to see if any or all are capable of extending the service life not only of PT class 3 durability poles but also PT class 1 durability poles to the extent that pole service life economy can be improved, and (ii) to see if any or all of them can effectively control existing centre rots in standing poles.

There are two final considerations concerning the use of any heartwood treatment in pressure treated class 3 durability poles. First, should any decision be taken to use heart treatments extensively, then provision should be made to allow for an eventual, adequate, evaluation of class 3 durability poles without heart treatment. Concerning this point, it can only be stressed again that, in the final analysis, any evaluation of the economics of supplementary treatments should be made relative to comprehensive, soundly based data on the performance of the basic pole population, whether untreated or treated class 1 durability, or pressure treated class 3 durability poles. Secondly, it is conceivable that if heart treatments were to be extensively used as routine prophylaxis, early in the life of pressure treated poles it could remove or reduce the incentive for treatment plants to improve the general standard of pressure treatments.

It is only when basic information, such as that referred to above, is known that rational decisions can be made regarding whether any supplementary treatment (i) is generally needed, (ii) is needed only for poles found to be failing early or prematurely or (iii) could be used most effectively and efficiently either as a prophylactic or fungicidal treatment.

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DEVELOPMENTS IN THE FORMULATION OF ORGANIC SOLVENT PRESERVATIVES FOR MILLED RADIATA PINE

R. S. Johnstone and W. D. Gardner

Summary

A detailed study is in progress of the effects of different concentrations of tri butyl tin oxide, pentachlorophenol, aldrin, waxes and resins in three different organic solvents when *Pinus radiata* is impregnated. Laboratory fungal and termite tests, resistance to checking, paint compatibility and field exposure tests are now established.

Introduction

The shortcomings of waterborne preservatives of the copper chrome arsenic type in the preservation of radiata pine (*Pinus radiata* D. Don) were outlined during the 16th Forest Products Research Conference in 1973.

In spite of their undoubted value in the pressure impregnation of natural round and rough sawn timber they have limitations on three major counts:

(1) Before impregnation timber has to be dried to about 30% moisture content and then re-dried after treatment. The distortion and additional checking that occurs at the second drying means that C.C.A.-treated timber must be dressed or milled after preservative treatment.

(2) An important corollary of the processing of treated timber is the hazard to the mill operatives, the wastage of the external zone of greatest treatment, and the disposal of the heavily impregnated shavings from milling operations.

(3) The colour of the finished product where other than a paint finish is required.

The increased cost of an effective organic solvent preservative may be more than compensated for by the additional re-drying cost of C.C.A. impregnated material plus the fact that a larger volume of the timber is processed, a proportion of which is subsequently dressed off.

Materials and Methods

An effective organic solvent preservative should induce in a timber species such as *Pinus radiata* the following characteristics:

(1) fungal and insect resistance

(2) resistance to checking

(3) water repellancy

(4) paint compatibility

In addition, the solvent carrier should transport the active components of the preservative as far as possible into the timber and any subsequent volatilisation or movement should not result in surface blooming or bleeding.

An experiment to determine the best combinations of these factors for radiata pine is in progress using three solvent types:

(1) a non-volatile aromatic oil

(2) a highly volatile solvent (methylene chloride)

(3) a moderately volatile solvent (mineral turpentine)

Different concentrations of tri butyl tin oxide and pentachlorophenol both separately and in combination were used in order to evaluate their fungal toxicity by laboratory and field tests. Aldrin at various levels was added to impart termite resistance.

Chlorinated and paraffinic waxes were included to confer water-repellency bearing in mind their possible effects on paint compatibility, and bulking agents of various natural and synthetic resins were added for the purpose of stabilising the timber.

The relationship between preservative deposition and each solvent carrier will be investigated by microscopic examination.

At the time of writing, all treatments had been completed and evaluations of effective properties have reached the following stages:

(1) Long term field tests are in progress at Pennant Hills (decay and termite) and Narrandera (high termite).

(2) Laboratory termite tests are almost complete.

(3) Laboratory fungal evaluation tests are in progress.

(4) Paint compatibility tests have now been established on north-aspected exposure racks at Pennant Hills for four months.

(5) Uncoated samples to measure the amount of checking have been similarly mounted for a period of four months.

Results and Discussion

Full results from this project are essentially long term but some important elements are already emerging.

(1) Degree of Checking

Many of the treatments are showing some signs of face checking and end splitting. As could be predicted, the material impregnated with C.C.A. salt is checking severely (see Figure 1), as is the untreated control (Figure 2). A set of samples treated with one of the newly formulated preservatives is shown in Figure 3. These results represent 4 months' exposure (1st August to 1st December) and their subsequent performance through the summer months will undoubtedly accentuate the differences between them.

(2) Paint compatibility

Samples impregnated with the non-volatile oil were completely incompatible with an oil-based primer.

A yellow discolouration of the white external coat plus blistering of the paint film was apparent at concentrations of P.C.P. above 1.0%.

High loadings (4.0%) of a resinous bulking agent also induced blistering of the paint film.

Full evaluation of these results will probably not be completed until at least 12 months has elapsed.

(3) Termite toxicity

In laboratory termite tests, all samples containing aldrin at and above 0.08% by weight were toxic to *Coptotermes lacteus* within one week of contact. Final results on the remainder of the tests should be available at the 17th Conference.

(4) Fungal tests

Laboratory fungal tests were not available at the time of writing but it is significant that exposed samples treated with T.B.T.O. already show a surface darkening by fungi in a similar form to the controls. Samples impregnated with C.C.A. salt, P.C.P., or a combination of P.C.P. and T.B.T.O. show little or no fungal stain.

These results should be regarded as preliminary indications only at this stage and it is expected that more decisive results will be on hand at the time of the Conference in May, 1975.

Topic 2/18

EVALUATION OF SOFT ROT FIELD TEST SITES IN N.S.W.

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

Summary

A potential test site of high soft rot intensity has been selected for pole *in situ* treatments at Wedding Bells State Forest in northern New South Wales.

No correlation was evident between soft rot intensity and either rainfall or temperature. A considerable difference was noted between the high intensity of attack on the hardwood stakes when compared to the softwood stakes.

Introduction

In recent years the timber preservation industry has become concerned about the destruction by soft rot fungi of wood treated with copper-chrome-arsenic preservatives especially in tropical and sub-tropical Australia.

The problem, which is largely confined to pressure-treated eucalypt poles, and other hardwoods in ground contact, has led to a search for new preservatives and *in situ* treatments, suitable for these areas.

As a corollary a suitable test site of known high soft rot severity was needed in N.S.W. and this paper describes the selection criteria used.

Materials and methods

1. Selection of a soft rot test site

Six sites were selected for evaluation as shown in Figure 1. The basic climatic data for these sites is given in Table 1.

These sites were chosen so as to provide three pairs of sites of approximately the same latitude, (see Table 1) and so that one of each pair was close to sea level. Ease of access and suitable terrain, plus a reasonable expectation that a long term test could be carried out without disturbance were also considered important considerations in selection of the sites.

TABLE 1. Climatic data for possible soft rot test sites in N.S.W.

Forest	Site Annual Rainfall 1973-74	Mean Temp. Range Max.	Min.	Site Elevation	Site Latitude
	(mm)	(^{o}C)	(^{o}C)	(m)	
Middle Brother S.F. 284	1924	16-26	6-16	427	31^{o}41'
Henry Kendall Forest Park	1924	16-26	6-16	1	31^{o}40'
Wedding Bells S.F. 360	2930	17-23	10-18	122	30^{o}15'
Newfoundland S.F. 827	2418	19-28	11-20	24	30^{o}15'
Whian Whian S.F. 173	4569	18-29	5-17	336	28^{o}30'
Mooball S.F. 342	3168	21-33	7-19	92	28^{o}30'

2. Test timbers - species and installation

Two species of timber were used, radiata pine (*Pinus radiata* D.Don.), and brush mahogany (*Geissois benthami* F.Muell.). These were cut into test stakes 457 mm long by 25.4 mm square. At each site ten hardwood and ten softwood stakes were driven into the ground to a depth of 150 mm, arranged in four rows, two of hardwood and two of softwood. Individual stakes were 500 mm apart.

3. Evaluation of test stakes

After periods of 21 and 47 weeks five hardwood and five softwood stakes were removed from each site for microscopical examination.

From each stake transverse hand sections were cut at the edge and centre at two levels, groundline and 100 mm above groundline. These sections were mounted in lactophenol cotton blue and examined at 600 X.

The intensity of soft rot attack was determined by estimating the average number of cells attacked in twenty microscope fields and using this to assign each group of five hardwood or softwood stakes at a given level and position to one of the following classes: no attack, 1-5% attack; 6-25% attack and + 75% attack. The classes 1 to 5% and 6 to 25% were based on actual counts where any doubt existed. The division between 26 to 75% and + 75% was estimated.

Results

The results obtained for the five stakes in each group for each exposure time, position and species are shown in Figures 2 and 3. It should be emphasised that these graphs show relative intensity (%) of attack.

Discussion

1. Selection of test site

In assessing the most suitable test site the following assumptions were made.

(a) The best criterion for selection of a site was the intensity of soft rot attack at the centre of the test stakes. This appears to bear the closest practical relationship to the service requirements of a good pole treatment, and

(b) A site was required where both hardwoods and softwoods would be attacked by soft rots.

With this in mind the decreasing order of suitability of the sites based on a 21 week test appeared to be as follows:

1. Wedding Bells S.F. 360
2. Henry Kendall Forest Park
3. Middle Brother S.F. 284
4. Mooball S.F. 342
5. Whian Whian S.F. 173
6. Newfoundland S.F. 827

When considered on the basis of a 47 week exposure the order appeared to be as follows, (see Figure 3).

1. Middle Brother S.F. 284
2. Henry Kendall Forest Park
3. Whian Whian S.F. 173
4. Newfoundland S.F. 827

Two test sites are not included in the 47 week test, Mooball where a severe storm washed away the test site, and Wedding Bells where the stakes were destroyed during roading operations. Since the general pattern was the same for 21 and 47 weeks in the undisturbed sites it seems reasonable to base the assessment on the 21 week data.

2. Effects of rainfall

There was no correlation between the intensity of soft rot attack and rainfall, (see Figure 4), at the test sites.

The area with the highest rainfall, (Whian Whian), showed a low intensity of soft rot and the site with the second highest soft rot had the lowest rainfall.

3. Effects of temperature

The temperature data presented in Table 1 represents the range for each forest but does not necessarily represent the microclimate at the test sites. No significant correlations can be drawn between temperature and soft rot attack.

4. General

The most significant factors to emerge were the large differences in soft rot intensity between the various test sites, and the considerable difference between the soft rot resistance of softwoods and hardwoods at all sites except Middle Brother S.F.

At four sites, Whian Whian, Wedding Bells, Mooball and Newfoundland, there was a substantial attack in the hardwoods but attack on softwoods was either negligible or absent.

As a result of this survey it is proposed to establish a soft rot field test at Wedding Bells State Forest. The two factors which most influenced this decision were the high level of soft rot attack in the hardwood stakes, and the occurrence of some attack in the softwood stakes.

A further minor consideration was the superior accessibility of this site compared to Middle Brother S.F.

Action will now be taken to fully document the soil and floral characteristics of the site and to establish suitable climatic monitors.

TWO DEVELOPMENTS IN PROTECTION AND USE OF WOOD

R. Johanson

I. Copper-Fluorine-Boron Highly Concentrated Diffusion Wood Preservative For Poles And Building Timbers

This subject concerns properties of the preservative and the methods of application of protective treatments by diffusion in vastly contrasting situations. Often large volumes of wood are involved but only small surface areas are accessible for preservative application. The amount of preservative that can be applied at any one time often is limiting and insufficient for adequate protection. To overcome this handicap was one of the reasons for developing these highly concentrated Cu-F-B diffusion compositions which consist of almost 100% active components and on elemental basis contain up to 40% of active elements.

Copper-Fluorine-Boron Preservative (Blue 7)

The compositions are based on the three elements - Cu, F and B - all of which have proven effectiveness against decay, insects and termites. The preservative is intended for treatment by diffusion of wood structures including old dwellings, boats, poles and such like. By having the three active elements, the build up of tolerance by wood destructive organisms, as is possible with less complex formulations, is less likely to occur. It is recognised that in many applications, particularly in the World of today, there are distinct advantages if a preservative is clean and safe in use and presents no pollution problems during the service life and subsequent disposal of an unwanted material.

The Blue 7 is of cream or paste like consistency and has thixotropic properties to assist in its application. Because of its intense blue colour it is also known as Blue 7. On contact with moist wood of eucalypts or pine the highly complex concentrates of Blue 7 break up into simple components for rapid diffusion of fluorides and borates and some copper. The copper component is slower moving, its function is to maintain high concentration in bore holes and near the applied surfaces to afford permanent protection in these areas against decay.

The theoretical chemistry and procedure for obtaining highly complexed concentrates, their properites, applications and loadings for various situations have been described in two recent publications. Laboratory tests on termiticidal effectiveness were carried out and results published. Laboratory tests of material treated with Blue 7 against Basidiomycetes (wood rotters) and soft-rot organisms are currently being made. This Cu-F-B development has been protected by an Australian Patent.

Protection of Poles in Service

Protection of eucalypt power poles in service is a complex problem as it involves heterogeneous systems. There are checks and cracks and different ages, and states of deterioration. There are different species and various degrees of susceptibility to decay.

For the present, protection of durable and non-durable species in service will have to be confined to the most vulnerable part of a pole. In most situations it is the cylinder of wood about 100 mm above ground and extending about 600 mm below ground level. The diameter sizes impose severe limitations on the composition of the preservative that can be used and on the method of its application.

There are large volumes of heartwood involved particularly in 350 mm and larger diameters while the accessible surface areas around the circumference or in bore holes are relatively small. For example, the ratio of volume to the surface area around the circumference for 250 mm diameter pole is 6.4 but for 510 mm diameter it is 12.8. And the ratio of volumes of cylinders of equal length is 1:4 for the two poles respectively. This difference suggests that the larger pole will require at least four times the theoretical loading necessary for protection of the smaller pole. A corresponding increase in total volume of bore holes or larger loading in shields, as the case may be, will have to be made if a subsequent concentration of the toxicants in wood is to be maintained.

Use of Bore Holes

The geometry of the holes will have to be carefully considered to ensure sensible distribution of the preservative in three dimensions while the accompanying reduction in the pole strength, because of holes, is to be kept to a minimum.

In our tests three and four bore hole models were used to calculate preservative loadings required for different diameter poles. It was possible to have narrow bores (<8 mm r) and to obtain high loadings of Blue 7. Thus for 400 mm diameter pole, introduction of 800 g of Blue 7 and the distribution of its fluorine content through 800 mm length cylinder could provide 2.5 to 7 times the safety factor on fluorine content alone. These values are based on anti-fungal effectiveness of fluorine in fluoride compounds as reported by Becker (1973) and Smith and Cockcroft (1967a, b). In our calculations we preferred to ignore contribution of copper and boron although both of these elements play an important role in Blue 7.

Apparently it is possible to choose a configuration of bore holes to produce negligible loss in strength as was found in compression tests using several species of poles in 300 to 500 mm diameter range. In fact reduction was found to be less than 5% and initiation of failure was not at bore holes which were placed under tension.

Use of Shields

As already stated, large pole sizes impose difficulties in obtaining adequate concentrations of the toxicants for control of destructive organisms. Even with Blue 7, the shields will have to carry large amounts of the preservative. Thus based on an average desired retention, say, 20 kg m^{-3} (2.62 kg m^{-3} of F element) in a section of a pole which has 250 mm diameter at ground line, the loading in the shield will have to be 127 mg cm^{-2}. As the pole diameters increase the loading in the shield will have to be correspondingly increased, and for 510 mm diameter poles 255 mg per cm^2 will be reached.

The complexity is further evident when the shield sizes are considered. While 250 mm diameter will require 4700 cm^2 to cover circumference to a depth of 600 mm, 400 mm diameter will need 7700 cm^2. Thus it appears that shields with different lengths and loadings of Blue 7 per unit area of the shield may be needed if recourse to overtreatment of the smaller diameters is to be avoided. Overtreatments by factor of 2, 3 and 4 have main disadvantage of costs although extra handling of longer shields may also be undesirable.

For the present, it is envisaged that at least four to five different shield sizes may be needed to accommodate different diameters. In addition, also it may be necessary to provide for different depths. As for example, in protection of a pole against soft-rot in some areas narrow shields to a depth of 300 mm only may suffice, but in others, it may be necessary to reach depths to 450, 600 or even to 900 mm.

Treatment of Buildings and Other Wood Structures

In situations where incipient decay is present or is likely to develop, as in subfloor regions, application of Blue 7 by painting or spraying should be most effective. In old neglected dwellings where affected timbers still have adequate strength but showing decay, application of a diffusion preservative could provide substantial saving in restoration costs.

The use of Blue 7 has been considered for protection of difficult parts in existing buildings particularly in window sills, window frames and various joints that are usually painted and which are subjected to a periodic wetting. In this category an old front fence was brushed with a composition similar to that of Blue 7, and although the fence remained unpainted protection of the joints is still evident after 5 years of Melbourne weather. An application of Blue 7 is also envisaged in boats where a preventative or remedial treatment of wooden structures by the diffusion preservative is the only practical means available.

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II. On Concept of Brucising and Oil Penetration in Karri (*Eucalyptus diversicolor*)

In an effort to increase surface loading of diffusible preservative-concentrate in rail sleepers, surfaces of unseasoned karri (*Eucalyptus diversicolor*) specimens were indented with various sharp and blunt objects. A desired effect was obtained by using a combination of incising and bruising which produced suitable cavities for the purpose. Apart from the increased retention of the chemicals there was also an extensive penetration by oil in the bruised areas, around the indentations, when the specimens were heated in oil at 100° to 110°C. The advantage of the bruised tissue as a supplement to incising became apparent for hot oil treatments of karri sleepers by the Boulton process. And to describe this novel incising with indentations, the words brucised and brucising were used by combining the two verbs - bru(*ised in*)cised. My colleague Frank Dale became very enthusiastic about the phenomenon, and constructed a machine to brucise sleepers as he described in his paper.

It was evident that the bruising alone without actual incisions was an effective aid in oil penetration during heating of unseasoned karri in an oil bath. In Figure 1, karri specimens are shown with 5 to 7 mm of oil penetration on one radial face. This effect was obtained when one radial face of the green specimens was modified by subjecting it to pressure with sufficient force to produce exuded droplets of moisture at end-grain faces. The opposite radial faces were protected against pressure effects and are intended to serve as controls: they are showing no oil penetration.

Various hypotheses were tested, some supported experimental results while others had to be discarded. It was postulated that formation of a hydroelastic compression wave was necessary to rupture polymeric structure of the moisture-filled vessels in green karri, or to clear pits, to enable freer replacement of water by oil during subsequent heating of the specimens in an oil bath.

In Figure 2, the effect of relatively free movement of moisture is evident when a tangential face of a karri sleeper was indented with four different tools and allowed to dry. The tool (a) is a conventional incising knife, it has a bayonet-like point and two sharp edges. The knife-made incisions (to 15 mm depth), dried faster than the cavities (to 15 mm depth) which were produced with the tools capable of bruising. This result is interpreted to mean that more moisture could move at a faster rate in brucised areas and, relative to the incisions, this moisture delayed drying.

This relatively free movement of moisture in brucised areas is well illustrated in Figure 3. Despite the fact that a large surface was exposed to drying when the tool (d) was used, it dried slower than the area (a) of similar dimensions which had been incised with the knife.

Obviously, the results obtained suggest that some fundamental change was occurring when vessels were subjected to the bruising process. In an investigation of this type one has to rely a great deal on intuition. As a working hypothesis, it was considered that the changes in the bruised

areas are mainly of a chemical nature involving rupture of hydrogen bonds and other rearrangements in polymeric structure of the unseasoned wood. Cracking and splitting of some vessels possibly also occurred and this may have produced an improved exchange of liquids, but to a limited extent only. A generation of considerable forces would be necessary to rupture hydrogen and other weak bonds and this would involve at least 7 to 14 kcal per mole. This approach has merits when interatomic and intermolecular dependence of the complex substances like wood is considered.

Understanding of the nature of the chemical changes involved when wood is bruised, could lead to a greater improvement in the penetration of liquids in dense and resistant species. Even in this exploratory investigation it was possible to induce improvement in penetration of hot oil into unseasoned karri wood as is evident from the appearance of the end grain of the specimens in Figure 4. The material used was from one piece which was cut in half to obtain the test specimen (a) and its control (b).

We may look upon this short account as a gleam through a window revealing forces and properties of wood, understanding of which could lead to improvements in existing processes and development of new ones.

Topic 2/20

THE MICRODISTRIBUTION OF PRESERVATIVE IN WOOD USING ELECTRON PROBE X-RAY ANALYSIS

H. Greaves

Conventional analysis techniques for determining preservative levels in treated wood usually involve destruction of the wood's anatomy, so that the actual distribution of preservative is arrived at by extrapolation. However, by using electron probe systems, such as the scanning electron microscope (SEM) coupled with X-ray microanalytical facilities, it is possible to perform in situ analyses of preservatives and their components, producing precise correlation of element distribution with biological fine structure. Unfortunately accurate quantification of results still remains unreliable, the main difficulties being the reproducibility and detection of all excited X-rays, matrix effects, and background or continuous fluorescence. Elaborate computerised programmes have been designed to obviate these and other analytical problems, and standards may be prepared using a matrix similar to that of the specimen under analysis, but quantification still presents difficulties. Qualitative results on the other hand may readily be used to provide valuable in situ comparisons of the elemental composition of selected structural features, and simple standards may be employed to yield semi-quantitative information.

In the work reported here* energy dispersion X-ray analysis was employed in conjunction with a Cambridge SEM to study the microdistribution of copper-chrome-arsenic and copper-chrome-fluorine formulations, both before and after leaching, in the sapwoods of *Eucalyptus regnans*, *E. maculata*, *Fagus sylvatica*, *Pinus radiata*, *P. sylvestris* and *Picea abies*. In the DBR facility work a wavelength crystal spectrometer for detecting emitted X-rays will also be used in conjunction with the SEM, since this combination will be much more sensitive to elements of low atomic number, such as fluorine and boron.

Sticks of wood were treated by a full cell process and retentions ranged from 12 kg/m^3 for *E. maculata* to 22 kg/m^3 for *P. radiata*. Matched material was then either air dried for 14 days or leached using a modification of the German standard DIN 52172. Specimens were prepared for SEM microanalysis by splitting c. 1mm thick radial sections from the treated sticks, mounting on microscope stubs, and coating with carbon by vacuum evaporation to a thickness of c. 70nm. Analyses coupled with structural examinations were conducted on each specimen at positions ranging from the surface to the centre of the treated wood. Measured amounts of the original treating solution was used as a standard for calibration of the instruments and for comparison with the in situ analyses.

The results indicated a considerable variability in preservative penetration. The main pathways for preservative movement in the softwoods was the rays, while in the hardwoods structural differences in preservative distribution was less marked (fibres excepted) although the rays were important in beech and were also well penetrated in mountain ash. In addition, vessels were significant pathways in the eucalypts, especially

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* Carried out at the Bundesanstalt für Materialprüfung, Berlin.

E. maculata. Poor treatment of fibres in both eucalypts was very marked, although in beech fibres the preservative levels compared favourably with vessels.

In all six wood species examined, both before and after leaching, the most striking analyses in terms of high element levels were provided by the various pit membranes (Figure 1). The crossfield pits and vessel to ray pits especially contained high levels of Cu, Cr, and As. In beech, where cases of well treated rays and adjoining vessels were sometimes encountered, the connecting pit membranes produced very high count rates.

Every SEM examination of unleached specimens revealed the presence, in varying amounts, of amorphous and crystalline cellular inclusions. Such deposits were very numerous in many cases and were limited to cell wall surfaces. It was found that they consisted of the three main preservative components, but in different ratios to each other. Rarely was the ratio of elements present in the deposits similar to the ratio found in examination and analysis of the treating solution. It was also interesting that a comparison of CCA crystals from the wood and from the treating solution not only showed different ratios and quantities of Cu, Cr, and As, but the crystals formed in the wood were much smaller than crystals formed from the treating solution itself.

In addition to differences in composition between cellular deposits and treating solution, the preservative components within cell walls were also distributed in differing ratios and in ratios which differed from the original treating solution composition. This effect varied from point to point in any specimen, with the exception of softwood pit membranes. Previous workers have noted that the ratios of the three elements in CCA is unaltered when wood is treated (Rudman 1966; Petty and Preston 1968), while Chou et al (1973) state that the Cu:Cr ratio is fairly constant, although Cu:As is more variable. The incidence of variability in element ratios recorded in the present study was greater in the hardwoods, while there were very few cases in which a similarity existed between hardwoods and softwoods in their ratios of Cu, Cr, and As. This point confirms that a different fixation mechanism exists in softwoods and hardwoods.

Spotted gum showed relatively poor and sporadic CCA penetration, especially for As. This observation, coupled with the fact that there were large pockets of unprotected cells in *E. maculata* may explain the incidence of premature failure due to soft rotting microfungi in CCA-treated spotted gum transmission poles in Queensland. Distribution patterns and penetration trends became clearer after the specimens were leached. Thus, the softwoods all behaved similarly and consistently produced higher levels of Cu than those detected in the hardwoods. *E. regnans* still yielded the highest Cr and As count rates of the six woods tested, while *E. maculata* gave the lowest levels detected for all three elements.

Cellular inclusions, both amorphous and crystalline, were much less frequently observed in all species after leaching, except *E. maculata*, in which the deposits on vessel walls were still present. There was a trend for the preservative components to be concentrated by leaching towards block centres in softwoods. This suggests that unfixed material, such as the observed amorphous and crystalline deposits, is redistributed by elements migrating both inwards and outwards rather than outwards only during leaching.

Nicholson and Levi (1971) have commented on the possibility of CCA redistribution by movement up and down poles in service during leaching, and it is clear from these results that a redistribution of preservative occurs under the conditions studied here.

Additional results of these studies have been given in more detail elsewhere, (Greaves 1972, 1974a, 1974b). The present report is tabled as a means of further dissemination of the more important results, and also to illustrate the potential and application of electron probe X-ray microanalysis in examinations of preservative treated wood. It can be seen that the instrument may be used for relatively rapid localisation of elements within cells, (e.g. wood, fungi, bacteria, insects, etc.), and since it has a resolution in the order of 10nm, it is possible to compare individual cell wall layers, such as in the secondary wall of wood cells. Furthermore, the low beam intensities used in the SEM avoid overheating and subsequent element migration, and destruction of the specimen.

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TECHNIQUES FOR EARLY EVALUATION OF *IN SITU* TREATMENTS FOR POLES

E. W. B. Da Costa

At the present time, there is an urgent need for rapid methods of evaluating *in situ* maintenance treatments to arrest or prevent deterioration of eucalypt transmission poles in service, either from peripheral soft rot in treated sapwood or from centre rots in untreated heartwood. A large number of treatments have been suggested (including penetrating oils; diffusing inorganic salts; diffusing organic compounds; and fumigants) which may be applied by brushing, soil puddling, inclusion in plastic-backed bandages, polyurethane foam or inserted cartridges or liquid. Many of them should on a priori grounds give adequate control: the major research problem is to devise means of proving that they do so and of assessing which is the best of several alternatives.

This problem is particularly acute with soft rot in treated poles. In many poles, soft rot has already penetrated deep into the sapwood, and can be detected microscopically in apparently sound wood. A mechanical or toxic barrier on the outside might therefore be almost useless. The ideal method of evaluating the comparing treatments would be by field and service tests, with normal inspections, but these would take several years to establish that a treatment was working reasonably well and many years to indicate which was the best of several alternative treatments. We need early evaluation methods and research work on these is being carried out. Most of them are based on bioassays, as chemical analyses even by sophisticated methods (such as SEM + secondary X-ray emission detection, or gas chromatography) do not always give reliable answers. This is because many fungicides are hard to analyse in wood; some (e.g. fluorine-boron compounds) may exist in the wood in several indistinguishable forms of differing toxicity; and we do not know the toxic limits for the variety of fungi occurring in the wood.

A major difficulty with diffusing preservatives, especially with complex mixtures of several toxicants such as copper fluoborate is that the formulation applied to the wood as a brush coat, bandage, cartridge etc. may be very different to that which is actually responsible for fungal inhibition deep in the wood. Some components will dissolve and diffuse rapidly without much change (e.g. fluoride ions), others such as cupric ions may diffuse slowly, may be adsorbed on wood substance as in partition chromatography; may combine irreversibly with wood components; or may be affected in composition or in toxicity by pH changes. Where large amounts of salts are applied to a small volume of wood, a uniform equilibrium mixture may eventually be obtained, but it is doubtful if this would apply in a normal pole bandage. Diffusion will continue through the sapwood into the heartwood (even if at a greatly reduced rate) and loss of the more diffusible components to the soil below the bandage will eventually occur.

The following evaluations are under consideration:

A – For field tests

1. Removal at intervals of small cores (e.g. 3/8 inch diam.; 3 inches deep) for detection of presence of viable soft rot fungi; for assessment of fungistatic effects; for CO_2 production

as a measure of continuing wood breakdown; for microscopic comparison of amount of soft rot with earlier samples; for chemical and physico-chemical analysis of diffusion patterns (including SEM-X-ray emission analysis). Such cores can be removed through bandages or brush treatments and the holes plugged with treated dowels or grouting material.

2. Measurement of decay progress by the pulsed electric current method of Shigo (dependent on increased cation content in decayed wood) using a small (¼ inch) plugged hole, or by testing hardness of wood at the sides of the hole.

B - For laboratory tests

1. Initial assessment of combined diffusing ability and toxicity of candidate fungicides in agar. These results cannot be applied directly to performance in service. The short diffusion time favours fast diffusing compounds, but on the other hand the absence of wood components allows some compounds such as pentachlorphenol to diffuse freely while they would be held back by adsorption or combination in wood.

2. Establishment of toxic limits for soluble salt diffusion preservatives (as applied) by weight loss of sawdust or wood blocks containing varying retentions tested under conditions where no loss of toxicant by diffusion could occur, again using natural soft rot inoculum. As explained earlier, this has the disadvantage that the actual fungicide balance in the wood will differ from that in the applied preservative.

3. Measurement of diffusion of toxicity using radial diffusion through spotted gum sapwood (and possibly attached heartwood) of toxicant applied to cambial face. This will again use natural soft rot inoculum and can be modified to allow samples of diffusate to be taken for bioassay and chemical analysis. This is the most promising laboratory method of assessing bandages and brush treatments but is rather laborious and long. Diffusion through a reconstituted wood matrix is being considered as a possible alternative.

It should be emphasized that all these methods have their place in rapid evaluation of *in situ* treatments. They are not simple, either in execution or interpretation, but they do offer means of objective quantitative experimental evaluation, which are far more reliable than theoretical expectations or chemical assessments.

IMPROVED METHODS FOR DETECTION OF INTERNAL DECAY IN POLES AND IN BUILDING TIMBERS

E. W. B. Da Costa

A major gap in research and industrial technology is the difficulty of detecting and measuring internal decay in outwardly sound poles. The traditional methods of manual sounding and (where decay is suspected) boring poles have repeatedly been shown to be unreliable even with experienced inspectors. They undoubtedly result in very heavy over-condemnation of poles. Although exact figures are difficult to obtain, it seems probable that in some areas 75 per cent of poles condemned for decay have been sound. Moreover, they occasionally fail to detect severe internal decay. The results are excessive replacement costs for wooden poles and especially for pressure impregnated poles, and a continuing accident hazard both to linesmen and to the public. As a first step to improvement, the number of "false positives" (i.e. poles condemned for decay but actually sound or insufficiently decayed to warrant removal) should be accurately assessed. All poles condemned or suspected from sounding should be bored horizontally in two directions at right angles at ground line and the extent of decay recorded before condemnation is confirmed. On removal, all condemned poles should be cross-cut at ground line and the amount of decay again recorded and compared with that assessed by boring. This procedure should be an important part of the necessary computer compilation of service data discussed in another paper. In fact, all poles removed for whatever cause, should be cross-cut at ground line (unless intended for re-use) and the amount of decay, if any, recorded. In collecting these data, it should be emphasized that a certain amount of over-condemnation is inevitable, if not desirable, in any system of inspection. The cost of damage or injury caused by unexpected failure under stress of a transmission pole could be greater than the cost of unnecessary replacement of poles but is probably nothing like that arising from vehicle collision. Over-condemnation is extremely variable in incidence, for causes which are probably psychological as much as technical, and pole using authorities should realize that both causes are susceptible to research and correction. Whatever system of inspection is adopted, it should be quantitatively evaluated against alternative systems on the following major criteria; number of false positives; number of false negatives (i.e. poles passed as sound, which should have been condemned); number of "uncertain" answers and of poles to which method is inapplicable; capital cost of equipment; running cost, including labour and repairs to equipment; and acceptability to pole inspectors, linesmen and engineers.

Objective methods of assessment

Because of the fallibility and high labour cost of traditional methods, many alternative physical methods of detecting internal decay have been tried. These have been reviewed by Eslyn, 1968. They include the use of X-rays and γ-rays, both of which proved unsatisfactory because equipment is expensive, inconvenient because of the shielding precautions necessary

and because they do not give an immediate answer if photographic film is used. Moreover, these forms of radiation do not discriminate consistently between sound wood and certain types of decay, especially incipient decay in hardwoods. A more recent development has been the use of sonic vibration, using signals from a resonant vibrator on one side of the pole to receiver transducers at various heights on the other side of the poles. This method, pioneered by Mr. A. D. Shaw of the Hydro-Electric Commission of Tasmania, has been tested by several pole using authorities in Australia with promising results and is discussed by T. J. Smith, in a paper presented to the 48th Conference of the Electricity Supply Association of New South Wales in 1973. Its major disadvantages are that it cannot be readily used with poles externally softened by decay or oxy-charring and that it is liable to give false positive readings when large cracks (internal or external) are present. Since it is essentially a comparative method, comparing transmission at a datum point well above ground level with that at points at or below ground level, it could give false negatives where decay extends well up the pole. The method is now being prepared for extensive trial use in Australia, but needs more testing on normal pole populations, rather than on poles selected on a non-random basis, to assess accurately its reliability. Because of the possibility of false positives from internal checks, it would at present be desirable to bore poles condemned by this method, for confirmation before removal.

The three methods mentioned have the great advantage that they leave the inspected pole attached and hence involve no risk of causing infection or weakening of the pole. Another method which has been used successfully in Europe is to force a hardened steel needle radially into the pole, recording the resistance to its penetration. This works reasonably well with softwood poles, but needs to be more robust to penetrate our dense eucalypts. It may be worth re-testing with an initial drilled hole so that the resistance to penetration is measured only in the critical zone 2-3 inches below the sapwood.

Some methods have been suggested using permanent "observation" holes drilled in the pole. This could involve merely probing the sides of the hole periodically for softness, but a much more promising method has recently been developed by Skutt et al. (Canadian Journal of Forest Research 3, 354-8, 1972) and more intensively by Shigo and Shigo (USDA Forest Service Research Paper NE-294, 1974). This method is based on the greatly increased conductivity in wood caused by the production of cations in the decay process and measures the resistance to a pulsed current passed between two electrodes contacting opposite sides of a narrow (2-3 mm) hole drilled in the pole. The method, originally developed for detecting decay in living trees, seems to have considerable promise in that its readings are not upset by internal checks and that decay can be detected independently at different depths in a hole drilled 200-300 mm into the wood. The holes are so small that a large number can be drilled without weakening the pole but a larger drill of at least 5-6 mm diam. would be needed in our hardwoods. Repeated measurements on the one hole by this or any other technique (such as probing, CO_2 measurement) suffer from the disadvantage that decay around the hole may be greater (from infection or from ingress of oxygen) or less (from infection by antagonistic organisms or from methods used to sterilize the hole) than that in surrounding wood. With the pulsed current method, if conductivity of decayed wood is markedly higher than that even of saturated wood, it might be possible to detect decay without injury to the tree by changes in electrical capacity or microwave absorption.

Boring of poles

Despite development of objective physical methods, it seems likely that for a long time to come, the final check on condition of a pole before it is removed will be by boring the pole and more attention should be paid to the numerous methods of doing this. An objective boring method has been tried in U.S.A. and in Japan by electronic measurement of torque required by a constant speed electric drill (J. W. Clark, U.S. Forest Products Laboratory, Madison, personal communication, 1974) and this approach may be worth further investigation. Labour costs could be cut by the use of 12-volt or battery powered electric drills (perhaps only for the first 40 mm, followed by hand-drilling) and methods of examining boring chips for detection of decay should be investigated. In all these approaches, the essential feature is that all concerned (pole inspectors, line engineers and research workers) should fully realize that an experimental approach is essential in the present state of the art and that correctly designed and biometrically analysed experiments can give reliable data, which will eventually enable an accurate comparison of methods on other than subjective grounds.

Detection of decay in building timbers

This paper is concerned mainly with detection of internal decay in poles, since this is of great concern to pole-using authorities at present, but it is desired to draw attention to the problems of detecting decay in building timbers. The use of treated rounds, either for pole-barn structures or as foundation piles for buildings, presents problems very similar to those met with in transmission poles. Detection of decay may be even more important and may justify greater inspection costs, but inaccessibility of timbers, especially those set in concrete or under buildings of low clearance, can present difficulties.

Detection of internal decay in sawn timbers is becoming more important with increasing emphasis on the conservation of historical buildings or artefacts, and on the rejuvenation of inner suburban dwellings. Here the emphasis is not only on detection of presence of decay but also on precise measurement of its extent, to decide the effect on strength and the application of of eradication measures. In many instances, inspection methods should not impair the appearance of the timber. Here the pulsed current method may be useful for large timbers, and for thin timbers even use of a moisture meter may show either presence of decay or at least of high moisture contents likely to be associated with decay. Vibratory measurements of stiffness may be applicable in some cases.

With decay in buildings, one of our major needs is an assessment of the frequency of its occurrence and the costs of repairing or replacing the damaged timbers. We also need more precise data on conditions conducive to, or associated with, decay. In the long run there will be more need for re-use or recycling both of buildings and of building components and rapid decay detection will be essential.

General

This paper does not set out to give recommendations on detection of internal decay, since the parameters on which a good recommendation could be based are not known. It aims to set out some aspects of the problem and to indicate lines of research, experimentation and recording of data which should be considered by all concerned in the problem.

HEALTH HAZARDS ASSOCIATED WITH TREATMENT AND DISPOSAL OF CCA TREATED TIMBER

F. A. Dale

(a) Pollution control in CCA treatment plants

The Australian timber treatment industry as a whole has given too little attention to the safe disposal of plant effluents.

When dry CCA salts were used these were sometimes spilt around the mixing tank or blown about by the wind. The "drip" from freshly treated timber remained on the ground unless it was blown or washed away and leaks from valves or pump seals were not fixed immediately. Any recovery of solution was done mainly to save money, control of pollution was a secondary consideration.

With increasing public concern in matters of pollution and the establishment of Environmental Protection Authorities or their equivalents in most States, this attitude is changing. One authority has already required that draining aprons be provided under bogies just removed from the cylinder, with a sump and a pump to return liquid preservative to the plant. It is significant that for some years past the Victorian Health Department has deliberately made it very difficult for farmers to obtain CCA salt for "do-it-yourself" treatment of fence posts by sap-replacement because of the risk to children or animals if the treating solution was ingested.

The yards of many CCA treatment plants still leave much to be desired. These should have enough area of sealed apron to collect all the drip from freshly treated timber, means of returning it to a sump and a settling tank to separate sediment before returning the liquid to the mixing or work tanks. In moderate to high rainfall areas the apron should have a roof. The area around the mix tank should be sealed and drained to a sump. The cylinder should have a test cock to prevent the door being opened while it still holds solution and this should be interlocked with the door closure. Rainwater from any area liable to contamination should be led to a suitable holding tank or trap, where it can be treated or passed through fresh wood waste to absorb active solution before it leaves the yard. Sludge forming in tanks because of hard water or for some other reason may need special treatment before burial. It should never be allowed to leave the plant as a surface deposit on treated timber.

Some areas of existing plants must by now carry potentially dangerous amounts of arsenic in the surface layers of soil. Once proper drainage aprons have been put down these contaminated layers should be removed and buried where they will not be disturbed. Alternatively the areas could be sealed with oil or bitumen to prevent toxic dust being carried about by wind and water.

While treated timber has proved completely safe to handle when dry, it is often handled while still wet after treatment. Gloves and aprons should be worn by anyone doing this. Some people are unaffected after repeated contact with wet treated surfaces, others may be storing up trouble for the future, particularly those liable to dermatitis caused by chromium salts.

All these are obvious measures which should be implemented as soon as possible with the object of reducing the risk of ingestion of arsenical dust, or of repeated skin contact with hazardous material, to a negligible level. Lack of action will almost certainly mean that the E.P.A. and other authorities will impose much more severe controls, which may be dictated by pressure from the media as well as a genuine concern for public safety. Moreover, they may be imposed without full consideration of all the facts.

(b) The disposal of treated waste

Most of the evidence on this problem comes from New Zealand, which has a much greater usage of CCA salts than Australia and where the Department of Health keeps a check on boiler and incinerator emissions and ash disposal.*

In New Zealand at the present time, offcuts, sawdust, shavings and sander dust can be safely disposed of by burning in the right type of burner under controlled conditions, because most of the arsenic remains behind in the furnace. There must be a safe upper limit to the amount put through a burner at one site in a given time, but to our knowledge no restrictions on this form of disposal have been imposed by the New Zealand Department to date, although waste containing about 400 tonnes of CCA was incinerated in 1966, and the amount must have increased substantially since then.

The collection and disposal of ash and soot from incinerators and boilers involves certain risks as they may contain up to 7% soluble arsenic. Careful burial of such waste to allow very slow leaching is essential to prevent this reaching nearby streams at dangerous levels. Chemical treatment to render the arsenic insoluble is another possibility.

The trend towards treatment of mouldings with preservatives in organic non-swelling solvents should gradually reduce the amount of CCA treated waste produced in the future. Machining of CCA treated timber is also undesirable for other reasons. It is wasteful and removes the most heavily treated material from close to the surface, besides involving the considerable risk of exposing untreated heartwood, particularly in large sections where its occasional presence is unavoidable.

The burning of CCA treated waste in domestic and rural situations must be prevented. Ash from domestic fires could be used on gardens or exposed to children and animals, while ash from burnt offcuts may be accessible to stock. A special hazard arises when offcuts are burnt in barbecue fires where arsenic can sublime on the surface of the meat. A poisoning of this type has already happened once to our knowledge.

Because high-temperature drying tends to give CCA treated pine a very light brown or straw colour, rather than the familiar green, purchasers of any treated pine should be specifically warned against burning the offcuts which should be buried or disposed of as garbage. The need to mark all sawn treated material to show that it has been treated requires urgent consideration by the industry.

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* Air Pollution Problems of Wood Burning by R. T. Douglas.
Conference on the Burning of Wood Waste - Auckland 1966 - Paper No. 9.

The question of the disposal of treated fence posts when they eventually fail has also been raised. Even when this does happen the bulk of the post, except for a foot or so at groundline, will still be usable. The present boom is used railway sleepers for garden construction suggests that treated posts will always be in demand, only that part which is completely rotten need be buried or burnt under controlled conditions. On a farm a stack of rotten posts would occupy such a small volume that it could be buried, or the posts could be used to fill eroded gullies. Alternatively they could be burned and the ash could be buried. There will always be uses for the bulk of condemned poles once people realize their potential for farm structures, retaining walls, culverts and other structures.

The ultimate solution to all these problems is the development of preservatives toxic only to insect pests and fungi. Until this is achieved, we must do all we can to ensure that the CCA preservatives, which are ideal in many respects, can be used without costly restrictions. Ideally, they should be reserved for use in ground contact, but this will only be possible when other preservatives, with better resistance to weathering, are readily available for the treatment of timber for above ground situations.

DECAY CONTROL IN PLYWOOD BY GLUELINE ADDITIVES

D. McCarthy and E. W. B. Da Costa

With increasing production of "water resistant plywood" and its use for structural rather than decorative purposes there has been increased demand for the production of rot-proof or at least rot-resistant plywood. This has followed a large number of examples of serious and expensive decay in plywood used in boats, caravans and for external cladding of buildings where the user wrongly believed that the description marine grade plywood in exterior grade plywood necessarily implied that the material could be used in applications where a decay hazard occurred.

The preservative treatments currently used in Australia for the rot proofing of plywood are alleged to be expensive and, more importantly, inconvenient to the manufacturer. Some of the difficulties are due to poor technology and poor plant control and the demand for new techniques and preservatives is high.

Experience over the last decade has shown that control of Lyctus, Anobium and termite attack can be achieved by incorporating certain toxicants in the glueline. This success has lead to thoughts that effective control of decay could be achieved by incorporating fungicides in the glue. In addition to the direct economic advantages of such a process to the plywood manufacturer other attractive features of the process would be fewer health or environmental problems in handling and sanding the treated plywood since the toxicants would be absent initially from the outer faces of the plywood.

The attractiveness of the glueline additive (GLA) approach to the preservation of plywood, the inadequacy of the GLA treatments commercially available and the demand of the industry and the Plywood Board of Australia for a fully successful GLA preservative induced the Preservation Group in D.B.R. to undertake research to this end.

The initial objective was to obtain protection of phenol-formaldehyde bonded *Pinus radiata* plywood of a maximum veneer thickness of 2.5 mm. The main difficulty in the task was expected to be the incorporation in the glue formulation of a non-glue reactive additive, with correct diffusion characteristics, that did not impair bond strength.

Fungicidal glueline additives have been used to some extent in Europe and apparently proved acceptable, but all European commercial products tested in our laboratory have been far too susceptible to decay for use in our own conditions. In view of the diverse likely uses of rot-resistant plywood we would have preferred to produce a material which could be used unprotected in any external above ground use, if not in ground contact, but have agreed with the industry that even material suited only for moderate decay hazards could be marketed. This would involve some control by industry of the manner of use and advertising of this product. Such a "rot-resistant" plywood would still have to meet the Australian Standard specification for <u>low</u> decay hazards before CSIRO could recommend its use, i.e. it would have to be as rot resistant as pine plywood treated with CCA preservatives to a retention of 5.6 kg/m^3 as in AS 1604.

A large number of candidate fungicidal formulations, in excess of 150, have been screened by a wood laboratory technique, whereby the ability of typical decay fungi to grow on the face veneer of treated plywood has been assessed. The most promising materials were arsenic in various forms, pentachlorophenol, oxine, and some fluorides.

The most promising of these materials were then submitted to a more severe soil-block decay test, after exposure in a vacuum oven to remove any free formaldehyde or phenol but without preliminary leaching. In these tests, the only preservatives which have yet shown promising results were pentachlorophenol and arsenic.

In contrast to earlier soil block tests (Da Costa, E. W. B., Hirst, K. and Osborne, Lynette D. "Laboratory evaluations of wood preservatives VIII Protection of plywood against decay fungi by incorporation of fungicides in glueline" Holzforschung Vol. 26 p.131, 1972). The tests were arranged so that the fungi could directly attack freshly sawn edges of the plywood. This is the normal location of attack in service and in many applications loss of strength in the edge 2-3 centimetres of the sheet would impair fixing to a dangerous extent. Those treated blocks showing resistance are being given further decay tests after a mild leaching, and further candidate fungicides are being given both screening tests and soil-block tests.

The position at present is that a number of treatment processes show some promise but as yet none have approached the effectiveness of veneer or plywood impregnation with 0.35 lb/cu.ft. (5.8 kg/m^3) of CCA. It is hoped to re-examine the problem at a more fundamental level to determine just how the fungicide is immobilized or encapsulated by the polymerized glue resin and whether variation in the P-F glue formulation may be necessary. These investigations will involve microscopic examination of preservative location and glue structure, possibly with the use of SEM X-ray analysis methods. In addition to laboratory screening and soil-block decay tests, it is intended to set up the more promising glueline fungicides in an above-ground exposure test under simulated severe service conditions.

TERMITICIDAL EFFECTS OF INSECTICIDAL GLUE-LINE ADDITIVES

C. D. Howick, N. Tamblyn and J. W. Creffield

The effectiveness of glue-line additives as plywood preservatives is of particular concern in the granting of quarantine approval for the plywood component of shipping containers. A number of commercially produced glue-line additives were therefore assessed in the laboratory when incorporated into plywood in the manner and at the strengths recommended by the manufacturers. Their effectiveness was compared with that of a dieldrin solution. Preservative details are shown in Table 1.

TABLE 1. Preservatives

Preservative	Reputed Composition (Percent)				Instructions for use
	Main Insecticides		Other components		
A	Heptachlor	35.7	Filler		5-7% on wet weight of glue
B	Heptachlor	11.1	Tetrachlorphenol Tributytin oxide Filler	 2.2	7-9% on wet weight of glue
C	Heptachlor Lindane	48.0 2.0	Wood powder	50.0	6-10 parts per 100 parts of wet glue (about 5.7-9.1%)
D	Aldrin Lindane	4.0 1.0	Tetra & Pentachlorphenol Tributyltin oxide Solvent	 1.2	12-15% on wet weight of glue
E	Aldrin Lindane	3.75 0.75	Monochlornaphthalene di-bucyl phthalate Other		12-15% on wet weight of glue
F	Dieldrin	10.0	Solvent (2-butoxyethanol)	90.0	6% on wet weight of glue

PLYWOOD

All preservatives were tested in plywood of $^{11}/_{16}$ inch nominal thickness made in this Division under carefully controlled conditions from mountain ash (*Eucalyptus regnans*) heartwood veneer. This plywood contained 3 inner laminations each $^{3}/_{16}$ inch thick with a $^{1}/_{16}$ inch veneer on both faces. The glue used was Monsanto PP 781 phenolformaldehyde resin. The glue spread was controlled very accurately at 60 lb/1000 square feet of double glue line calculated on the weight of the resin without additives.

Topic 2/25

WEATHERING

The small specimens ($3\frac{1}{2} \times {}^{3}/_{4} \times {}^{11}/_{16}$ inch) used for the termite test were given a severe artificial weathering treatment before exposure to termite attack. This weathering consisted of 3 periods each of 5 days in the vacuum oven at 60°C and 25 inch vacuum. After the first and second periods the specimens were pressure impregnated (200 psi) with water and allowed to soak overnight before air drying and returning to the vacuum oven. This severe weathering schedule was given in an effort to render the treatments sufficiently susceptible to attack for comparisons of their relative performance to be made.

TERMITE BIO-ASSAYS

The method of test was generally similar to that developed by Gay and colleagues and used in previous assessments reported to you, except that we now use 5 replications in separate jars, and in this particular test reduced the exposure period from 84 to 42 days. Two termite species were used, *Nasutitermes exitiosus* and *Coptotermes acinaciformis*.

Results of the termite assessments are summarized in Table 2.

TABLE 2. Results of Termite Bio-Assays

Preservative	Preservative Retention lb/ft of plywood		*N. exitiosus*		*C. acinaciformis*	
			% eaten[1]	% survival	% eaten[1]	% survival
A	Total[2] Heptachlor	.151 .054	4.4	3.1	4.0	65.3
B	Total Heptachlor	.195 .022	21.0	60.2	15.4	71.7
C	Total Heptachlor	.213 .102	3.2	0 (in 41 days)	2.8	67.1
D	Total Aldrin	.322 .013	4.0	13.5	6.6	72.6
E	Total Aldrin	.322 .012	12.1	21.0	10.9	70.5
F	Total Dieldrin	.129 .013	6.9	1.4	10.8	71.1
Untreated controls	-		62.7	76.4	39.8	72.9
Unfed Colony	-		-	32.6	-	69.5

[1] All percentages are calculated on the oven dry weight of untreated controls before test.

[2] By "total" is meant the complete additive including filler or solvent.

COMMENT

(a) Preservative A

This glue additive has performed very well and is equal to or slightly better than Preservative D in termite resistance. However, the amount of heptachlor in the wood is a lot higher than the corresponding content of chlorinated hydrocarbon insecticide in Preservative D and for this reason we would think that any approval of Preservative A as an insecticidal treatment for plywood in shipping containers would be dependent on an assessment of whether it is safe to use. The much inferior performance of Preservative B is an indication that to reduce health hazard by any considerable reduction in heptachlor content would impair its termite resistance.

(b) Preservative B

Based on the results obtained, this preservative is not sufficiently effective against termites and we would therefore be reluctant to recommend it unless the heptachlor content was at least doubled or even trebled. This would of course again raise the question of health hazard, but it would then have an advantage over the Preservative A formulation because of its high fungicidal content.

(c) Preservative C

Although this glue additive has proved highly effective against termites, it appears, by comparison with Preservative A that its heptachlor content is unnecessarily high and that it could probably be halved without significantly impairing its insecticidal properties. However, even with this reduced content of heptachlor we would think that any approval for its use in shipping containers would be dependent on an assessment of the health hazard.

(d) Preservative D

This preservative performed well, though probably because of the more severe weathering it was not as completely effective as in some earlier tests. It has the advantage of containing a high content of fungicide and a very much lower concentration in the wood of chlorinated hydrocarbon. Even if the lindane is added to the aldrin the figure of .013 lb/ft^3 rises to only .017 lb/ft^3 which seems to suggest a lower health hazard than the heptachlor contents of 3 and 6 times this amount in the Preservative A and Preservative C.

Despite the small amount of attack which occurred we consider that the present termite tests have confirmed the earlier ones and that it is reasonable to regard this preservative as a yardstick for comparison of other formulations.

(e) Preservative E

We understand that this formulation is still experimental. In the present termite tests and in some preliminary tests with decay fungi it has not proved as effective in preventing attack as the older Preservative D formulation and at this stage we would be reluctant to recommend it for treatment of plywood in containers.

(f) Preservative F

Dieldrin dissolved in butyl cellosolve (2-butoxyethanol) was included in the test so that it could be compared at low concentration in the wood with the much higher levels of heptachlor in the Preservative A and Preservative C treatments and also compared with the Preservative D.

Although heptachlor (before weathering) is more toxic in wood to termites than dieldrin (weight for weight) we have been concerned that its greater volatility would affect its permanence. The results of the present test strengthen this expectation and indicate that dieldrin alone, at upwards to twice the loading used (probably as low as .020 lb/ft^3), should give satisfactory termite resistance. If health hazards are to be considered it therefore appears that dieldrin or aldrin are preferable to heptachlor because they remain effective during weathering at lower concentrations in the wood.

THE EFFECTS OF INSECT GROWTH REGULATORS ON WOOD-DESTROYING INSECTS

John French and Peter Robinson

SUMMARY

Bioassays using an insect growth regulator (juvenile hormone analogue) on filter paper and impregnated into wood specimens induced the development of superfluous soldiers in *Coptotermes acinaciformis*, *Mastotermes darwiniensis* and *Nasutitermes exitiosus*. The nymphs of *C. acinaciformis* and *N. exitiosus* were very susceptible to low doses of the juvenile hormone analogue (JHA) (0.1 - 0.05%) and developed into intercastes. Repellent behaviour was witnessed in workers of *M. darwiniensis* when placed with JHA treated wood, both leached and unleached specimens. The JHA at 1.0 and 0.5% prevented adult emergence of *Lyctus brunneus* from within treated wood veneers. At the 0.25% level of JHA, larval activity was observed but no adults emerged. The possibility of using JHA-type compounds in future timber preservation is briefly discussed.

INTRODUCTION

As was pointed out in the 16th Forest Products Conference in 1973 (French 1973) that feasible alternatives other than organochlorines (aldrin, dieldrin, DDT, chlordane, heptachlor etc.) in termite control are being investigated as part of a new pest management strategy (French 1975). The approach is aimed at disruption, not so much eradication, of the wood-destroying insects in the protection of wood products. Substitutes for the broad-spectrum, persistent organochlorines must also be persistent yet have minimal hazards to man and the environment. Insect growth regulators which have most of the above criteria may be suitable candidates. These compounds, such as juvenile hormone analogues (JHA) are currently under test in this Division. JHA's may interfere with oviposition, delay larval metamorphosis and affect caste differentiation in termites (Lüscher 1972, Wanyoni and Lüscher 1973 and French 1974) and produce nymphal intercastes. Wanyoni and Lüscher (1973) showed that low doses of JHA (0.02 mg) inhibit moulting, at slightly higher doses prevent development of replacement reproductives and alates and at the highest doses (0.4 mg) lead to pre-soldier formation. Our paper offers similar evidence and describes the effects of JHA on several termite species (*Coptotermes acinaciformis* Frogg., *Mastotermes darwiniensis* Frogg., and *Nasutitermes exitiosus* (Hill)) and a wood-destroying lyctid beetle (*Lyctus brunneus* (Stephen)). To our knowledge this is the first report of any effects of a JHA on the growth and development of *L. brunneus*.

MATERIALS AND METHODS

Colonies of *C. acinaciformis* were collected from mounds in the field near Canberra, *M. darwiniensis* from Townsville, and *N. exitiosus* from near Seymour. *Lyctus brunneus* beetles were obtained from laboratory cultures that have been maintained in this Division for several years by A. Rosel. All insects were kept in laboratory cultures prior to exposure to the JHA (Altozar: ethyl 3,7,11-trimethyldodeca-2,4-dienoate).

Termite bioassays - All bioassays were set up within glass petri dishes. Each dish had a thin water agar (1.0%) base (2 mm depth), onto which a similar depth of Plaster of Paris was poured, and the whole allowed to stand for 24 hrs prior to introduction of JHA treated filter papers (9 cm diam.) or wood specimens (25 x 15 x 5 mm of *Eucalyptus regnans* F. Muell. sapwood) and termites.

Initially, concentrations of 1.5, 1.0, 0.7, 0.5, 0.3 and 0.1% solutions were used on all termite species. However, early experiments at this range of JHA gave poor survival of *C. acinaciformis* during the test period (21 days), so lower concentrations of 0.2 to 0.05% JHA solutions were selected.

Individual filter papers were treated with 0.2 ml of each JHA concentration, evenly pipetted onto the 9 cm diam. surface, and the solvent allowed to evaporate prior to placing within the petri dish and introducing the termites. Five replicates per concentration with five solvent controls were arranged per bioassay. Batches of 45 large workers and 15 small workers of *C. acinaciformis* and *N. exitiosis* (French 1974) and 10 randomly selected workers of *M. darwiniensis* per dish were set up.

Preliminary tests (unpublished data) had shown that the JHA had repellent properties against *N. exitiosus*, so a small test was arranged to determine if such was the case using *M. darwiniensis*. Unleached and leached (7 days continuous washing at 36°C) wood specimens were impregnated with 1.5% and 0.6% JHA solutions which were applied using a 29 inch vacuum (30 mins.) and a pressure of 200 p.s.i. (30 mins.).

Test conditions of 26°C and 80% R.H. were selected for *C. acinaciformis* and *N. exitiosus*, whereas *M. darwiniensis* were kept at 32°C and 60-70% R.H. All bioassays were examined every 3 days and any morphogenic or other effects recorded.

Lyctus brunneus bioassay - Starch laden wood veneers (75 x 25 x 3 mm *E. obliqua* L'Herit. sapwood) were impregnated with 1.0, 0.5, and 0.25% JHA solutions. A synergist, piperonyl butoxide, was added at concentrations of 4.0, 2.0 and 1.0% solution strengths. The treatment regime was a vacuum pressure of 29 inches for 30 mins.; 200 p.s.i. for 60 mins.; air dried for 7 days and sterilized at 50°C for 30 mins. prior to test. Two replicates per concentration with 10 beetles (unsexed) per concentration per petri dish were set up. The veneers were raised slightly by placing them on top of glass microscope slides within the dishes. All petri dishes were conditioned in the dark at 26°C and 80% R.H. and the test period was 15 weeks.

RESULTS AND DISCUSSION

Termite bioassays - The treatments with JHA on the filter papers had a progressive morphogenic effect on the number of workers that were induced to presoldiers within 3 weeks depending on the concentration of JHA added. In all termite bioassays presoldiers were formed within 14-16 days at the 0.5% JHA levels. There was some slight variation in the *M. darwiniensis* cultures as regards time of formation of presoldiers. Cultures kept more than 10 months in the laboratory produced presoldiers within 14 days when tested during the winter months, whereas another bioassay carried out in spring with freshly collected workers took 25 days to produce presoldiers.

This may indicate a seasonal variation in the effects of termites, particularly *M. darwiniensis*, to various concentrations of JHA. However little information is available on the seasonal variation of the ratio of workers to soldiers in most termite species and even less on the hormonal balance of this ratio over time. Further studies are continuing to examine this aspect in an endeavour to use insect growth regulators in termite control with the maximum disruptive effects. The higher levels of JHA proved toxic to *C. acinaciformis* as was shown by Wanyoni and Lüscher (1973) with the effects of JHA on damp-wood termites of the *Zootermopsis* spec ies. Although the lower doses (less than 0.1%) produced morphogenic effects, it is possible that they may inhibit moulting over a larger period of test (Wanyoni and Lüscher 1973).

Nymphs of *C. acinaciformis* and *N. exitiosus* (we had no *M. darwiniensis* nymphs) were very susceptible to doses of JHA. Both species of termites produced intercaste nymphs after 18 days even on the 0.1% JHA solutions. Unfortunately, when these intercastes were set up for further investigation there was high mortality and we are unable to assess whether or not these individuals were capable of producing progeny.

The repellency test using *M. darwiniensis* was a little inconclusive. Repellency was based on the number of workers recorded on the treated wood specimens at each inspection. However, on the unleached specimens, within 2-3 days there was a definite trend away from the blocks when compared with the numbers feeding on the solvent and untreated controls. In the leached specimens, there was a slight trend away, though not as pronounced as in the unleached specimens; which suggests that sufficient JHA was "fixed" within the wood to produce some degree of repellency. Again, this feature of a possible repellent effect of JHA on termites is under investigation (using a choice and a no-choice situation) and in the field. If this should prove positive, coupled with fungal attractants (now under test) and a selected-specific poison (= mirex) or moulting inhibitor (= phenyl urea compounds), one may disrupt termite colonies so severely as to prevent further attack on wood products. The environmental hazard would be minimal as such a strategy would be extremely target-specific. What is required is an Australian source of naturally produced JHA-like and/or repellent compounds which would decrease our present dependence on overseas JHA supplies (see Yazaki, Hillis and French 1975 in this Conference). Another facet of our research is the formulation of possible new preservatives using JHA-like natural products with oils and fungicides added. We consider that the probability of newer and environmentally cleaner timber technology is hopefully closer to hand in light of the rapid advances in biological knowledge and the constraints on the current world supply and distribution system.

Lyctus brunneus bioassay - The results (Table 1) show that at JHA doses of 1.0 and 0.5% there was no adult emergence after 15 weeks after the parent beetles had laid eggs. At 0.25% JHA solutions there was larval activity, as witnessed by the presence of small amounts of frass under the veneers, but no beetle emergence. Due to the limited availability of beetles at the time of testing, no solvent controls were set up with the synergist. Also, due to shortage of time, the veneers were neither x-rayed nor dissected and viewed microscopically. So it is not clear if the JHA acts as an ovicide, larvicide or a general growth inhibitor. Such effects have not been recorded previously for lyctid beetles, and this suggests a possible new control method for wood destroying beetles. Under test is a larger version of this experiment and an experiment using JHA with arsenic in a glueline additive.

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TABLE 1. Showing the number of beetles of *L. brunneus* emerging from JHA treated wood veneers after 15 weeks after the parent beetles had laid eggs

Ref. # veneer	JHA (%) treatment	Synergist added %	JHA loadings Kg/m^3	After 15 weeks	
				Numbers adults emerged	Larval activity as shown by frass produced
1	1.0	0	4.32	0	-
2	1.0	0	4.62	0	-
3	1.0	4.0	4.20	0	-
4	1.0	4.0	4.88	0	-
5	0.5	0	2.47	0	-
6	0.5	0	2.75	0	-
7	0.5	2.0	1.94	0	-
8	0.5	2.0	2.46	0	-
9	0.25	0	1.24	0	+
10	0.25	0	1.13	0	(+)
11	0.25	1.0	1.21	0	-
12	0.25	1.0	1.18	0	(+)
13	Solvent	0	0	0	+
14	control	0	0	0	(+)
15	Untreated	0	0	4	+++
16	control	0	0	0	+++

Key: (+) = Slight frass visible; + = Moderate frass visible;
+++ = Copious amount of frass visible.

Topic 2/27

COMPARATIVE TESTS OF SUPERFICIAL COATINGS AND DIP-DIFFUSION TREATMENTS FOR LYCTUS-IMMUNIZATION OF VICTORIAN EUCALYPT FRAMING TIMBERS

N. Tamblyn and A. Rosel

1. Background

In June 1971 many members of the Victorian pest control industry attended a wood borer conference at the CSIRO Forest Products Laboratory. At this conference there was some dispute as to the effectiveness of spray treatments in preventing Lyctus attack in Victorian eucalypt house-framing timbers. It was then agreed that the Forest Products Laboratory, Division of Building Research, would set up tests to prove or disprove their contention that such treatments are often ineffective and should be abandoned - probably in favour of a dip-diffusion process applied at the sawmill. These tests have now been completed and results are here briefly reported.

2. Spray treatment of frames

Logs from 5 trees each of messmate stringybark (*Eucalyptus obliqua*) and of mountain grey gum (*E. cypellocarpa*) were sawn to obtain timber of approximately 76 x 38 mm (3 x 1½ inch) cross section containing as much sapwood as possible. Generally the round face in this timber was left intact to retain the full depth of sapwood. This timber was air dried and used without dressing to make 24 small nailed frames of each species. Each frame consisted of 2 horizontal pieces about 305 mm (12 inch) long nailed top and bottom to 3 uprights about 178 mm (7 inch) long. As far as possible each frame was matched to contain material from each of the 5 trees of the species it represented.

As timber in a house frame erected in summer may often be exposed to Lyctus infestation for several weeks before spraying, the test frames were divided into two groups - (a) frames inoculated with Lyctus beetles 4 weeks before spraying, and (b) frames inoculated 8 weeks before spraying. For this inoculation each frame was caged separately with 20 beetles.

Twelve different spray treatments were given as summarized in Table 1. The emulsions were made by dissolving the insecticide in toluene, adding the emulsifying agent (a mixture of "Atlox" ionic and anionic compounds) and then blending in the water. A small amount of "Prosol 155" (a clear very high boiling mineral oil) was included so that a slight oiliness would be retained in the surface deposit of insecticide. A typical emulsion was made as follows - toluene 1.75, dieldrin 0.50, "Prosol 155" 0.50, emulsifier 0.075, water 97.075 (all figures as percent by weight). After spraying, frames were placed in a warm room (about 27°C and 70% relative humidity) and held there throughout the test. After the first inspection at 9 months, frames were re-inoculated with Lyctus beetles.

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TABLE 1. Results of Spray Treatments (Frames)

Spray % W/W	Spray Application	Timber Species*[1]	No. of Lyctus beetles emerged*[2]			
			Inoculated 4 weeks before spraying		Inoculated 8 weeks before spraying	
			at 9 months	at 19 months	at 9 months	at 19 months
0.5% dieldrin emulsion	Thorough*[3]	MS	4	135	15	68
		MGG	nil	18	11	31
	Careless*[4]	MS	nil	67	27	84
		MGG	4	270	29	148
0.5% aldrin emulsion	Thorough	MS	4	130	3	51
		MGG	12	56	13	82
0.5% aldrin emulsion (no Prosol)	Thorough	MS	3	401	nil	362
		MGG	12	56	13	82
0.5% aldrin in mineral turpentine	Thorough	MS	nil	400	nil	117
		MGG	nil	101	nil	203
	Careless	MS	nil	293	1	159
		MGG	nil	303	nil	180
0.75% lindane emulsion	Thorough	MS	16	60	35	54
		MGG	6	33	34	41
	Careless	MS	10	24	65	93
		MGG	8	25	17	112
2% chlordane emulsion	Thorough	MS	42	422	157	867
		MGG	66	587	184	472
Control-mineral turpentine only	Thorough	MS	nil	532	3	424
		MGG	4	224	nil	222
Control-water only	Thorough	MS	30	194	125	341
		MGG	91	570	180	486

*[1] MS = messmate stringybark; MGG = mountain grey gum.

*[2] Determined by counting emergence holes.

*[3] All wood thoroughly coated and joints well jetted.

*[4] Bottom face of bottom board not sprayed, no special attention to joints.

3. Diffusion treatment of frames

Timber from the same logs used in the spray tests, cut similarly to retain the maximum depth of sapwood, was given a diffusion treatment while still green. For this treatment the timber was cut into 610 mm (2 ft) lengths, dipped momentarily in the concentrated (30% w/w) preservative solutions, and then block stacked under polythene wraps to prevent drying for periods of 4 and 6 weeks. This diffusion was done during August-September and temperatures taken frequently in the diffusion stacks ranged from 10.6 - 14.4°C.

After the diffusion the timber was air dried fairly rapidly and the 610 mm lengths then cross-cut into 2 horizontal and 3 vertical pieces so that every piece used in the frames would have at least one end where any untreated sapwood would be exposed. Frames were identical with those used in the spray tests and were similarly inoculated each with 20 Lyctus beetles before placing in the same heated room as the sprayed frames.

The preservative solutions used and the results obtained are summarized in Table 2.

TABLE 2. Results of Diffusion Treatments (Frames)

Preservative solutions % w/w		Diffusion period	Timber species	No. Lyctus beetles emerged	
				at 9 months	at 19 months
Solution A		4 weeks	MS	NO EMERGENCE	NO EMERGENCE
Boric acid (H_3BO_3)	13.8		MGG		
Borax ($Na_2B_4O_7.5H_2O$)	16.2	6 weeks	MS		
Water	70.0		MGG		
Solution B		4 weeks	MS	NO EMERGENCE	NO EMERGENCE
Boric acid (H_3BO_3)	24.0		MGG		
Sodium fluoride (NaF)	6.0	6 weeks	MS		
Water	70.0		MGG		

4. Further laboratory tests

To investigate further the effectiveness of the dip-diffusion treatment and also the effect of different block stacking periods, additional material of 76 x 38 mm (3 x 1½ inch) cross section from all trees was end matched with that used in the diffusion-treated frames and treated at the same time. This additional material was cut as 610 mm (2 ft.) lengths, dipped green, and block stacked for periods of 2, 4 and 6 weeks (temperatures 10.6 - 14.4°C). After fairly rapid air drying a single 178 mm (7 inch) long specimen was cut from the centre of each piece. To ensure exposure of any untreated wood this 7 inch specimen was then cut longitudinally through the sapwood and again cross-cut to yield 4 small specimens about 89 mm (3½ inch) long by 38 mm (1½ inch) square cross section. These small specimens together with matched untreated controls were tested for Lyctus susceptibility by the standard breeding technique developed by Rosel (1). Results are summarized in Table 3.

TABLE 3. Effect of Diffusion Period (Small Specimens)

Preservative	Tree No.	No. of Lyctus beetles emerged*[1]					
		Block stacked 2 weeks		Block stacked 4 weeks		Block stacked 6 weeks	
		MS*[2]	MGG*[2]	MS	MGG	MS	MGG
No. 1 (see Table 2)	1	3	nil	nil	nil	nil	nil
	2	nil	nil	nil	nil	nil	nil
	3	nil		nil	nil	nil	nil
	4	nil	nil	nil	nil	nil	nil
	5	2	2	nil	1	nil	nil
No. 2 (see Table 2)	1	nil	nil	nil	nil	nil	nil
	2	nil	3	nil	nil	nil	nil
	3	nil	nil	nil	nil	nil	nil
	4	nil	nil	nil	nil	nil	nil
	5	nil	4	nil	3	nil	nil
UNTREATED CONTROLS	Beetles emerged from		Tree 1	Tree 2	Tree 3	Tree 4	Tree 5
		MS	145	92	184	70	321
		MGG	63	11	119	117	250

*[1] Total emergence from 4 specimens each 89 x 38 x 38 mm (3½ x 1½ x 1½ inch).

*[2] MS = messmate stringybark; MGG = mountain grey gum.

5. Discussion

Although the spray treatments gave some protection during the first year they were all ineffective in varying degree when inspected at 19 months (i.e. about 9 months after the second inoculation). This was irrespective of whether the spray was applied thoroughly or carelessly. It might be argued that spraying before any infestation could occur would have produced better results but this appears to be very doubtful in view of the heavy subsequent emergence from those frames which showed no visible attack at the first inspection. Under the warm room conditions all beetle emergence from the first inoculation would surely have been completed before 9 months and the heavy subsequent attack would therefore indicate that the insecticides used do not have a high degree of permanence when applied as a superficial coating. This is in accord with the findings of Morgan and Purslow (2) who have shown that in superficial treatments volatilization of insecticides such as lindane and dieldrin is very considerable (up to 69% for lindane) in a period of 2 years at ambient temperatures.

The dip-diffusion treatments as used in the frames have so far given complete protection despite the fact that any untreated sapwood present was exposed at one end of each of the 5 members in each frame. The commercial attractiveness of this treatment must depend to a great extent on the length of the block stacking period required which in turn is dependent on the temperature during the diffusion period. Results from the frames and the small specimens indicate that a diffusion period of 4 weeks would be desirable at temperatures within the range 10-15°C. However as

rate of diffusion is approximately doubled for each 20°C temperature rise this period could be reduced to about 2 weeks by block stacking in sheds heated to about 30-35°C. With higher temperatures it could be further reduced provided drying of the timber could be prevented.

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DUTCH ELM DISEASE BEETLE IN AUSTRALIA

J. R. J. French and A. Rosel

INTRODUCTION

In January of this year, live specimens of the smaller European elm bark beetle, *Scolytus multistriatus* (Marsham) (Coleoptera: Scolytidae) were collected by one of the authors (A.R.) from elm branches in Melbourne. The discovery of this insect is extremely important, as it is one of the main vectors or carriers of the Dutch elm disease fungus, *Ceratocystis ulmi* (Buism.) C. Moreau. Dutch elm disease is one of the most devastating tree diseases of our age and annually the cause of the loss of many thousands of valuable elm trees in the northern hemisphere. The presence of the beetle in Australia is thus of considerable importance, though fortunately, at present it does not appear to be carrying the pathogenic fungus.

Distribution of the beetle in Australia

In Australia, elms infested with *S. multistriatus* have been found in a number of parks and gardens within 10 km radius from the centre of Melbourne. Whether the beetle is more widely distributed in Australia is as yet unknown. However, there are no records or specimens of *S. multistriatus* collected in Australia in any Australian museum and none have been received from Australia by the British Museum. To our knowledge no previous surveys of this insect have been published in Australia. However, elms have been planted as ornamentals throughout the temperate regions of Australia, this includes Tasmania. In Melbourne and Sydney, elms have been extensively planted in streets, parks and gardens. In Canberra, and towns in the northern tablelands, such as Armidale (about 900 km north of Sydney) they have many elms planted as shade trees.

As in the northern hemisphere, the beetle has only been collected from elm species.

Status of the beetle in Australia

The amount of damage as observed by the number of emergence holes, or shot-holes, in the bark of attacked elm branches in Melbourne, and the number of live beetles collected suggests that this Scolytid has been in the area for at least two, and probably, several years. At present *S. multistriatus* is not causing any wholesale destruction of elms but it seems likely that very heavily infested limbs, and the occasional tree, may die from ring barking caused by larval feeding in the cambial zone. However, if spores of the pathogenic fungus are introduced into Australia, it is almost certain that the disease would spread rapidly through the elm population in Melbourne and beyond to elms in other towns, and probably to other States. The effect of the loss of elms as an ornamental tree in parks, streets and gardens cannot be readily calculated in monetary terms in our present highly urbanized society, but their aesthetic value to our urban community is almost beyond estimation.

Current investigations in Australia

This Division has contacted all State Departments of Agriculture and Forest Commissions, Australian Museums, the British Museum, the Parks and

Gardens Department in Melbourne and the Commonwealth Department of Plant Quarantine, and informed them of the presence of *S. multistriatus* and its potential hazard. None of the institutions contacted had any specimens of the beetle in their collections, indicating that this is the first known record in Australia.

The beetle is being reared in our laboratory. Data on its life cycle in Melbourne compares similarly to the life cycles of northern hemisphere beetle populations. Together with culturing the beetle, isolations have been made from various life stages and from infested elm materials to detect the presence of *C. ulmi*. So far, none of the fungi isolated have been identified as the pathogen. Although this does not mean that the disease is not in Melbourne, it is the considered opinion of an American authority on this Scolytid that the disease would have manifested itself by now if present. He mentions that the situation in Australia and the West Coast of North America are similar, namely, the vector is present, but not the disease.

Requests have been sent to research workers in Canada, U.S.A. and England to obtain information on current research and control methods on the Dutch elm disease.

Control measures

At present, there is no practicable method known by which the beetle, *S. multistriatus* can be eradicated in areas where it is well established and where there are many elms. However, some degree of control is possible by a combination of sanitation felling, insecticide spraying and possibly breeding resistant varieties of elm. Meanwhile sanitation felling of infected trees or branches is one segment of control which can readily be carried out immediately with little cost other than labour, as a chain saw and a bark destroyer of some kind are all that is necessary in the way of support for this beetle population control method.

As dead and dying elm material is used for breeding by the beetles, the prompt destruction of these materials is recommended. All dead and dying trees should be removed and burnt. Trees that are weakened, for instance, by drought conditions are more likely to attract beetles, so that pruning of all dead and dying branches should be carried out. These procedures must be thorough and repeated over all the elm population if possible, as adults of *S. multistriatus* are capable of being blown or flying for considerable distances, probably several kilometres.

Research in England has shown that a more aggressive strain of the causal fungus *C. ulmi* can be transmitted without the aid of bark beetles (Gibbs, 1974). There is clear evidence of disease transmission either along the common root system of elms or across root grafts between neighbouring trees. Further, the researchers consider that sanitation felling could not be expected to check such disease transmission unless trees were felled before the fungus had reached the roots. The already strict quarantine control to prevent the import into Australia of any elm wood, even as dunnage, is very necessary if we are to avoid introduction of the fungus.

The insecticide methoxychlor has been partially effective for controlling the beetle in trials in the United States (Peacock, 1973). Again this is a costly business and there is the added risk of damage to neighbouring crops

or gardens due to drift. Any spraying programme must be carefully considered in light of the environmental impact.

In Europe and North America experiments have been conducted with a systemic insecticides and fungicides which can be watered on to the ground around the roots or injected into the trunk (Kondo and Huntley, 1974) and in Australia a small collaborative experiment with Dr. John Peacock's group from the United States is proposed to assess the effectiveness of an aggregation pheromone technique (Peacock et al., 1974) in obtaining data on flight patterns and beetle populations.

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BEHAVIOUR OF CURRENTLY AVAILABLE EXTERNAL FINISHES FOR WOOD

K. R. Bootle

A continual flow of new commercial products shows the interest in natural finishes despite the smaller amount of timber now used for cladding.

In the clear finish field products along the lines publicised by Princes Risborough Laboratory several years ago are being examined by us. These materials, from overseas commercial interests, have a small amount of inorganic pigment as ultra-violet absorber but not sufficient to mask the character of the timber. However they have a varnish-like surface build, so when they fail, as they do quite readily over any fine checks in the wood, there is a break away of the full depth of the coating along such checks, resulting in an unattractive appearance, difficult to restore satisfactorily. Carefully applied to a perfect surface such products behave well but this state of affairs is seldom possible in practical building.

In regard to the oil-based finishes whose genesis was the Madison formula circa 1957 there has been a change towards a much lower oil content because of the problem of fungal invasion, often resulting in an unacceptable degree of darkening of the finish. The fungicides that have been used, such as mercurials, pentachlorophenol, tri-butyl tin oxide, have been unsatisfactory, at least in the concentrations acceptable from the health angle, so there is much interest in other fungicides, hopefully of relatively low mammalian toxicity. Some of those being considered are:-

Busan 35 (3', 5' dichloro 4' hydroxyacetophenone)

Captafol (N(1,1,2,2 - tetrachloroethyl thio) 3a, 4, 7, 7a - tetra hydrophthalimide)

Fungitrol 11 (N-trichloromethyl thiophthalimide)

Giv-gard DXN (6 - acetoxy - 2,4 dimethyl - m - dioxane)

Skane 8 (2 - n - octyl - 4 - isothiazolin - 3 - one)

The oil based products commercially available range from very light to fully obscuring pigmentation, the latter generally giving better service life, presumably because of better protection of other constituents and wood surface from ultra violet degradation. However the comment is often made that they obscure the character of the timber; this is true of dressed surfaces, but unless the wood is very absorbent one would not normally recommend them for dressed surfaces. A sawn surface generally has enough "woody" character revealed by the action of the saw.

The trend in surface coatings generally seems to be towards the use of acrylics; the absence of unpleasant solvents, the ease of application and brush clean-up have obvious advantages. Fungal invasion is much less noticeable than on most oil-based natural finishes. In a current test series, embracing all types of commercial natural finish, an acrylic was the outstanding product from aspects of both clean appearance and integrity of coating. This ability of acrylics to maintain a cleaner surface is also noticeable on our test panels of exterior pigmented paints, in contradistinction to their behaviour when first introduced a decade ago; at that time the coating was too soft and allowed deep penetration of dirt.

Black and Mraz of the Madison Laboratory have reported (1) significant improvement of the wood substrate in regard to swelling and ultra violet degradation when it has been given a preliminary brush coating of certain chemicals, such as ammonium chromate, ammoniacal copper chrome arsenate, copper and iron molybdates, copper ferricyanide, ammoniacal copper oxide and copper pentachlorphenate.

They claim that such treatment gives much better service life to coatings transparent to ultra violet radiation, such as silicone and acrylic latex. The silicone finish was especially impressive, though it has not been normally accepted as a finish because of cost, and flow and curing characteristics. As an aside, our limited experience with silicones a decade or more ago was unfavourable. It is proposed to test some of these suggested pretreatments in 1975.

The water-based acrylics have limitations when used on their own in pale colours; soluble extractives from many species penetrate and discolour them unless an oil-based primer is used. Such a primer is not very compatible with the water-based acrylic and spreadability is often affected. Desai, Dolenko and Clarke of the Ottawa Laboratory have reported (2) success on western red cedar with salt-latex primers based on ammoniacal zinc carbonate or zinc thiocyanate with a 10% solids acrylic latex. Some trials with ammoniacal zinc carbonate have been carried out by us on blackbutt with inconclusive results. The salt-latex solution seemed rather too watery for even spreadability. After six months northerly exposure at 45°, all panels, whether with salt-latex, acrylic primer, oil primer or three coats of acrylic top coat without primer, are all free of stain so perhaps all one needs is patience.

References

1. Black, John M. and Mraz, Edward A. 1974. Inorganic Surface Treatments for Weather-Resistant Natural Finishes. U.S.D.A. For. Service Research Paper FPL 232.

2. Desai, R. L., Dolenko, A. J. and Clarke, M. R. 1973. Salt Polymer Compositions in Wood Protection. Proc. IUFRO Conference, Pretoria, South Africa.

WATER REPELLENT TREATMEMTS FOR PLATFORM FLOORING

K. R. Bootle

As a result partly of the fact that most floors are now covered (and therefore can accept some imperfections) and partly of the increasing competition from sheet materials, there is an increasing tendency to nail strip flooring into final position as soon as bearers and joists have been placed. This means that the seasoned boards are usually subjected to several months of weathering before the building is closed in and roofed.

For a number of years some builders who used cypress pine in this way have claimed that the application of sump oil gave it sufficient protection.

In 1972-73 observations were made on an all-brick job, where the builder used one mopping of oil initially, followed by a second one at the start of bricklaying. Initial moisture content was mainly 13% but soon reached 16% on exposure. Even after the roof was made weatherproof the presence of the wet plaster walls kept many areas of floor too wet for moisture meter readings. An examination of the floor three months after completion of wet trades, and after sanding, showed deep oil stains at butt joints and plenty of gaps, between boards, of 2 mm width.

In order to be able to make a direct comparison between various types of possible treatments, flooring panels 1800 mm x 900 mm of brush box, tallowwood and cypress pine were treated with resin sealer, microcrystalline wax, engine oil and proprietary water repellent and exposed to the weather for nine weeks of winter weather, during which 125 mm of rain fell in a number of well scattered falls.

Moisture contents reached the following figures:

Cypress pine with resin sealer	20.5%
" " " wax	20.5%
" " " engine oil	22%
" " " water repellent	18.5%
" " untreated	22%
Brush box with resin sealer	19%
" " " wax	20%
" " " engine oil	19%
" " " water repellent	19.5%
" " untreated	19.5%

After the timber returned to e.m.c. joints opened up as much as 2 mm. Iron staining around the nail holes was considerable on the hardwood.

Panels treated with engine oil present problems in sanding, for the paper clogs very quickly. Even when the oily surface layers are removed from the floor the presence of oil is likely to manifest itself again after a number of hours, and some discolouration of pale timber can be expected.

The wax coating was very slippery when first applied and at the end of the test period was very difficult to remove by sanding because of excessive clogging of the paper. The alternative is to give a preliminary wash down with turpentine but this is obviously too hazardous to be practical on a large scale on the building site.

Taking the two treatments considered most practicable, namely the water repellent (Cellavit) and resin sealer (Spartan), test panels of radiata pine of size 1800 mm x 900 mm were exposed for four months (June to October) during which 127 mm of rain fell. The moisture content of the pine when laid was in the range 11.5 to 12.5% and the solutions were mopped on liberally. Within four days, despite absence of rain, the moisture content reached 18%. After rainy periods the moisture content reached 20-21% but was mainly around 15-17%. There was no significant difference between the moisture resistance of the two treatments but the water repellent did keep the surface cleaner, probably due to its fungicidal constituent.

After the panels had been allowed to dry under cover they were sanded, an average of 1 mm being removed. Areas intentionally stained by leaving steel nails on the surface during exposure required an additional 0.5 mm to remove the discoloration. The gaps between the boards were mainly 1 mm but some exceeded 1.5 mm.

Samples of flooring grade particleboard approx. 470 mm square, of urea and phenolic bonded types, were exposed for five weeks in November-December during which time 80 mm of rain fell in six separate falls. Water repellent (Cellavit) and resin sealer (Spartan) were each applied in one coat to face and edges. Treated panels and controls all increased in edge thickness by about 1 mm, while the treated panels were no more stable than the controls in their other dimensions.

The lending authorities in their booklet of acceptable standards of construction, at Clause 25, require that both strip flooring and sheet flooring used in platform construction where a decorative finish is required are to be sealed with a water repellent at the time of fixing.

It is suggested by our experiments that the treatments are of no benefit in stabilising the flooring, whether it be strip or sheet. If a floor of decorative quality is to be obtained the flooring should be either fully protected from the weather at all times or at least not fixed into final position until stable indoor conditions are achieved.

TOPIC 2 COMMENTS

2/1c The effect of selection for vigour and straightness on wood quality parameters
W.J. Smith and P.J. Allan

2/2c Physiology of wood formation in Honduras caribbean pine
W.J. Smith and Jill M. Fett

2/3c Age estimation in cypress pine on the basis of wood anatomy
Jill M. Fett and W.J. Smith

2/4c Withdrawn

2/5c Growth stress in wood, its assessment, variation and alleviation
W.E. Hillis, S.C. Chafe and A.N. Rosza

2/6c The formation of shakes in living trees
W.E. Hillis, J. Bauch and Y. Yazaki

2/7c Natural components that are toxic and repellant to termites
Y. Yazaki, W.E. Hillis and J.R.J. French

2/8c Withdrawn

2/9c The need for a better definition of the term "sapwood"
K. Cokley

2/10c Copper arsenate as an alternative to CCA
N.A.H. Smith and A. Zosars

2/11c Comments on the need for a substitute for boron
J. Norton and M. Kennedy

2/12c Current studies on drywood termites
C.D. Howick

2/13c Collaborative preservative tests with the International Research Group on Wood Preservation
E.W.B. Da Costa

2/14c Prolonging life of transmission poles in service
R. Johanson

2/15c To protect use of arsenic
R. Johanson

2/16c Withdrawn

2/17c Influence of extractives and the chemistry of wood constituents on wettability and penetrability
K. Cokley

2/18c Plantations of durable Eucalyptus spp.
R. Johanson

2/19c Forest products resources from urban forests
J.R.J. French

2/20c Changes in heartwood extractives with high temperature drying
A. Moffatt and J. Norton

2/21c The wood quality subject groups of IUFRO
W.E. Hillis

THE EFFECT OF SELECTION FOR VIGOUR AND STRAIGHTNESS ON WOOD QUALITY PARAMETERS

W. J. Smith and P. J. Allen

The effects that genetic gains in vigour and stem straightness obtained in Queensland-grown *P. elliottii* var. *elliottii* are having on wood properties are being investigated.

In one such study involving sixteen 12 year old open-pollinated half-sib families of parents preselected for superior vigour and straightness, appropriate additive genetic correlations were estimated and used together with other genetic parameters to predict wood property movements correlated with improvements in height, diameter and stem straightness in this population.

The results indicate a generally depreciative effect on certain wood quality parameters as a correlated response to selection for parameters associated with higher volume production, and a generally beneficial correlated response to selection for improved stem form.

There are indications that the selection of taller breeding stock can be expected to be accompanied by a moderate depreciation in grain spirality and cell wall organization (microfibril angle), in their progeny a moderate increase in percentage latewood, and a slight increase in basic density, with no real effect on tracheid length.

Selection for larger diameter would also be accompanied by a moderate depreciation in grain spirality, but with no evident effect on the other wood properties due to correlated response. This difference between effects of selection for the two growth parameters is of interest in relation to their relative influence on correlated wood property movements, with height evidently generating more effective response.

Selection for improved stem straightness can be expected to give progeny not only straighter but also having wood with much straighter grain (the highest degree of correlated response observed), appreciably improved cell wall organization, slightly longer tracheids, and slightly more dense but very slightly more uniformly textured (i.e. with somewhat lower percentage latewood).

It would seem that more emphasis on selection for straightness could be considered as a means of improving wood quality parameters. It will be noted that simultaneous selection for vigour and straightness generate counter-responses in respect of several features. In addition, the pre-selected traits themselves are subject to genetically correlated movement.

The nett correlated response to simultaneous selection for improved vigour and straightness has not yet been estimated. The problem of predicting nett correlated movements in traits associated with more than one characteristic under selection is a difficult one we are attempting to resolve, and any suggestions as to suitable statistical procedures would be welcome.

Topic 2/2c

PHYSIOLOGY OF WOOD FORMATION IN HONDURAS CARIBBEAN PINE

W. J. Smith and Jill M. Fett

The physiology of wood formation in *P. caribaea* var. *hondurensis* and the effect of certain climatic and edaphic factors affecting it are being studied over a three-year period in trees of two age-classes at two locations in Queensland (16-22 yrs and 3-7 yrs at Byfield in Central Queensland and Danbulla in North Queensland). Two years' observations have been completed at Byfield, and one at Danbulla, and some comparisons of growth patterns between locations and with those previously studied in *P. elliottii* and *P. taeda* at Beerwah are now possible.

Observations made include the times and rate of wood increment, the types of tissue formed throughout the growth cycle, and the inter-relationship of apical and cambial meristematic activity and certain environmental factors. Earlywood, latewood and false latewood cell diameter, rate of cell division and percentage latewood are amongst features being determined.

Certain marked differences between Honduras Caribbean pine and slash and loblolly pines are evident.

The former produces wood throughout the year, while the latter two produce none for three to four months.

Earlywood initiation in var. *hondurensis* is in mid to late winter, rather than early spring, and slightly later at the more northerly site.

Latewood production commences in late summer to early autumn, rather than early summer, giving about eight months' earlywood and four months' latewood production, compared with about three months' earlywood, six months' latewood production and three months' dormancy in the other two species.

Var. *hondurensis* has larger diameter cells in both the earlywood and latewood components, particularly the former.

Although the rate of cell production in var. *hondurensis* seems to be somewhat faster than in slash and loblolly pines, the difference in this respect is not as great as might have been expected, so that the former's appreciably superior annual increment is due predominantly to its longer growing season and larger mean cell diameter, with its faster rate of cell division playing a lesser but still significant role.

The superiority of the Danbulla radial increment over that at Byfield in the same year is definitely associated with an appreciably faster cell production rate, since the former's mean cell diameter was smaller. Rather surprisingly, this was particularly so in the earlywood, and yet there was no difference between localities in percentage latewood that year. The northern site had more intraring uniformity in cell diameter.

Percentage latewood was much lower in Caribbean than in slash and loblolly pine, as expected.

Despite observations in this and previous morphological studies that Caribbean pine continues terminal growth throughout the year, and the general inference that it shows no evidence of terminal dormancy, the type of wood being formed is definitely relatable to changes in the appearance and physiological behaviour of the apical meristem.

There are indications that between-year variation in rainfall at the one site affects radial increment and percentage latewood mainly through its effect on rate of cell production rather than cell diameter, particularly during latewood formation.

One practical aspect involved in this work includes the capacity for external visual selection of Caribbean Pine stock for tree improvement work with patterns of incremental growth which will give maximum productivity of wood with preferred features by relation to known site factors.

This and previous work has shown great potential for exploiting the very wide variability in physiological variation in this species reflected in equally variable patterns of wood formation.

It is planned to extend the study to other locations, particularly in Southern Queensland.

Topic 2/3c

AGE ESTIMATION IN CYPRESS PINE ON THE BASIS OF WOOD ANATOMY

Jill M. Fett and W. J. Smith

In silvicultural research in Queensland aimed at developing improved management techniques and productivity in cypress pine (*Callitris* spp.) stands in drier areas where this is the major timber resource, it has been found that age in young stands is at least as important a parameter as basal area in determining the magnitude of basal area increment (1).

The ability to arrive at a reasonable age estimate for cypress pine trees has assumed importance as a useful tool in furthering this work.

Age determination from ring counts on wood samples has previously been considered impracticable, but some promise is offered by the results of a preliminary study on a five-tree sample from a population with an estimated regeneration establishment age of 37 years.

Despite a profusion of confounding "false latewood" bands, seasonal rings which are possibly semi-annual were discernible from low-power (35x) stereo-microscopic examination of alumina-rubbed transverse sections. The average ring-count compared very closely to the regeneration establishment age.

However, classification of the very narrow, often indistinct "annual" rings by this method was often rather subjective. It could be made more objective by higher-powered transmitted light microscopy on microtomed sections, a very time-consuming process.

The use of more sophisticated techniques such as densitometric analysis of contact radiographs could allow more precise ring classification and age estimation, and a suggestion is made, in view of the importance of this dry-area resource, for more work in this area.

Reference

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GROWTH STRESS IN WOOD, ITS ASSESSMENT, VARIATION AND ALLEVIATION

W. E. Hillis, S. C. Chafe and A. N. Rozsa

Growth stresses are associated with utilisation problems of some fast-grown, short rotation eucalypts. A method of estimation of these stresses is needed to ascertain their extent, how they may be alleviated and how they affect utilisation. Of the methods used, that of Nicholson appears the most suitable giving accurate and reproducible data. However, it is time-consuming, it depends on a short pot life adhesive, damages small trees, and does not measure internal stresses. A search was made for another method which overcame these disadvantages, but so far no improved technique has been found. Less direct methods which enable data to be collected readily and which can be related to Nicholson figures, are being examined.

A number of elite trees of *E. grandis* have been selected in Coff's Harbour, by the Forestry Commission of N.S.W., and progeny raised from them. In view of the severe splitting of some logs obtained from *E. grandis* grown overseas, the growth stress was determined on the above elite trees. All the values were of a low order and symmetrical around the tree. The progeny could not be examined as their size was too small for the use of the Nicholson technique but will be examined when sufficiently large.

As a first stage in the study of the alleviation of growth stress a model system has been developed. This consists of one unstressed wooden strip glued to another held under tension. The changes in stress in the sample under different conditions is being studied.

THE FORMATION OF SHAKES IN LIVING TREES

W. E. Hillis, J. Bauch and Y. Yazaki

Splits or shakes are observed in freshly-fallen logs from mature trees. They may be due to bad felling practices or to high peripheral growth stresses, but there is little information on the contribution internal conditions of the tree make on the formation of these shakes. Logs from some trees have extensive star-shaped, heart shakes which must be present in living trees as they contain or are felled with extractives. The shakes in *Dacrydium nausoriensis* and *D. nidulum* contained almost pure podocarpic acid which was not present in the heartwood more than 1 cm from the shake. Brown streaks in the heartwood indicated heartwood had been present. Shakes could not be found in *D. franklinii* and fresh cross-sections of this species contained neither podocarpic acid nor wet-wood. *D. cupressinum* has shakes containing podocarpic acid and also wetwood although there is no information on their inter-relationship. Through the courtesy of the New Zealand Forest Research Institute at Rotorua a fresh sample of *D. cupressinum* free from shake was obtained. Neither wet-wood nor podocarpic acid were present.

Shakes may begin to form in young trees in association with wet-wood formation. Attention is being given to the existence of this latter defect as a contributing cause to the splitting of logs.

NATURAL COMPONENTS THAT ARE TOXIC AND REPELLANT TO TERMITES

Y. Yazaki, W. E. Hillis and J. R. J. French

It was pointed out at the 16th Forest Products Research Conference 1973 (J. R. J. French, Topic 3/43) that awareness of the ecological consequences of pesticide use should be the major concern in pest control. Cypress pine has been used for some time as a termite resistant timber without known disturbance of environmental situations. Also appreciable amounts of cypress pine residues are available and the extractives of these species are known to have repellant and toxic properties. An investigation has been commenced to fractionate the extractives and determine whether components responsible for anti-termite activity can be removed from the residues profitably and used as preservatives. In addition, knowledge of the chemistry of the active components may indicate the source of other compounds with similar properties.

Successive extraction of sawdust with petrol, ether and methanol have yielded 4.2, 2.3 and 2.9% extractives respectively and of the bark 11.4, 5.7 and 8.2% respectively. The extracts have been submitted for bioassay and are being analysed and further fractionated.

Topic 2/9c

THE NEED FOR BETTER DEFINITION OF THE TERM "SAPWOOD"

K. Cokley

The term "Sapwood" is cited in most timber specifications, certain legislation, advisory and reference publications e.g. Queensland Building Timber and Specifications for their Use (QFS Pamphlet No. 5) by C. J. J. Watson and in many S.A.A. Standards on Timber and Timber Products. In all cases there are restrictions on certain uses or requirements in terms of preservative treatments. All of these local references in turn imply the definition in terms of AS 01-1964 which states that "Sapwood" is:-

> "The living outer layers of the tree in which its food materials are conveyed and stored".

Dr. Chattaway also defines the sapwood not only in terms of the tissue where changes such as formation of heartwood extractives and structure e.g. tyloses have not occurred but also again in terms of living cells.

The AWPA defines it is -

> "The outer light-coloured wood of the tree stem which is physiologically active while the tree is growing".

This definition is significant in that the continued requirement of cell viability after falling is omitted.

In practice attempts to substitute any of these definitions into standards etc. are impracticable. Industry in the open forest hardwoods defines it as the "pale, non-durable" area and in most of the Rain Forest Species where there is no colour difference, it is defined principally in terms of starch presence or absence. In softwood the colour differentiation is variable between and within species e.g. *P. radiata* as compared to Hoop Pine. Chemical tests e.g. the benzedine reaction are also extremely variable. Industrially there is in these species a tendency to think in terms of "penetrated or treatable wood".

The position in terms of definition is further complicated by the introduction of sub-division such as "Intermediate Wood", "Transition zones", "Inner Sapwood" and "Lyctus Susceptible Sapwood". The presence of preservatives, particularly oil-type, augments the problem.

I suggest the overall position is not satisfactory and is confusing to the industry and user. It is impossible for industry to assess whether:-

(i) cells are viable

(ii) physiological changes such as transformation to heartwood constituents and cell changes e.g. tyloses have occurred.

(iii) In species e.g. Yellow Walnut with non-symmetrical areas of "included sapwood or heartwood", the definition of outer layers does not apply. Conversely if the starch test is used as the criterion, then absence for any reason of the amylose faction which gives the blue colour, is again confusing if the result is then issued as "free of sapwood", (this is the present position in rain forest timbers).

Topic 2/9c

I would suggest that the AS01 definition be amended to broadly the AWPA definition or alternatively to something similar to the following:

> "Primarily the outer layers of the tree, or the zones which have been physiologically active in the growing condition and which are frequently of a lighter colour than the "truewood", but which in all cases contain water soluble carbohydrates present either as polysaccharides such as starch or simple saccharides such as glucose or mannone".

COPPER ARSENATE AS AN ALTERNATIVE TO CCA

N. A. H. Smith and A. Zosars

Years of use have brought CCA formulations a pre-eminence among Australian preservative users that no other wood preservative can match. This comfortable position is now beginning to erode however.

The escalating cost of the preservation itself, uncertainty of the salt forms in the preservative, total dependance on overseas supplies of the constituent salts, fluctuating supplies, a growing awareness of its variable ability to control "soft rot" in eucalypt poles and its incapacity in controlling marine borers in angiosperm species makes the search for a substitute desirable.

Such a substitute has become available. It can be described as a copper tetra arsenate and is a high purity by-product of Copper Refineries of Townsville. Preliminary studies have shown that it will make a satisfactory CCA formulation with the use of chromic acid but the chromium must however still come from overseas.

Used alone a means of solubilization was the use of a high pH ammoniacal buffer solution. Although the percentage of solubility was variable, solubilities in the order of 25-30 percent as copper were consistently achieved therefore 5% working solutions should present no stability problems aside from the ever present aroma of ammonia.

This copper arsenate complex is reminisent of a previous formulation "Chemonete". Like this older formulation it exhibits high fire resistance and because there is no chromium should present no drastic problems in gluing processes.

There are more than adequate supplies of this copper arsenate to supply the full Australian supply if it were used as CCA substitute and this supply would be continuous and dependant only on the rate of the copper to be refined.

COMMENTS ON THE NEED FOR A SUBSTITUTE FOR BORON

J. Norton and M. Kennedy

Over the past 2 years there has been a fluctuation in the quantities of Boron Salts available to Queensland timber treaters, and it is understood that other areas are also experiencing difficulties. There has also been a 50% price rise in Boron salt costs. Although present procedures, techniques and analytical methods are by now well established and practicable, it has been found necessary to introduce new preservatives that can be used in times of Boron shortages or in the long run can completely replace Boron Salts.

The alternate preservative must be cheaper than or comparable in cost with Boron Salts, and should be compatible with current boron stocks so as to reduce waste and pollution in charge area. Finally it should be capable of being used in current treatment plants with minimal change to existing treatment processes.

Preservatives that fall into these categorys are Sodium Fluoride and Dieldrin/Aldrin emulsions. Both preservatives present their own problems. In the laboratory, pure Sodium Fluoride has a maximum solubility of about 4%. Under plant conditions of commercial sodium fluoride and individual town water supplies the average solubility of the salt is between 2½% and 3%. Above this level, solute saturation occurs. For effective treatment of timber, treatment plants must work as close to 2½% NaF as possible as well as increasing schedules by half as much again because of a slower penetration rate when compared to boron.

Sodium Fluoride also has strong, corrosion properties. In the initial stage of change-over these properties may be decreased by using a boron-fluoride mixture, and later, in the absence of boron, the corrosion can be reduced with pH adjustment using Soda Ash or Trisodium phosphate.

The second alternative is dieldrin/aldrin emulsion. Although this preservative can be used in open tank treatment, it can also be used effectively in cylinder treatments, thus freeing available boron supplies for use in open vats. The biggest problem with this preservative is the accurate determination of solution concentrations. Problems may also occur with toxicity-pollution with this preservative.

As commented neither of these two preservatives is a direct replacement for boron and modification to both preservatives and procedures will be required for their use. It is desirable to continue to endeavour to develop an alternative preservative to either sodium fluoride or the chlorinated hydrocarbons.

Topic 2/12c

CURRENT STUDIES ON DRYWOOD TERMITES

C. D. Howick

Further to the establishment of the West Indian Drywood Termite (*Cryptotermes brevis*) in the Maryborough area in Queensland the necessity for more complete knowledge of drywood termites has become apparent.

Studies on the genus *Cryptotermes* are part of a cooperative project with CSIRO Division of Entomology, involving a complete review of indigenous Australian and "tramp" species. Work at DBR includes studies on laboratory culturing of the following indigenous species:

Cryptotermes primus

Cryptotermes secundus

Cryptotermes queenslandis

Cryptotermes gearyi

Procryptotermes sp.

and the development of a standard laboratory bio-assay technique therewith. Other projects include studies on:

(a) A system for species determination by examination of faecal pellets.

(b) Susceptibility of a range of wood species.

(c) The formation and development of supplementary reproductives.

(d) Soldier/pseudergate ratios and soldier production by groups of various sizes.

(e) Inter-specific moisture requirements.

COLLABORATIVE PRESERVATIVE TESTS WITH THE INTERNATIONAL RESEARCH GROUP ON WOOD PRESERVATION

E. W. B. Da Costa

Research in Australia has always been handicapped by our isolation from other centres of research and opportunities for direct collaboration are to be welcomed. In wood preservation research, an excellent avenue for this has been available for the past five years or so in the International Research Group on Wood Preservation ("IRG"). Originally a meeting of scientists from 12 OECD countries to exchange information and coordinate research on wood preservation, it now has members in 51 countries. In recent years, the Group has been concerned with the improvement and standardization of laboratory and field techniques for evaluation of wood preservatives and has organized several "ring" tests in which matched preservative-treated specimens are distributed to several laboratories for testing either by a standard method or by the method normally used in each laboratory. The results of these have demonstrated the complexity of the ecosystems involved, even in pure culture tests. There has therefore recently been an expansion of fundamental studies on the biology and ecology of the organisms concerned.

Since full membership is restricted to scientists or laboratories actively engaged in research in relevant fields, the annual meetings and the corresponding committees are an unrivalled forum for stimulatory exchange of ideas. Australian members, and other Australians, have for some time been involved in exchange of information, but it would be desirable to collaborate actively in joint projects, especially those involving evaluation techniques. Such collaboration would be welcomed by IRG committees. With rapidly increasing international trade in preservative-treated or durable woods, there are moves for internationally accepted certificates of quality, and Australia needs to have a voice in their formulation. We believe many of our evaluation techniques to be superior, at least for Australian conditions, to those used in Europe, but this can only be shown by cooperative tests.

The Preservation Group is cooperating in an IRG "ring" test to determine the effect of timber substrate on the performance of CCA-treated specimens in tropical marine environments. We may in the future cooperate in field and laboratory tests against fungi and termites. It is hoped these will largely involve tests of fundamental research interest, as well as comparison of evaluation techniques.

PROLONGING LIFE OF TRANSMISSION POLES IN SERVICE

R. Johanson

If any lesson is to be learnt from last year's so-called energy crisis, it is that not only petrochemicals but also most products requiring energy input will cost more and more. Every commodity is affected and in turn the cost of labour. The substitute material or alternatives to the wood transmission poles including underground plastic-coated cables, cement and iron poles, or the combination of these materials, correspondingly will cost more also.

It is not difficult to foresee a situation in which replacement of a pole in service at an average of $1000 will become intolerable and engineers will be looking for ways of prolonging the field performance. There is no fundamental reason why the life of a pole should be only 20 years and not 100 years. If after 20 years of service the pole is still as new, it should be suitable for another 20 years. The extension of the service life can continue until the condition of the pole deteriorates beyond an acceptable point or the maintenance cost becomes prohibitive.

In the present world there is very little justification, if any, for an excessive preoccupation with obsolescence but rather every effort should be made to make things last longer including poles. This would apply also to the poles already in service, to durable and non-durable species, to pressure impregnated and to untreated poles.

Topic 2/15c

TO PROTECT USE OF ARSENIC

R. Johanson

Arsenic occupies a unique place in wood preservation, it is an essential component of CCA (Copper-Chromium-Arsenic) preservative which is highly resistant to leaching. And while it is a powerful poison it is not in the same category as the horror elements such as Beryllium, Cadmium and Mercury. Also, on many grounds health wise, arsenic can be considered much safer than Lead or Nickel. By all accounts, arsenic is relatively safe because powerful antidotes are available and in non-fatal accidents recovery is usually complete and without permanent damage to the organism. This is not the case with most toxic inorganic and organic pesticides.

Arsenic has proved its merits and still could be useful in most human activities, but because of its historic background it is feared by laymen and irrationally legislated against even by enlightened authorities. Because of what appears to be such an anomaly, the delegates may consider making a formal approach to the Government Authorities, Universities and business firms with interest in the use of arsenicals, to sponsor research on relevant issues. Just how dangerous is arsenic as a pollutant and in what form? What degree of contamination can be tolerated in different environments? Preparation of relevant available biochemical information and also information suitable for public education on proper use of materials containing arsenic. Other aspects may arise which will require answers.

INFLUENCE OF EXTRACTIVES AND THE CHEMISTRY OF WOOD CONSTITUENTS ON WETTABILITY AND PENETRABILITY

K. Cokley

Queensland has in excess of 300 utilisable species, ranging from the exotic softwoods through the open forest hardwoods to the multiferous rain forest species. In all avenues of preparation e.g. kiln drying, preservative treatment and gluing there are two factors which are significant. These are the wettability characteristics (involving also moisture diffusion) and penetrability of liquids or vapours. It is well known that a number of species are extremely variable in these properties e.g. most heartwoods are difficult to penetrate by water in the liquid phase but are reasonably readily penetrated by water in the vapour phase are non-wettable by most non-polar solvents, especially those of high viscosity paraffinic nature, but are readily penetrated by polar alcohols or aromatics such as benzene. Even pH, and ions in solution are variable in effect and separation can occur.

There is a difference in softwoods and hardwoods. Studies which have been conducted over the years show that this variability occurs both within and between species.

This may be illustrated by Spotted Gum (*Eucalyptus maculata*) where there is a marked difference between material from near Canberra, to that in the Grafton area and this difference progressively increases into central Queensland where the latter is frequently very hydrophobic. Characteristics may change abruptly with site.

In most cases the problem is associated with organic extractives. In this regard Brush Box and Tulip Oak provide outstanding examples. This effect generally increases as the moisture content decreases. The chemical nature of this can be demonstrated by steaming or solvent (soxhlet) extraction of specimens which are then compared to unextracted material. These problems are additional to structural aspects of the species.

In addition there are, in certain areas and species, inorganic deposits found deposited primarily in the vessel lumens. These include aluminium and calcium salts and again have the effect of impeding liquid flow and of precipitating certain preservative ions. This has been found one of the reasons for the slow penetration rate and steep gradients of fluoride in a number of rain forest species. This is again demonstrated by pretreatment with acid and comparison with matching untreated material.

These phenomena are some of the reasons why most local species are more readily treated by heat processes using alkaline salts such as borax, or alternatively by light solvent mixtures such as mineral turpentine or ethanolic mixtures.

It has been found that a mixed indicator system, using the principle of phase separation, will effectively indicate when the problems of wettability occur and action should be taken to reduce the problem.

In conclusion it is my firm opinion that examination of extractive type and concentration, and studies on effective solvent/preservative systems is of major importance to the industry.

Topic 2/18c

PLANTATIONS OF DURABLE *EUCALYPTUS* SPP.

R. Johanson

Although, at present, plantations of slow growing durable eucalypts may appear economically unsound, this situation may change in 20-30 years. By then people may be prepared to pay premium prices for durable species, particularly if for some uses the natural durability is augmented by preservative treatment. Small plantations of durable eucalypts could be of great value to future generations for research and for evaluation of such species in the context of 21st Century conditions.

A country with the resources of Australia should be able to afford to spend a minute amount on preserving this unique national heritage. The durable eucalypt poles perhaps also have some potential value and perhaps even more than 'Blue Poles'. Will the delegates be prepared to submit a resolution calling for establishing such plantations?

Topic 2/19c

FOREST PRODUCTS RESOURCES FROM URBAN FORESTS

John French

Managing urban forests for aesthetic and economic reasons is not a new concept. For instance, Zurich (500,000 population) covers over 9,200 hectares of which 24% is forested. Can we manage, and do we need to manage, our rapidly expanding urban areas for such values? With over 88% of Australians living in urban situations, I believe the answer is definitely yes!

No nation can afford to waste what today may appear a potential product, but tomorrow a wanted one. New techniques are required by foresters, horticulturalists and city planners to foster urban forestry as a multiple-purpose forest management activity.

Urban forestry would awaken the public to the awareness of wise resource use - and lead to a basic conservation ethic - a 'land ethic'; especially when forest-management is seen at first-hand in the suburbs. Trees should be cut as environmental assets, not as 'liabilities', adding to the present serious solid-waste pollution problem.

Future city managers could convert trees to usable products-producing pulpwood, chipwood, sawlogs, mulch and other fibre products. Also, fruit and nut trees could be planted and maintained. Intensive management of highways, nature strips, airports etc. could provide urban woodlands, producing forest products on a sustained-yield basis. Such products assist in a cities economic viability. For example, in Philadelphia, over 1½ million board feet of sawlogs and more than 3000 cords of pulpwood are harvested from parks and streets each year.

Urban forestry requires new and imaginative planting and harvesting techniques. Portable chippers, loaders and machinery to handle variable sized trees are needed. Research is essential for refinement in management, to determine the most suitable tree species, disease resistant trees, pollution-tolerant shade trees and so on. Such forests can provide an outdoor classroom for all members of society.

The challenge to foster urban forestry then, will encourage the wise use of resources, yielding aesthetic and economic benefits to man. Also, make an important contribution to society from all levels of the forestry enterprise.

Topic 2/20c

CHANGES IN HEARTWOOD EXTRACTIVES WITH HIGH TEMPERATURE DRYING

A. Moffatt and J. Norton

In preliminary investigations, a redistribution of extractives in the heartwood of Hoop Pine (*Araucaria cunninghamii*) and Slash Pine (*Pinus elliottii*) has been found after these species were seasoned from green-off-saw by the high temperature kiln drying technique.

The investigation was implemented after it was found that increased penetration of the heartwood by preservative chemicals occurred in treatment of the high temperature dried samples compared with the penetration of preservative obtained in air seasoned control samples.

It was found that extractives migrated towards the periphery of the board.

Further investigation into this property is to be implemented as this change in chemical distribution in the wood could cause changes in other properties such as wetability of the dried wood surface.

Other changes in heartwood extractives have been recorded in North Queensland plymills. Northern Silky Oak (*Cardwellia sublimis*) veneers from both Coastal and Tableland areas, after high temperature drying showed a darkening of the extractives giving a banded effect to the veneers.

This problem was overcome by momentarily dipping the veneer in a solution of Borax before drying.

Topic 2/21c

THE WOOD QUALITY SUBJECT GROUP OF IUFRO

W. E. Hillis

At the October 1973 Meeting of IUFRO Division 5 (Forest Products) in South Africa, the Wood Quality Subject Group S5.01 was reorganized into seven Working Parties. The approach was that the titles of the Working Parties should show their inter-relationship with each other so as to facilitate collaborative meetings. Also the titles should make clear our awareness of the increasing shortage of good quality wood, the necessity for the most desirable properties to be developed and the need for the greatest utilisation of the forest for the benefit of mankind. The Working Parties established are as follows:

S5.01.1 Normal Wood Formation - Chairmen: P. R. Larson (U.S.A.), V. Necesaný (Czech.)

S5.01.2 Significant Variations in Normal Wood Formation - Chairmen: G. K. Elliott (U.K.), A. Fahn (Israel)

S5.01.3 Secondary Wood Changes - Chairmen: J. Bauch (W.Ger.), T. Higuchi (Japan)

S5.01.4 Effect on Properties of Genetic Factors, Environment and Forest Practices - Chairman: J. M. Harris (N.Z.)

S5.01.5 Desired Properties for End Use - Chairman: E. Bulgrin (U.S.A.)

S5.01.6 Bark Properties and Utilization - Chairmen: E. L. Ellis (N.Z.) R. W. Kennedy (Can.)

S5.01.7 Quality of Plantation-Grown Woods - Chairmen: W. E. Hillis (Aust.) G. Scaramuzzi (Italy)

The main Symposium being organised by the Wood Quality Subject Group for the XVIth IUFRO Congress to be held in Oslo, Norway on June 21-26, 1976 is entitled "Wood Property Requirements for End Use". A number of minor symposia are also under consideration.

The elected Leader and Deputy Leader of the Wood Quality Subject Group are W. E. Hillis (Aust.) and P. R. Larson (U.S.A.) from whom further details of the Group's activities can be obtained.

The other Groups are Wood Engineering (J. G. Sunley, Eng.; D. E. Kennedy, Canada); Wood Protection (M. Fougerousse, France; J. W. W. Morgan, Eng.); Wood Processing (R. A. Hann, U.S.A.; C. H. Banks, Sth. Africa); Tropical Woods (D. Noack, W.Ger.; J. M. Yavorsky, U.S.A.). The final re-organisation of the Working Parties in these Groups is not yet available.

TOPIC 3

Fibre Utilisation

3/1 Characteristics and behaviour of bushfire smoke
R.G. Vines

3/2 Integrated Photosynthetic Product Industries (IPPI)
G. Cartside

3/3 Explosive defibration of wood chips
H. Manners and A.J. Watson

3/4 Wood fibre - synthetic polymer composites
G.M. Irvine, A.J. Michell, J.E. Vaughan and D. Willis

3/5 The adhesion of polythene to wood surfaces
G.N. Christensen and H.F.A. Hergt

3/6 Pulping studies on plantation-grown *Eucalyptus deglupta* from Papua New Guinea
F.H. Phillips and A.F. Logan

3/7 Pulping of unbarked wood
A.J. Watson and H.G. Higgins

3/8 Estimates of sawmill residues in Queensland
D.M. Greve

3/9 Utilization of *P. radiata* sawdust in the production of bisulphite, NSSC and refiner groundwood pulps
P.J. Nelson

3/10 Digestibility of cellulosic wastes
C.J. Mardon

3/11 Oleoresin stimulation in *Pinus radiata*
A.A. Sioumis

3/12 Some bark properties of Queensland grown conifers
D.M. Greve and R.J. Bell

CHARACTERISTICS AND BEHAVIOUR OF BUSHFIRE SMOKE

R. G. Vines

SUMMARY

In the spring of 1970, smoke from a series of large prescribed fires in Western Australia was collected in a light aircraft and analysed for mineral ash, tar and other carbonaceous components. The approximate size of the smoke particles was determined; and concentrations of various gases in the smoke were measured. Diffusion properties of the smoke were also studied.

Further observations were made in 1972, 1973 and 1974. In 1972, a new and simpler method of estimating smoke quantities was developed, the results obtained being essentially the same as those found earlier. For the large-scale prescribed fires in Western Australia, the total weight of smoke particles produced appears to be between 1½ and 3% of the mass of forest-litter burnt.

INTRODUCTION

The results of Australian work on this subject have been reported in three earlier papers (1,2,3). It appears that bushfire smoke is unlikely to be a health hazard, for even large fires will not give rise to dangerous concentrations of pollutants in the air above them. To this extent, the smoke from bushfires is in no way to be compared with the emission of noxious gases from industrial complexes.

The major problem is, of course, particulate concentrations. Close to a large fire, smoke can be so dense that visibility is reduced to a few hundred metres, and this can be a nuisance both to vehicles on the ground and to aircraft. However, in this connection, there is a real difference between wild-fires and prescribed burns - for with adequate planning, and sensible fire-management, the smoke nuisance from the latter can be minimized.

Preliminary Findings

In the Australian experiments, a light aircraft was flown through the smoke columns from a series of large prescribed fires in Western Australia: as a result, the following statements can be made.

1. Particle size - Most smoke particles were less than 1μm in diameter, the majority being about 0.1 μm: but there were some very large particles (tarry in nature and obviously agglomerates), which were up to 50 μm across.

2. Particulate concentrations - In thick smoke, the concentration of smoke particles appeared to be between 10^5 and 10^6 per cm^3.

3. Smoke Composition - This was variable, but was on average: tar* ∿55%, carbon ∿ 25% and ash ∿ 20%.

4. Gaseous Combustion Products - In different parts of the smoke column, both close to the fire and down-wind, typical concentrations of the various components were:-

CO, 0.5 - 2 ppm.

CO_2, up to 150 ppm above clean air level.

O_3, often 0.02-0.03 ppm in the extended smoke column (as for clean air). However, concentrations close to the fire were invariably less than this ($\sim$0.00 ppm); though far downwind, at the top of the column, they were sometimes more - being as much as 0.06 ppm.**

Oxides of nitrogen, 0.00-0.02 ppm.

NH_3, not detected.

SO_2, 0.00-0.01 ppm.

Dangerous concentrations of any of these gases in the smoke columns were never recorded. It thus appears that reduced visibility, arising from smoke build-up, is the most undesirable feature of any large fire.***

Smoke Diffusion

For all the fires studied, when winds were between 28 and 56 km/h, the smoke spread out in a narrow fan with an included angle between 12 and 13°. A photograph of an extended smoke column from a wild-fire in Queensland (observed by a Gemini space-craft) shows exactly the same feature; and this interesting result is probably due to the fact that turbulent transport cross-wind is roughly proportional to wind-speed.+ From the measurements, it is estimated that coefficients of turbulent diffusion were of the order of 10^7 cm^2 sec^{-1} in every case.

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* A brief investigation of the carcinogenic properties of this tar was kindly carried out by Professor George Christie in the Pathology Department of the University of Melbourne. Though the results of tests on mice were inconclusive, the tar from the bushfire-smoke collected in the aircraft appeared much less carcinogenic than the coal-tar and benzpyrene used as controls.

** In more recent work in Western Australia, use of an ozone analyser of fast response has shown that the concentration of ozone can, in fact, rise above ambient, depending upon the length of time the smoke is exposed to sunlight. Thus ozone concentrations up to 0.1 ppm were detected in the upper parts of a smoke column well downwind of the fire area (4). It follows that photochemical reactions result during the prolonged exposure of smoke to sunlight: and it is proposed to investigate this matter further, by making simultaneous measurements of NO_x concentrations on those occasions when O_3 concentrations are higher than normal. No information is yet available regarding the effects of mixing bushfire smoke with those industrial pollutants in the air above big cities.

*** In Western Australia, measured "visual ranges" varied from about 200 m in thick smoke, to 8 km, or more, in diffuse haze.

\+ The spread of smoke is important in planning prescribed burning operations and, if accurate meteorological forecasts are available, smoke can be kept away from populated areas.

Smoke Quantities

It is important to know the mass of smoke produced from a given quantity of fuel. In the Western Australian experiments carried out in 1970, estimates were obtained by measuring smoke-concentrations over the lifetime of each fire and comparing the integrated smoke-flux with the amount of forest-litter consumed. For each of the typical, large-scale prescribed fires, the total weight of solid particulate matter entering the atmosphere was between 1½% and 2% of the mass of fuel burnt.

These estimates, requiring measurement of total smoke-fluxes, were time consuming, and it was hoped that simpler methods of obtaining accurate smoke to fuel ratios could be developed. This has now been done, by determining carbon dioxide concentrations in the air above a fire at the same time as smoke is collected (Evans, King, MacArthur, Packham and Stephens to be published).

The principle is as follows:-

When fire consumes a 100g sample of fuel (which is largely composed of cellulosic material), approximately 183g of CO_2 is obtained. This mass of CO_2, as well as the smoke produced on burning, is diluted by mixing with air: and, if diluted by a volume of x cubic metres, the resulting concentration of CO_2 is $\frac{183}{x}$ gm^{-3} above normal. Thus, by accurately measuring CO_2 concentrations in the air in the vicinity of a fire, it is possible to estimate x - which, by definition, is that volume of air containing the combustion products from 100g of fuel sample. But, if at the same time as the CO_2 measurements are made, the smoke concentration, c, is also determined,* then the mass of smoke derived from the fuel is equal to the product of c by x.

Proceeding in this fashion, Evans, King, MacArthur, Packham and Stephens (5) have collected smoke samples in an aircraft, simultaneously measuring CO_2 concentrations in the air with an airborne infra-red gas analyser. During the spring of 1972 when they worked above a further series of prescribed fires in Western Australia, they obtained over the lifetime of each fire smoke to fuel ratios of between 1½ and 3%: this is essentially the same result as that found during the earlier measurements in the spring of 1970.

The new method has the distinct advantage that it is not necessary to know fuel-quantities on the ground, for these are derived from the CO_2 analyses. Further, since measurements are made over a relatively short period, variations in smoke yield can be followed during the progress of a fire.

The technique was used early in 1973 to obtain smoke to fuel ratios during a hot burn in extensively piled windrows at Benalla, Victoria. The large windrow-fuels were dry, and the smoke yield was correspondingly less than in the earlier prescribed fires: over a period of two hours

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* Smoke concentrations may be determined by optical means: in the Australian work a nephelometer was usually used, as well as direct filtration methods.

the measured values were 0.21%, 0.26%, 0.34% and 0.43%. It will be noted that the smoke to fuel ratio increased progressively with time.* The composition of the smoke from this hot windrow-fire was also very different, the proportion of "tar" being considerably reduced, whilst "ash" was increased.

The method is obviously versatile, and it should be possible to determine the smoke yield of wildfires - or, for that matter, fires occurring in different fuel-types, or at different seasons of the year. Indeed, it is hoped that such measurements can be made in the near future.

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* Using the same technique, investigation of the smoke from a wild-fire in the Northern Territory in 1974 gave a smoke to fuel ratio of little more than 1% - significantly less than in the cooler prescribed-burns in Western Australia. The implication is that, the hotter the fire the more complete is combustion, and particulate yields should be thereby reduced.

INTEGRATED PHOTOSYNTHETIC PRODUCT INDUSTRIES (IPPI)

G. Gartside

At the last Forest Products Research Conference (1973) a new project area under the general title of IPPI was reviewed. This paper gives some detail on the developments that have taken place in this study area since then.

The aim of IPPI is to make better use of land and plants. These elements have to be used in such a way as to provide renewable resources. At the same time efficiency in the use of farm and processing inputs such as energy and minerals, in the broadest sense, will preferably be high. These considerations lead us to a study of the growing of plants suitable for simultaneous processing into a range of products in the general classifications of consumer products, food and energy. In the first of these categories, fibre products are the most important element. It is probable in order to achieve high efficiency in resource use, including energy and minerals inputs, that the harvested plant should be available for long periods each year, in its vegetative state, and that all or most of the cropable plant should appear in products.

The past two years have been concerned with analysing the range of vegetative plant constituents and the range of products that can be made. In this way new areas of research have been established, and ways of utilising expertise in other research establishments have been set up.

Systems Studied

The fractionation of lucerne has been studied in detail in a collaborative project with the CSIRO Division of Animal Physiology. Lucerne is grown extensively as animal fodder and since it can be grown and harvested over long periods of the year it is commercially dehydrated to yield a valuable dry animal feed. However, such dry or green feeds as are developed from lucerne are too rich in protein for ruminant animals or too high in fibre content for non-ruminants. In a simple fractionation process the green lucerne is milled and crushed to extract protein rich juices. From these juices protein concentrates can be produced suitable for pigs, poultry or even humans. The fibre rich fraction with its reduced protein content is an ideal feed for ruminant animals. A costing exercise showed that this processing could be very profitable in this country with a processing plant handling 20,000 tonnes or more of lucerne per year. It would be more profitable, give a more efficient lucerne usage, and have a greater potential profitability than the existing dehydration industry.

In addition to the animal feed trials, the fibre rich fraction was assessed as a fibre resource. Fibre boards made with the fibre fractions alone or with additives did not approach in strength that of commercial boards. Analysis of the fibres showed that although a substantial proportion were long fibres (3 to 4 millimetres) they were thin walled and easily damaged. Thus paper made from the pulped fibre fraction or from a long fibre pulp obtained after fibre fractionation was no stronger than that from an average quality eucalypt pulp.

In Australia plants as new fibre resources are of high interest particularly if they can provide long fibre. The use that is made of the non fibre fraction of the plant is critical to the development of the long fibre resource. Techniques developed in the lucerne study seemed appropriate. Thus as the lucerne study approached completion a survey of plants that contained valuable long fibre was started.

The United States Department of Agriculture had done such a plant study and determined that kenaf (*Hibiscus cannabinus*) was a potential fibre resource. At the beginning of 1974 the Department of Northern Development asked that a small scale study being conducted by CSIRO be accelerated. The proposal is that kenaf is to be grown and processed to pulp and paper in Northern Australia, in the first instance in the Ord Irrigation Area, as a means of introducing industrial development to northern agricultural areas. The study so far has centred on the techniques and economics of processing green kenaf as distinct from the USDA research that has concentrated on dried kenaf. In the Ord kenaf can be grown and cropped over most of the year. The green kenaf tops provide a valuable fodder. The bark and the wood can be separated easily by crushing and screening. Protein concentrates can be profitably extracted from the juices obtained in the stalk crushing. Thus two fibre fractions and two animal feedstuffs are obtained from the green plant. The kenaf bark yields high quality pulps but the wood yields a chemical pulp comparable only with average eucalypt pulp.

The CSIRO Agro Industrial Research Unit is studying the industrial potential of elephant grass as a source of protein and fibre. The work is agronomically orientated, with the field work being conducted at South Johnstone in Queensland. The CSIRO Division of Chemical Technology is participating in two ways. Field equipment for the plant fractionation has been built and loaned. Pulp trials and morphological studies are being done on a variety of plant samples. Also at South Johnstone a small amount of abaca (*Musa textilis*) is to be grown. A hybrid of abaca has been developed in the Philippines which grows so prolifically that mechanical harvesting and pre-pulping treatment appear feasible. It may well be that large quantities of a very valuable fibre resource will be available at much lower than the current market price again provided that other plant fractions can be utilised profitably. Some preliminary fractionation work has already been done in our laboratories on banana plants which are in the same botanical family.

The stimulation of resin formation in pines by the injection of small amounts of paraquat is covered in a paper by Sioumis in this Conference. This work is an adjunct to the IPPI studies. Here the utilisation of a wood resource, *Pinus radiata* thinnings, may become economic due to the increase in a plant component. Again plant fractionation yields resins and fibre with the likelihood of increased profitability because of better plant utilisation.

Basic Research Studies

It has been realised during the IPPI project development that some plant fractions are rich in cellulose but do not contain valuable fibres. For example, the cutting of wood yields sawdust, the cleaning of bagasse yields pith, and the cropping of grain and seeds leaves straw. The profitable

utilisation of these fractions would enhance the efficiency of the cropping and could also allow other plants to be cropped that cannot now be grown profitably. A research project has been established that will investigate ways in which the cellulose can by hydrolysed to sugars, and in which cellulose rich fractions can be made highly digestible to ruminant animals. Mardon gives some details in his paper.

A project on the growth and harvesting of algae has been established in the Division. Its primary aim is the tertiary treatment of sewage wastes. However, the work will be of importance to the utilisation of plant juices which are quite similar to animal waste liquors.

As mentioned earlier, a plant survey is being conducted looking at a variety of dicotyledon plants both cultivated and indigenous. Among these are the leguminous plants in the crotaleria and sesbania families. These plants do not require the application of nitrogenous fertilizer for optimum growth. A significant part of the cost of growing kenaf is that for nitrogenous fertilizers. The plant survey takes as its starting point the excellent studies done by the USDA. A small team has been set up to analyse plant samples both chemically and morphologically. Any promising plants will then be subjected to agronomic and fractionation research.

EXPLOSIVE DEFIBRATION OF WOODCHIPS

H. Mamers and A. J. Watson

Introduction

Explosion pulping is a technique for defibrating wood chips by an explosive release of a relatively high digester pressure at the end of a predetermined cooking cycle. The best known explosion method is that of the Masonite process, where woodchips are shattered by a rapid expansion of steam from initial digester pressures of some 7,000 kPa and temperatures of some 285°C (1).

The high temperatures required to give the necessary steam pressures for the Masonite process tend to hydrolyse the resultant pulps to an extent which renders them unsuitable for papermaking; although, of course, Masonite pulps find extensive use in the building board industry.

A novel explosion process under development at the CSIRO, Division of Chemical Technology substitutes high pressure carbon dioxide for steam as the working fluid in the explosion step. This breaks the temperature-pressure relationship inherent in the Masonite process and holds potential for a rapid pulping method suitable for the production of papermaking fibres.

Carbon dioxide explosion pulping

The process basically consists of contacting water immersed chips with carbon dioxide at pressures up to 4,900 kPa; heating the carbon dioxide/water/chip mixture to 140-200°C; maintaining the temperature for a period of minutes and then exploding the digester charge by rapid release of pressure into a suitable collecting vessel.

On an experimental scale, the digester used has been an electrically heated stainless steel tube 57 mm i.d. by 320 mm long. The base of the digester was formed by a pneumatically operated Worcester series 45 ball valve with a 2" (51 mm) bore. Upon completion of the cook, the valve was opened to discharge the digester contents into an evacuated 45 litre explosion tank.

The variables investigated during the course of the experimental programme have included

(1) Wood species (*E. regnans, E. hemiphloia, P. elliottii*)

(2) Carbon dioxide pressure (2,100-4,900 kPa)

(3) Cook temperature (100-200°C)

(4) Cook time (0-30 min.)

(5) Cooking chemicals (sulphites, sulphides, hydroxides and carbonates of ammonia and alkali metals)

(6) Liquor/wood ratio

(7) Digester geometry

(8) Explosive discharge rate

Results and discussion

In general terms, the experimental results to date have indicated that

(a) Hardwoods defibrate more readily than softwoods at a given set of experimental conditions

(b) Hardwoods can be defibrated at lower cooking temperatures than softwoods

(c) The addition of sulphites (i.e. sodium sulphite) improves the colour of the pulp and the extent of defibration at a given yield relative to cooks with no additives present

(d) High carbon dioxide pressures promote better defibration than lower carbon dioxide pressures

(e) The extent of defibration at given experimental conditions is governed by the rate of pressure release; a fast release giving better defibration than a slow release

(f) Mechanical attachments, such as expansion nozzles fitted into the base of the digester, tend to decrease rather than improve the defibration efficiency.

Properties of pulps prepared from *P. elliottii* by explosion pulping are given in Table 1. The control groundwood sample was prepared by laboratory Bauer refining *P. elliottii* chips from the same bulk sample as used in the explosion work.

The colour of the explosion and groundwood pulps was similar, indicating the potential of the explosion process for the production of bleachable furnishes.

Conclusions

(1) Explosion pulping with carbon dioxide offers the possibility of a relatively low energy method of defibrating woodchips.

(2) The softwood pulps produced in the higher yield ranges indicate a potential suitability for inclusion in newsprint and similar bleached furnishes.

Acknowledgements

The authors would like to thank Mr. N. C. Grave for his contribution to the earlier stages of the experimental work and Mr. R. B. Bain for the pulp evaluations.

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TABLE 1. Properties of *P. elliottii* pulps prepared by carbon dioxide explosion

Digester pressure at explosion:- 4,900 kPa

Liquor:- 50 g/l Na_2SO_3

Liquor:wood:- 10:1

Pulp	Yield %	Cook Conditions			Freeness (l.s.f.)	Bulk (cc/g)	Tear index	Break length (km)
		Cook temp. °C	Time to temp. min.	Time at temp. min.				
SE 13	91	180	11.6	zero	74	2.57	2.1	1.8
SE 17	89	200	12.1	zero	363	2.92	3.6	1.7
SE 19	82	200	12.0	10	251	2.63	5.5	3.8
P. elliottii groundwood	89	-	-	-	80	2.94	1.0	0.5

WOOD FIBRE-SYNTHETIC POLYMER COMPOSITES

C. M. Irvine, A. J. Michell, J. E. Vaughan and D. Willis

Introduction

A long term programme on wood fibre-synthetic polymer composites has begun with a view to using wood fibre as a reinforcement in materials to be used in packaging and building. Ultimately it should be possible to manufacture "reconstituted wood" from cellulosic fibres derived from short rotation production forests utilizing mechanical harvesting, or even from non-woody plant crops. A range of such products could be expected to have uniform and controlled properties. Such a development would reduce labour costs, permit complete utilization of the fibre source and would reduce the need for, and environmental pressures on, mature production forests. Current developments in particle board manufacture and dry forming will make such an objective a commercial reality within the next decade.

In such composites, fibres are packed together as closely as possible within a continuous polymer matrix (either thermoplastic or thermosetting) such that the properties of the fibres rather than those of the matrix are the dominating factors for strength and stiffness. It is possible to prepare composites with highly orientated fibres as in wood itself. A recent development suggests that composites with a high work of fracture, a characteristic feature of wood, could be obtained by using fibres whose lumina had not collapsed. Such products could be considered as a reinforced "foam" of low density. The properties required of fibres for reinforcement are different from those necessary for papermaking so that composites could provide an outlet, complementary to that offered by pulp and paper, for woody material unsuitable for structural uses. Thus, unlike the ideal papermaking fibre which needs to be flexible and is usually delignified to a greater or lesser extent, the ideal fibre for reinforcing a composite should be stiff and lignin need only be removed in so far as is necessary for the fibres to be separated without damage. Part of our research is aimed at achieving this, preferably using only heat and mechanical energy, but possibly needing small amounts of chemical. One such approach is that of explosive defibration described in Topic 3/3 by Mamers and Watson.

Paper-Polyethylene Composites

A paper-polyethylene system was chosen for initial investigation because it provided a simple means of obtaining large quantities of undamaged fibres mixed with small amounts of highly viscous molten polymer. This was accomplished merely by interleaving sheets of paper and polyethylene or by using sheets of pre-coated paper and building up the structure by lamination under pressure.

Particular attention has been given to the flexural properties of the laminates as preliminary calculations suggested that the bending stiffness rather than the tensile strength would be the factor determining the sizes of members required for engineering applications. Moreover, the bending stiffness was found to provide a more sensitive indication of the susceptibility of the composite to moisture. The machine direction bending stiffness of a composite at 65% RH made from pre-coated paper has been found

to be comparable to that of 30% glass filled nylon but the cross-direction modulus is rather less. The flexural yield strength and tensile strength of the composite are also somewhat lower than those of the reinforced nylon but the impact strengths are comparable. A number of grades of paper have been used to make the composites and it would appear that the flexural properties are relatively independent of the strength or stiffness of the original paper sheet. Thus, the value of the bending stiffness of a composite made from newsprint and polyethylene was 70 percent of that obtained for a composite made from similar proportions of sack kraft and polymer, whereas the various strength properties of the newsprint were only about 25 percent of those obtained for the sack kraft.

Unfortunately, these composites all lose stiffness when exposed to moisture, as does wood itself. A cheap means of inhibiting this loss is probably the most important prerequisite for the utilization of wood fibres as reinforcements. One possibility is the introduction of a limited number of crosslinks between the fibres. Therefore, the paper sheets were reacted with formaldehyde so that their linear swelling in water was reduced by about 50 percent, before lamination into the composites. At this level of cross linking the folding endurance and tear index of the papers at 65% RH are much reduced but the burst index and breaking length are little affected. However, the wet breaking length and the wet ring crush values are improved several fold compared with those of an untreated sample. The bending stiffness of the laminates over a range of humidities from 32-87% RH is little affected by the treatment but the wet stiffness relative to an untreated sample is improved several fold. Another method of reducing the susceptibility of paper to moisture is to partially acetylate the paper or make the sheets from partially acetylated fibres. When pulps are acetylated to levels above 10 percent acetyl the sheets made from them are much weaker than those made from untreated pulps. The bending stiffness of composites made from such sheets is also lowered. However, the loss of stiffness of the composite at higher humidities and when wet with water is reduced relative to that of a control laminate. Laminates made from acetylated papers had only slightly reduced stiffnesses compared with control laminates and the loss of stiffness at higher humidities was also reduced with the effect being particularly marked for samples soaked in water for 24 h. Thus, a composite, made from the acetylated paper, at 87% RH retained approximately 80 percent of its stiffness at 32% RH and approximately 40 percent following soaking for 24 h.

This system has proved convenient for studying effects of fibre treatments on composite properties with the relative quantities of components being controlled easily. Moreover, unlike thermosetting systems, there is no doubt as to the extent of the reaction being reproducible. The disadvantages are that it is not easy to envisage an economic method of large scale production and the loss of stiffness when wet is only partially inhibited by chemical treatments. The composites will also lose stiffness when heated but some improvement in this regard could be obtained by changing the polymer to high density polyethylene or polypropylene.

Paper-Polyester Composites

An interest in making rigid, water-resistant tubular composites containing a high proportion (about 70% by weight) of lignified cellulose fibre prompted an investigation of composites formed from paper and unsaturated polyester

resins. The latter, extensively used with glass fibre reinforcement, consist of a solution of a polyester in a monomer, usually styrene, polymerization of which under neutral conditions can be initiated at ambient or comparatively low temperatures to yield a hard, water-resistant resin. The uncured resin has inherent flexibility in formulation to achieve specific end properties and has the additional advantage of relatively low viscosity so that it will penetrate paper or fibre assemblies far more readily than, for example, molten polyethylene.

Initial experiments involved winding newsprint, saturated by dipping in catalysed polyester, on a mandrel and allowing the resin to cure in the cold to yield a hard composite containing some 60% resin. Surplus resin adhering to the surface of the paper was not exuded under any practical winding tension. The resin content was reduced to 40% by passing the paper between pressure rollers before winding on the mandrel, but at this resin level negligible interlaminar adhesion was obtained after curing. Studies of composites made in a platen press from multiple layers of polyester-saturated newsprint showed that during curing pressures greater than 3.5 MPa (500 psi) would be required to effect any significant reduction in the resin content or to improve the interlaminar adhesion at the lower resin levels.

Direct coating of paper with polyester, using a doctor blade metering system, gave variable results attributable both to changes in resin viscosity during coating (the resin was precatalysed) and to extremely rapid penetration of newsprint by the polyester. At the line speeds attainable almost complete saturation of the paper occurred irrespective of the blade clearance employed. Heavier or less absorbent papers showed some improvement but penetration was often slow or irregular so that excessive coating time was required with consequent reduction in throughput and loss of the volatile styrene component leading, in turn, to difficulties in the curing reaction.

Composites containing 35-45% polyester were obtained by a transfer coating technique in which catalysed polyester was metered by doctor blade on to a cellophane strip which was then rolled up in contact with newsprint strips to allow complete absorption of the resin coating. The paper strips were then stacked and allowed to cure at ambient temperature under a pressure of 1.6 MPa (230 psi) to yield laminates of uniform composition. Reproducibility of resin content was generally within 2%, and loss of styrene from the resin system was found to be negligible.

Interlaminar adhesion in these composites depended critically on the percentage of polyester present, being good at resin contents above 45%, very variable in the range 40-45%, and nil below 37%. The efficiency of curing of the resin matrix, measured by a standardized extraction procedure, decreased as the proportion of fibre in the composite was raised and correlated with the observed fall off in adhesion. The presence of lignin, which might be expected adversely to affect the free-radical curing reaction, was shown not to be the dominant factor in the poor curing at higher fibre contents by a series of experiments with composites made from handsheets prepared from blends containing varying ratios of lignin-rich eucalypt groundwood and an essentially lignin-free bleached eucalypt soda pulp. At the 40% resin level, the curing reaction was least efficient in composites containing the chemical pulp as the major fibre component.

Further investigation has shown that the most likely cause of incomplete curing of the resin at low levels of impregnation is not lignin but oxygen trapped within the pores of the paper.

With a change to a hot-curing polyester system it was possible to take advantage of the lower viscosities available and obtain, at the same pressure, well-bonded newsprint/polyester composites containing 37% by weight resin. The machine direction bending stiffness of these laminates at 65% RH was 6550 MPa, 20% greater than that of a 35% polyethylene/newsprint laminate. In cold-cured systems stiffness increased with the proportion of resin present, reaching 8080 MPa at 60% resin content, but was still inferior to that of hot-pressed newsprint laminates containing only 25% phenolic or 42% urea-formaldehyde resins.

Economic considerations demand that the proportion of polyester in the composite be kept to a minimum. This requirement, coupled with the fact that acceptable mechanical properties can only be achieved by sacrificing the chief advantage of unsaturated polyesters as a matrix material - curability at low temperatures and pressures under neutral conditions - suggests that they are unlikely to provide a useful matrix for the preparation of structural composites with a high content of cellulosic fibre.

THE ADHESION OF POLYTHENE TO WOOD SURFACES

G. N. Christensen and H. F. A. Hergt

The adhesion of solid films, whether of glue or of surface coatings, to wood surfaces is generally accepted as depending on the operation of interatomic forces across the interface between the wood and the overlying film. This assumption has not been seriously questioned for about the last 40-50 years. Prior to that there was some support for the notion that the mechanical locking of the film (applied in liquid form and then hardened) into the pore structure of the wood was at least as important for adhesion as the specific molecular forces.

After reviewing the past evidence which led to virtual rejection of the so-called "mechanical theory" of adhesion to wood, and bearing in mind the improved mechanical properties of commercial adhesives and surface coatings since then, it seemed that the possible contribution of the mechanical component of adhesion to wood joint strength warranted a further look.

Our approach has been to make joints using as "adhesives" materials expected to have a minimum of physical or specific adhesion in an attempt to determine the maximum strength attainable by mechanical adhesion alone. Clearly these materials had to be solid at room temperature but with a melting point preferably below 160°C. Some initial experiments were made using low melting point metal alloys based on bismuth, e.g. Wood's metal, as the linking medium. It was found that once the difficulties of forcing the molten metal to penetrate the pore structure of the wood surface had been overcome, breaking stresses of approximately 4.2 MPa in lap shear tests and 2.0 MPa in tension perpendicular to the surface could be attained with hoop pine and about half these values with coachwood. As the liquid metals do not wet wood surfaces (in the physical-chemical sense), penetration is restricted to the larger pores only at the pressures we were able to use. These pores consisted of the vessels alone in the case of coachwood but tracheid lumina in the case of hoop pine.

Subsequent work has been largely with polyethylene, which has been shown to completely wet wood surfaces when molten and to penetrate as far into accessible voids as its molten viscosity will allow. At the same time polyethylene is chemically inert and assumed to have very low specific adhesion to wood surfaces. Tests showed in fact that when pressed against regenerated cellulose film or non-porous glassline paper separation was spontaneous as soon as the sandwich cooled down. As the work proceeded, however, limitations to this assumption became apparent. It was found that oxidation or other changes to the surface of the polyethylene during bonding under some circumstances led to a significant increase in specific adhesion.

In the early tests, commercial low density polythene film (LDPE) was used. With 2.5 mm hoop pine veneer and pressing at 0.7 MPa and 145°C, bond strengths of about 2.8 MPa for lap shear and 1.6 MPa for tension perpendicular tests were obtained. Despite the fact that wetting and penetration by the LDPE were much better than by Wood's metal, the strengths of the polythene bonds were considerably less, suggesting that the poor mechanical properties of the LDPE itself were the factor limiting joint strength.

Linear or high density polyethylene (HDPE) is a stronger, tougher material. Two types of HDPE were tested. HDPE (Ho), by courtesy of Hoechs Australia, was supplied as pure polymer powder from which we pressed our own film. HDPE (UC) was preformed film supplied by Union Carbide containing 200 PPM anti-oxidant and also given a Corona treatment to improve handling properties. Joint strengths for two wood species are shown in Table 1, together with the yield points of the polymers themselves. Although the differences between bonds with HDPE and LDPE can be explained by their yield points, the differences between the two HDPEs cannot. The high relative strengths in tension perpendicular for the (UC) film may point to an increase in specific adhesion with this material, possibly derived from the corona discharge treatment of the surface following manufacture.

Table 2 shows joint strengths for veneers of several species bonded with HDPE (Ho) at 160°C and 0.7 MPa. An interesting feature is that joint strength was generally greater for the species of higher density (and of lower porosity) and is thought to result from the greater resistance to deformation of the thicker cell walls as the polythene is pulled out of the pores during test. Although after test some polythene remained embedded in the wood surface (and thus required some rupture of polythene) there was little if any evidence of wood failure. In comparison the same veneers bonded with Tego film broke mainly by wood failure and at higher values. In addition the tensile strengths perpendicular to the surface were usually greater than the corresponding lap shear values and in the range of 5-9 MPa. This suggests that specific adhesion is in fact playing the major part in the Tego bond. On the other hand, if the HDPE bond is due to mechanical adhesion alone, it cannot be dismissed as entirely negligible.

In an attempt to eliminate any remaining specific adhesion by the HDPE to wood, the surface of the veneer was treated just prior to bonding with a high boiling point liquid. This was either silicone oil or glycerol, at least one of which should resist displacement by polythene. From the results in Table 3 it is seen that only in the case of glycerol applied at the rate of 6% of veneer weight was there any reduction in strength. This could have been due to associated swelling effects causing cell-wall softening. The results otherwise support the assumption that the bond strengths were derived from mechanical rather than specific adhesion.

When first forming joints with HDPE, it was found that great variability in the results was obtained, with lap shear strengths often as high as 7 MPa. The highest adhesion failure recorded was about 9.6 MPa in shear and 7.7 MPa in tension but usually wood failure (hoop pine) occurred before these values were reached. It is now thought that these high values are associated with changes to the surface of the polymer when it is exposed to air at temperatures near or above its melting point. When steps were taken to reduce such exposure during preparation of our own films and during bonding of the veneers, consistently lower results were obtained. In the case of commercial LDPE film abnormally high results were uncommon, presumably due to the protection afforded by the anti-oxidants present. Conversely exposure of HDPE (Ho) film to discharge from a Tesla coil gave high bond strengths even though thermal effects were eliminated.

Conclusions

It appears probable that bonds of moderate strength can be found between polymers and wood which depend for their strength mainly on mechanical inter-

locking of the two components. Such bonds would be stronger the better the mechanical properties of the polymer and, up to a limit, those of the wood.

When specific adhesion is present as well, very strong joints are possible which could possibly be better than those depending on specific adhesion alone.

TABLE 1.

COMPARISON OF DIFFERENT POLYETHYLENES - BREAKING STRENGTHS OF WOOD BONDS AND POLYMER YIELD POINTS

Hoop pine	Lap shear(s) (MPa)	Tension perpendicular (T) (MPa)	T/s	Polymer yield point (MPa)
LDPE film	2.76	1.45	0.53	10.9
HDPE (Ho)	4.48	2.98	0.67	30.2
HDPE (UC) film	5.08	3.63	0.71	28.9
Mountain ash				
LDPE film	3.30	1.72	0.52	10.9
HDPE (Ho)	5.47	3.20	0.59	30.2
HDPE (UC)	7.05	6.92	0.98	28.9

TABLE 2.

BREAKING STRENGTHS (MPa) OF HDPE (Ho) BONDED VENEERS OF VARIOUS SPECIES

Species	Lap shear(s)	Tension perpendicular (T)	T/s
Karri	6.08	3.71	0.61
Spotted gum	5.72	3.10	0.54
Coachwood	5.45	3.34	0.61
Tulip oak	5.41	2.91	0.54
Silvertop ash	4.86	2.94	0.61
Mountain ash	4.69	2.80	0.60
Hoop pine	4.48	2.98	0.67
Klinki pine	4.19	2.78	0.66
Poplar	4.09	3.46	0.85
Radiata pine	3.77	2.25	0.60

TABLE 3.

SURFACE TREATMENT TO LESSEN SPECIFIC ADHESION - BOND STRENGTHS (MPa) FOR HOOP PINE AND HDPE (Ho)

Treatment	Lap shear(s)	Tension perpendicular (T)	T/s
Untreated	4.48	2.98	0.67
6% silicone oil	4.50	3.00	0.67
Glycerol up to 4.5%	4.59	3.05	0.66
6% Glycerol	3.35	2.14	0.64

PULPING STUDIES ON PLANTATION-GROWN *EUCALYPTUS DEGLUPTA* FROM PAPUA NEW GUINEA

F. H. Phillips and A. F. Logan

Introduction

The importance of new plantations as the major source of the world's future pulpwood supplies is widely recognised. In tropical areas in particular, the secondary regrowth established after clear felling operations is of doubtful value to the pulp and paper industry. However, advantages can be gained by replanting selected fast growing species which should present fewer processing problems, possess superior pulping and papermaking properties and yield larger volumes of wood per hectare than mixed species (sometimes in excess of 100) which form the virgin growth of tropical rainforests.

With the commencement of the export of wood chips to Japan from the Gogol timber area, Papua New Guinea (PNG) and the increasing interest shown by commercial organizations in other PNG forest areas as a source of pulpwood chips, the question of fibre renewal in the form of plantations needs to be considered. Based mainly on silvicultural requirements, a number of species viz: *Eucalyptus deglupta, Terminalia brassii, Eucalyptus teretecornis, Acacia auriculiformis, Gmelina arborea, Albizia falcataria, Anthocephalus chinensis, Elaeocarpus multisectus, Melaleuca leucadendron* and *Casuarina* spp. have been suggested as potentially suitable for reforestation. According to an FAO project report (1), *Eucalyptus deglupta* (Kamarere) is the outstanding plantation prospect for lowland rainforest sites in Papua New Guinea because of attributes such as its high initial growth rate and volume production, ability to become a prolific seeder at an early age and resistance to serious disease and fungal or insect attack.

Previous work (2,3,4) on limited samples has indicated the suitability of *E. deglupta* for kraft pulp production. However, the basic density of the wood from this species can vary widely and the availability of plantation material from Keravat, PNG provided a useful range of samples for a more detailed study of pulping and papermaking potential. It is anticipated that the suitability of *E. deglupta* for use in the production of unbleached and bleached sulphate, neutral sulphite semi-chemical (NSSC) and possibly other pulps will be investigated. Furthermore, an assessment of the effects of age, site quality and defect will be made to provide a basis for determining a suitable rotation age for pulpwood supplied. It is possible that this species could be used for plantation establishment in northern areas in Australia.

Wood Samples

The wood samples ranged from 3 to 20 years of age and were from 3 different sites; five dominant and co-dominant trees were sampled in each age class, except classes 4, 8, 14 and 15. Disks were cut from top to bottom of the log at 10 per cent intervals of the merchantable length and an assessment was made at the Forest Products Research Centre (PNG) of the amount of defect present (5).

Disks from the 11 positions along the merchantable log, from each of the 5 trees per age class, were cut into chips (ca. 25 x 20 x 3.5 mm) on a laboratory chipper. Composite chip mixtures for subsequent pulping investigations were then prepared for each age class by mixing chips from 5 trees in proportion to their merchantable volume.

The basic density of these plantation-grown *E. deglupta* samples ranged from 331-407 kg/m^3 and there was a tendency for the basic density to increase with age although this was not always consistent. From the viewpoint of pulping and papermaking, wood of this density range should be advantageous but, for chip export and digester productivity, higher values would be preferred to enable a greater weight of fibre to be handled in any one batch or operation.

Sulphate Pulping

All age classes of *E. deglupta* were pulped with the same amount of total alkali (13 per cent) and also with varying amounts of total alkali to obtain a pulp of maximum screened yield for each age class sample. The latter data will allow useful comparisons to be made, particularly because of the importance of pulp yield in any economic evaluation of pulping potential.

All age classes pulped readily by the sulphate process with moderate amounts of alkali and good yields were obtained for each sample. As the age of wood sample increases, there is a tendency when pulping with a constant amount of alkali towards lower Kappa numbers and an increase in screened pulp yield. When maximum screened yield is considered, a similar increase in yield with age is evident. There is also a general indication that less alkali is required to produce pulps of maximum screened yield for the older wood samples (see Figure 1). For samples from the better quality sites, there is a tendency towards an increased screened yield with sample age, as mentioned above, but no distinct trend is evident for the poorest site.

Harries et al. (5) found that there was a much greater percentage of defective wood in those samples taken from the poorest site with impeded drainage but from the present pulping investigations, there is no apparent correlation between the amounts of defect and the screened yields at constant cooking conditions. One would expect a decrease in yield for samples of high defect particularly if this was present in the form of rot or decay. It is probable that most rot present in the wood samples was screened out with the undersize material after chipping and a similar effect may occur during commercial operations. Furthermore, there is no evidence to show whether the defect as measured was all grossly defective wood or merely discoloured wood which would not have any serious deleterious effect on pulping properties.

Many of these pulps have yet to be evaluated, so that detailed comments on paper strength properties are not possible. However, papermaking properties of the pulps both at maximum screened yield and prepared with constant total alkali (13 per cent) for the 6, 11 and 13(B) year old wood samples are available and are illustrated in Figure 2. Evaluation of the pulps prepared with 13 per cent alkali enables a comparison of strength properties at relatively low Kappa numbers and the maximum screened yield pulps should show whether there is any variation at higher Kappa numbers.

On beating, all 6 pulps illustrated attained particularly good levels of strength both in bonding strength (bursting strength, breaking length and folding endurance) and in tearing resistance (the 6 year old sample being substantially lower than the others) and these pulps should be suitable for a wide range of end uses. The pulps of maximum screened yield and consequently of higher Kappa number developed slightly better strength properties than those prepared with 13 per cent alkali.

Preliminary bleaching tests on the 6, 11 and 13(B) year old *E. deglupta* pulps have been carried out using a CEHD sequence. All pulps bleached easily and were produced in good yields at high brightness (86.4-89.4). Together with the satisfactory pulp strength properties the results suggest that these pulps should also be suitable for many bleached paper grades.

Printability Tests

The use of hardwoods for the production of off-set printing papers is greatly dependent on the surface properties which can be attained. In particular, vessel picking tendency is recognised as one of the major drawbacks in the successful usage of these woods. Results of printability tests, involving the measurement of surface roughness and vessel picking tendency of bleached sulphate pulp handsheets from 6, 11 and 13(B) year old samples were compared with some Australian mixed eucalypts used for the manufacture of fine papers. *E. deglupta* handsheets had substantially higher picking tendency but lower surface roughness than the eucalypt papers and on the basis of these limited tests it seems that close control of beating and size press application would be necessary before satisfactory off-set printing could be achieved with this species. Colley and Ward (6) have found that the high picking tendency of *E. deglupta* pulps, in comparison, for example, with mixed ash type eucalypts from regrowth forests, can be attributed to the properties of both the vessels and fibres making a remedy more difficult to achieve.

Black Liquor Investigations

Problems can be encountered in the burning of hardwood pulping liquors in a kraft mill recovery system during both evaporation and combustion operations. Ideally, a good quality black liquor should be of low viscosity and possess good swelling properties. A limited number of tests showed that the viscosity of *Eucalyptus deglupta* black liquor increases with age and the swelling value decreases. Also, as the alkali used for cooking is increased, the quality of the resulting liquor improves. In comparison with an "average" quality commercial wood sample of mixed eucalypts the *E. deglupta* black liquors had lower viscosity and better swelling properties which suggests that recovery operations on these black liquors could be performed without much difficulty.

Discussion

Further work such as NSSC pulping tests, pulping of unbarked wood samples, pulp bleaching, and more extensive vessel pick and black liquor tests are contemplated and the effect of age on wood volume has yet to be considered. However, it has been established that 3-20 year old plantation-grown *Eucalyptus deglupta* wood samples ex Keravat were of low basic density (331-407 kg/m^3) and sulphate pulping, bleaching and

papermaking properties were very satisfactory. The pulps should be suitable for use in both unbleached and bleached paper grades. It appears that trees in the 10-20 year old range will be more suitable than younger trees because of lower alkali requirements to cook to a given Kappa number, higher pulp yield and slightly better pulp strength properties, although against these benefits is the fact that black liquor quality deteriorates with increasing age.

The apparent suitability of *E. deglupta* for the establishment of plantations in Papua New Guinea for pulping and papermaking does not reduce the necessity for investigating the potential of further species for reforestation. Already there is evidence of some shortcomings of fast grown *E. deglupta* with respect to soft rot and decay, a restriction to well drained sites for optimum growth conditions, low basic density, vessel picking problems which may limit usage in the production of off-set printing papers and the obvious inherent dangers of a monoculture. Indeed, preliminary pulping studies at our laboratory on other potential reforestation species have indicated that some may be at least as suitable as *E. deglupta* for pulping purposes or even possess improved properties. To obtain the maximum benefits for pulping and papermaking it may be advisable to replant with a number of species so that optimum quality for different end uses can be attained by mixing different plantation species before pulping. This allows the various components in the wood mixture to compensate for any deficiency in the individuals.

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PULPING OF UNBARKED WOOD

A. J. Watson and H. G. Higgins

The increasing demand for pulpwood is directing attention to a better utilization of the tree. This is illustrated in the increased use of sawmill residues for pulping and in the attempts to utilize tops, branches, bark and even roots for the production of pulp. The use of tops and branches will involve the use of relatively small diameter logs. Bark removal costs from small diameter logs are high per tonne of wood. This cost could be avoided if the logs could be chipped and pulped without first removing the bark.

Recent work on two year old stems of *E. globulus* (Cromer, R. N. and Hansen, N. W. - Appita 26(3): 187 (1972)) and on 2, 7 and 16 year old *E. viminalis* (Nicholls, J. W. P., Phillips, F. H. - DFP Tech. Paper No. 58 (1970)) had shown that the inclusion of the bark had no serious effects on pulp yield or quality. More recently (Watson, A. J., Higgins, H. G. and Bryant, L. H. - Appita 28(3): 180 (1974)) in pulping trials on small diameter trees and branch wood of *E. sieberi* showed that even when the samples contained appreciable amounts of rough outer bark, the main effects were an increase in Kappa number and a darker pulp. There was only a small reduction in strength properties even with samples containing 25-30 per cent bark.

Further trials have been made on unbarked and barked logs of *E. regnans* and on branch wood from mature trees of *E. diversicolor*.

Kraft pulps prepared using 15% total alkali from a young tree of *E. regnans* (age 12-15 years) were similar in yield, Kappa number and most strength properties whether made from unbarked wood or matched material from which the bark had been removed. However, the tearing strength was lower for the sample containing bark. Bark comprised about 14 per cent of the unbarked sample. However, pulp made from the bark had a much higher Kappa than pulps made under the same conditions from the wood or the wood/bark mixture. It was evident that if a high percentage of bark was present higher concentrations of alkali would be required for a satisfactory cook.

Kraft pulps prepared using 12% total alkali from the unbarked and barked branchwood of *E. diversicolor* (ranging from 15 cm to 33 cm diameter over bark) showed little variation in yield or quality. The logs had only a narrow band of bark and in no case did it comprise more than 10% of the whole sample.

It would appear as a general rule that the smooth barked eucalypts can be pulped satisfactorily without removal of the bark. Even with species containing some rough outer bark such as *E. sieberi* the unbarked wood can be pulped satisfactorily but more cooking chemicals are required and yield and quality are somewhat lower.

The use of unbarked pulpwood can have various advantages. The inclusion of the bark will increase the yield of papermaking fibre per hectare. Yield of pulp per hectare will also be increased as logs too small for economic

bark removal can be considered as a pulpwood source. Against this there are the problems in chipping and screening, particularly with stringy-bark species, the higher demand for cooking chemicals and the increase in extractives which will increase the load on the recovery section of the pulp mill and the higher dirt content of the bark (grit, charcoal, etc.) which could increase wear on chipper knives and screens and introduce cleaning problems, especially with bleached pulps.

ESTIMATES OF SAWMILL RESIDUES IN QUEENSLAND

D. M. Greve

At the 1973 Forest Products Research Conference the following was recommended and agreed upon: "F.P.L. should make in co-operation with the appropriate industry organizations, Forest Service and State Departments, a more detailed survey of location, quantities and type of forest products residue with the objective of offering advice on the most appropriate method for their utilization. Such a survey would provide useful outlets for current F.P.L. research on residue utilization."

In Queensland, the Department of Forestry is in the process of making such estimates but at the time of writing this paper they are not sufficiently complete for inclusion here. However, it is hoped to be able to present these estimates to the conference in May, 1975.

As a basis for our estimates we are using 1973/74 figures for sawmill log inputs, together with sawn recovery figures based on sawmill studies in Queensland.

The basis of calculation for the different species groups are as follows:-

Forest hardwoods

Log input figures available are in nett hoppus volumes and these are firstly converted to gross hoppus volumes by adding a defect allowance. This allowance averages about 25% of G.H.V. over all species in all areas of Queensland but does vary somewhat from this figure for individual areas. A factor of 1.27 is then used to convert gross hoppus volume to gross true volume, and net true volume, or true solid wood volume is then calculated from this by subtracting a non-wood volume. This non-wood volume is obtained by assuming that 50 percent of the defect allowance is actually wood and the remaining 50 percent unusable material or air space.

The total volume of residue can then be obtained by subtracting sawn wood volume, and this can be further broken down into sawdust, slabs and offcuts by assuming a figure of 20 percent of net hoppus log volume for sawdust. This figure is based on an estimate by Ironside*.

Rainforest timbers

Calculations are similar to those for forest hardwoods, the only difference being that in this case the whole defect allowance is assumed to be useless material.

Conifers

Again, method of calculation is similar to that described above but no allowance is made for defect.

It is also proposed to make estimates of planer shaving and bark and of forest residues which would be expected in due course to supplement any operation of sawing residue and it is of course necessary to take cognizance of the extent to which some or all of these may be already committed.

* Ironside, G. E., How Much Mill Residue? Australian Forest Industries Journal, August, 1973.

UTILIZATION OF *P. RADIATA* SAWDUST IN THE PRODUCTION OF BISULPHITE, NSSC AND REFINER GROUNDWOOD PULPS

P. J. Nelson

The more efficient use of *P. radiata* wood in the forest products industry has resulted in the availability of larger amounts of high quality sawdust. Debarking of logs prior to sawmilling operations has not only yielded offcuts which can be converted directly to wood chips but also sawdust which is free from bark. A world wide interest in the pulping of sawdust has been stimulated by the increasing cost and scarcity of pulpwood and the relatively low price of sawdust. In Australia the utilization of *P. radiata* sawdust as a raw material for pulp production is possible because there are locations where sawmills and pulp mills are in close proximity. Two such situations would be at Mt. Gambier, South Australia and at Myrtleford, Victoria.

Kraft pulping of *P. radiata* sawdust has been investigated by New Zealand workers (1) but there is no information available on the bisulphite, NSSC and refiner groundwood pulps from sawdust. Samples of these three pulps were prepared and a preliminary assessment made of their suitability for blending with similar pulps from *P. radiata* wood chips.

The sawdust used in this study was taken from the bandsaws used in the initial breakdown of *P. radiata* logs at the Mt. Gambier State Sawmill, South Australia. Fractionation of a portion of it on a set of screens showed that 48 per cent of the sawdust was of particle size between 0.9 and 1.65 mm. No attempt was made to evaluate the effect on pulp yield and pulp properties of removing the finer fraction from the sawdust. The average fibre length of a bisulphite pulp prepared from the sawdust was 1.3 mm whereas the average length for pulp from chips was 2.5 mm.

Bisulphite pulping

Sawdust was easily pulped by the bisulphite process and compared to wood chips the cooking times at 170° were approximately 30 min. shorter. The pulp yield at a particular Kappa number was only marginally lower than that for a pulp prepared from chips from a 23 yr. old *P. radiata* tree (2). Pulping of *P. radiata* sawdust by the kraft process gave pulps in yields which were about 4 per cent lower than those from wood chips (1). The good pulp yields together with the ease of pulping show that the bisulphite process is well suited for the production of pulp from sawdust.

The most likely way of utilizing bisulphite pulp from sawdust would be by blending it with pulp manufactured from wood chips. A pulp blend containing 10 per cent sawdust pulp and 90 per cent of a chip pulp was prepared and its papermaking properties evaluated. The property of the unblended chip pulp most affected by the sawdust addition was the tear index which decreased by 10 per cent for the unbeaten pulp and 30 per cent for the beaten pulps. The effect of the addition of sawdust on freeness, breaking length, bulk and burst was small. The data indicates that small amounts of sawdust pulp can be added to bisulphite pulp from wood chips without serious disadvantages.

Topic 3/9

NSSC pulping

A NSSC pulp was prepared from sawdust in good yield and compared to pulp from wood chips it had lower bulk, about 70 per cent of the breaking length and tear index and about 40 per cent of the burst index at the same freeness level. There would be a large saving in energy in the manufacture of NSSC pulp from sawdust because very little would be needed to defibrate the wood due to its fine particle size. The pulp evaluation data indicates that NSSC pulp from sawdust could be added to similar pulps from chips in small amounts without any serious effects on pulp properties. The good properties of the sawdust pulp prepared in this study suggest that NSSC pulping of a mixture of pine sawdust and eucalypt chips may be possible especially as a report (3) has described the successful pulping of pine sawdust and birch wood chips.

Refiner groundwood pulps

A refiner groundwood pulp was made from sawdust and blended with a commercial refiner groundwood pulp in amounts of 10, 20 and 30 per cent. The addition of 10 per cent sawdust pulp to the commercial pulp resulted in a decrease in the breaking length and burst index by about 10 per cent and an increase in the tear index and bulk. The blend containing 20 per cent sawdust pulp had a greatly reduced tear index and burst index whereas the breaking length was not affected to the same extent. Increasing the amount of sawdust pulp from 20 to 30 per cent gave a pulp which, after the same amount of beating, showed a further decrease in breaking length, an increase in freeness and tear index and no change in the burst index.

The results show that 10 per cent of refiner groundwood from sawdust could be blended with pulp from wood chips with very little effect on the pulp properties. This could be done by preparing the two pulps separately or refining a mixture of sawdust and wood chips. The lower cost of pulp from sawdust due to reduced raw material cost and lower consumption of energy would mean that the economic benefits to be gained from using a pulp blend would be substantial.

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DIGESTIBILITY OF CELLULOSIC WASTES

C. J. Mardon

The waste from agriculture and forests in Australia is a potentially important source of food and fuel and there is still ample potential for increased production of special crops for either purpose. Further, IPPI processing schemes being developed in this Division involve the fractionation of various plants to yield food, energy, chemicals and fibre. The utilization of these plant fractions in an economic and socially desirable way is the key to the success of these programs. Low-grade fibres considered unsuitable for paper or fibre-board may be processed to make feedstuffs for ruminants or hydrolysed to sugars to provide a substrate for fermentation or a substitute for molasses. This paper discusses some aspects of the production of feedstuffs for ruminants.

Looking briefly at the wastes already available, it is clear that enormous quantities of agricultural and forestry residues exist and the majority of these have a high lignocellulose content. In fact, it is because of this high content that they are of negligible value as animal feedstuffs and are regarded as wastes. Wheat straw and bagasse are the biggest crop residues, but there are also the straws from other grain and seed crops, wood, bark and sawdust from sawmills, forests and chipping plants, vegetable wastes and animal manures. Wheat straw alone amounts to about 15 million tonnes annually, while sawmill residues amount to more than 4 million tonnes and wood left in the forest as branches and stumps equals 10 million tonnes. About 3 million tonnes of bagasse are produced annually, but about 60% of this is burnt to raise steam at the sugar mills, leaving about 1.2 million tonnes surplus. The conversion of boilers to coal firing could significantly increase the amount of bagasse fibre available for papermaking and other uses. The quantity of bark wastes from chipping plants and paper mills has increased rapidly in recent years, but it is difficult to get precise estimates of the quantities available.

Generally speaking however, the disposal of these wastes is a problem and much of it is left on the ground or burnt. Unless economical means of converting these wastes to useful products can be found, the high cost of collecting and transporting these potentially valuable resources will continue to prevent their utilization as sources of food and energy.

Urban solid wastes are also a source of organic materials. Domestic refuse consists of 50-70% cellulose, mainly in the form of paper, cardboard, garden and kitchen wastes. The variable composition of urban wastes creates some problems for their utilization, but economical techniques for the separation of metal, glass, plastics and inorganic matter from refuse could allow the utilization of this cellulosic material. Sewage sludge also contains a lot of organic matter and nitrogen, but it is generally low in fibre content. Pulp mill tailings are another possible source of fibres.

There have been many arguments about the relative merits of raising animals and growing crops to produce food for man, but it can be said that livestock offer a way of utilizing land resources that cannot be

used directly to produce human food; they can utilize waste products of the food industry and they can, in the case of ruminants, synthesize proteins and vitamins, and release energy from low grade raw materials including cellulose and non-protein nitrogen (e.g. urea).

Ruminant Digestive System

The most unusual feature of ruminants is their digestive system and in particular their multicompartmented stomach. They are commonly referred to as having four stomachs. The true stomach or abomasum, that part comparable to the stomach of man, is preceded by three other compartments known as the rumen, reticulum and omason.

When food is swallowed by a ruminant, it first enters the rumen-reticulum compartments which are not well separated and provide 80-85% of the total stomach capacity. This large organ, retaining a high moisture content, maintains a large bacterial and protozoal population under near anaerobic conditions and functions as a fermentation vat. Strong muscular movements keep the contents agitated and the animal secretes large quantities of alkaline saliva, perhaps 10 litres/day in a sheep and 85-100 litres/day in a cow, which neutralise the volatile fatty acids produced by the microbial fermentation. The pH in the rumen ranges from 5 to 7 (depending upon diet and time after feeding) and the temperature is about 39°C.

The main features of the rumen phase of digestion include:

(1) Fermentation of sugars, starches and cellulose to produce volatile fatty acids, principally acetic, propionic and butyric acids, which are absorbed and used by the animal for energy and various synthetic functions.

(2) Synthesis of microbial protein from protein and non-protein nitrogen in the diet.

(3) Synthesis of the B-vitamins and vitamin-K.

The microbial protein and vitamins pass through to the abomasum where they are digested in acid-pepsin and the amino-acids so formed are used by the animal.

Although cellulase activity of the rumen microflora is high, lignocellulose feedstuffs are only partially degraded; that is, only part of the potential energy is made available for animal production. Also, even after the cellulose and starches have been hydrolysed to sugars, only about half of that carbon is converted to fatty acids - the rest is converted to carbon dioxide and methane in the same way as an anaerobic fermentation in a sewage sludge digester - so the live-weight gain for a given quantity of feed digested is not as high as might be expected. The theoretical stoichiometric equation for the conversion of sugars to fatty acids is as follows:

50 moles hexose $\rightarrow$ 100 moles acid + 60½ moles CO_2 + 33½ moles CH_4 + 27 moles water

The conversion of sugars to acids takes place much faster than the hydrolysis of cellulose, so that high concentrations of sugar or starch in the diet can be assimilated quickly, but they can also diminish the digestibility of the fibre. This can be caused by depletion of non-carbohydrate nutrients by the bacteria, by an excessive production of acid, or inhibition of the cellulase by sugar.

It is possible to simulate the digestive system of ruminants in the laboratory by so-called "in-vitro" digestion, a two-stage process in which the ground feedstuff is digested at 39°C for 2 days in a mixture of rumen fluid taken from a fistulated cow or sheep and a bicarbonate buffer, and then another 2 days in acid-pepsin to break down any protein present. There is generally a good correlation between the results obtained by this technique and "in-vivo" trials with live animals, but it is important to emphasise that the digestibility value obtained by either method is only a measure of the proportion of feedstuff dissolved during the digestive process and it is not so well correlated with live-weight gains because different feeds produce different proportions of acids, CO_2 and CH_4, thus deviating from the theoretical stoichiometric equation for glucose. Inadequate nitrogen or other elements in the feed could also cause deviations. Fine grinding may substantially improve the "in-vitro" digestibility without making much improvement in the "in-vivo" digestibility because fine particles tend to be carried out of the rumen before they are completely digested.

Methods of Increasing the Digestibility

It has been observed that acid hydrolysis, fine grinding or X-ray treatments can increase the digestibility by increasing the proportion of water soluble sugars and low-molecular-weight polysaccharides, but the fibre remaining is not necessarily made more digestible by these methods. High levels of tannins or other polyphenols can negate even these improvements by "fixing" the cellulase proteins and stopping all metabolic activity. While aspen wood tends to respond well to such treatments, some types of leaves, bark and Masonite gun pulp contain so much extractives that even the soluble sugars contained in them would be of little use to the animal.

Many workers have found a strong negative correlation between digestibility and lignin content, but the lignin is not only a diluent, it also impedes access to the cellulose microfibrils and appears to be loosely bonded with the hemicellulose in the secondary walls of the cells. The differing structures of grasses, legumes, hardwoods and softwoods cause the digestibility to vary even when the overall composition is much the same.

Various techniques have been tried to improve the digestibility, such as swelling the wood structure with alkali or steam, partial hydrolysis, partial degradation with wood-rot fungi, cellulolytic bacteria or enzymes, composting or delignification. Most of these processes appear to be too expensive as a means of providing straight roughage in non-drought periods, though they might be feasible for the provision of a substitute for grains in feedlots, summer feed for areas lacking a good cover of vegetation through the summer, to increase carrying capacity, as auxiliary feed for

dairy cattle or as a backstop for bad years. The most promising processes appear to be swelling with alkali or steam, partial hydrolysis with high-pressure steam, partial degradation with white-rot fungi, composting with animal manures or some combination of these. Sawdust, small shavings, shredded or hammer-milled materials are the most suitable forms for converting into feedstuffs, though wood chips could be used if some form of mechanical defibration were included in the process.

We have set up an apparatus in this laboratory for in-vitro digestibility tests on various cellulosic materials using sheep rumen fluid and three standard forages of known digestibility. The aim of this work is to measure the digestibility of various agricultural and forestry wastes before and after various treatments. A pressure vessel is being used to determine the effect of various treatments with high-pressure steam and other samples tested include pressed residues from our IPPI work and Asplund pulps, etc. This work may be followed with fungal tests to determine whether the rate of fungal growth can be increased by steaming.

OLEORESIN STIMULATION IN *PINUS RADIATA*

A. A. Sioumis

Recent studies by naval stores researchers at USDA have shown that paraquat, a herbicide, can be used to induce resin soaking some metres above the treatment level in trees of *Pinus elliotti* and *P. palustris*.

A systematic study of the paraquat induced resinosis in *P. radiata* is now being carried out at the Division of Chemical Technology by examining the concentration effects, time taken for oleoresin formation from date of application of paraquat, method of application, number of applications, age of trees and seasonal changes.

The paraquat solution was applied in a 2.5 cm bark-chipped streak one third the trunk circumference, 0.3 m above ground level. Other methods of application such as drilling have also been used.

Stimulation of *P. radiata* trees by applying gramoxone solutions resulted in a considerable increase in the petroleum ether extractives.

The steam volatile fraction contained mostly α- and β-pinenes, the latter being the predominant one.

We are particularly interested in increasing the β-pinene content because of its use as a starting material for the synthesis of other chemicals.

A thirty fold increase in petroleumether extractives was obtained while studying the paraquat induced resinosis in a 10 year old *P. radiata* tree.

Visible external symptoms resulted from the paraquat treatment. The exudation of oleoresin through the bark of a treated tree for more than 7 m above the treatment area was very pronounced.

Because of its high labour content the possibility of a traditional turpentining operation in Australia is rather uneconomical. However, there may be possibilities of developing new and specialised industries, based on renewable resources, especially suited to those forests where thinning is taking place or in the pockets of *P. radiata* which are uneconomically placed for other timber processing purposes.

SOME BARK PROPERTIES OF QUEENSLAND GROWN CONIFERS

D. M. Greve and R. J. Bell

At the present time information on the bark properties of Queensland grown conifers is extremely limited. Most of this bark is not being utilized to its full potential and, in fact, a large proportion is either being left in the bush or burned wastefully.

With the increasing availability and use of coniferous species, more and more bark is being produced and the need to find more viable uses for this material is becoming more urgent. It is considered that knowledge of some of the physical characteristics of bark and how these vary between species and locations will assist in finding a solution to the problem.

Work has recently commenced on a study designed to determine some of the physical properties of Queensland grown hoop, slash, loblolly and Caribbean pines in their areas of major occurrence. The properties which will be determined initially are: thickness, basic density, moisture content, percentage fibrous material and fibre length.

Only a small sample is being taken initially so that some information on the bark properties of these species will be available in a relatively short time. Six trees of each species in each of their major areas of occurrence are being sampled. Three of these are from the lower end of the diameter range of material being marketed and three from the higher end. Where possible, bark samples are obtained from both the butt and the top (75 mm D.U.B.) of each tree.

In most areas, collection of samples is carried out during normal logging operations. If there is no commercial felling of a particular species at the time of sampling, the lower diameter range samples are obtained by felling unmerchantable stems while for the higher diameter range, samples are taken from the butts only of standing trees.

Samples are collected twice during one year. Once after a dry period and once after a wet period.

Procedure

The methods used in determining the various properties are as follows:

Bark Thickness

A scale is used to measure thickness on all four edges of each sample and the mean calculated. These figures are taken to the nearest millimetre.

Basic Density

This is determined on a green volume-oven dry weight basis. Bark samples are soaked prior to volume determination to prevent water absorption

during the measurement period and volume is determined using a method described by Heinrichs and Lassen.*

Moisture Content

When samples are collected they are immediately sealed in plastic bags and forwarded to the laboratory where they are then reduced in size before green weight is determined. Moisture content is obtained using the oven drying method but not before green volumes are determined.

Percentage Fibrous Material

A small piece of bark is macerated and slides made. Then, under a 50X magnification on a projection microscope a random dot grid is used to determine the percentage fibrous material as the number of dots touching fibrous material divided by the number touching solid material of any type and expressing the result as a percentage.

Fibre Length

Further slides of the macerated bark are made, and, under a projection microscope, fibric length is determined using an electronic tracer and counter, as the mean of the length of 200 fibres.

TABLE 1. Summary of Results

Species	Age (yrs)	Position in tree	Thickness (mm)	Basic Density (Kg/m^3)	Moisture Content %	% Fibrous Material	Fibre Length (mm)
Hoop Pine	17½	Butt	10	498	129.10	52.31	1.29
		Top	5	444	144.20	44.02	1.53
	34½	Butt	10	505	117.43	55.81	1.15
		Top	4	459	141.10	47 69	1.48
Slash pine	14	Butt	12	349	60.30	45.33	2.66
		Top	3	285	133.95	47.17	2.50
	22	Butt	19	389	34.80	46.94	3.06
		Top	3	399	68.70	63.86	2.82

Results and Discussion

Table 1 sets out some of the early results for hoop pine from Imbil and slash pine from Beerburrum. Some of the results for the other species and other areas are also available but are incomplete at this stage so have not been included. However, the results for loblolly and Caribbean pines from Beerburrum tend to be fairly similar to those shown in Table 1 for slash pine.

* Heinrichs, J. F. and L. E. Lassen. Improved Technique for Determining the volume of Irregularly Shaped Wood Blocks. Forest Products Journal 20 (4) : 24.

TABLE 2. Rainfall Prior to Sample Collection

	Collection date	Rainfall (mm)		
		April	May	June
Imbil (Hoop)	11/6/74	76.2	120.4	31.2
Beerburrum (Slash)	19/6/74	45.8	59.2	56.6

Bark thickness, as expected, is less towards the top in both species than it is at the base, but the difference between top and butt is much greater with slash pine than it is with hoop. The average thickness for the whole tree tends to be much the same for young trees of the different species while for older trees, slash pine has considerably thicker bark than does hoop pine.

The basic density of bark, on the other hand, is generally higher for hoop than for slash pine with an increase with age for both species, although this increase is much greater with slash pine. From the butt to the top of the tree the density tends to decrease for all samples of hoop pine and for the younger samples of slash pine, while for the 42 year old slash a slight increase in density was the result.

Again, as expected, moisture content of bark from the tops of trees is higher than that from the butts. It is also higher in young trees than in older trees but the differences are much less in hoop pine than in slash pine. Overall, the hoop pine moisture contents are higher than those for slash pine but this could possibly be partly attributed to higher rainfall during the month preceding sample collection (see Table 2).

The quantity of fibres in the bark of both species, whether from the butt or the top of the tree, or from old or young stems, does not vary greatly from an average of about 50%. However, with hoop pine the percentage fibrous material is higher towards the butt while with slash pine the opposite situation occurs with the greatest percentage being towards the top of the tree.

In Figure 1, percentage fibrous material is graphed against fibre length for both ages of both species. Although there is insufficient data involved to form any strong conclusions, it appears that a negative correlation exists between these variables between the butt and the top of the trees. While fibre lengths are fairly similar for both ages of hoop pine, with the younger stems giving slightly higher results, the opposite occurs with slash pine with the older stems giving the greatest bark fibre length. A point which could be significant in the utilization of this material is that the bark from the tops of the older slash pine stems, while having by far the highest percentage fibrous material, also has a relatively high fibre length.

One factor contributes to the difference in fibre length between hoop pine and slash pine barks is the very short fibre length of the outer bark of hoop pine in which the fibres are aligned horizontally rather

than vertically as is the case in the inner bark. This outer fibre length approximated 0.6 mm over all samples as opposed to more than 3.0 mm for the inner bark fibres.

In summary, it appears that slash pine generally has thicker bark than hoop pine, while density and moisture content are lower than for hoop pine and fibre length greater. Percentage fibrous material was variable but significantly higher in the bark of tops from older slash pine stems than from younger slash and both ages of hoop pine.

TOPIC 3 COMMENTS

3/1c A rapid micromethod for estimating ellagic acid
W.E. Hillis, L.S. Lau and A.N. Rosza

3/2c Use of bark in paper pulp and reconstituted board
W.J. Smith

3/3c Disposal of wood waste by chemical techniques
J. Norton

3/4c The quality of radiata pine bark extract
Y. Yazaki and W.E. Hillis

A RAPID MICROMETHOD FOR ESTIMATING ELLAGIC ACID

W. E. Hillis, L. S. Lau and A. N. Rozsa

Ellagic acid in the free or combined form or both, is present in all tissues of eucalypts, in oak, chestnut and several other species. The amount present varies within and between trees of the same species and between species. Ellagic acid causes costly difficulties in the manufacture of pulp and its products from wood. It affects adversely the wet strength of bonds of phenol-formaldehyde adhesives with wood. In the combined form as ellagitannins, it conveys resistance to wood destroying fungi.

In view of the influence of ellagic acid on wood quality, a rapid and accurate method for its determination is needed to assist quality assessment. Moreover, it is desirable to be able to follow the fate of ellagic acid during the utilisation and processing of the wood.

We have developed a gas liquid chromatographic method which has yielded results rapidly and accurately in the examination of a range of samples. It is suitable also for pure methylellagic acids which are found in some eucalypt woods but these could not be resolved accurately from ellagic acid with the columns used. Gallic acid also could be determined but at a lower column temperature.

Extracts or dried, ground or sectioned wood samples were soaked overnight in dry pyridine and aliquots were silylated under controlled conditions. Samples were analyzed on a silicon-gum coated gas chromatographic column. The total time for an analysis was about 30 min. The averages of analyses on one sample showed variations of ± 5% for extracts and ± 8% for wood and non-soluble samples.

The amount of ellagic and methylellagic acids in samples varied considerably within a species. The following averaged percentage results illustrate the variations in content of total ellagic acids (calculated on dry wood basis):- *Eucalyptus cypellocarpa* 0.37 and 0.64; *E. pilularis* 1.60, 0.51, 0.10, 0.12, less than 0.05; *E. dives* 0.25; *E. camaldulensis* (slow grown wood) 0.43, 0.25, 0.16, (fast grown wood) less than 0.05; *E. sideroxylon* (heartwood) 0.14, 0.13, (sapwood) 0; *E. platypus* less than 0.05. Deposits collected from commercial pulping operations contained before and after acid treatment 0.12 and 6.4, 0.04 and 5.1, 1.57 and 100% ellagic acid respectively.

Topic 3/2c

USE OF BARK IN PAPER PULP AND RECONSTITUTED BOARDS

W. J. Smith

Increasing interest is being shown in the utilization of bark as a fibre source, particularly for pulp and paper production. Following experimental demonstration much earlier, there are now a number of installations in other countries using bark percentages understood to be as high as 20% quite successfully in pulps intended for a range of bleached as well as unbleached uses.

Experimentally and/or commercially, both coniferous and hardwood barks have been found useable, including those from mixed rainforest species.

Australian pulp-mills seem to have been much slower to test the feasibility of effecting economies which may accrue from avoiding expensive and probably wasteful debarking or, alternatively, off-setting haulage and/or debarking costs by utilizing this residue.

The suitability of at least smooth-barked Eucalypts has been demonstrated by Watson *et al.* (1) and earlier workers referred to therein.

A Queensland-based hardboard producer has been manufacturing high-grade hardboard from a wide range of open-forest hardwoods, processed bark-on, for about twenty years. Essentially, only the bark of the ironbarks is excluded. Fibrous and flaky-barked species are processed as well as the smooth-barked Eucalypts.

It has been stated coniferous bark can be incorporated in particleboard without detriment, again up to at least 20% in content but, to the writer's knowledge, this is not yet being done commercially in Australia. Perhaps conviction by laboratory-scale trials on local species is needed to secure more complete utilization of the standing resource.

Another paper presented at the Conference (2) provides some evidence of the potentially useful properties of Queensland-grown indigenous and exotic conifers, including the availability of a fibrous component averaging about 50%, with fibre lengths of from 1.15 - 3.06 mm (depending on species, age and position in stem). The exotic pine barks have particularly useful fibre lengths of the same order as those for some coniferous wood, but all of the material is evidently potentially useful.

It is suggested that early pulping trials be undertaken to evaluate the suitability of the more important softwoods and hardwoods for "bark-on" processing for pulp and paper, hardboard and particleboard production as an extension of the limited experimental and even more limited commercial work here in this area. Also that such trials should test the feasibility of the admixture of separately batch-processed barks as an alternative to "bark-on" processing.

This latter should be particularly checked for use in particleboards, where the bark might serve as a core material processed normally if not completely satisfactory as an admixture with the normal stock. (One

southern board already effectively uses a hardboard core to softwood outer layers in a "sandwich" board). A further alternative here would be batch pulping of the bark for admixture to the normal stock or for the improvement of board surface characteristics.

Any promising results of previous or currently proposed work should be followed up by commercial trials to encourage early implementation of research results and minimise any unnecessary waste.

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Topic 3/3c

DISPOSAL OF WOOD WASTE BY CHEMICAL TECHNIQUES

J. Norton

In view of the emphasis of legislative bodies and communities on anti-pollution control and the increasing awareness of fire risks the conventional method of wood waste disposal by burning required review. Under certain conditions, particularly for softwoods, recovery operations for chips, pulp etc. for reconstituted materials is practicable, similarly recovery of forest waste is under technical and commercial review.

There are a number of areas where these alternatives are not viable or economic and these situations, other means of disposal are necessary. Chemical by-products can offer some solution e.g. tall oil products in plantations, stock food bases, but in Queensland there are again limited markets. It is significant that the sugar industry has now demonstrated the viability of bagasse as a fibre source.

Alternatives being investigated to some degree by this Department consist of:-

(i) carbonisation of the wood waste in simple electric furnaces to produce a "charcoal-type" product disposal of which does not present significant pollution problem.

(ii) Reduction of the wood waste by chemical oxidation using e.g. sulphuric acid/peroxide digestion. This produces two stages of product viz:

(a) "charcoal-type" material where oxidation is stopped

or

(b) a total digestion of the woody tissue to what may be termed a "Wood Ash" solution. If necessary, the excess acid is neutralised with ammonia and calcium salts.

Comment on these and other developments would be welcomed.

Topic 3/4c

THE QUALITY OF RADIATA PINE BARK EXTRACT

Y. Yazaki and W. E. Hillis

The potential of radiata pine bark tannin as a basis for a wood adhesive has been demonstrated by others. If the bark from local sources is used as a basis for an extract industry, methods to monitor the quality of the extract during production will be necessary. It has been found that fractionation of extracts of the bark using Sephadex columns gives profiles representing different amounts of mono-, oligo- and poly-meric compounds.

About 10% of an aqueous extract contains monomers which have been identified, 10% of di- and trimeric compounds and the rest polymeric flavans.

To improve yield and quality of extracts, the bark has been extracted with hot 1% solutions of sodium bisulphite, sulphite and carbonate.

The profile and chromatograms of the bisulphite extract indicates either the polymers have been partly ruptured to low molecular weight compounds or a larger amount of low molecular weight compounds have been extracted. These latter compounds may be responsible for the improved adhesive behaviour. Sodium carbonate and sodium sulphite solutions have a similar but weaker effect. It was found that extensive treatment with the reagents increased the proportion of polymeric materials considerably. It is intended to carry out the comparison of extracts with known profiles and adhesive behaviour to determine the sensitivity of the method for analytical purposes.

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Atanackovic, A.	WTD	1/17
Bamber, R.K.	WTD	2/2, 2/8
Barnacle, J.E.	DBR	1/10c, 2/15, 2/16
Bauch, J.	DBR*	2/6c
Bell, R.J.	DFQ	3/12
Bootle, K.R.	WTD	1/35, 2/29, 2/30
Buick, R.G.	ANU	1/7c
Chafe, S.C.	DBR	2/5c
Chapman, P.	WTD	1/35
Christensen, G.N.	DBR	3/5
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Davis, R.	DFQ	1/4c
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Eccles, D.B.	DFQ	2/3, 2/7
Edwards, D.W.	WTD	2/18
Fett, Jill M.	WTD	2/2c, 2/3c
French, J.R.J.	DBR	2/26, 2/28, 2/7c, 2/19c
Fricke, K.	DBR	1/22
Fung, P.Y.	DBR	1/4, 1/5
Gardner, W.D.	WTD	2/17
Gartside, G.	DCT	3/2
Gough, D.	DFQ	1/24
Grant, D.J.	WTD	1/29

Author	Organisation	Topic
Greaves, H.	DBR	1/1, 2/20
Greve, D.	DFQ	1/34, 1/2c, 1/3c, 1/6c, 3/8, 3/12
Grossman, P.U.A.	DBR	1/28
Groves, K.W.	ANU	1/7c, 2/12
Hartley, J.	WTD	1/23
Hergt, H.F.A.	DBR	3/5
Higgins, H.G.	DCT	I.P.4, 3/7
Hillis, W.E.	DBR	1/1c, 2/1, 2/9, 2/12, 2/5c, 2/6c, 2/7c, 2/21c, 3/1c, 3/4c
Howick, C.D.	DBR	2/25, 2/12c
Ironside, G.	WTD	I.P.5
Irvine, G.M.	DCT	3/4
Johanson, R.	DBR	2/19, 2/14c, 2/15c, 2/18c
Johnstone, R.S.	WTD	1/3, 2/17, 2/18
Keating, N.R.	TRADAC	1/3c
Kennedy, M.	DFQ	2/11c
Kloot, N.H.	DBR	I.P.3
Krilov, A.	WTD	I.P.5
Lau, L.S.	DBR	3/1c
Leicester, R.H.	DBR	1/20, 1/31
Lhuede, E.P.	DBR	1/4, 1/6, 1/11c
Liversidge, R.M.	DBR	1/1, 1/2, 1/4
Logan, A.F.	DCT	3/6
McCarthy, D.	DBR	2/24
McCombe, B.	DBR	1/14, 1/15, 1/18
McCormack, R.	FTB	1/13
McKenzie, W.M.	DBR	1/7
McKittrick, D.J.	FCV	1/11c
Mamers, H.	DCT	3/3
Mardon, C.J.	DCT	3/10
Michell, A.J.	DCT	3/4
Moffatt, A.	DFQ	2/20c
Nelson, P.J.	DCT	3/9
Norton, J.	DFQ	2/11c, 2/20c, 3/3c
Opie, J.E.	FCV	1/8

Author	Organisation	Topic
Palmer, R.E.	DBR	2/10
Phillips, F.H.	DCT	3/6
Pitt, W.	WTD	2/18
Plomley, K.F.	DBR	1/37
Reardon, G.F.	DBR	1/21
Robinson, R.	DBR	2/26
Rosel, A.	DBR	2/27, 2/28
Rosza, A.N.	DBR	2/5c, 3/1c
Ronan, N.M.	ANU	1/7c
Schmidt, J.	DFQ	1/30
Simpfendorfer, P.	DBR	1/18
Sioumis, A.A.	DCT	3/11
Smith, N.A.H.	DFQ	2/10c
Smith, W.J.	DFQ	I.P.2, 1/30, 1/5c, 2/3, 2/7, 2/1c, 2/2c, 2/3c, 3/2c
Stashevski, A.	DBR	1/36
Tamblyn, N.	DBR	2/13, 2/25, 2/27
Vaughan, J.E.	DCT	3/4
Vines, R.G.	DCT	3/1
Watson, A.J.	DCT	3/3, 3/7
Waugh, G.	DBR	1/11, 1/13, 1/11c, 2/5
Wickett, H.C.	FDWA	1/26
Willis, D.	DCT	3/4
Wright, J.P.	FCV	1/11, 1/12, 2/6
Yazaki, Y.	DBR	2/6c, 2/7c, 3/4c
Zosars, A.	DFQ	1/4c, 2/10c

KEY:

DBR	CSIRO, Division of Building Research
DCT	CSIRO, Division of Chemical Technology
DFQ	Department of Forestry, Queensland
DMS	CSIRO, Division of Mathematics and Statistics
FCV	Forests Commission Victoria
FDWA	Forests Department Western Australia
FTB	Forestry and Timber Bureau, Canberra
TRADAC	Timber Research and Development Advisory Council
WTD	Wood Technology Division, Forestry Commission of N.S.W.
I.P.	Invited Paper
*	Visiting Scientist, Hamburg, West Germany

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Sincere thanks are due to Rosemary Hamilton and Joyce Lloyd for the typing, Margot Moser and Nina Mummé for the printing, collating and binding, Maureen Stepan and Veronika Gaszner for cover design and drafting work, Jan Collins for checking and Wallace Hastie for photography.

Organising Committee: W.G. Keating
J.E. Barnacle
H.F. Heath
A.J. Michell

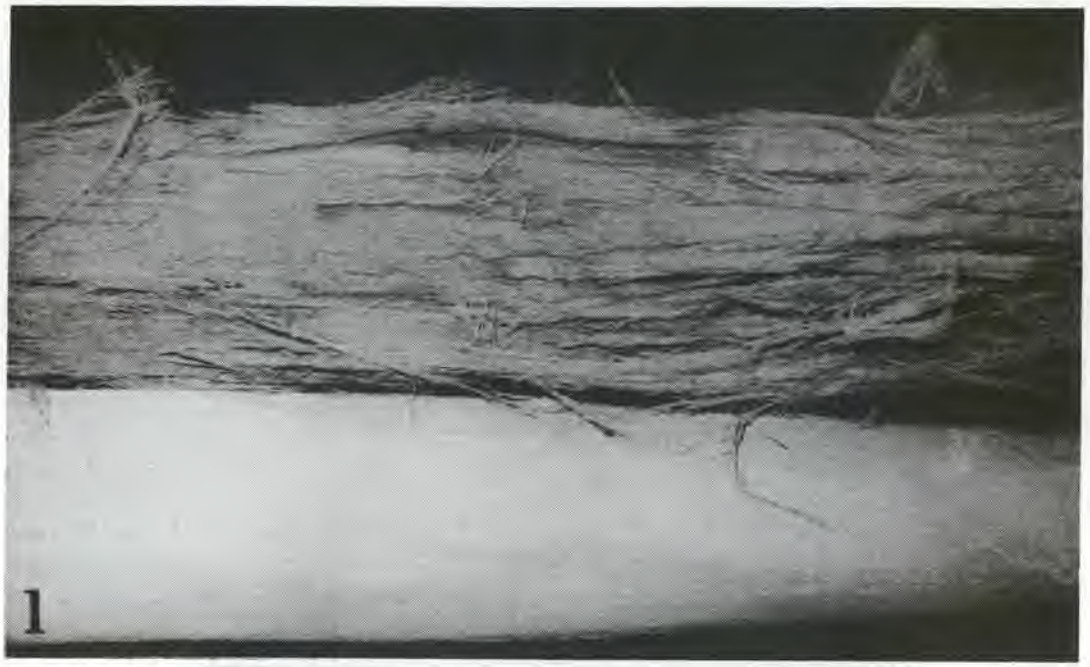


Figure 1. Edging of E. obliqua, showing cleanly removed bark. Steamed for 1½ hours.

Figure 2. P. radiata peeler log, to illustrate ease of bark removal. 2 hours steaming.

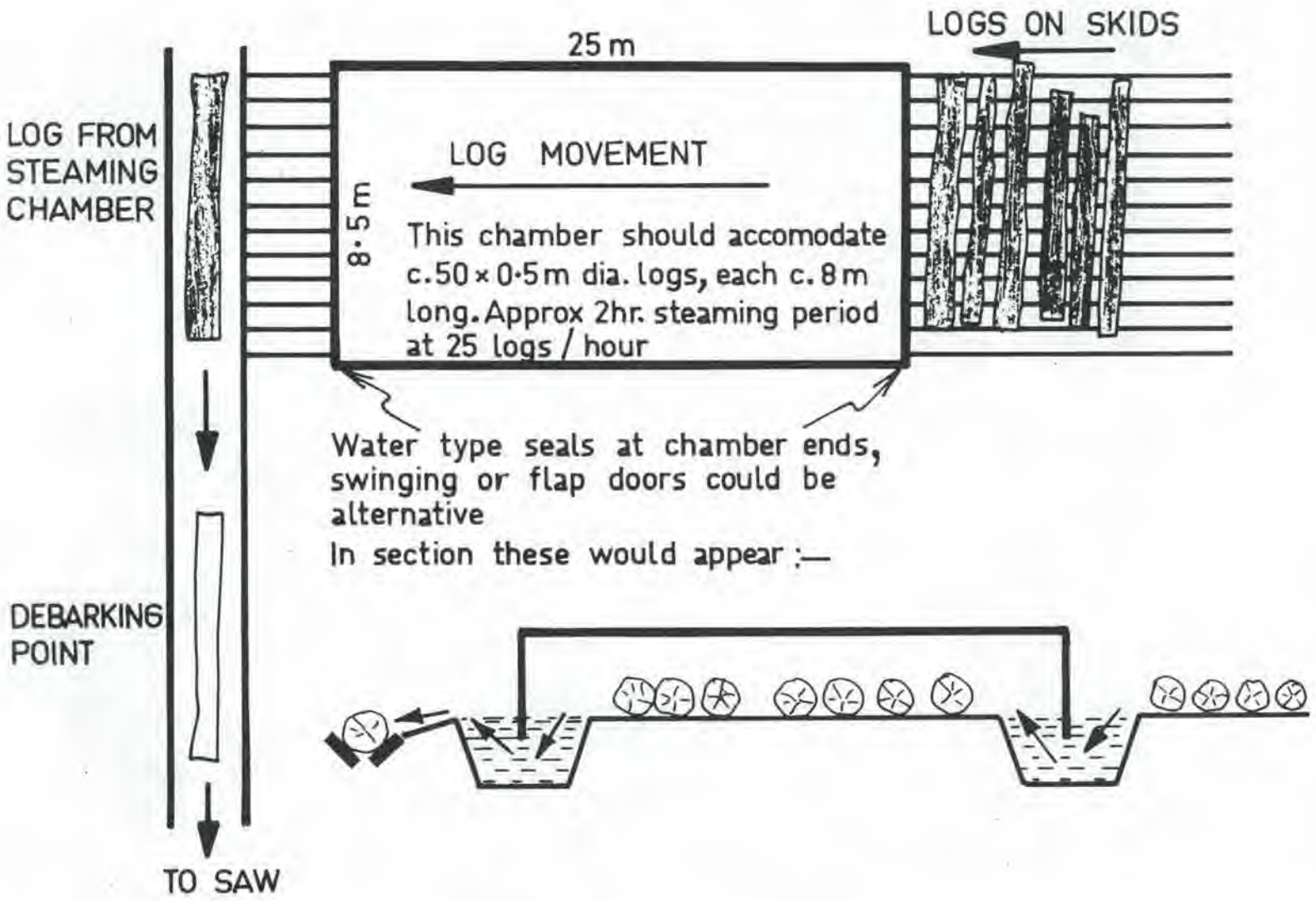


Figure 3. Diagrammatic representation of a simple steaming chamber.

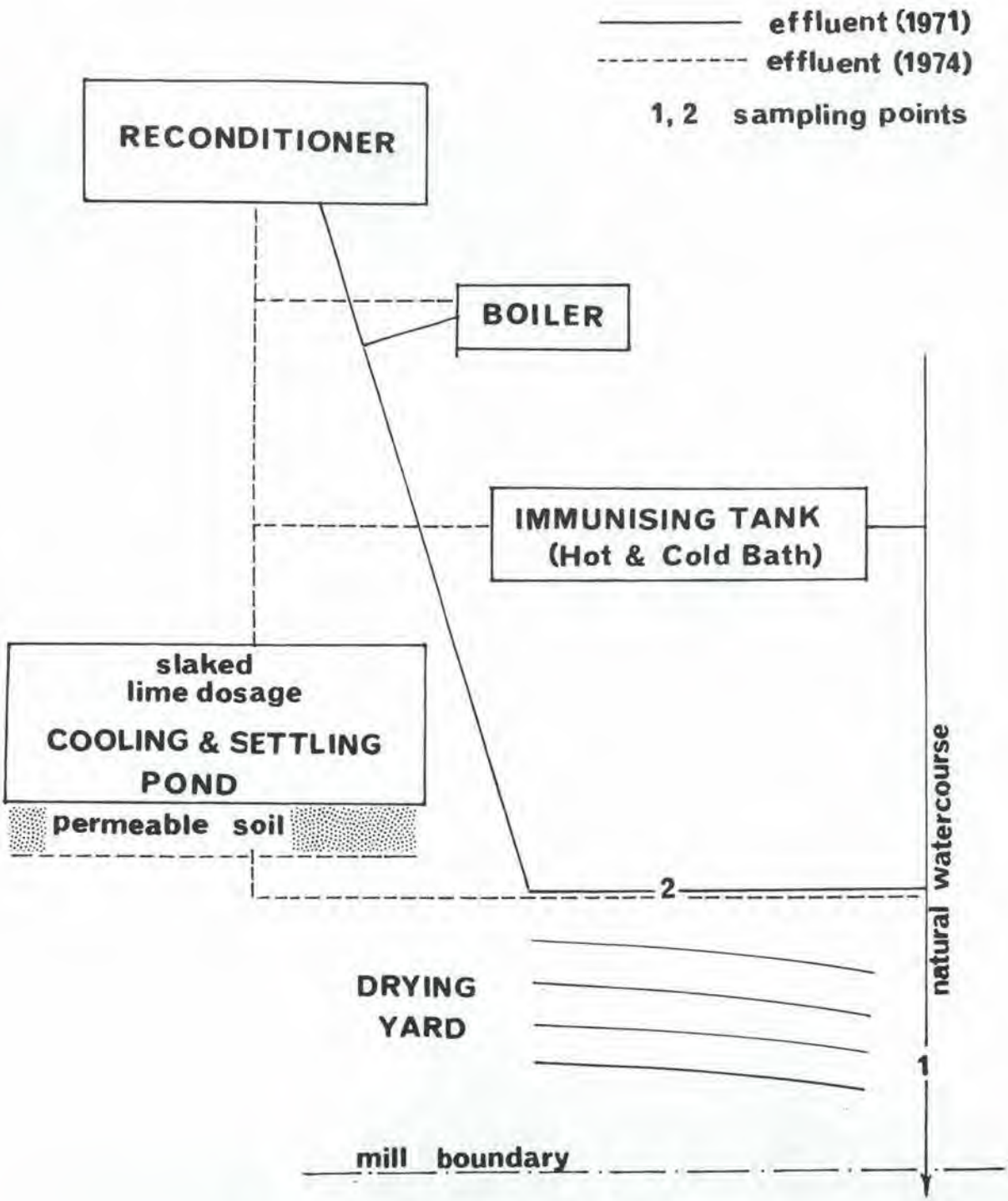


FIG. 1 EFFLUENT FLOW

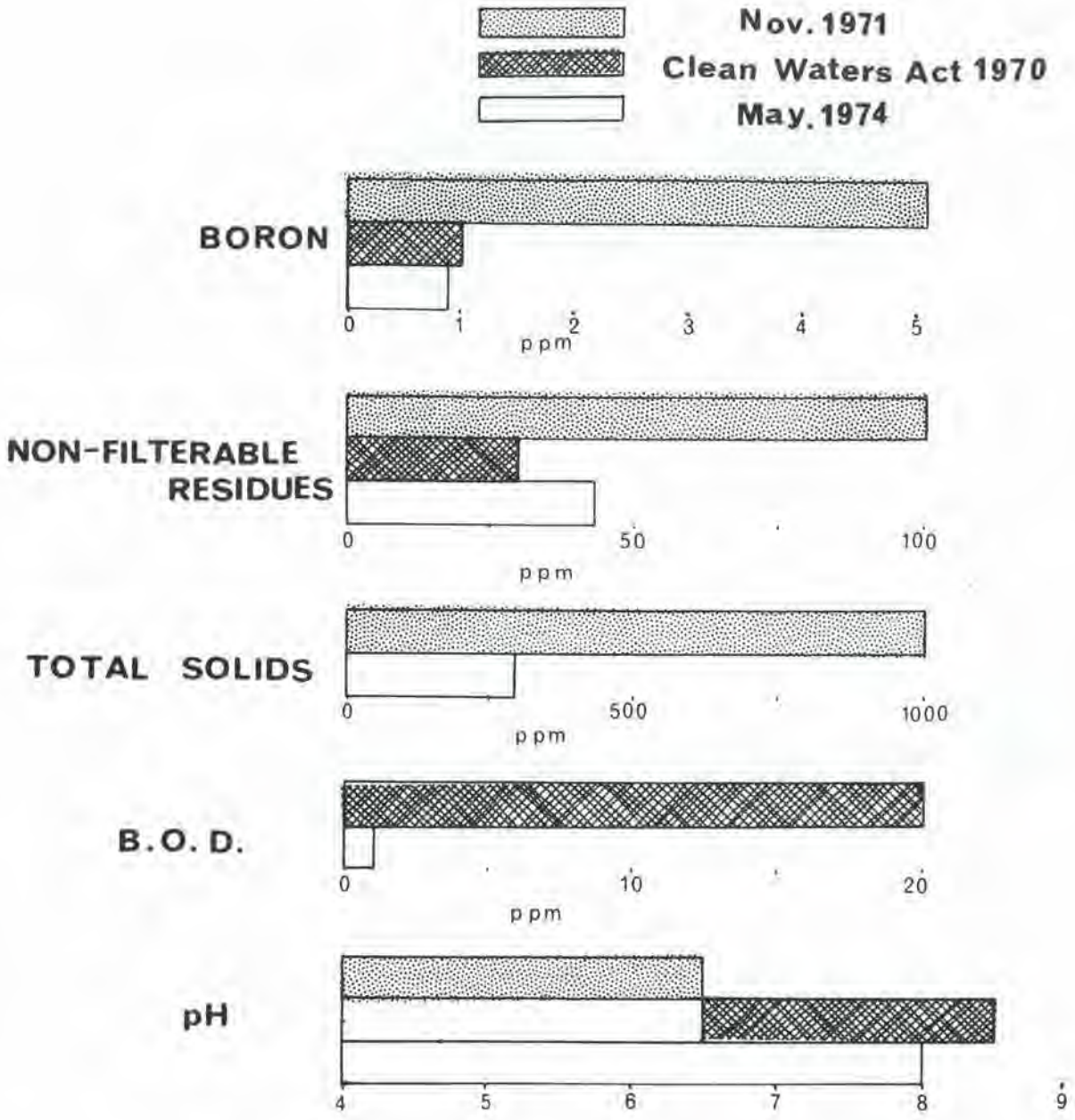


FIG.2 GRAPH SHOWING IMPROVEMENT IN WATER QUALITY

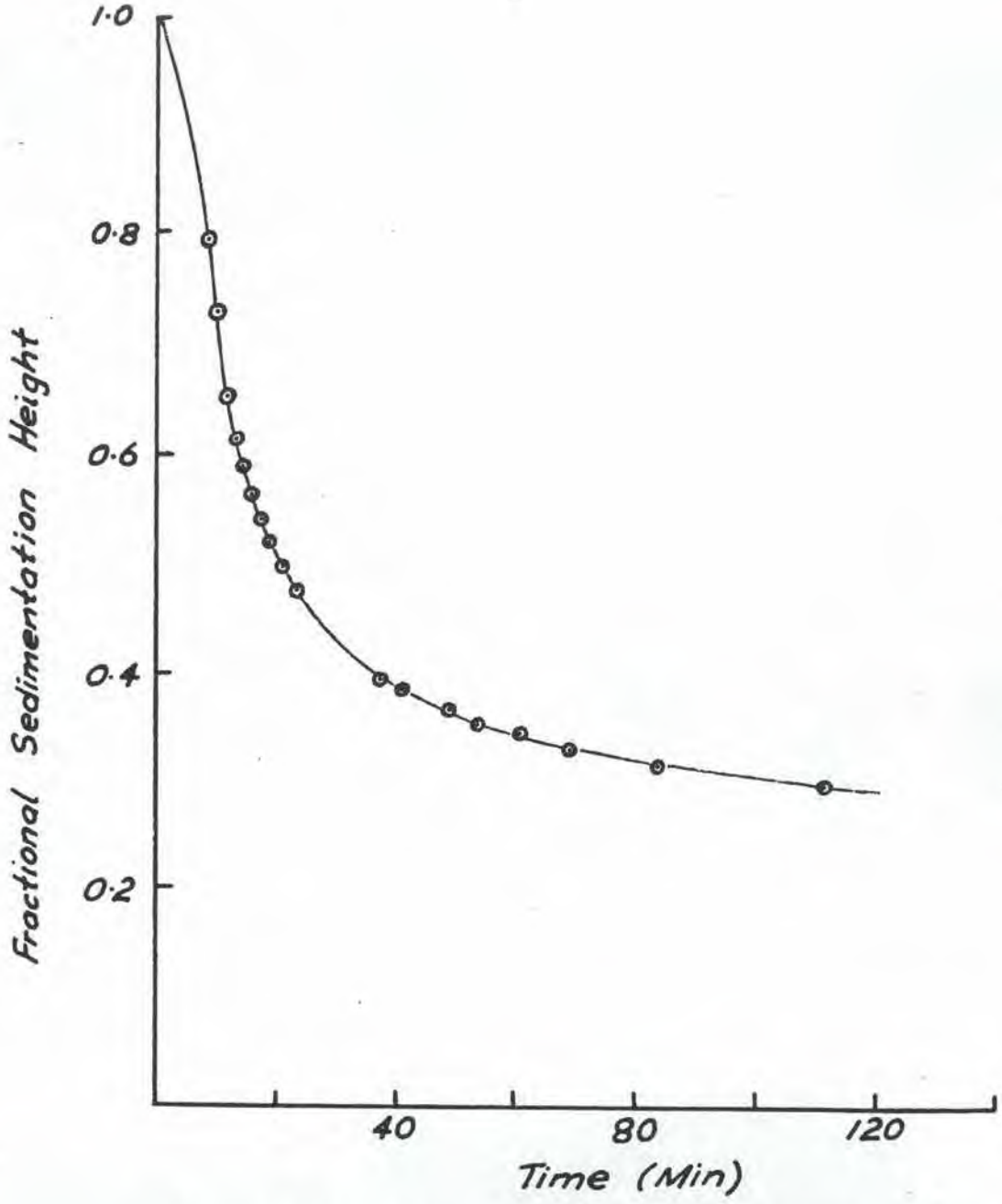


Figure 1. Sedimentation Curve for Treated Effluent

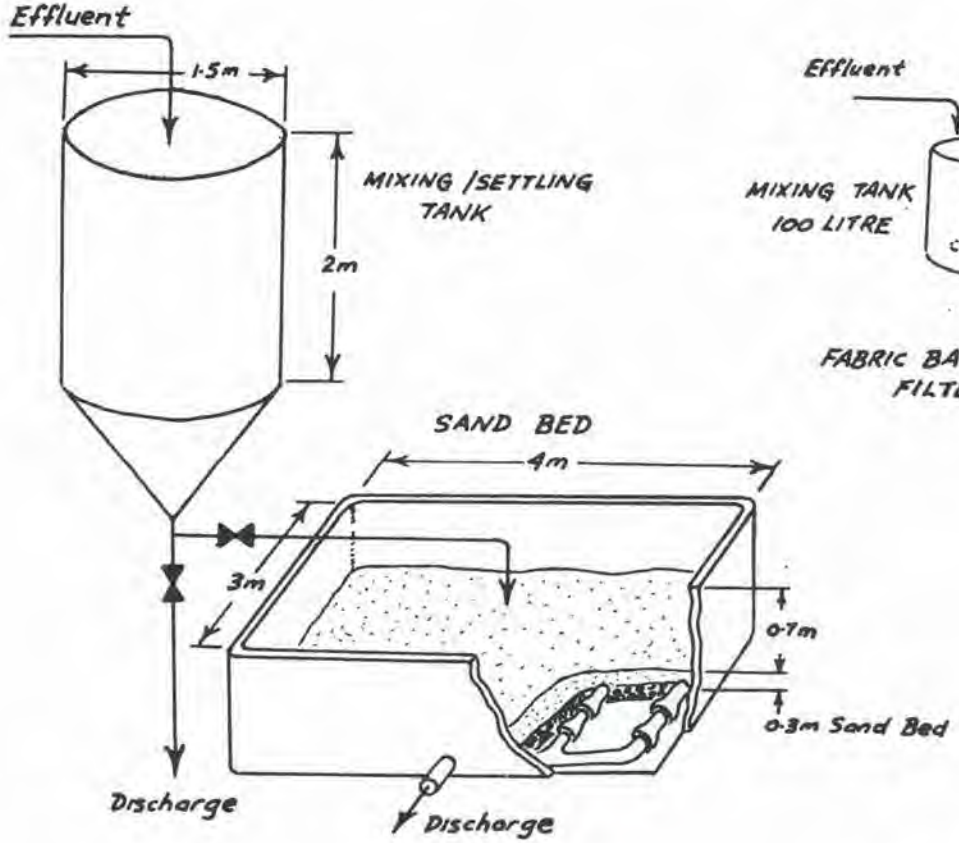


Figure 2. Batch Operation

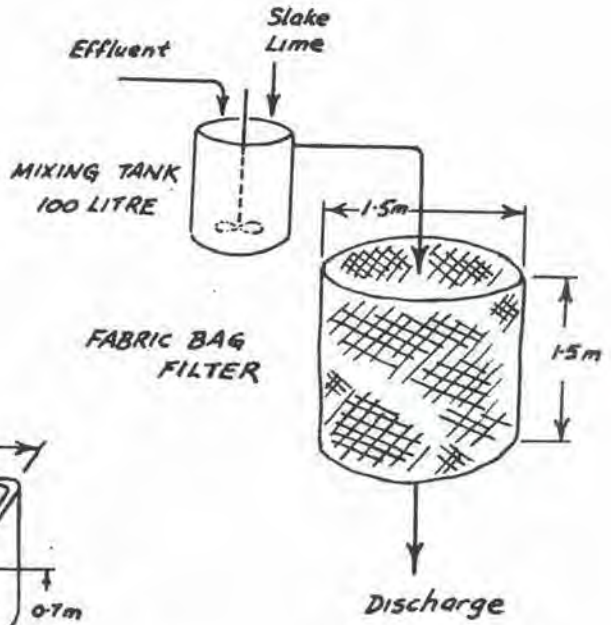


Figure 3. Continuous Operation

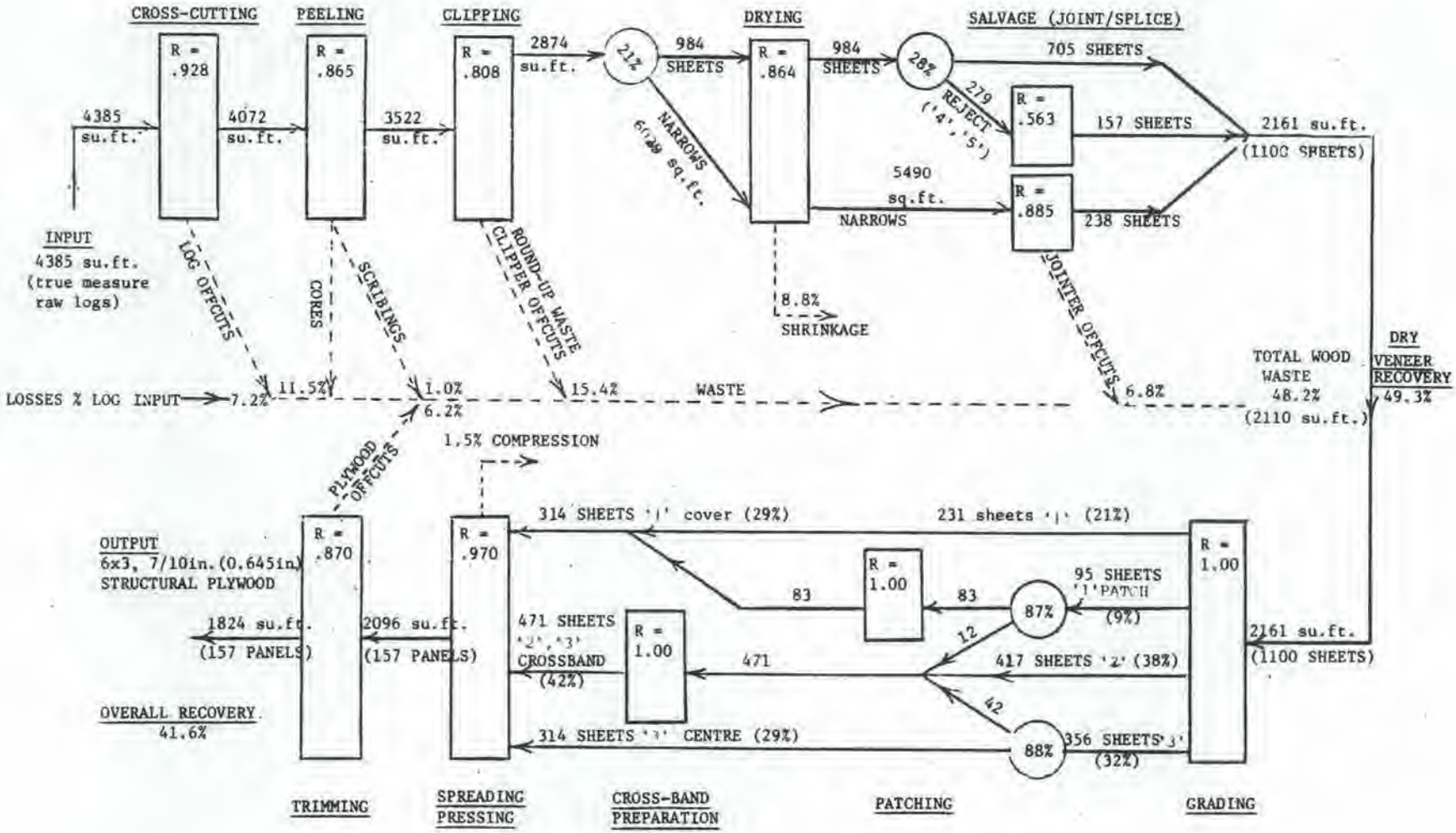
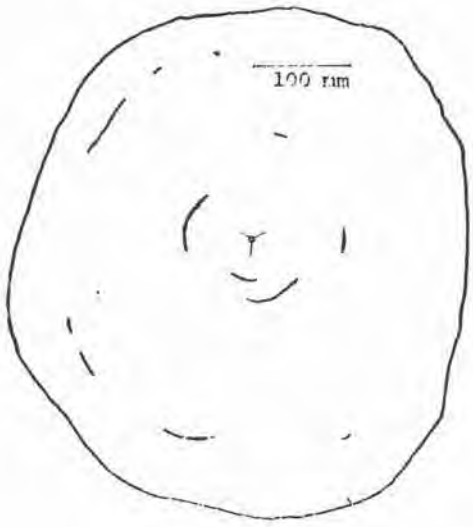


FIG. 1 RESULTS OF COMMERCIAL TRIALS OF REGROWTH MOUNTAIN ASH ex TOOLANGI

LOG NO. 1

BUTT



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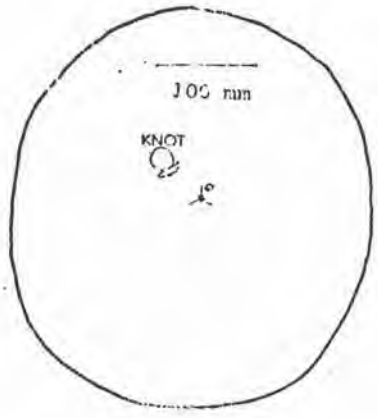
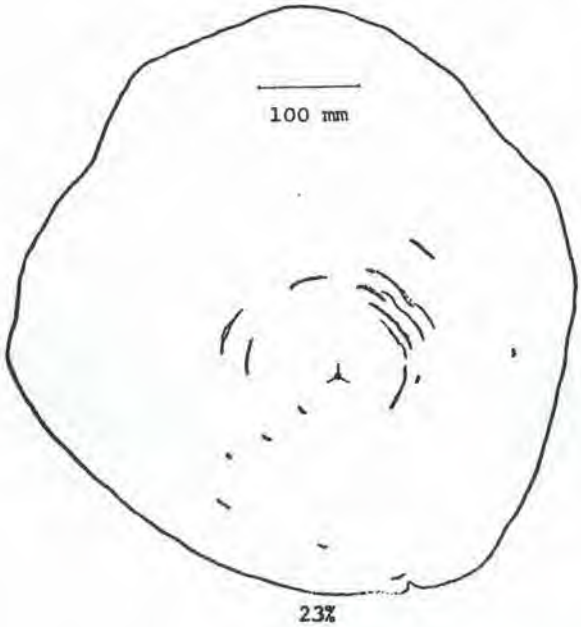


15%

LOG NO. 2

BUTT



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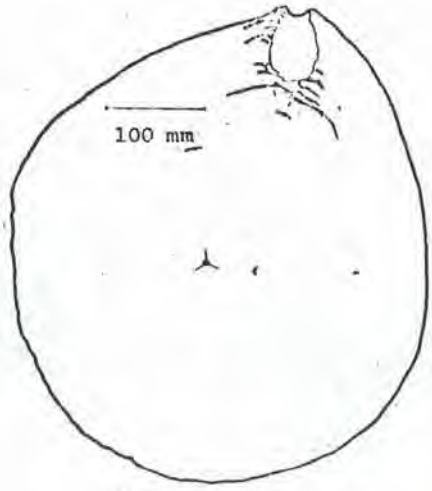

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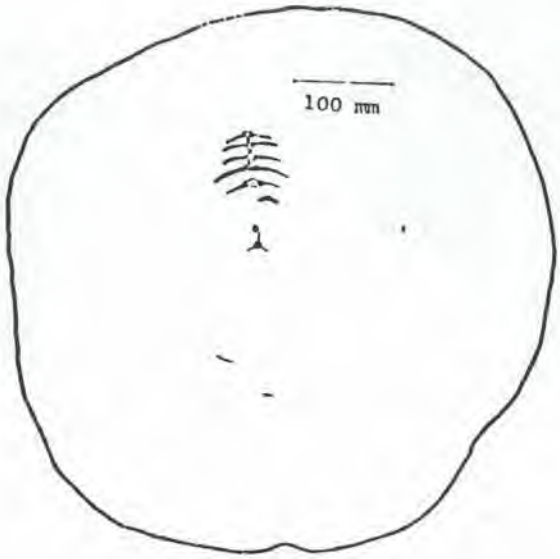
FIG. 2a DISTRIBUTION OF GUM VEINS AND POCKETS ON LOG END SECTIONS
LOGS 1 and 2
Yield of clear veneer after round-up for billet adjacent to end is indicated

LOG NO. 3

BUTT



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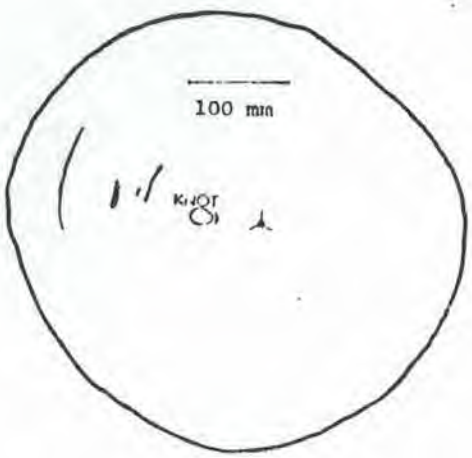

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LOG NO. 4

BUTT

20%

TOP

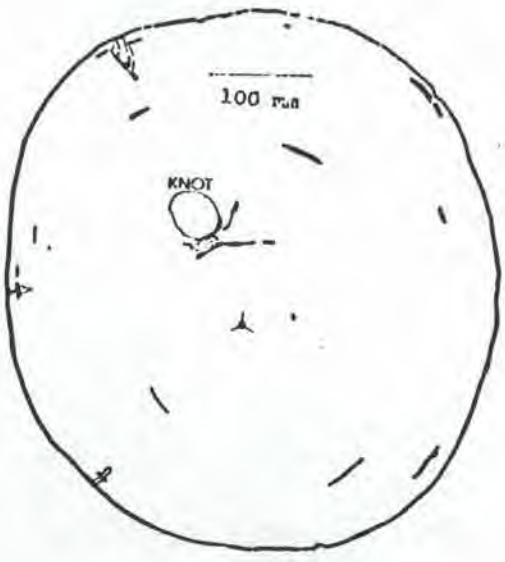

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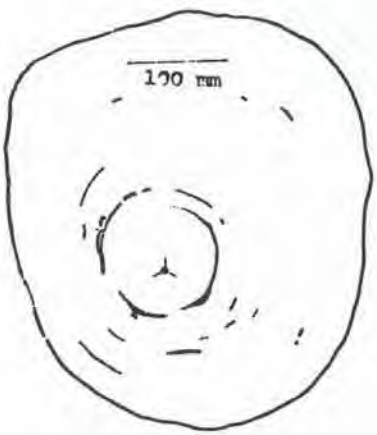
FIG. 2b DISTRIBUTION OF GUM VEINS AND POCKETS ON LOG END SECTIONS
LOGS 3 and 4
Yield of clear veneer after round-up for billet adjacent to end is indicated.

LOG NO. 5

BUTT



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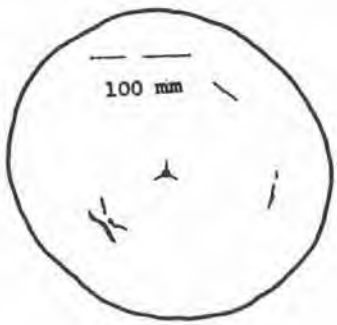

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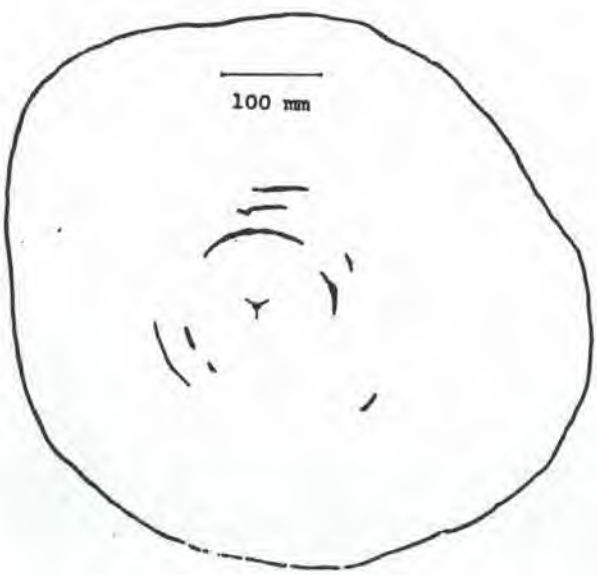
LOG NO. 6

BUTT



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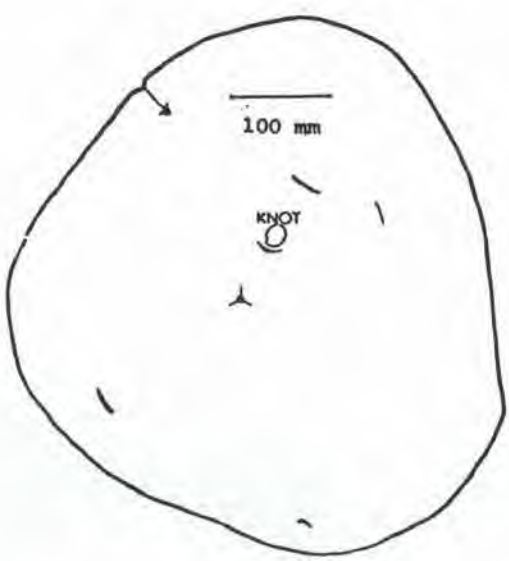


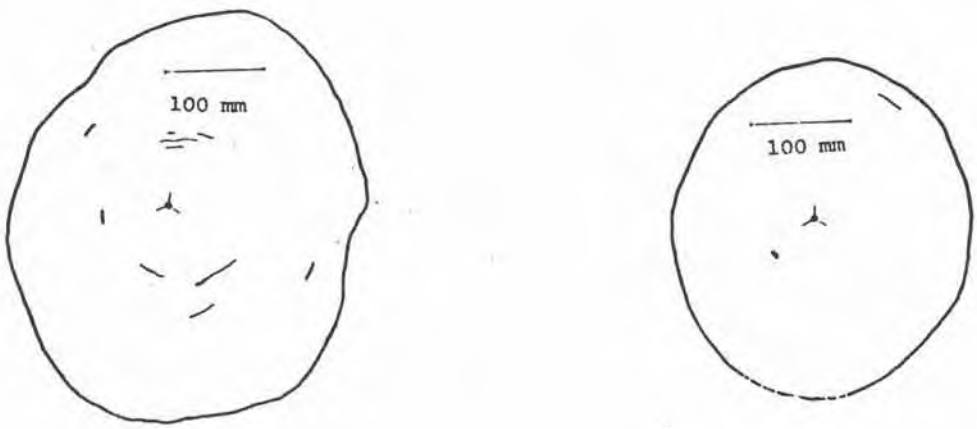
11%

FIG. 2c DISTRIBUTION OF GUM VEINS AND POCKETS ON LOG END SECTIONS
LOGS 5 and 6
Yield of clear veneer after round-up for billet adjacent to end is indicated

LOG NO. 7

BUTT

TOP



6%

38%

FIG. 2d DISTRIBUTION OF GUM VEINS AND POCKETS ON LOG END SECTIONS
LOG 7
Yield of clear veneer after round-up for billet adjacent to end is indicated

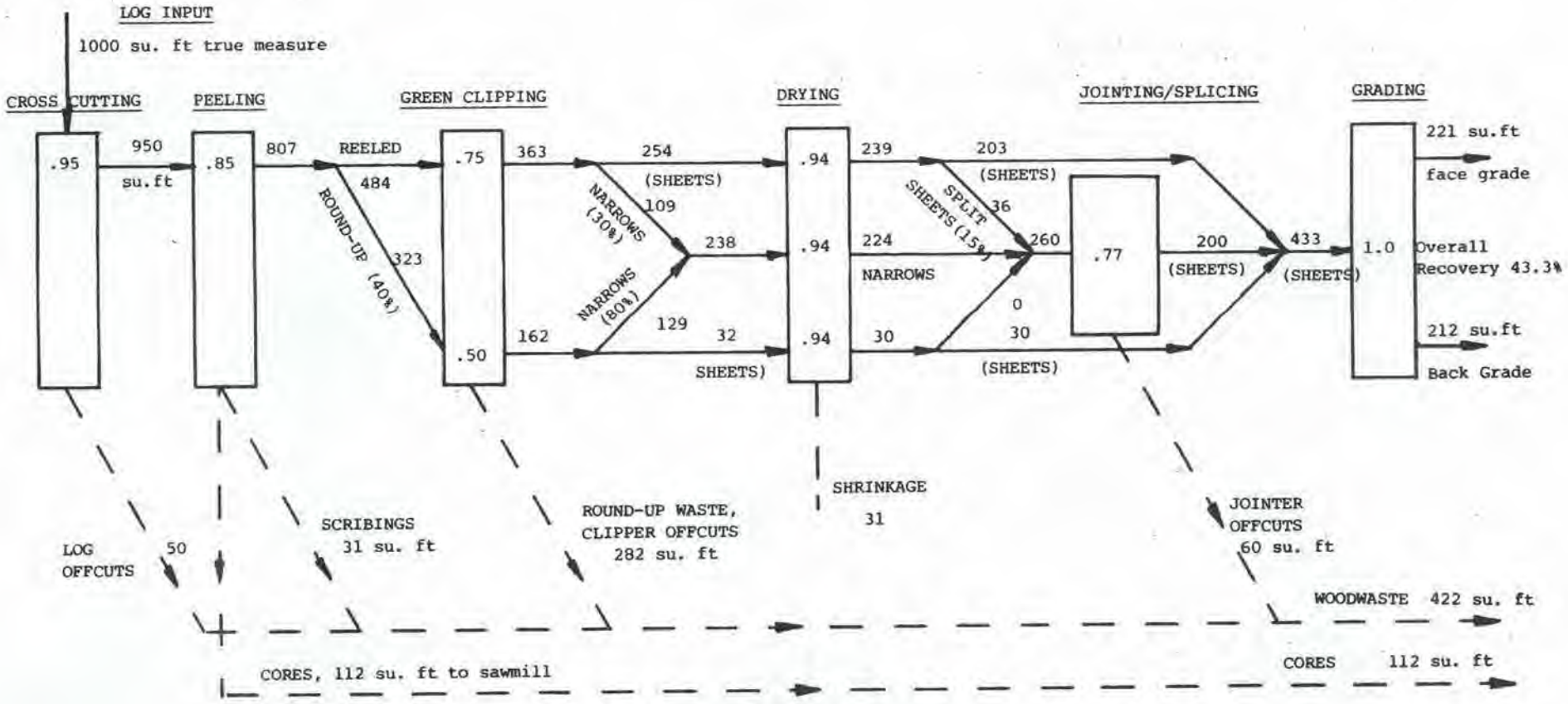


FIG. 1 RECOVERY MODEL FOR CONVERSION OF CEDAR LOGS INTO COVER VENEER

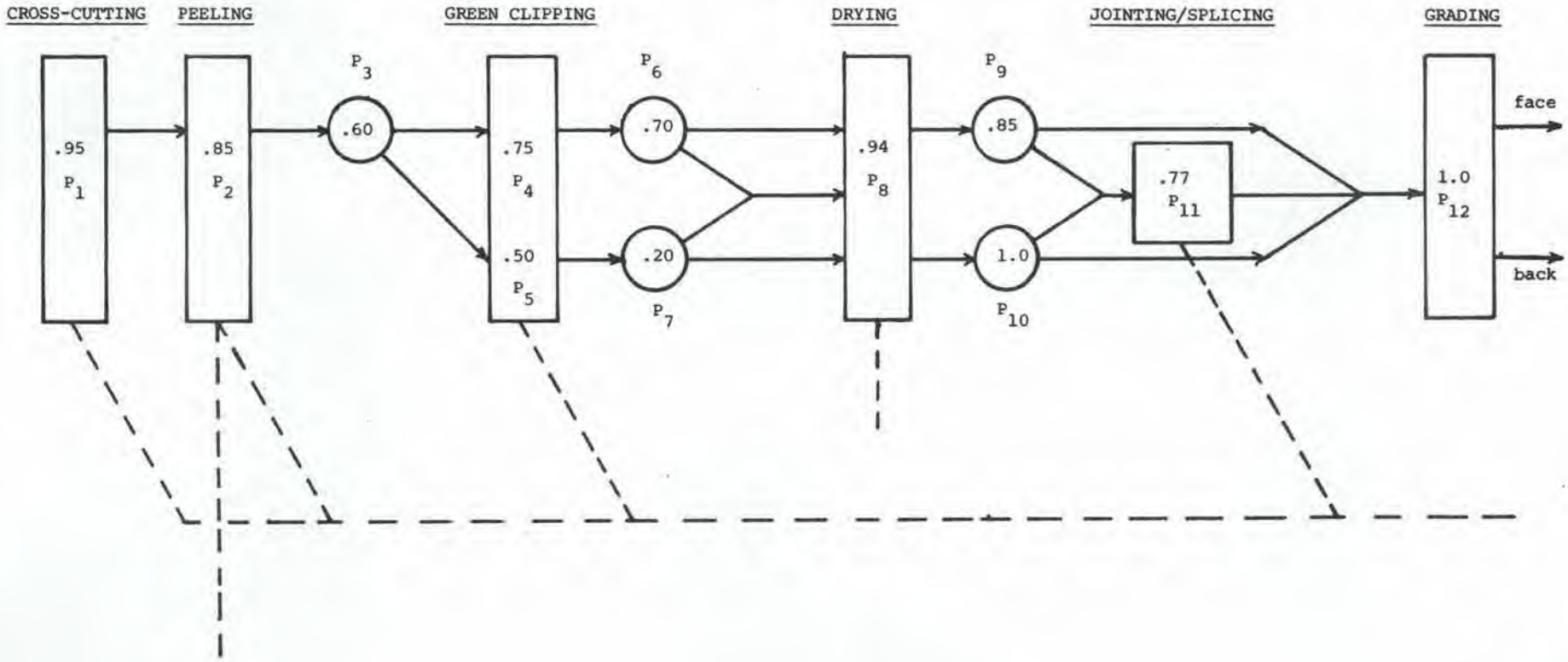
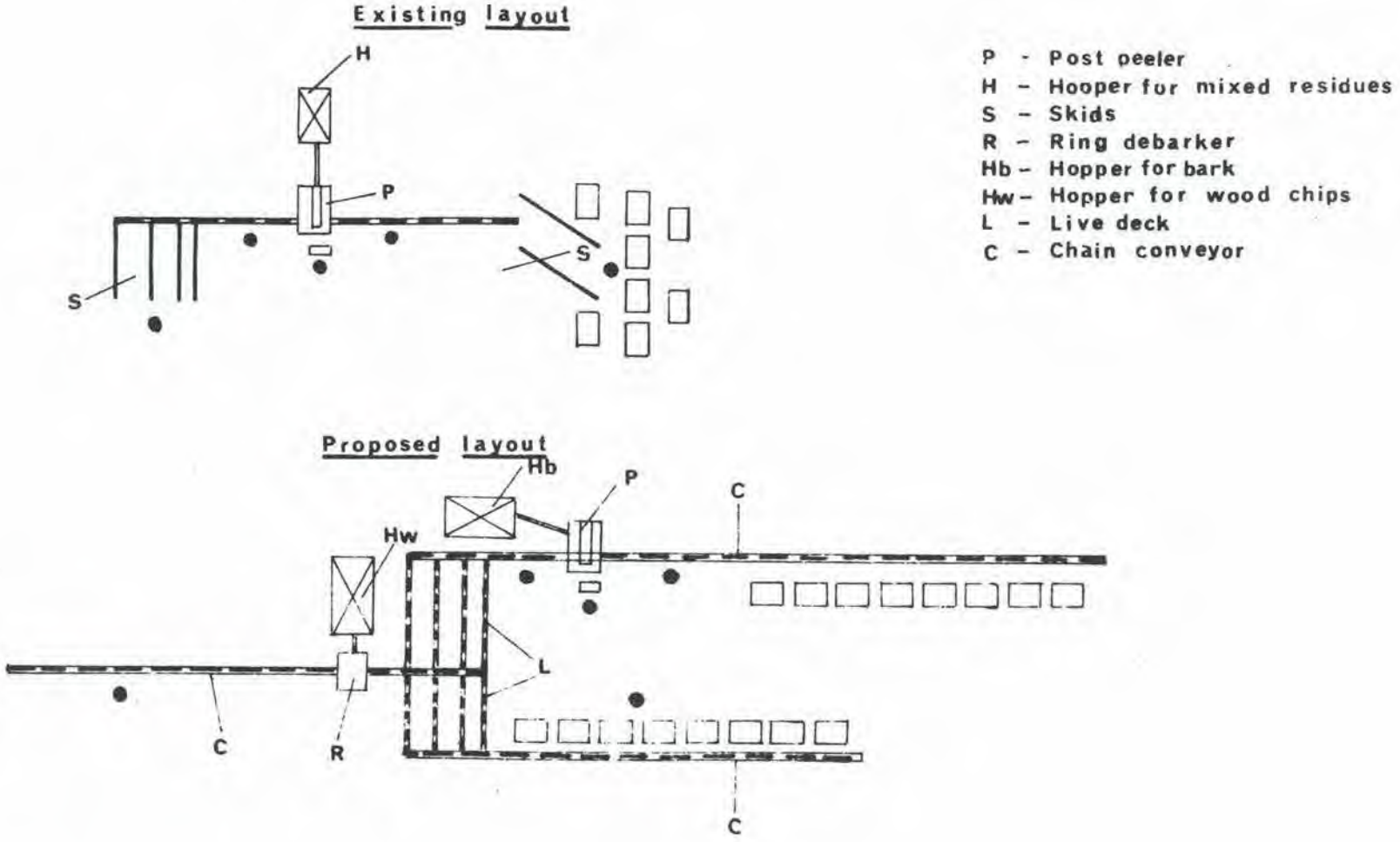


FIG. 2 NETWORK PARAMETERS FOR CONVERSION OF CEDAR LOGS INTO COVER VENEER



P - Post peeler
H - Hooper for mixed residues
S - Skids
R - Ring debarker
Hb - Hopper for bark
Hw - Hopper for wood chips
L - Live deck
C - Chain conveyor

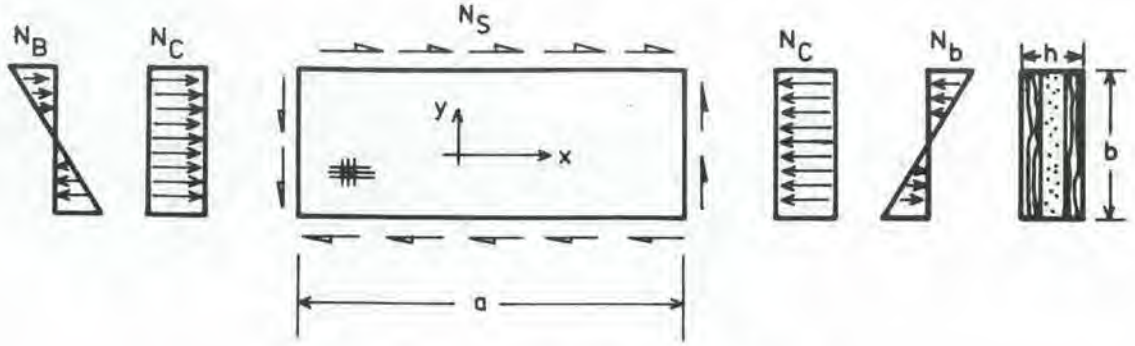


FIG. 1 NOTATION FOR PLYWOOD DIAPHRAM

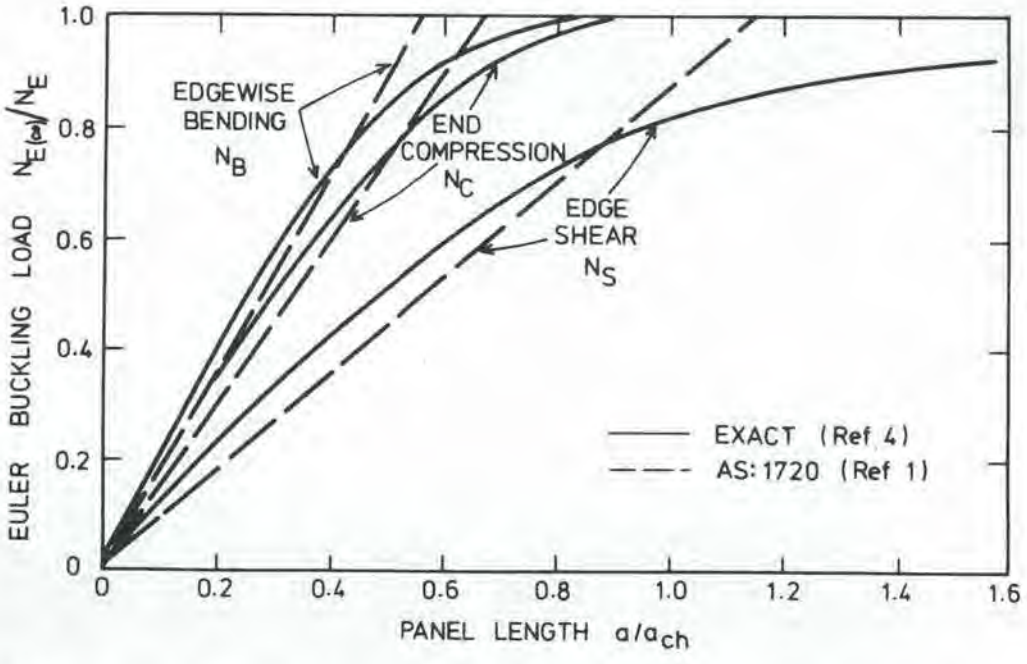


FIG. 2 EFFECT OF SHORT PANEL LENGTH ON EULER BUCKLING LOAD

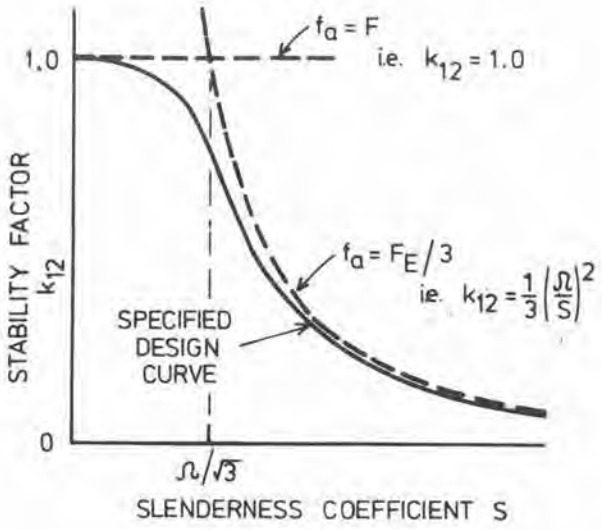


FIG. 3 EFFECT OF SLENDERNESS ON STABILITY FACTOR

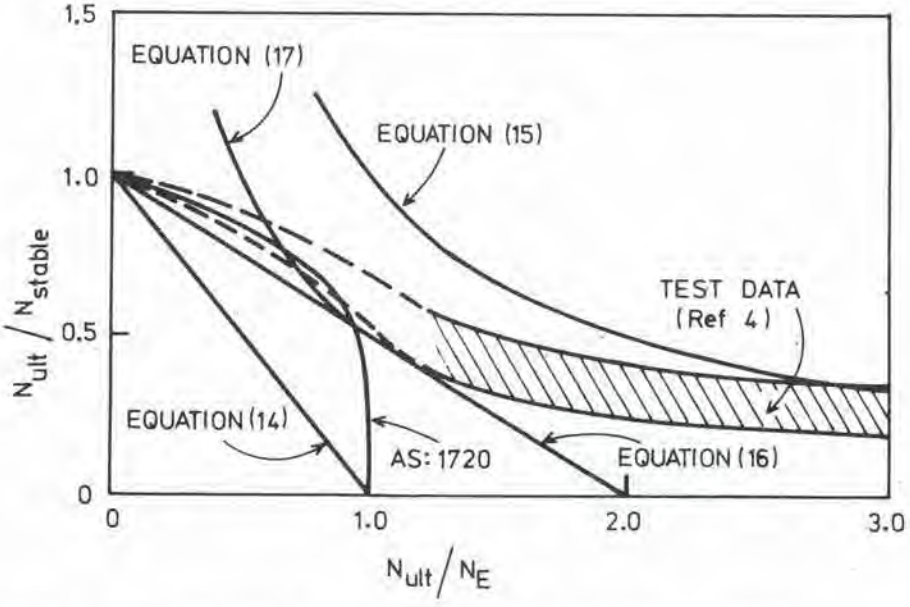


FIG. 4 ULTIMATE STRENGTH OF PLYWOOD WEBS SUBJECTED TO END COMPRESSION

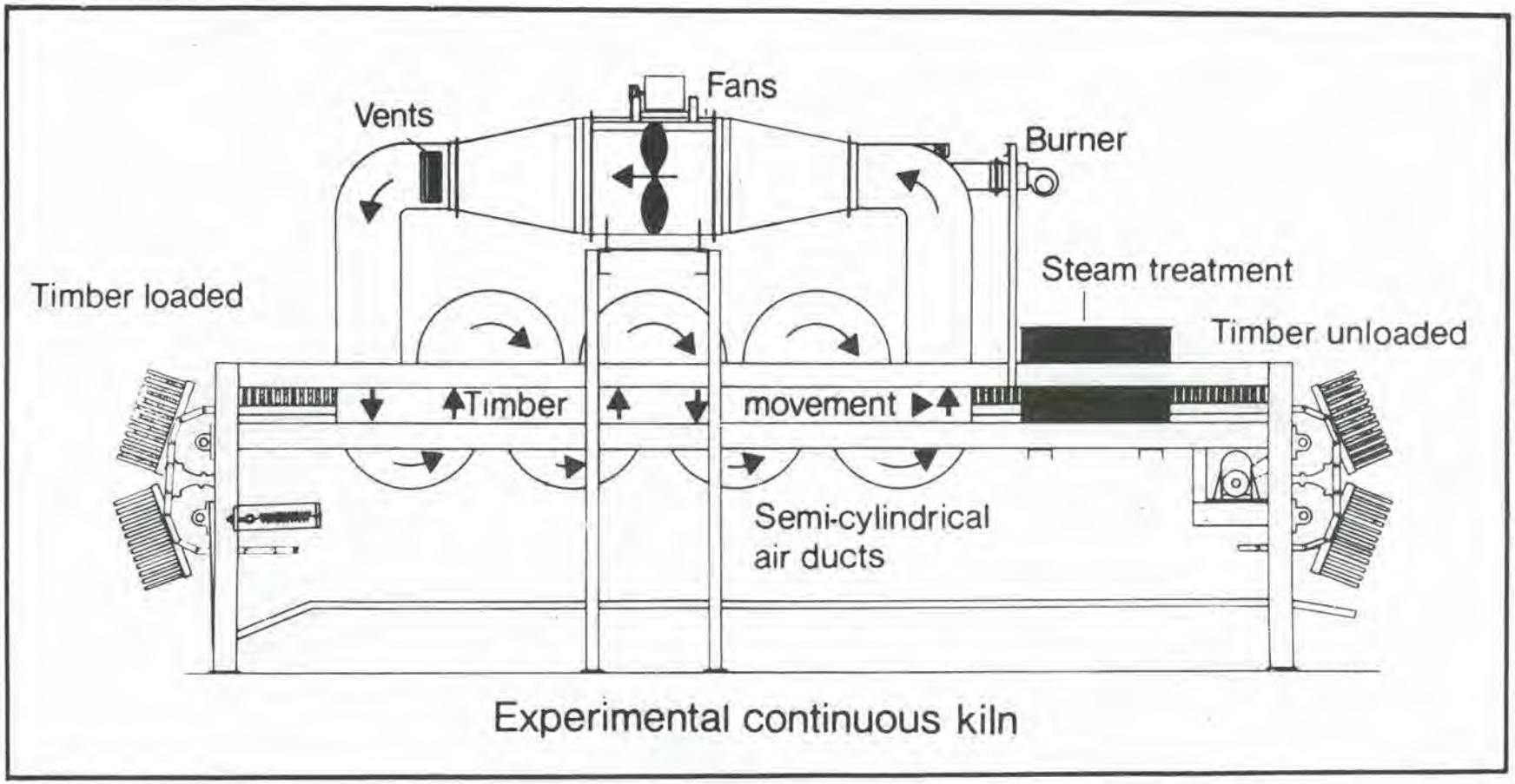

Fans
Vents
Burner
Steam treatment
Timber loaded
Timber unloaded
Timber
movement
Semi-cylindrical
air ducts
Experimental continuous kiln

Figure 1.

FIGURE 1. Moisture Content variation across the stack for different sticker thicknesses.

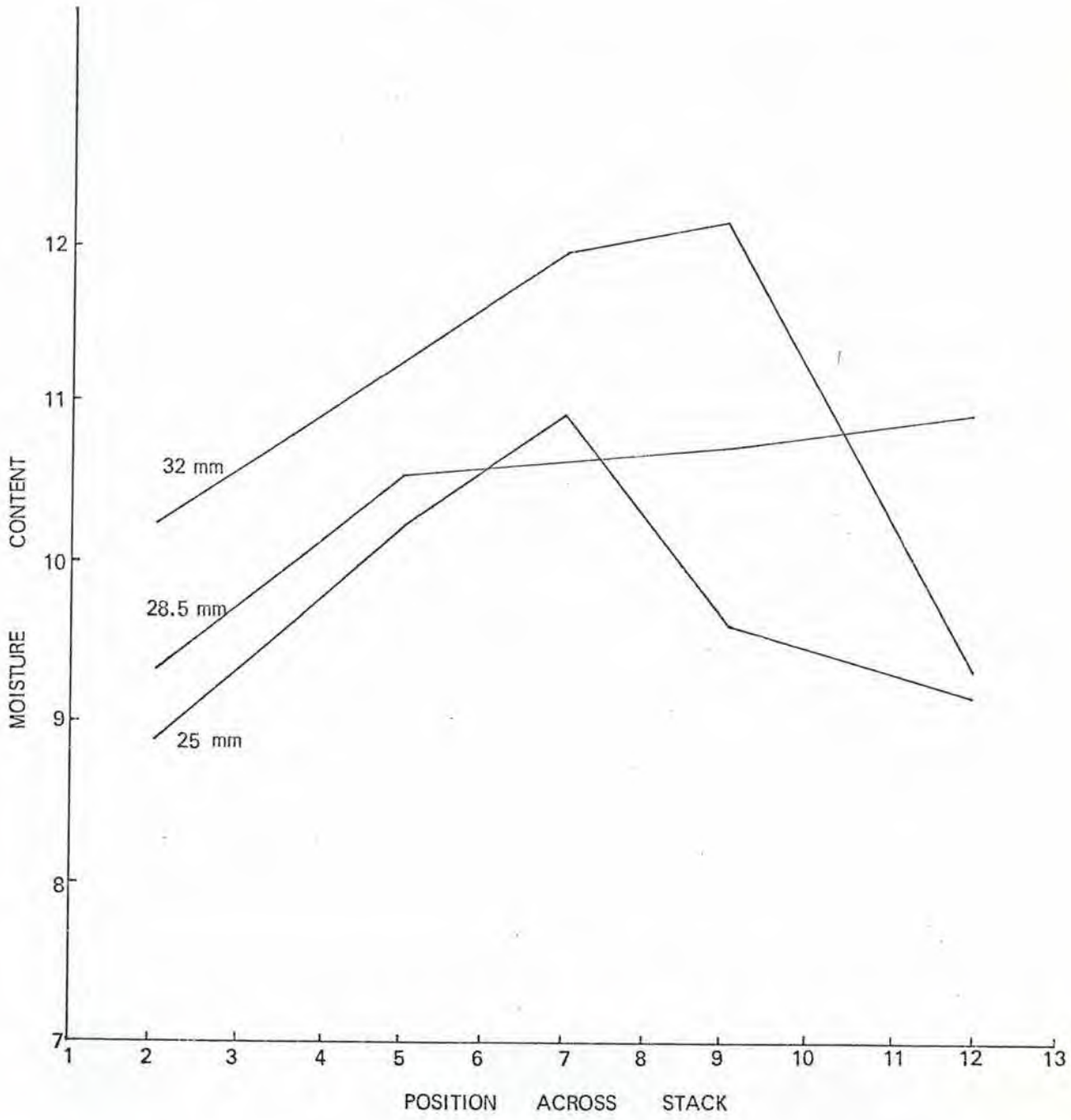
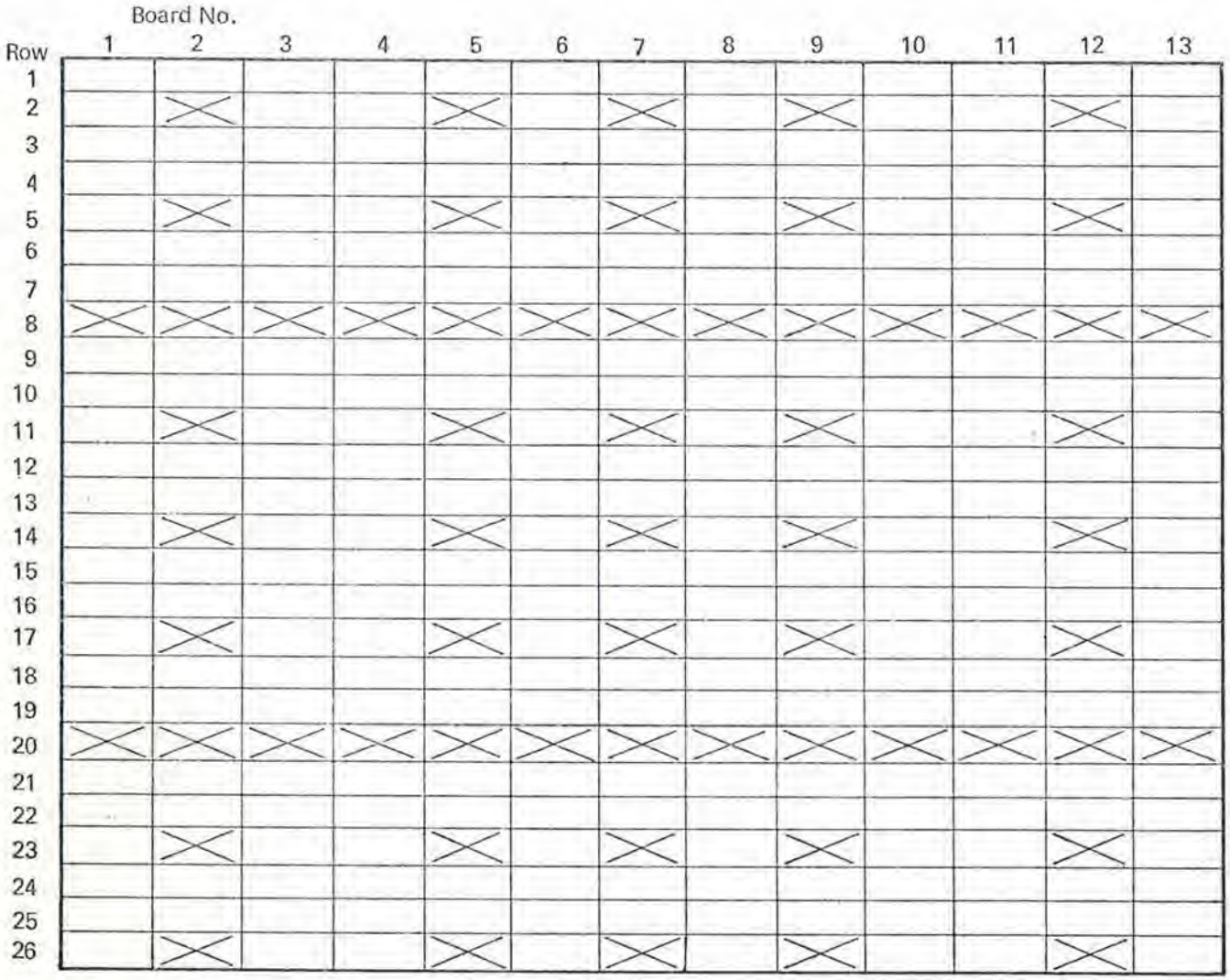


Diagram of Stack Cross-Section, showing:-

Systematic Sampling for Moisture Content.



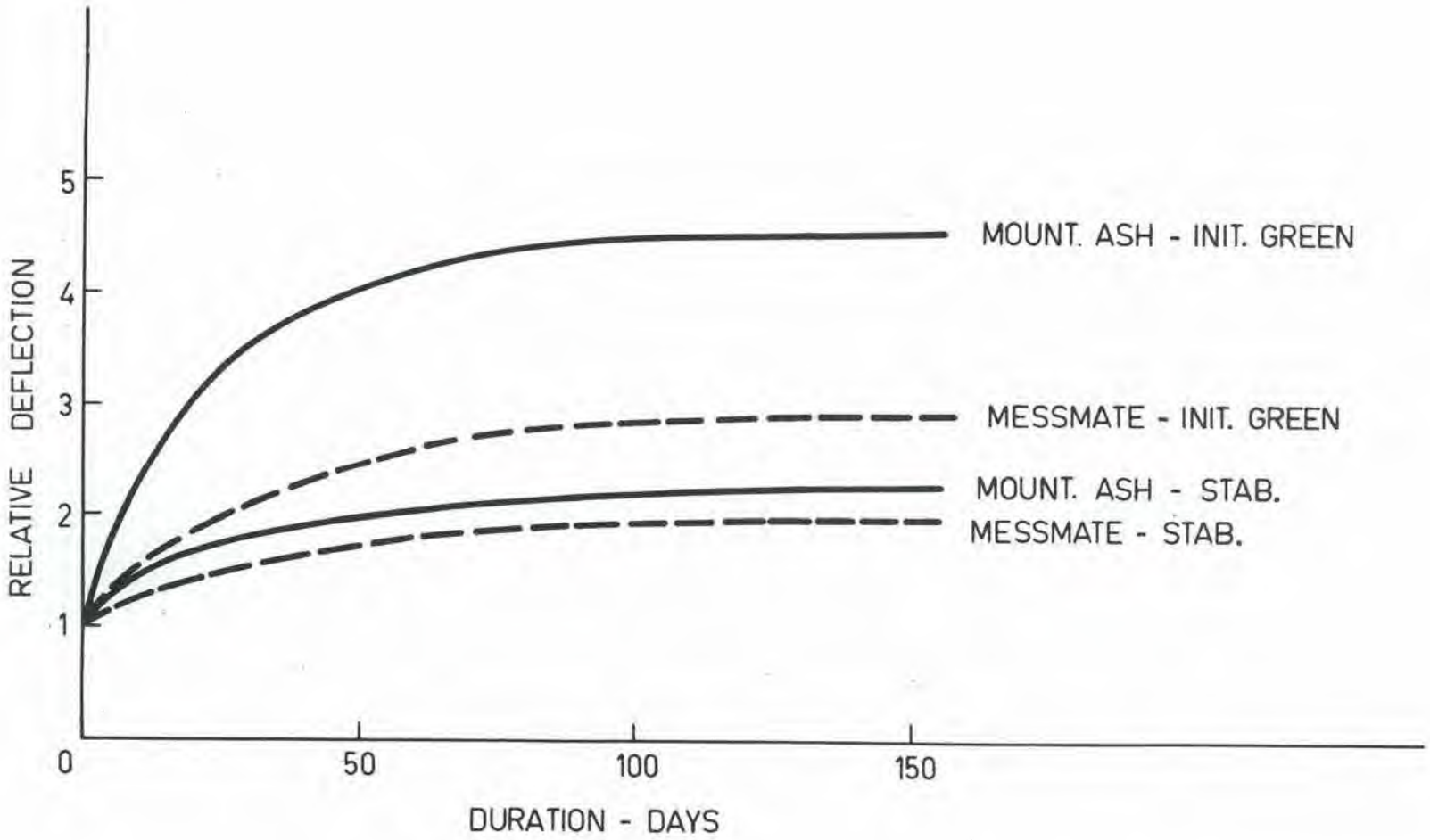
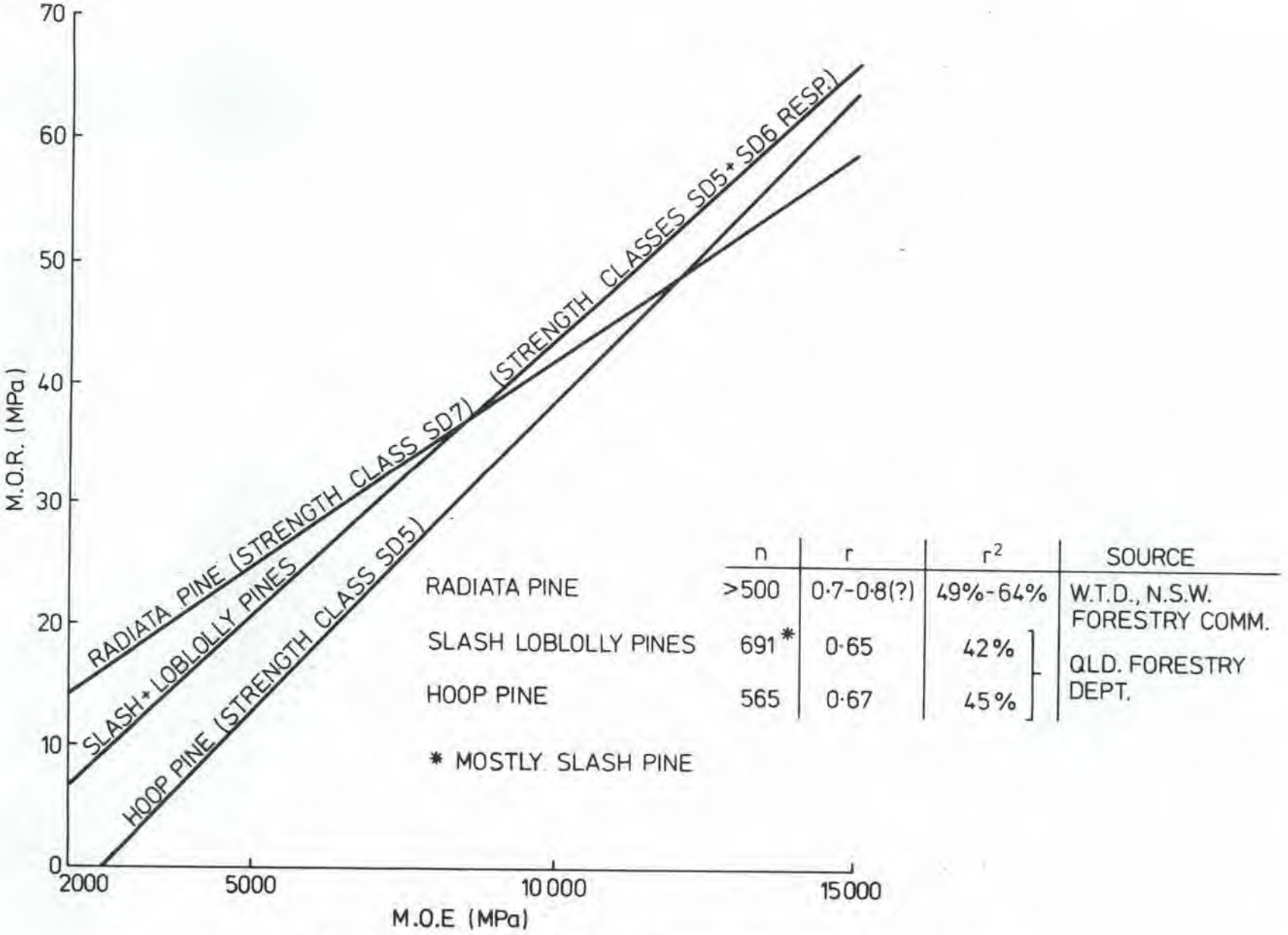


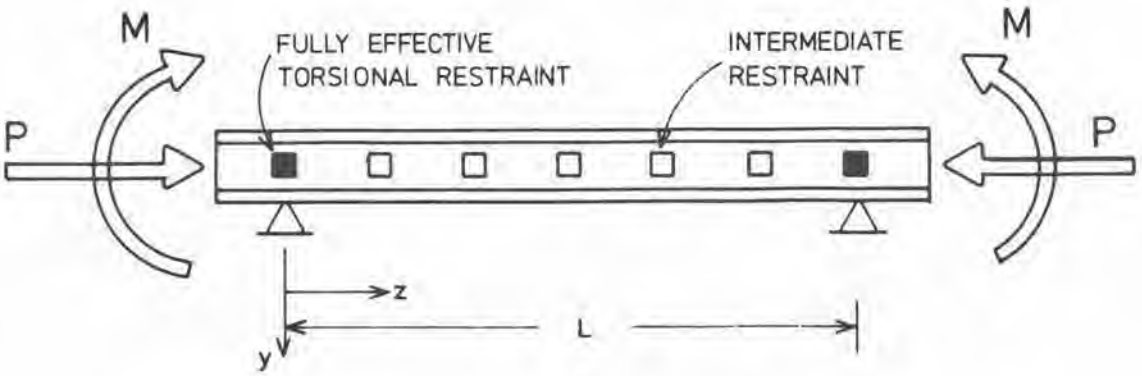
FIG. 1 DEFLECTION — TIME CURVES FOR BEAMS OF INITIALLY GREEN, AND "STABILISED" WOOD



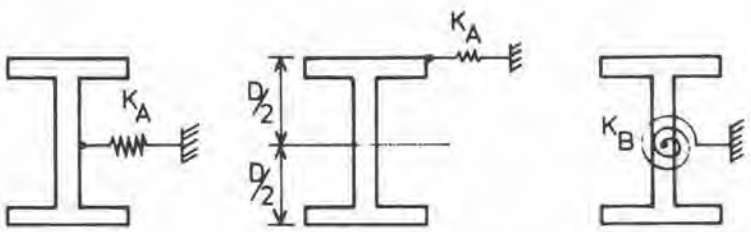
	n	r	r^2	SOURCE
RADIATA PINE	>500	0·7-0·8(?)	49%-64%	W.T.D., N.S.W. FORESTRY COMM.
SLASH LOBLOLLY PINES	691*	0·65	42%	QLD. FORESTRY DEPT.
HOOP PINE	565	0·67	45%	

* MOSTLY SLASH PINE

FIG. 1 - M of R v M of E. Regression lines for some Australian grown conifers of comparable cross-sectional dimensions



(a) Column or Beam



(b) Column lateral restraint

(b) Beam lateral restraint

(c) Beam torsional restraint

FIG. 1 NOTATION FOR COLUMN AND BEAM

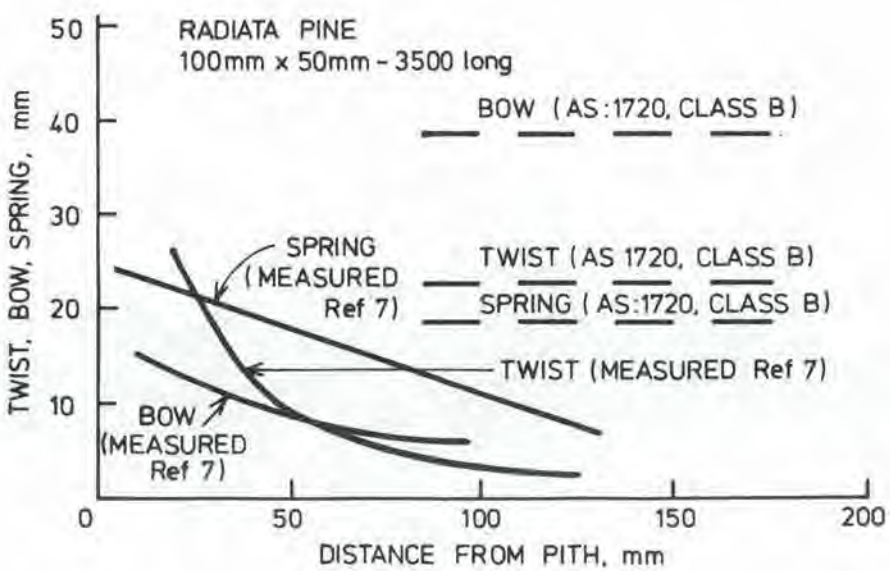


FIG. 2 MEASURED CROOKEDNESS OF RADIATA PINE SCANTLING

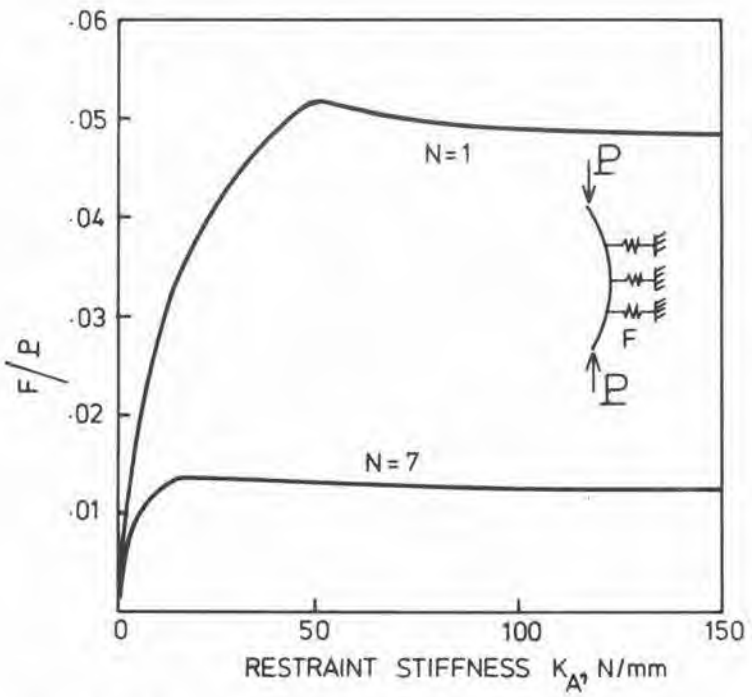


FIG. 3 MAXIMUM RESTRAINT FORCE F AT DESIGN LOAD

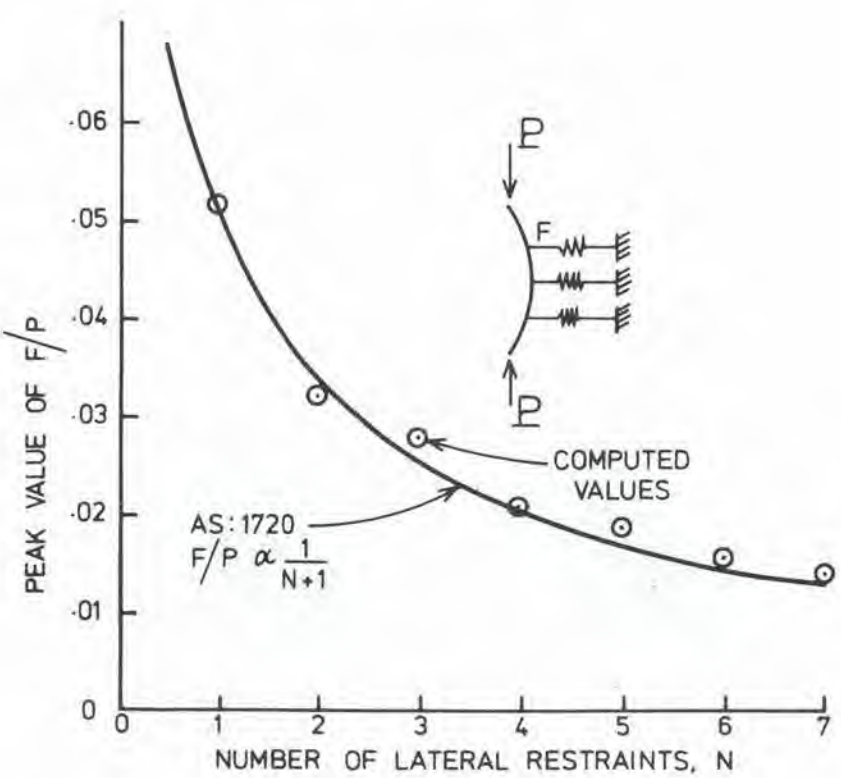
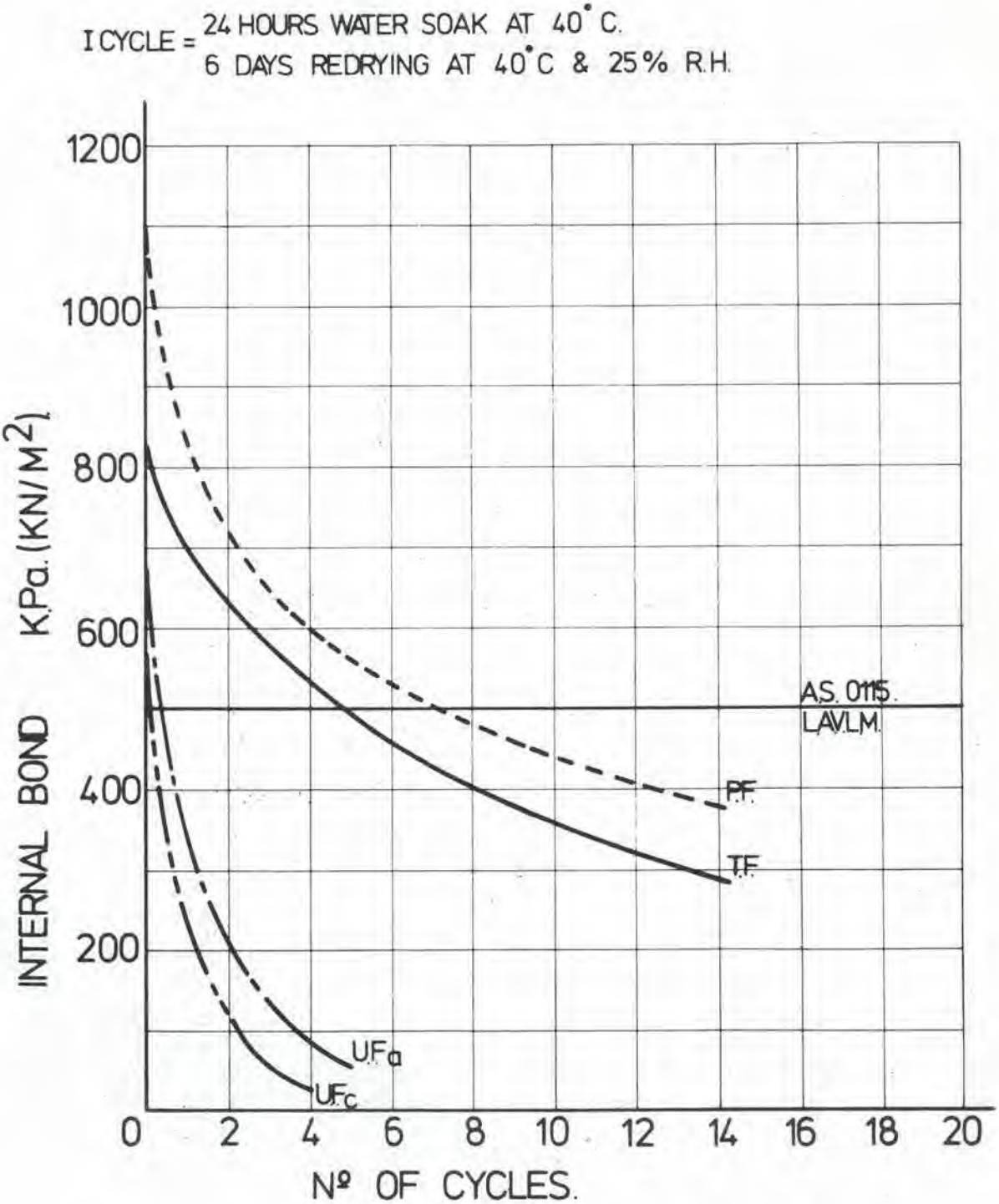


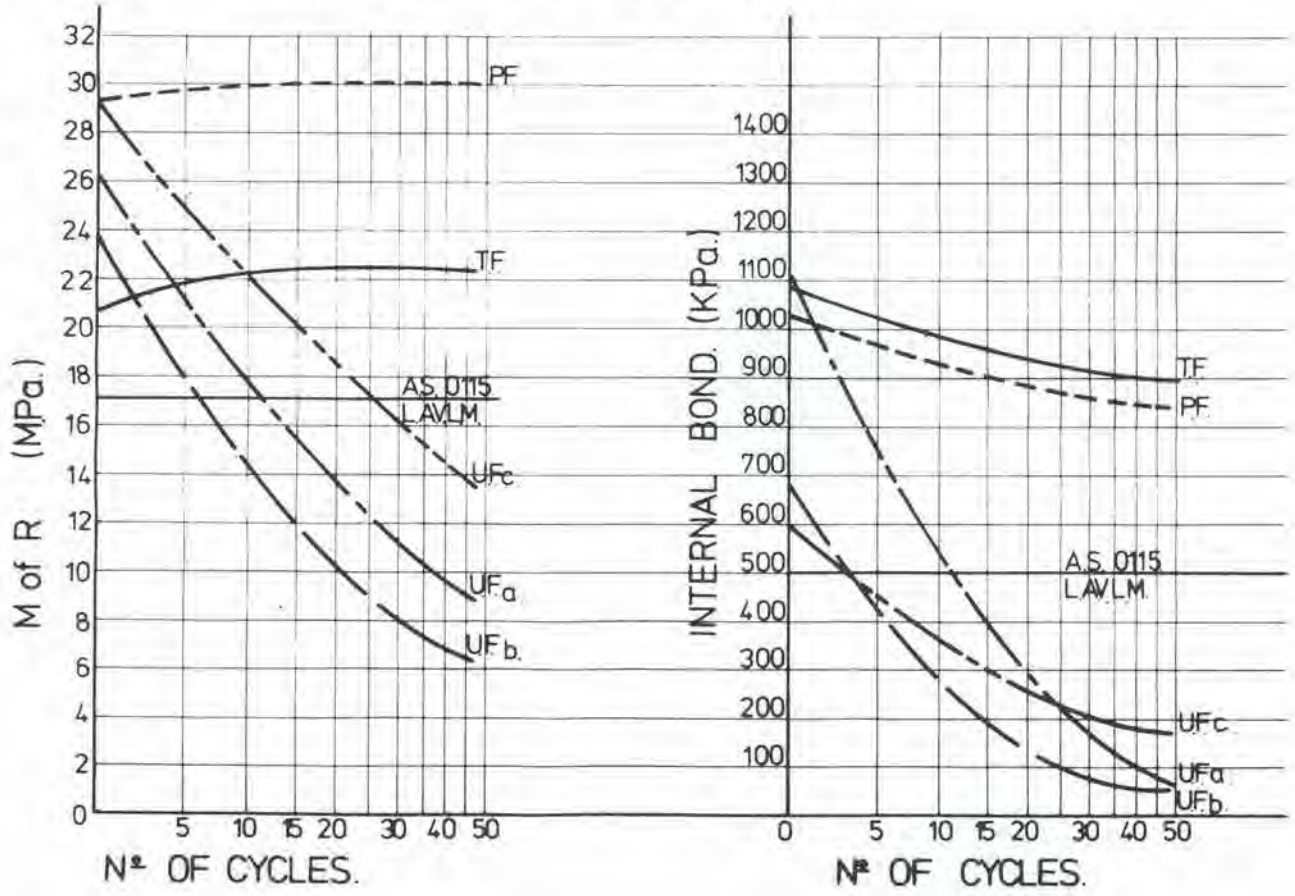
FIG. 4 PEAK RESTRAINT FORCE

EFFECT OF ACCELERATED AGEING ON INTERNAL BOND.



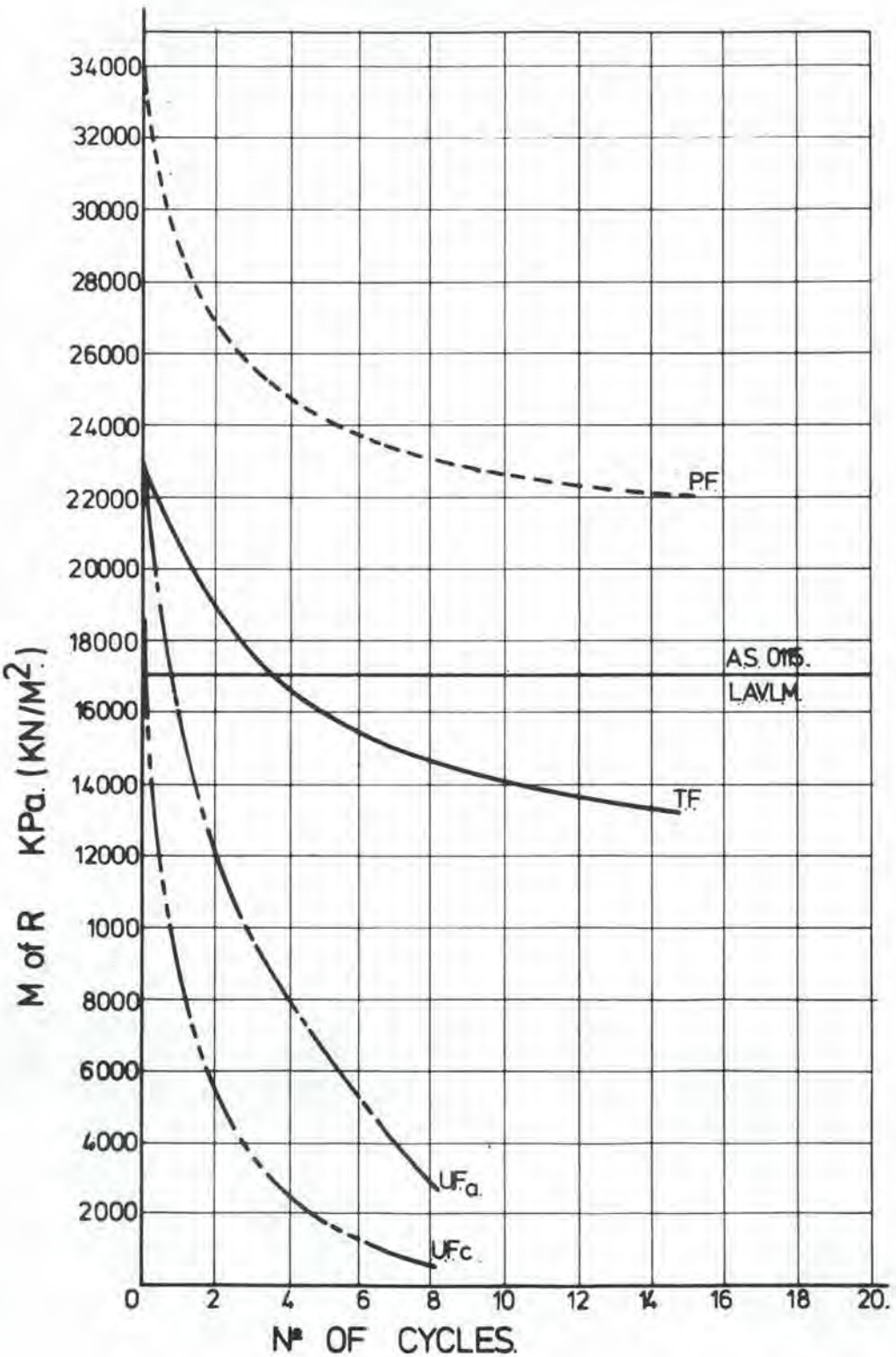
EFFECT OF ACCELERATED AGEING IN AIR-VAPOUR ATMOSPHERE. ON MECHANICAL PROPERTIES OF PARTICLE BOARD.

1 CYCLE = 7 DAYS AT 40°C & 86% R.H.
7 DAYS AT 40°C & 25% R.H.



EFFECT OF ACCELERATED AGEING ON M. of R.

1 CYCLE = 24 HOURS WATER SOAK AT 40°C.
6 DAYS REDRYING AT 40°C & 25% RH.



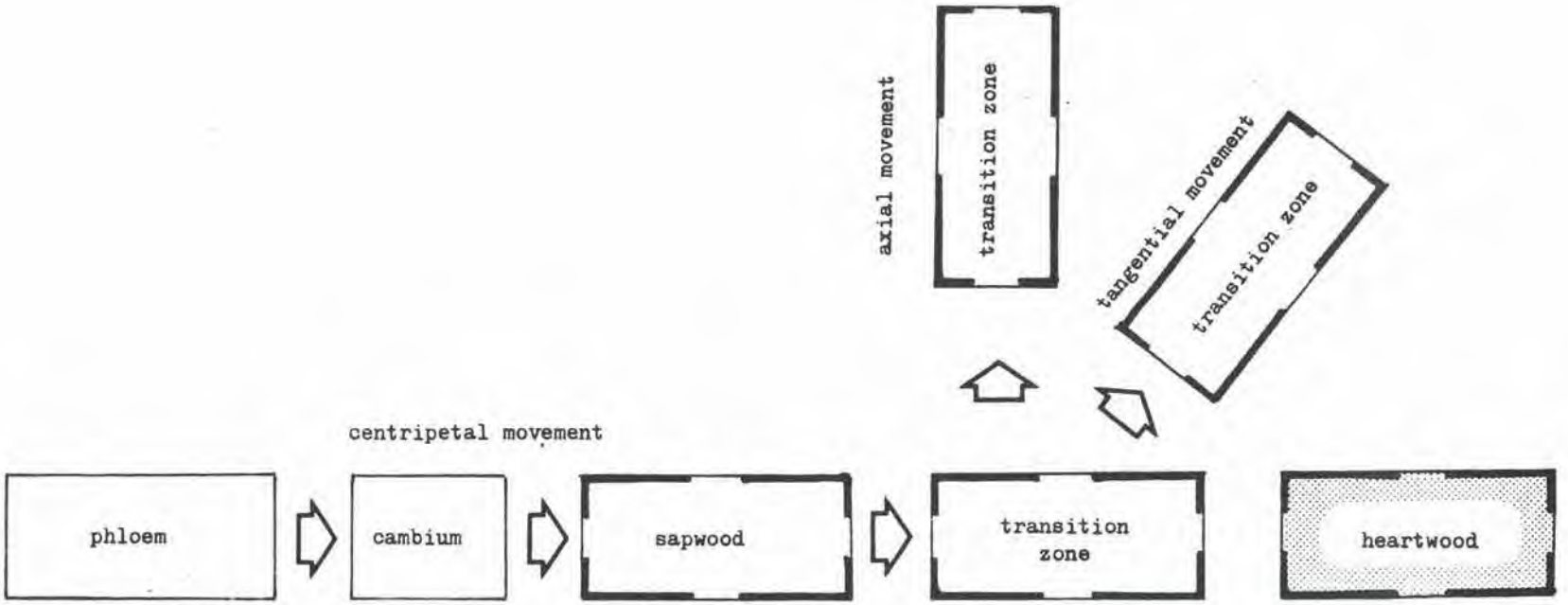
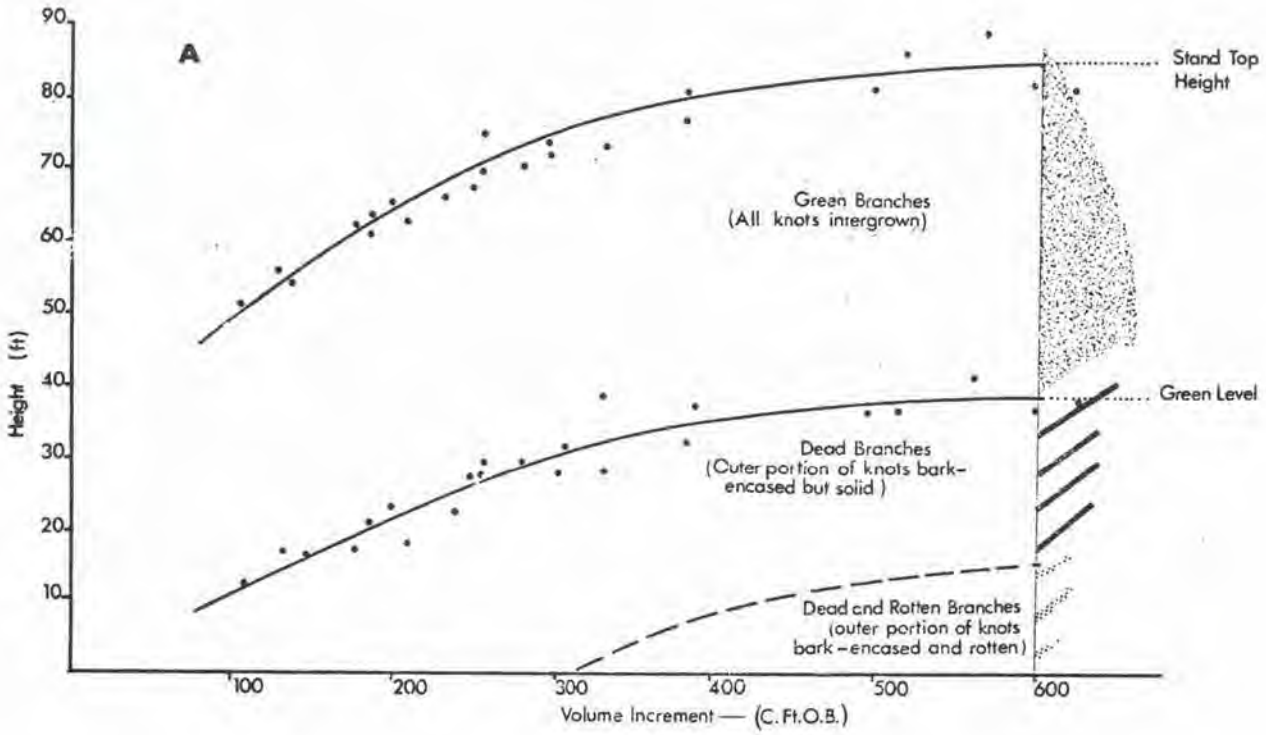


Fig. 1. Diagram illustrating the suggested pathways for the movement of a heartwood inducing substance in sapwood.

Fig. 2. Scanning electron micrograph* of the transverse surface of the sapwood/intermediate wood zone in Eucalyptus saligna. The vessels in the sapwood (upper) are free of tyloses whereas the vessel in the intermediate zone (lower) is occluded with tyloses. Green specimen, solvent dried, coated with carbon followed by gold. 9 Kv, X400.

Fig. 3. Radial longitudinal surface of the same material as Fig. 2. Microtechnique as in Fig. 2. The sapwood vessel (V) (left side) is free of tyloses. Tyloses (T) can be observed developing in the vessels of the intermediate wood simultaneously in each vessel cell. X100.



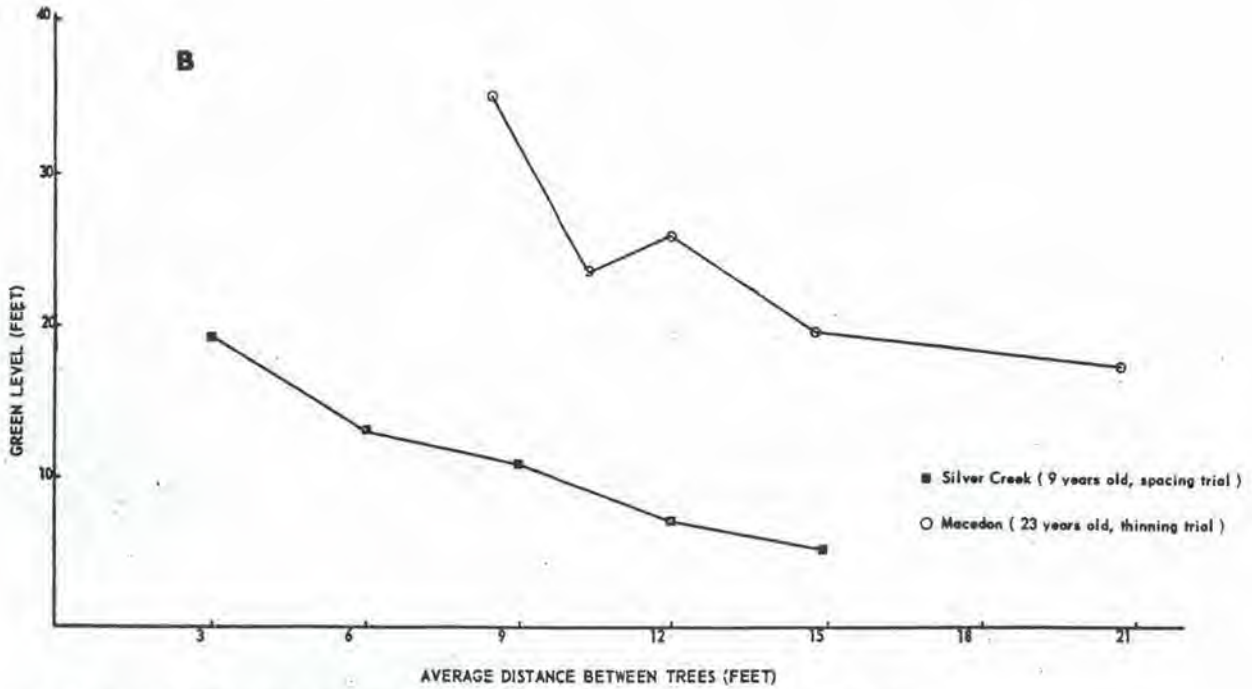


FIG. 1 A. Variation in green level, crown depth and knot condition associated with tree height and site quality.

B. Variation in green level associated with stand density.

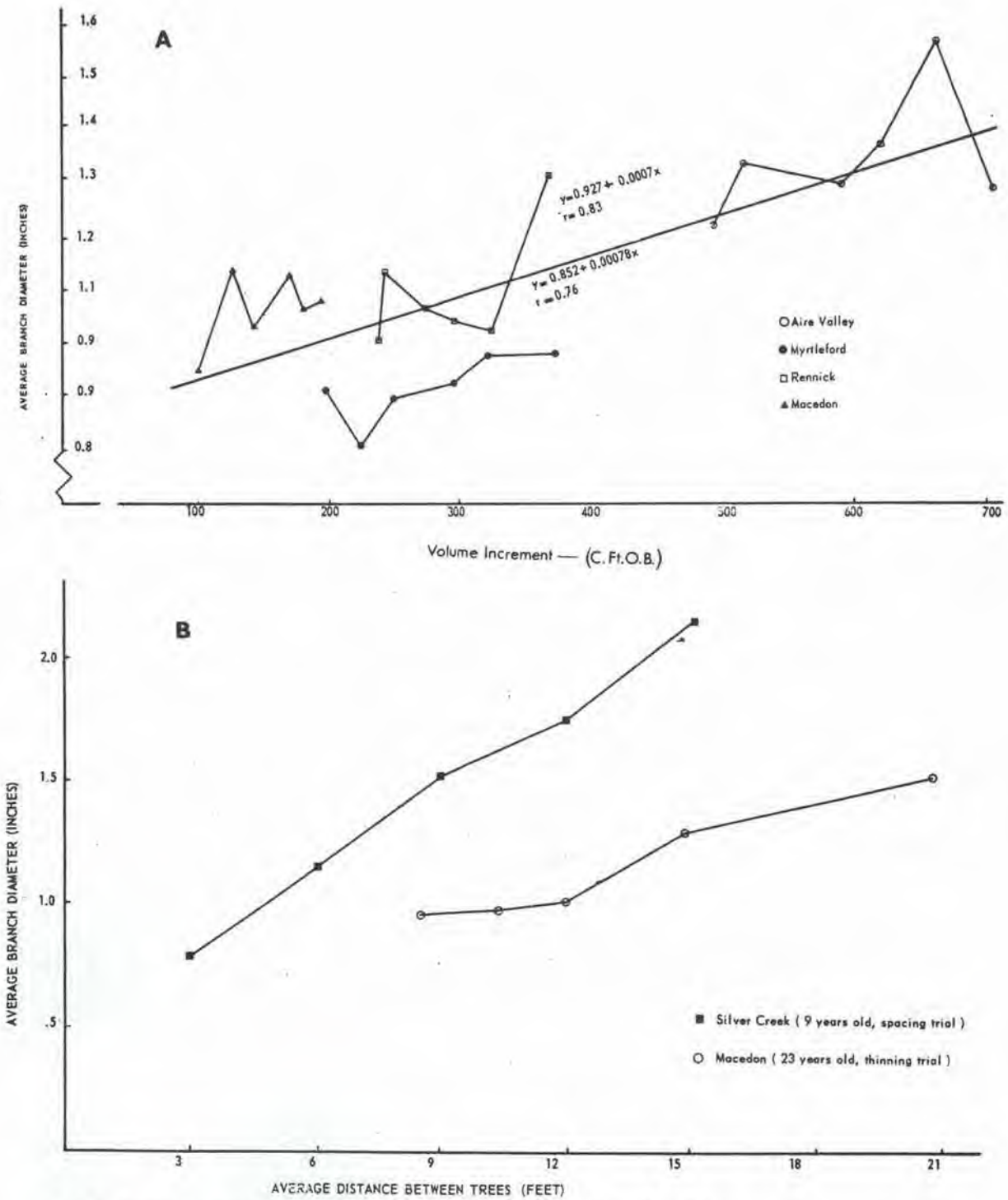


FIG. 2. Variation in average branch diameter with A. Site quality and locality (16 year old stands)
B. Stand density.

Fig. 1. Control, X 1200. Axial tracheids and radial resin canal.

Fig. 2. Weathered, X 1300. The tissue of the radial resin canal (asterisk) is lost. Splitting between the axial tracheids has occurred at the ends of the radial resin canal and in the adjacent areas (arrowed). Fungal hyphae and spores are present.

Fig. 3. Weathered, X 3000. Shows lumen surface of axial tracheid. The tori is lost from the bordered pits. Splits have formed at the edge of the pit apertures. The tracheid wall shows areas of delamination.

Fig. 4. Weathered, X 2500. Lumen surface of axial tracheids. Splits have occurred in the tracheid wall (arrow) and between the tracheids (double arrow).

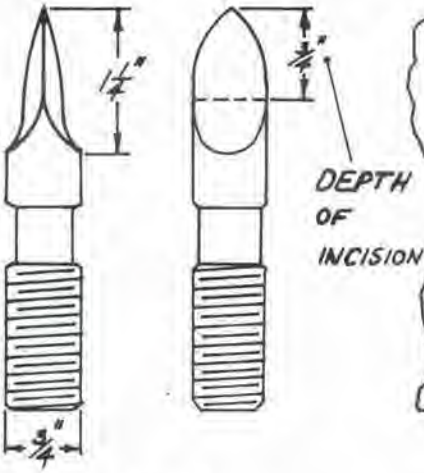
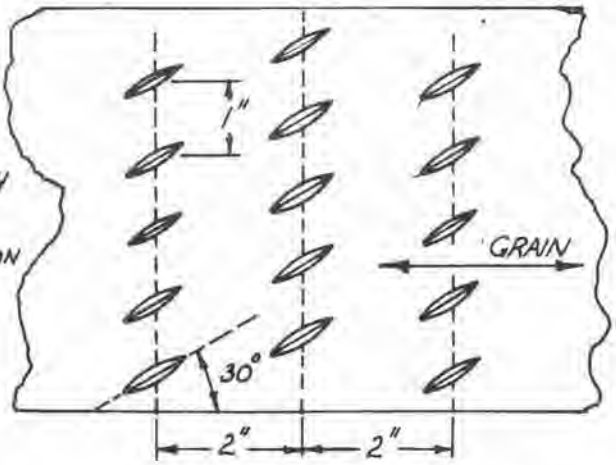


FIG. 1
"OYSTER"-"BLADE" INCISING KNIFE USED ON ORIGINAL D.F.P. MACHINE



PATTERN OF INCISIONS PRODUCED BY SAME MACHINE

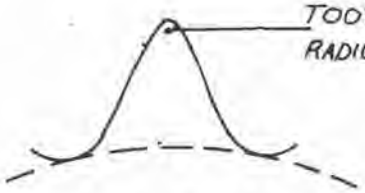


FIG. 2
TRANSMISSION TOOTH FORM

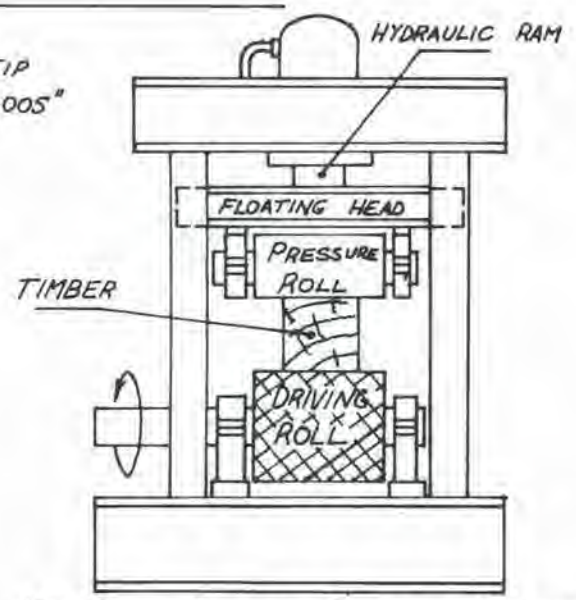


FIG. 3 ROLLER CRUSHING MACHINE

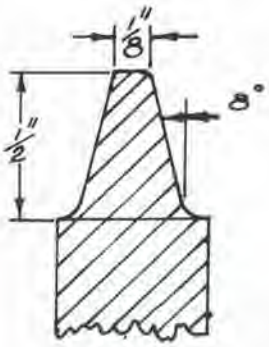


FIG. 4
CROSS SECTION OF TOOTH

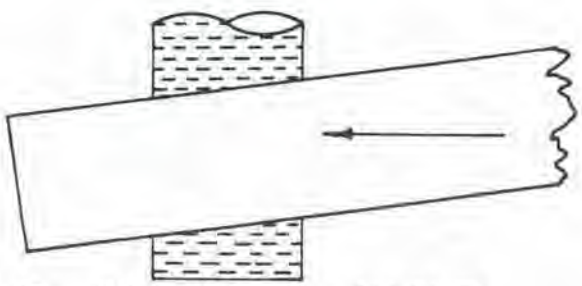


FIG. 5 WIDE ROLLER ALLOWS INCISING AT ANGLE TO GRAIN

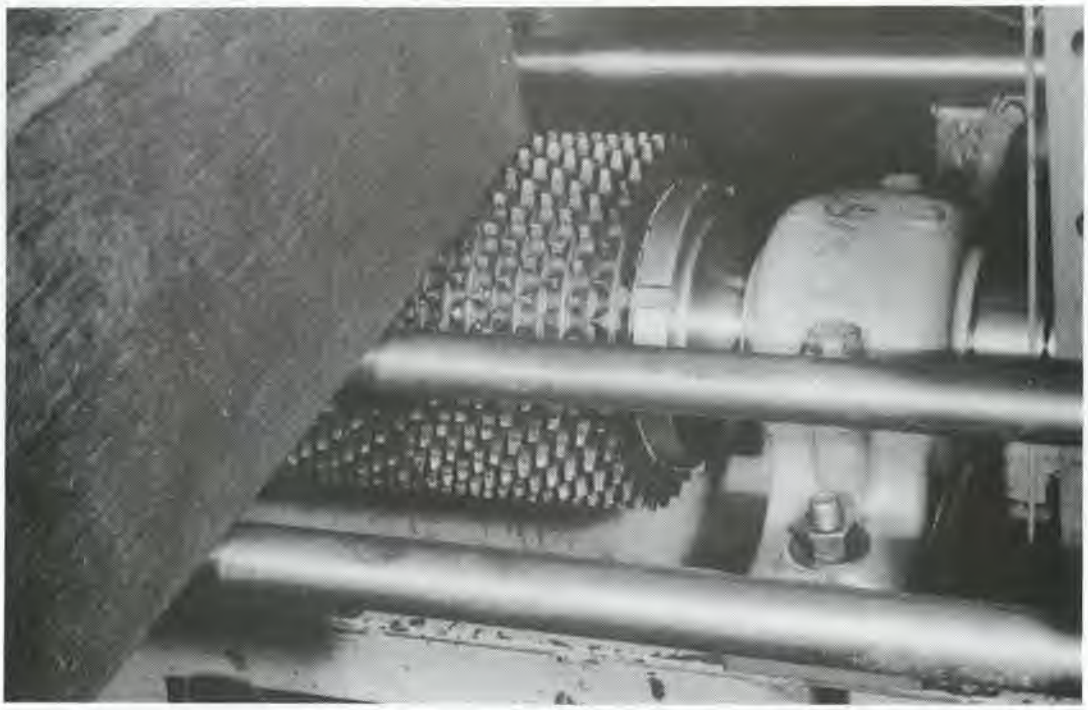


Figure 6. Close up of incising roll.

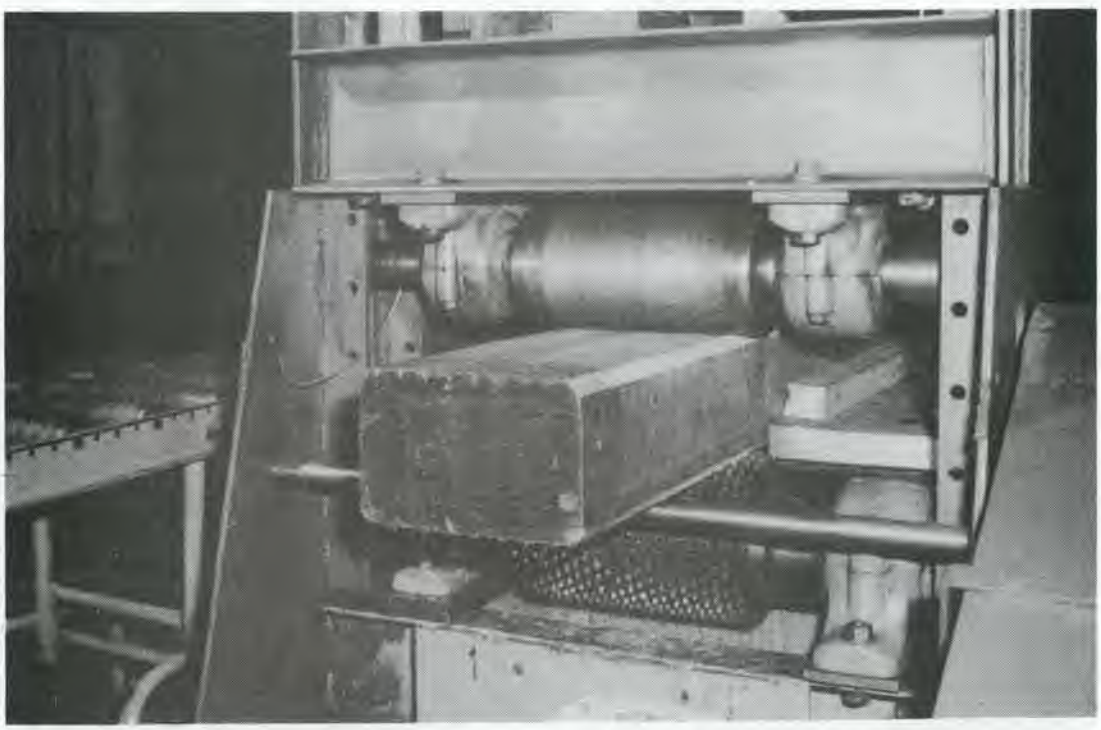


Figure 7. Machine in operation.

PANELS BEFORE EXPOSURE

PANELS AFTER 4 months' EXPOSURE

FIG. 1 FACE CHECKING—CCA SALT

PANELS BEFORE EXPOSURE

PANELS AFTER 4 months' EXPOSURE

FIG. 2 FACE CHECKING — UNTREATED CONTROLS

PANELS BEFORE EXPOSURE

PANELS AFTER 4 months' EXPOSURE

FIG. 3 FACE CHECKING—ORGANIC SOLVENT PRESERVATIVE

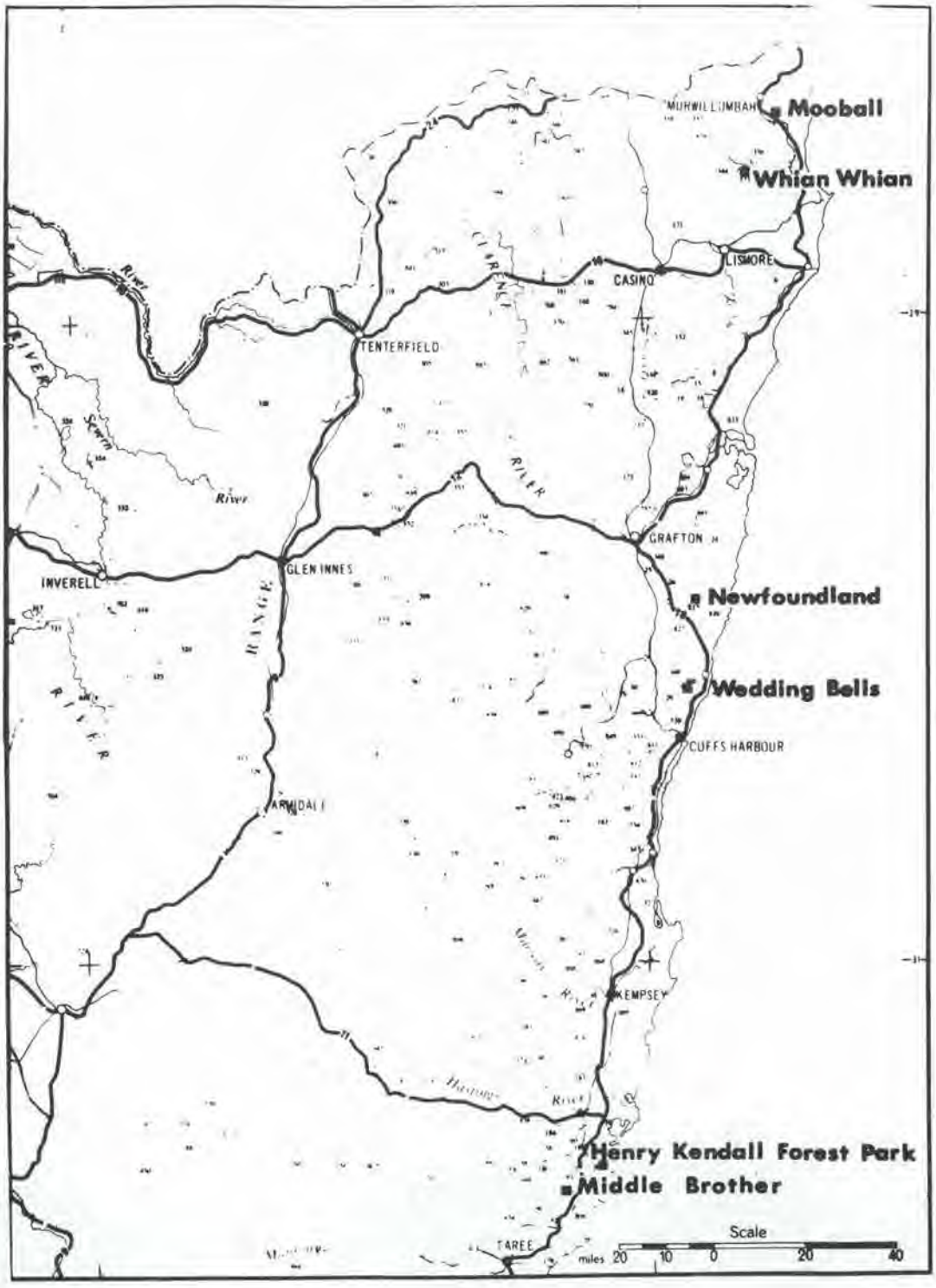


Fig. 1. Location of possible soft rot field test sites in northern N.S.W.

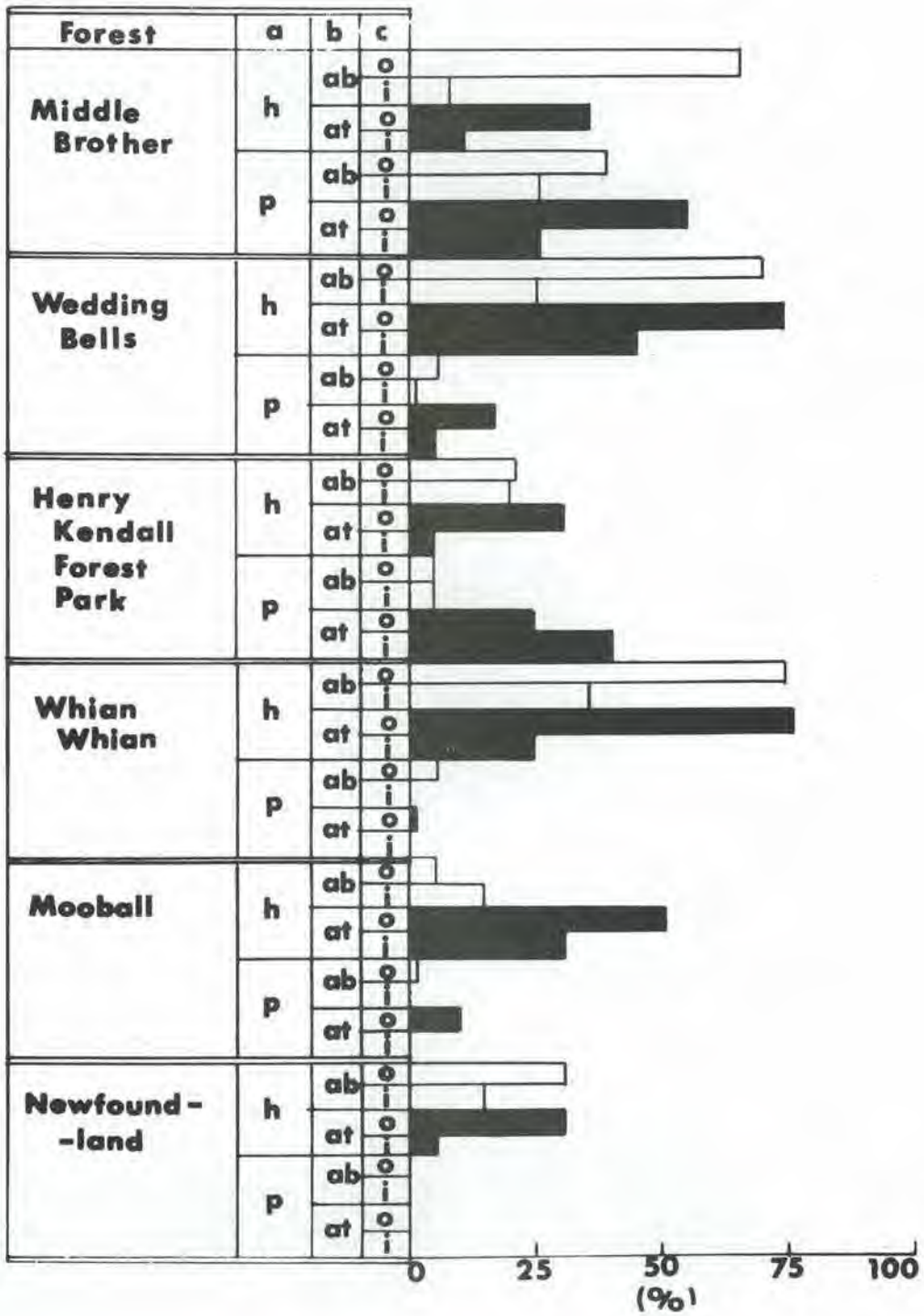


Fig. 2. Relative soft rot attack after 21 weeks.

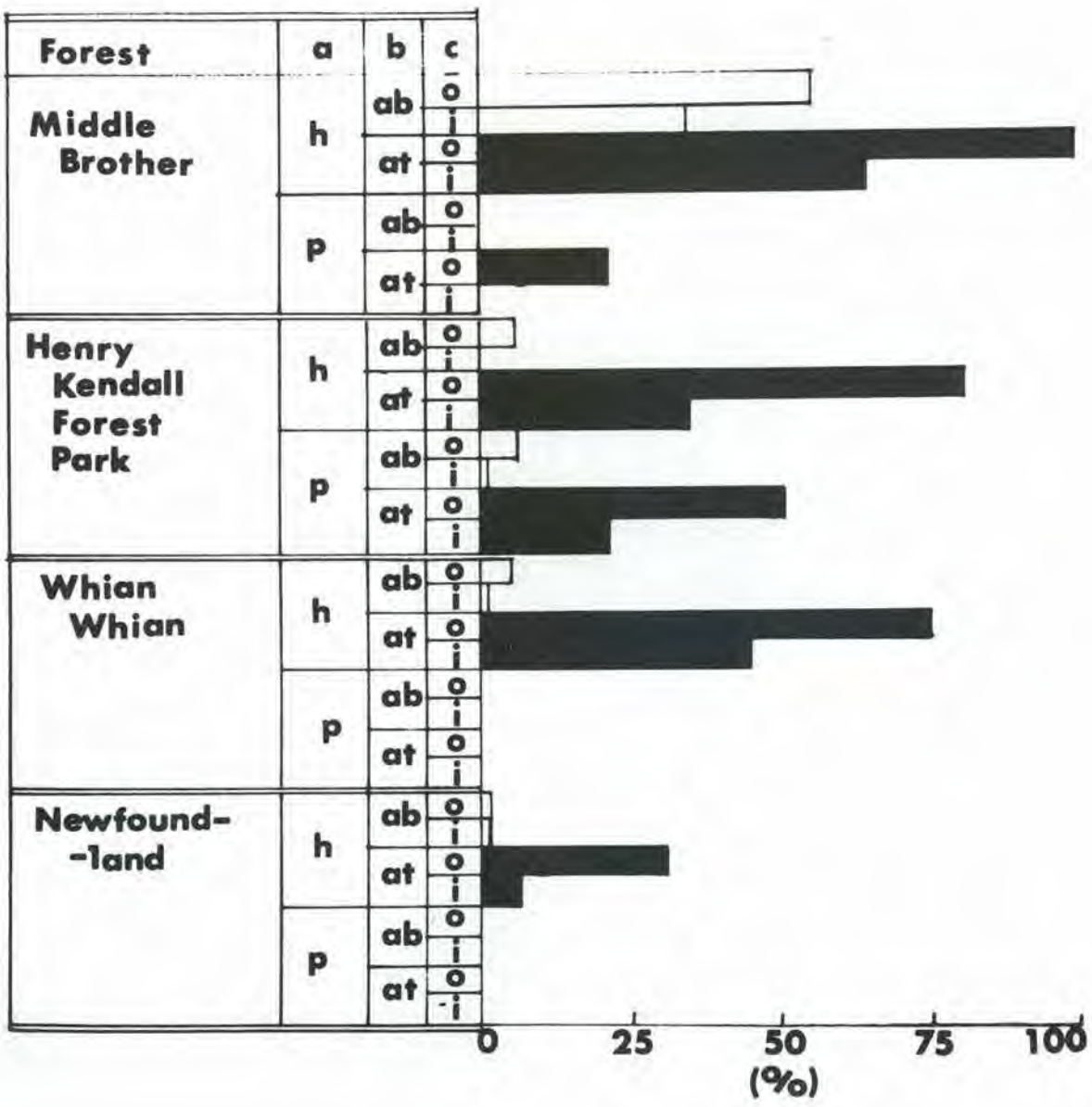


Fig. 3. Relative soft rot attack after 47 weeks.

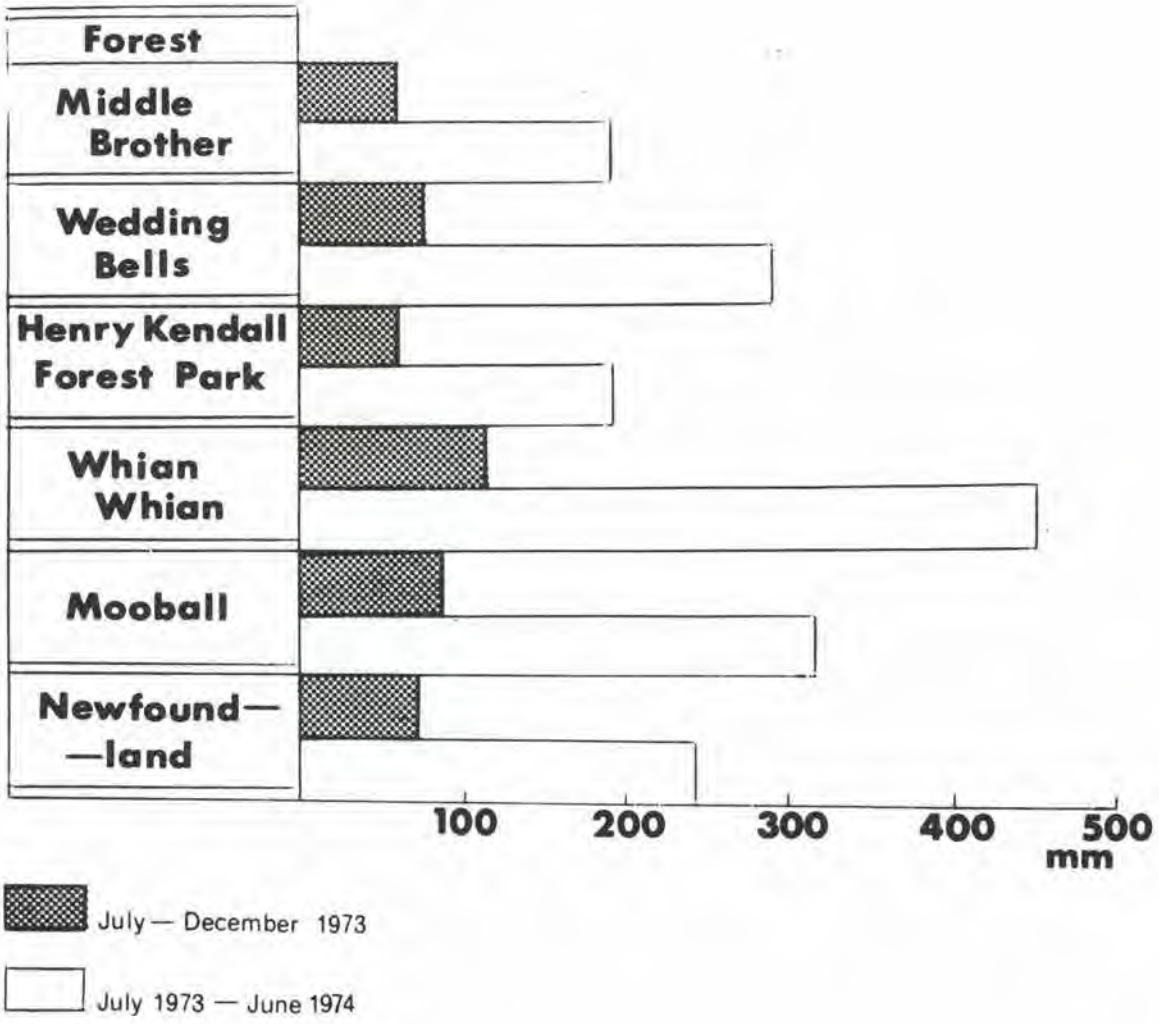


Fig. 4. Rainfall at possible sites during the test.

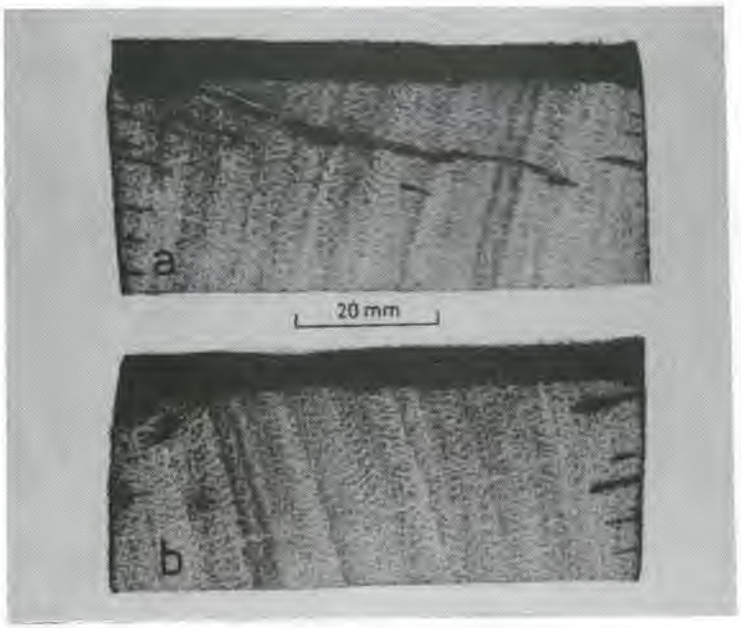


Fig.1. The improved penetration in unseasoned heartwood of karri specimens (a) and (b) during heating in oil. Only one radial face was modified while other faces were left intact as controls.

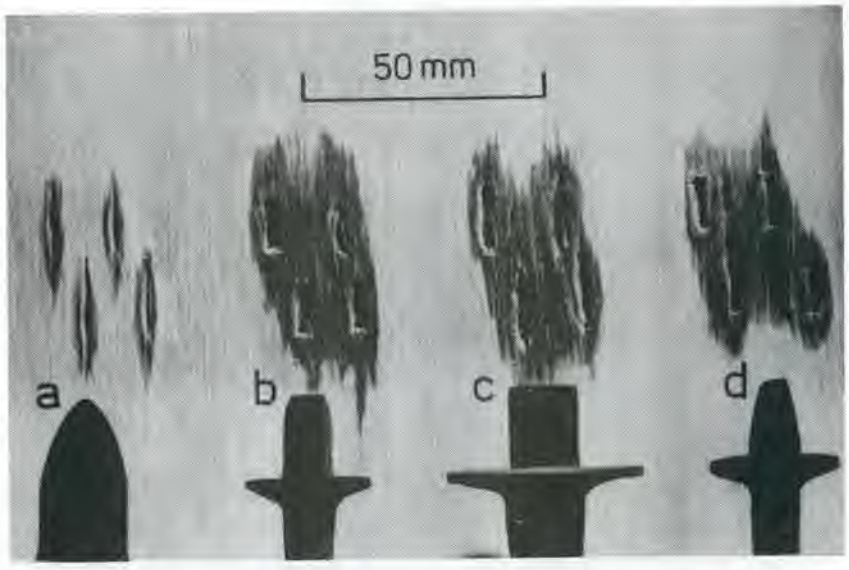


Fig.2. The effect of incising and brucising on the flow of moisture during drying in karri. In (a), incisions were made with an incising knife; the cavities in (b), (c) and (d) were produced with brucising tools.

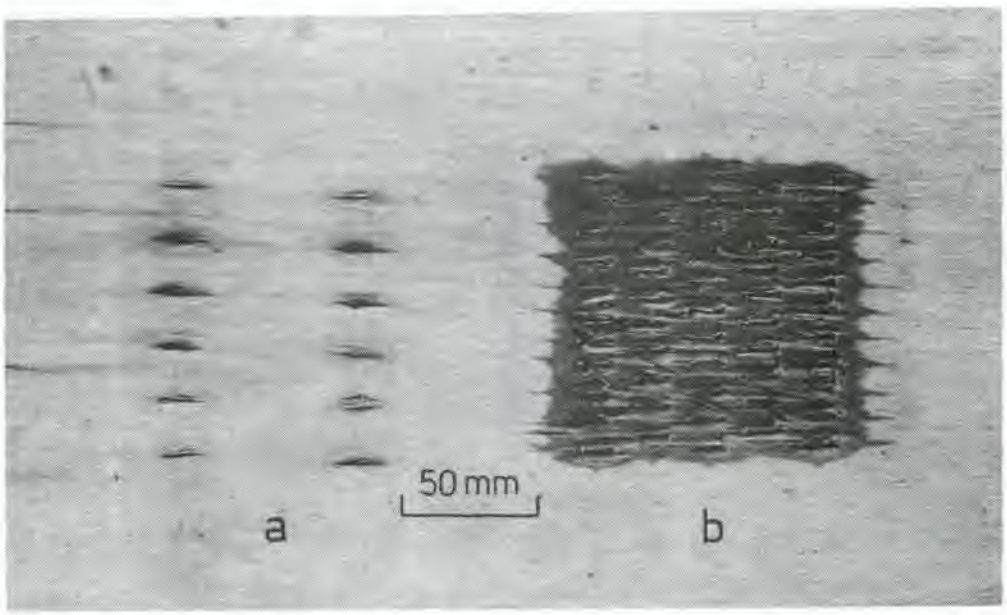


Fig.3. The effect of incising and brucising on the movement of moisture to the surface during drying in karri. The incised area (a), dried before the brucised area (b) which was made with the tool (d) shown in Fig.2.

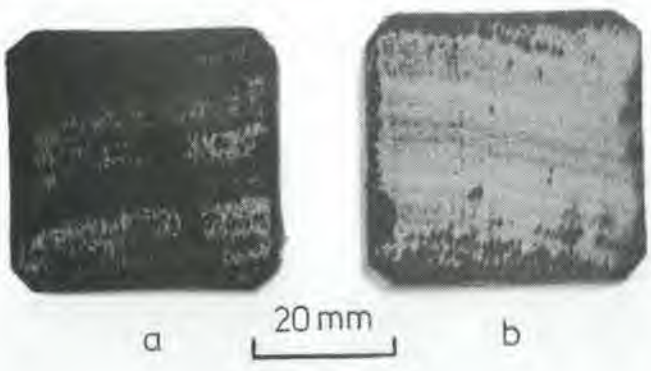
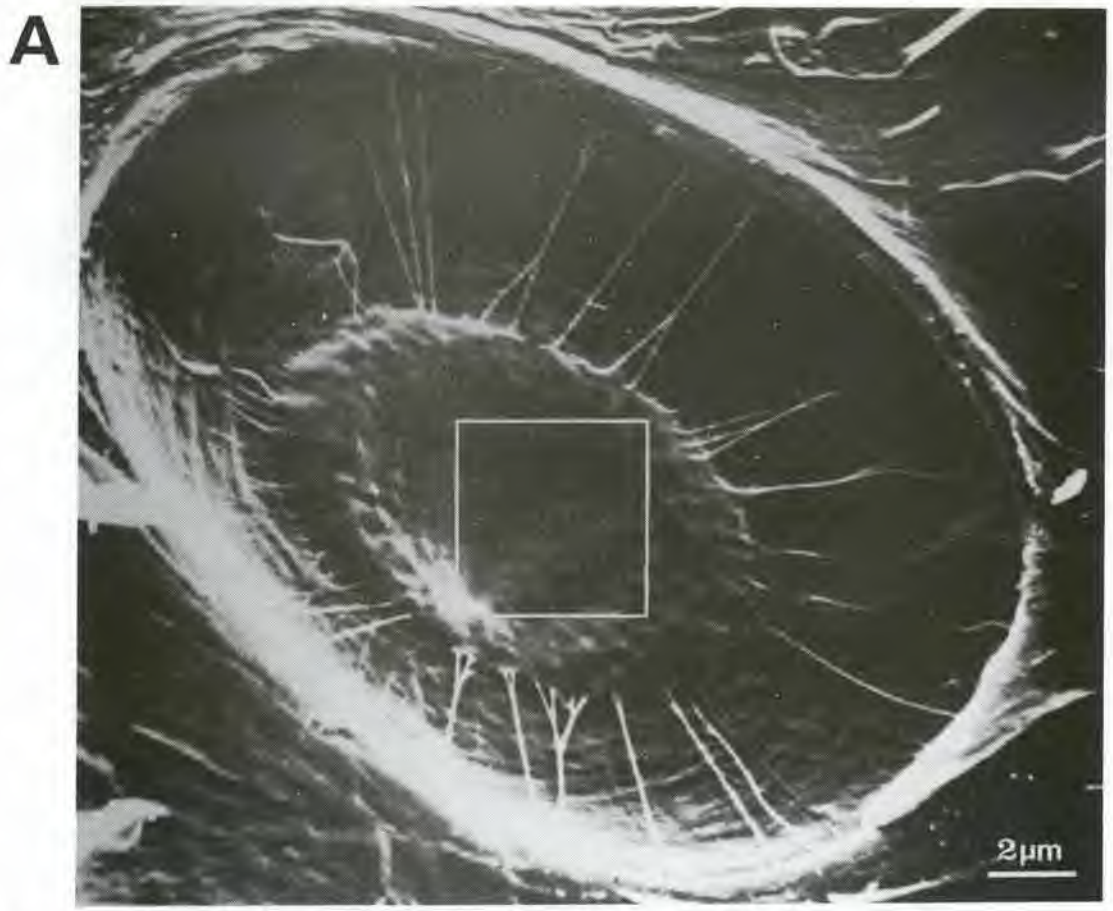


Fig.4. The improved penetration in unseasoned karri heartwood during heating in oil. The specimen (a) was modified while the specimen (b) was left intact as control.



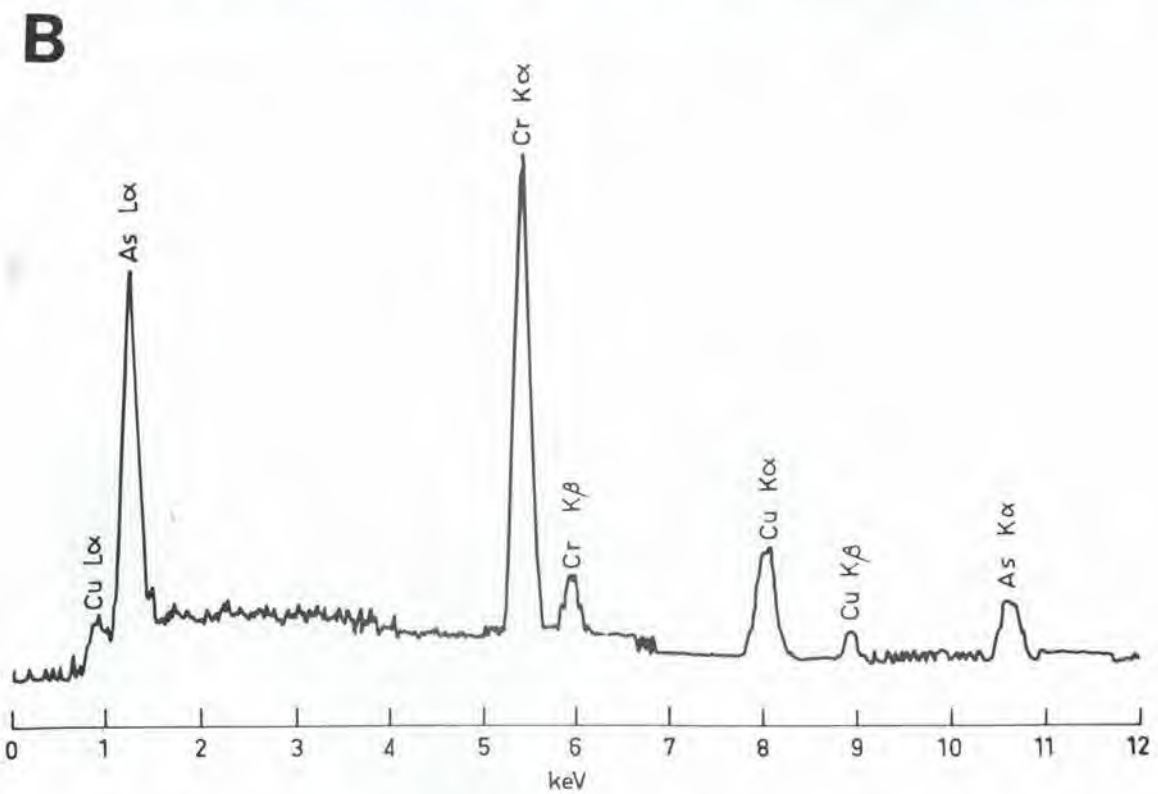


Figure A - Radial view of bordered put in Pinus radiata. In situ X-ray microanalysis performed within the outlined square.

Figure B - Typical X-ray microanalysis showing elements located in the torus, within the outlined square.

FIGURE 1

Eucalyptus deglupta sulphate pulp

Effect of age on maximum screened yield and total alkali required

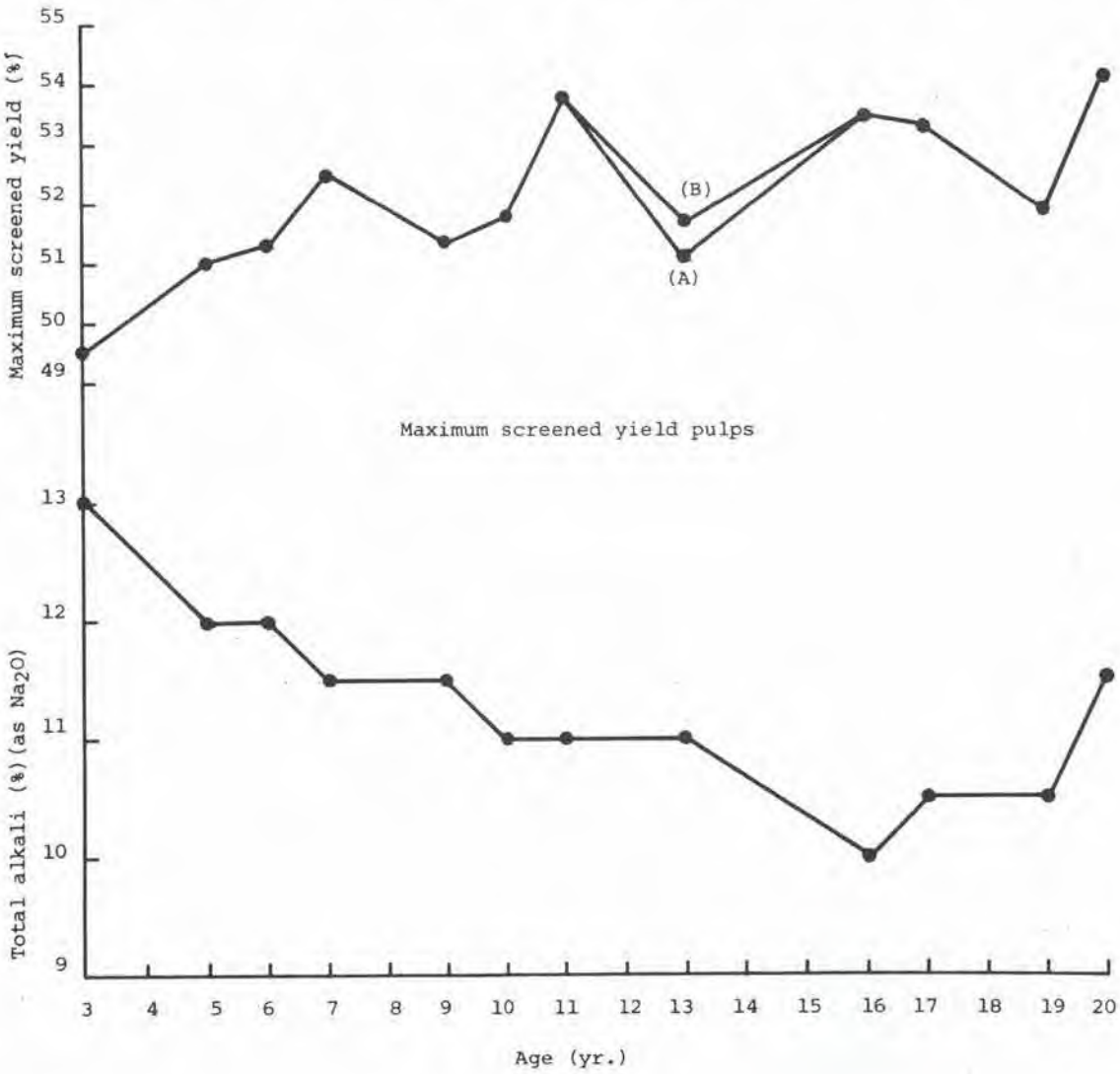
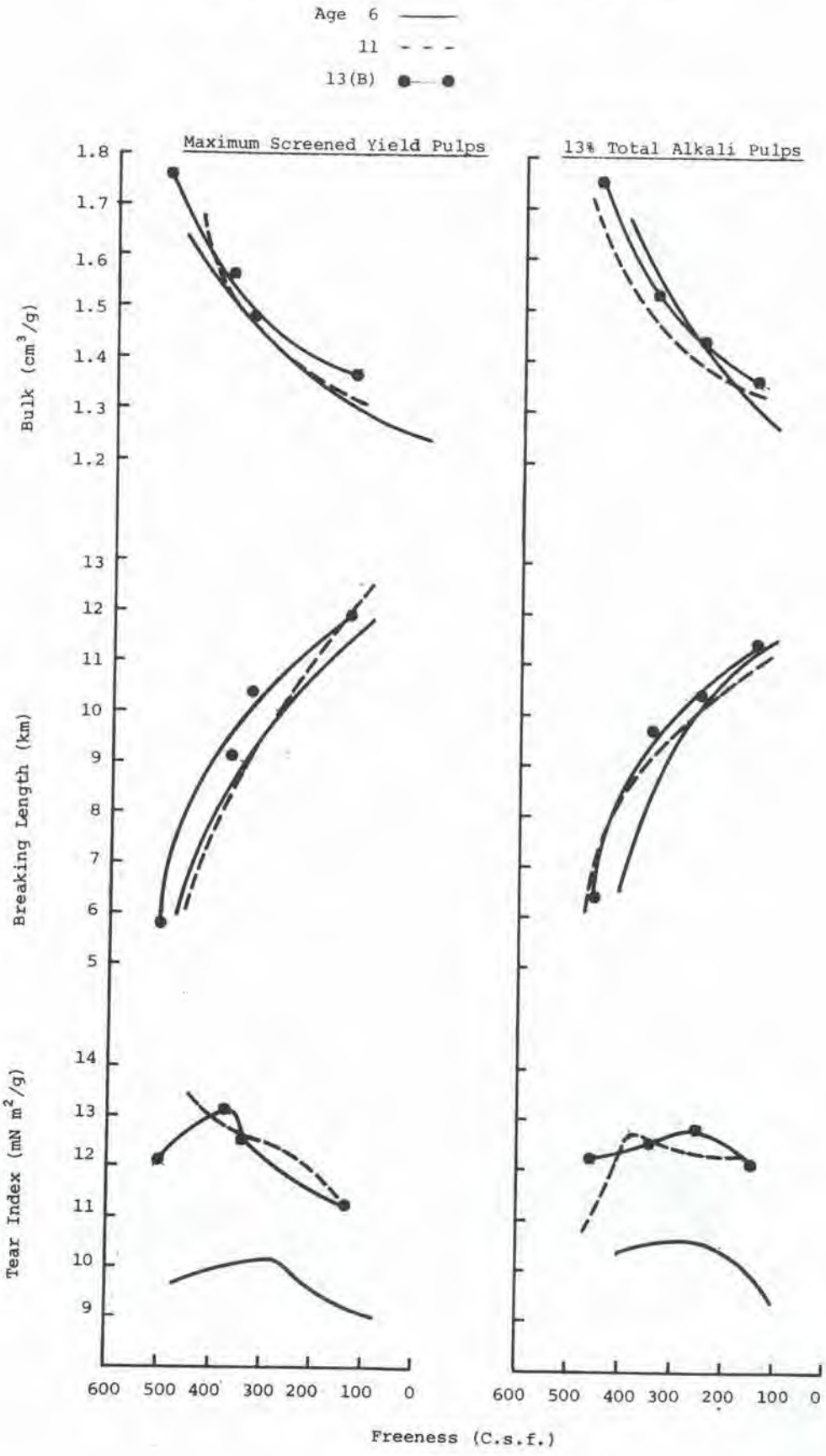


FIGURE 2

Papermaking properties of unbleached sulphate pulps from plantation-grown *Eucalyptus deglupta*



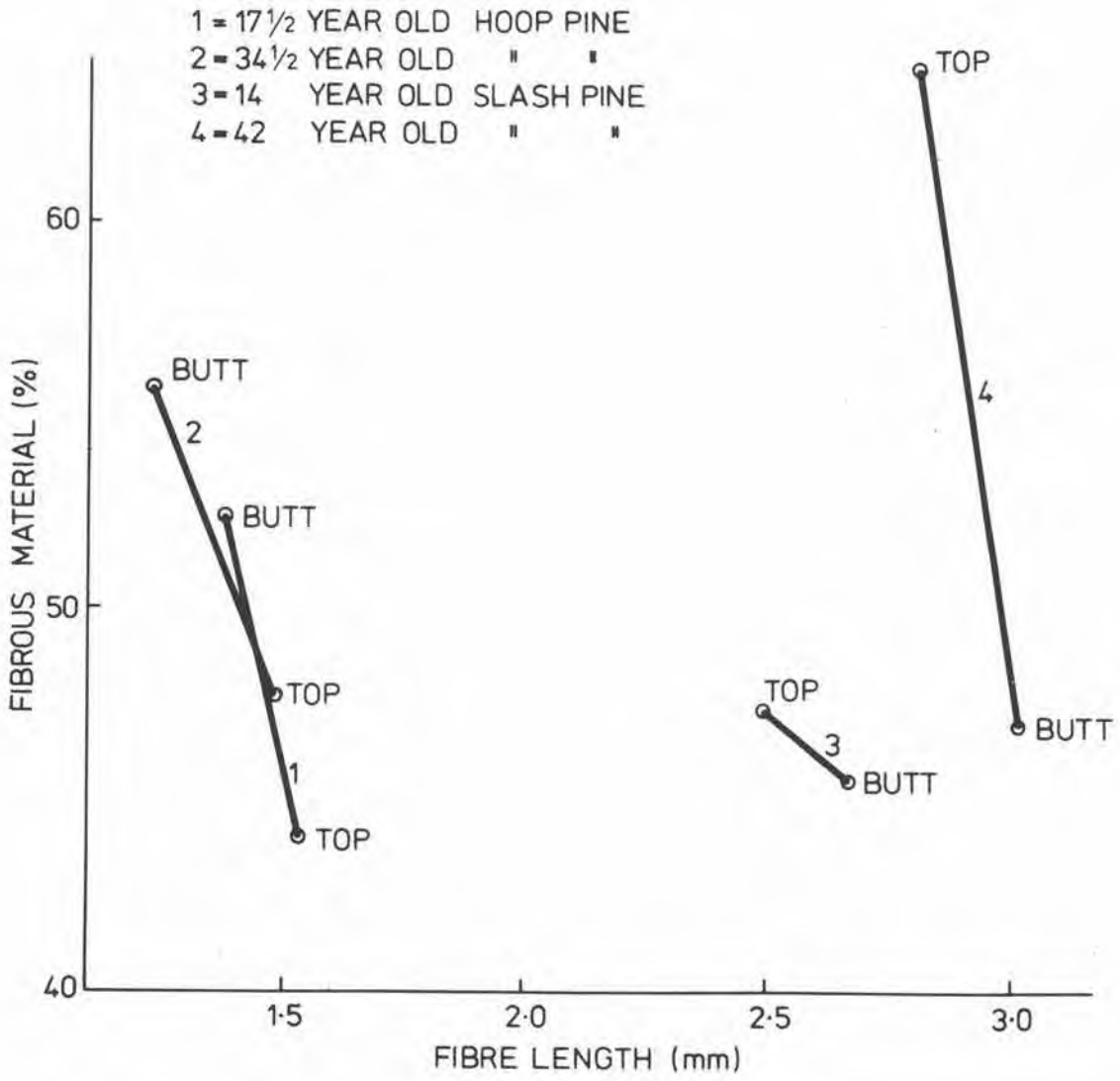
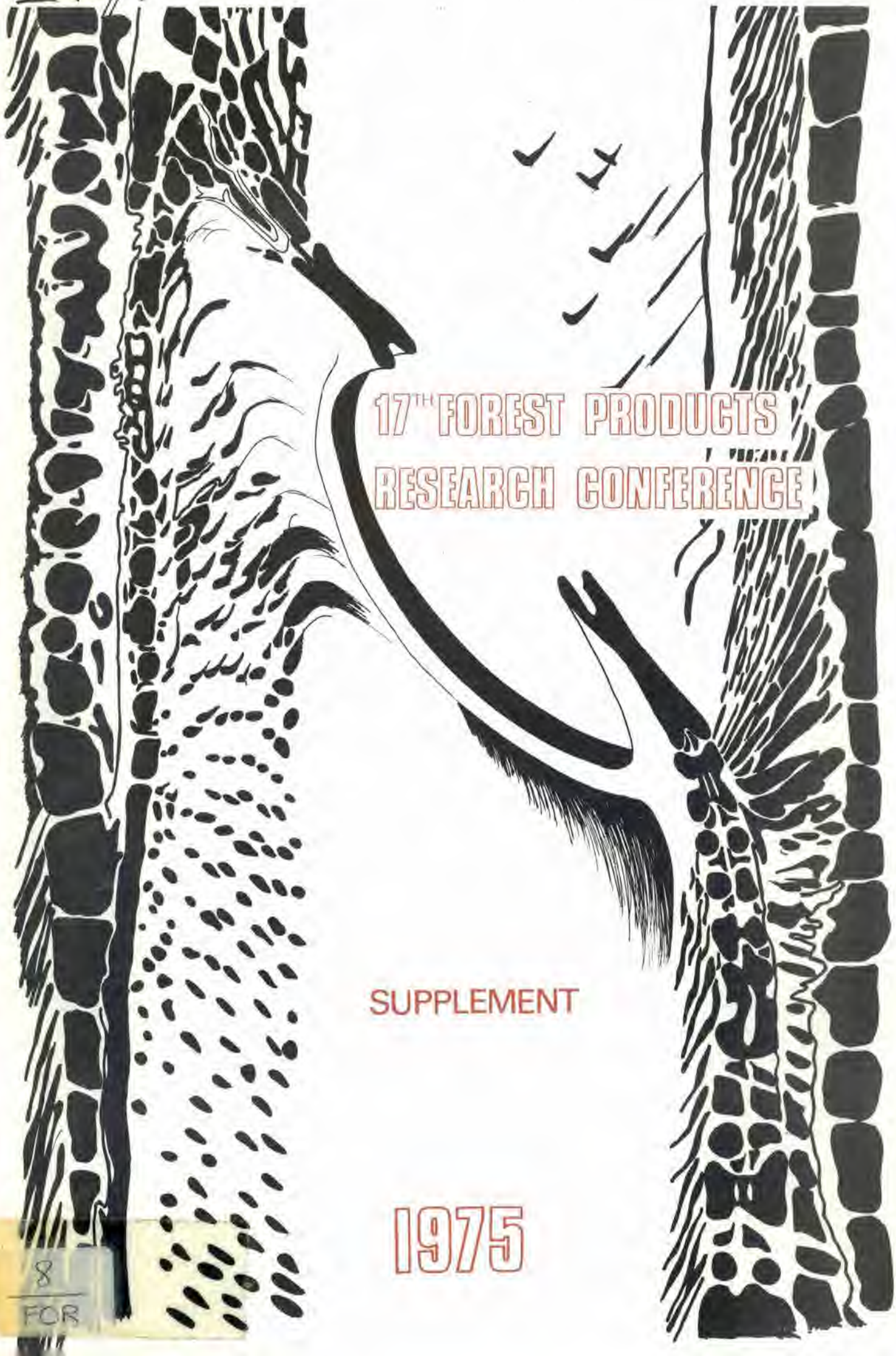

1 = 17½ YEAR OLD HOOP PINE
2 = 34½ YEAR OLD " "
3 = 14 YEAR OLD SLASH PINE
4 = 42 YEAR OLD " "
FIBROUS MATERIAL (%)
60
50
40
BUTT
2
BUTT
TOP
1
TOP
TOP
3
BUTT
TOP
4
BUTT
1·5
2·0
2·5
3·0
FIBRE LENGTH (mm)

FIGURE 1

VOL. 2 (Supp.)



17TH FOREST PRODUCTS RESEARCH CONFERENCE

SUPPLEMENT

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17TH FOREST PRODUCTS RESEARCH CONFERENCE, MAY 1975

FOREWORD

Recorded in this supplement are the essential papers required to provide the continuity for planning the next conference. These are the report on the outcome of the recommendations from the 16th conference, recommendations from the 17th conference and the results of the questionnaire on the aims and format for future conferences. The opportunity is taken to record the keynote address given by Mr. L. H. Bryant. Other papers included are the working group reports, Wood Preservation Committee report and three addendum papers relating to topics 1/22, 2/27 and 3/8.

Organising Committee:- W.G. Keating
J.E. Barnacle
H.F. Heath
A.J. Michell

17th FOREST PRODUCTS RESEARCH CONFERENCE, 1975

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KEYNOTE ADDRESS

FOREST PRODUCTS RESEARCH CONFERENCE - SOME THOUGHTS ON ITS FUTURE

L. H. Bryant

This is the first time that the Forest Products Research Conference has met at the Highett laboratories of the Division of Building Research and the last time that I shall attend the Conference. Since I have been present at 11 of the 17 Conferences and, grey beard that I am, was at the very first one held in 1946, this may be the reason that I have been asked to give what the Organising Committee is pleased to call the keynote speech. Another reason may be because at the last Conference I expressed some support and understanding of why the re-organisation of the Division of Forest Products had been made even though I was critical, like everyone else, of the way the decision had been implemented. For whatever reasons, I thank the Organising Committee for this opportunity to address the Conference in general terms.

Firstly, let me, on behalf of you all, express thanks to CSIRO and to all those officers of the former Forest Products Division and the present Divisions of Building Research and Chemical Technology for the hard work they have done in organising the technical and social aspects of these Conferences. Particular thanks for past efforts must go to Lon Wymond and his helpers; we all appreciate too, the work of Doug Howick and now Bill Keating and their committees, particularly for the compilation and distribution before the Conference of the work to be presented. To me this is a major achievement and one of the very real benefits of such a gathering.

Looking back over the proceedings of past Conferences, it is interesting to note how the subjects discussed have changed - from a pre-occupation with the properties and utilisation of a wide range of species to the present situation where relatively few species are studied and broader matters such as resource conservation, materials handling and ecological issues tend to be discussed.

In the 29 years since the first Conference, we have seen a tremendous growth of industries based on plantation grown softwoods, the gradual development of larger production units for sawn hardwoods, a preservation industry, a fibre board industry and a chip export industry which, if properly directed, will reduce our residue problem and increase the productivity of our hardwood forests. We have also seen the birth and growth of technically oriented industry organisations such as the Radiata Pine Association of Australia, the Plywood Association of Australia and the Timber Preservation Association of Australia. Still more recently a vigorous branch of the Institute of Wood Science was formed. Consultants competent in most phases of forest products research are more numerous and the Australian Government, through the Australian Industry Research and Development Grants Board, will partly offset the cost of industrial R. & D. work whether carried out by approved laboratories, registered consultants or employees of the industry, who do not now have to be professionals.

So far as the technology of sawing, peeling, chipping, pulping, drying, gluing and protecting wood is concerned, this Conference, through its participating organisations, has most of the answers. Indeed as Eric

Ellwood said at one of the earlier Conferences, "If we could only apply the knowledge we already have to our industry we could forget about these conferences for a while".

If we are dissatisfied with the way in which the research results are being applied by industry, where does the problem lie? Bob Sutherland maintains that this is primarily a matter of communication and from the number of organisations set up to communicate on various levels within our industry it would seem that this is well recognised by everyone. I say this because there are some 40 odd organisations within the Australian forest products scene concerned with promotion, education, research and development, marketing, planning, management and, dare I say it, just plain old fashioned price fixing. Many of them, even if they do not plan research, certainly talk about it. I won't dazzle you with a list of their initials but one of the more recent ones has the somewhat curious sounding acronym of F.R.A.P. (Forest Products Research Advisory Panel). From the above it follows that I don't really think communication is the problem. If one exists, and I believe it does, industry must take the major responsibility for its failure to adapt research results to its particular needs. I believe that this is largely because there has been insufficient attention paid in the past to the employment and support by management of competent R. & D. personnel to liaise with research people and translate the results, with their co-operation, into practice. I can say with absolute certainty that to a research worker nothing enthuses him more than an attempt to translate the results of his research into practical reality. However, the position is improving and I suspect that it will get better as the industry becomes less fragmented.

The original purpose of this Conference was to review the programmes of the Division of Forest Products, the then Queensland Sub-Department of Forestry and the N.S.W. Forestry Commission to avoid overlapping and to establish priorities. Other Australian forest services were also represented as was the Forestry and Timber Bureau and the forerunner of the Department of Forests, Papua New Guinea. Many conservators attended the early Conferences. Later New Zealand was represented and those university departments with an interest in the field. More recently representatives of industry associations were invited. This expansion is not necessarily a bad thing but as we all know it has meant a very crowded agenda with little time for an exchange of views in depth by delegates and this to me is the real drawback of the present situation. At the last Conference there was some discussion on the need to redefine conference objectives. John Beesley said, and I quote him in part, "Perhaps a redefinition of the purpose of this Conference could act as a guide to the sort of papers wanted and what should be in them. I think that the purpose of this Conference has changed over the years and a restatement of objectives might serve to bring things into perspective. Could we perhaps leave that for the organisers of the next Conference? The sort of things that come up obviously are: is it an opportunity for those people in research to show what they are doing? Is it simply window dressing to convince industry that we are really working for their benefit? Is it an attempt to educate industry - in which case have we all the right people here to be educated and are we the right people to educate them, or just what is our function? Why are we gathered here - this group of people representing diverse interests? What do we aim to get out of it?" Well said John!, but without attempting to answer your questions I think that the Conference is more important than ever now with the loss of the Forest Products Division and the greater diversification of research interests and I want now to make some suggestions for its improvement.

I have referred to the very crowded agendas of recent Conferences which prevent discussion in depth. In earlier days when preservation matters tended to dominate the whole of the Conference agenda a Preservation Sub-committee was formed which met once or twice a year and reported back to the Conference. This group, under Norm Tamblyn's chairmanship has been very successful. It has representation from the D.B.R., the Forest Services of Victoria, Queensland,

Papua New Guinea and N.S.W. and representatives of the T.P.A.A. and R.P.A.A. attend for part of the time. Meetings are long enough for detailed discussions, usually two or three days. I wish to suggest that we set up more of such committees or working parties along the lines of the Preservation Committee or the working parties set up by the Australian Forestry Council to plan forestry research. One such group should be concerned with drying and I am pleased to inform you that at a recent seminar held by the Institute of Wood Science on high temperature drying, those attending unanimously agreed that this Conference be asked to approve of such an action. I believe that, if a similar sub-committee or working party were set up in a number of other areas, research and its application to industry would be facilitated and more time would be available at this Conference for discussions arising from recommendations of the working parties.

In the remaining time left to me I should like to mention some areas where some working parties could usefully function.

Residues	An informal group exists with representation from D.B.R., D.B.T., T.R.A.D.A.C., T.A.C. and W.T.D. which has met twice since the last Conference. A more formal arrangement could be helpful especially where travel is involved since some departments authorise travel more readily for formally recognised groups. I therefore suggest that this group be approved as a working party by this Conference.
Adhesives	This is a critical field where indepth discussion and planned research are badly needed.
Wood Quality Assessment	The need for such a group will, I am sure, be supported by all delegates and its importance is embodied in Recommendations 1 and 2 on this subject adopted at the last Conference.

I could go on. There is probably a need for a working group on reconstituted products such as fibre and particleboard.

Before concluding I wish to take a few minutes to speak about a matter, which if not adequately understood and practised by our industry, could be disastrous. Everyone pays lip service to it but with some notable exceptions it is not practised in a professional way. Perhaps we need another working party - I refer to quality control. Recent instances in N.S.W. in the fields of preservation and glulam production have been a sad reminder to us at W.T.D. that, even though management may lay down sound procedures for quality control, failures can occur which are very damaging to the prestige of the organisation concerned and to the industry in general. In my experience the system usually breaks down because market demands and production pressures prevail and the quality control officer, if one exists, does not get adequate backing from management when the crunch comes. I am aware that the Radiata Pine Association of Australia is contemplating the setting up of an independent quality control authority and I welcome this as an important augury for the future. On behalf of the Association of Mechanical Timber Graders, Tony Anton, Bob Sutherland and I have investigated the certification mark system operated by the Standards Association and have been impressed by the facilities available. For the manufacturer, provided a Standard exists covering his product, the Mark provides an independent assurance to his customers that articles are being produced under an effective system of quality control to meet that particular Standard. The use of the Mark will also afford protection against competition from sub-standard products since the scheme provides independent supervision and checking by S.A.A.

As I see it this scheme places the onus on the manufacturer to maintain an effective system of quality control. Its basic advantage is that the Licence may be suspended or revoked if the Association finds evidence that the Mark is being ineffectively used. Because the S.A.A. is independent of industry it can take independent action - a thing which most industry controlled schemes are reluctant to do. To all sections of our industry concerned with quality control I recommend a study of this quality assurance scheme.

RECOMMENDATIONS AND RESOLUTIONS OF THE 1973 FOREST PRODUCTS RESEARCH CONFERENCE

Review by N Tamblyn

At the 16th Forest Products Research Conference held in Melbourne on May 28th to June 1st 1973 a number of recommendations and resolutions were proposed and adopted. Action taken by the Divisions of Building Research and Chemical Technology relevant to these proposals is summarised herewith.

TOPIC 1 - WOOD QUALITY ASSESSMENT

RECOMMENDATION 1

An investigation of the between tree and between species variability of wood quality determinants such as growth stress gradients, basic density, fibre dimensions and permeability amongst shorter rotation eucalypts intended to be the subject of intensive regeneration programmes and tree improvement work.

Relevant Work

The growth stresses of 30 elite trees of E grandis at Coff's Harbour have been assessed so that inheritance in the progeny can be examined when they are large enough for sampling. A comprehensive study has been made of the between-tree and between-family (progeny group) variability of growth stress, growth rate, basic density and kino occurrence in E regnans. Also, inter-relationships between these factors have been investigated. In a further study, the growth stresses and external tree characteristics of 120 E regnans trees are being determined for later correlation with log quality and sawn timber recovery. These trees are also being used in an attempt to develop more rapid and simpler techniques for growth stress assessment.

Work is in progress to determine the extent to which growth stresses are associated with anatomical features which might affect end uses. Possible association between lignin content and growth stresses is being examined.

Equipment has been designed to facilitate collection and storage of data for computer analysis relating to the dimensions of anatomical elements of juvenile wood in short rotation eucalypts and to changes which occur in these elements with the age of the cambial tissue producing them. A measuring device has been developed to enable more rapid and accurate collection of fibre length data including data on broken fibres.

Research has been planned, but not yet commenced in the laboratories, to study genetic and sylvicultural variations in the decay resistance and treatability of wood from young trees of short rotation eucalypts. For this purpose a comprehensive sampling of provenances of E regnans from Victoria has been made in collaboration with the Forest Research Institute. Arrangements have also been made with the Department of Forests, Papua New Guinea, to sample provenances of E deglupta for future work on decay resistance as a possible early indicator of susceptibility to heartrots.

The Division of Chemical Technology has done a considerable amount of work on the pulping characteristics of plantation grown E deglupta from Papua New Guinea. This work will be reported to the Conference under item 3/6. Also they have collaborated with the Forest Research Institute in assessing the effect on pulping and paper-making properties of differences in basic density between families of E regnans.

RECOMMENDATION 2

Research on the origins, developments and prospects of amelioration of defects of importance to the consumers. The individual defects studied will depend on the species and the environment. Specific problems to be considered are associated with distortion potential, kino viens, surface deterioration, knots and stability.

Relevant Work

In continuation of work on growth stress relief treatments, the holding of trees in a state of checked growth by application of defoliant sprays is currently being evaluated. It is hoped that this technique of arresting growth without quickly killing the tree will give time for creep to occur in highly stressed areas and thus lead to considerable reduction of stresses. In the further study of growth stresses a model system has been developed to better examine those conditions which may lead to their amelioration and to decrease in the potential for distortion.

Other work on growth stresses has been directed at identifying the causes for their wide variability in trees which are orienting towards the vertical, after having been displaced. This work has already enabled identification of prime factors involved in growth stress generation and has indicated the basic cause of differentiation of tension wood in hardwoods and compression wood in softwoods. Also, it has led to identification of the main factors involved in shrinkage of wood and the strong influence of external forces on tissue variability. Further, it has shown that external forces and corresponding effects on growth stresses influence changes in cell wall thickness, in the microfibril angle in the structurally important S2 layer, in the type and amount of lignin formed, and in the stiffness, strength and shrinkage of the wood.

Study of the origin and development of defects has shown that kino viens in the cambial region of eucalypts evolve greater amounts of ethylene than adjacent regions of undamaged cambium and that they can be initiated by the administration of ethylene. Circumstantial evidence has indicated the importance of edaphic factors in kino vein formation and work in this area is continuing.

TOPIC 2 - UTILIZATION OF SMALL HARDWOOD LOGS

TOPIC 5 - WHOLE TREE - ANY TREE - UTILIZATION

RECOMMENDATION 1

That, as matters vital to the conversion of small hardwood sawlogs, investigations be carried out into:-

(a) sawmill scale and process design, materials handling and
(b) development of log grading requirements as related to specific end uses and management regimes

Relevant Work

An investigation is under way to determine the economics of milling small hardwood logs by various sawmilling systems. Initially it is proposed to use three milling systems but later this may be extented to five. As part of this investigation studies are in progress to relate external appearance of the logs and growth characteristics of the trees to the quality and type of product obtainable from them. To assist in this work a peeling microtome has been assembled to enable continuous assessment of wood quality throughout a log.

The information from these studies will form the basis for future log grading

rules but extensive testing will be necessary to determine their reliability.

RECOMMENDATION 2

That investigations be made into changes occurring in wood chips in outside stock piles in Australia. Such investigations to include aspects of biological control of chip degradation and also the possibility of their wider application within the timber industry.

Relevant Work

Work on problems of outside chip storage has continued in the Division of Building Research but has so far been concentrated on chip storage of mixed tropical rain forest timbers in Papua New Guinea. Initially this work proceeded slowly as only experimental chip piles were available but it is now accelerating with the commercial export of chips from Madang to Japan. The amount of microbial deterioration in the commercial piles appears to be greater than expected from previous tests at Vanimo and a detailed microscopic assessment is now under way. Tests of the biological control of fungal staining by antagonistic organisms have given promising results in the laboratory but rather poor results in a small experimental pile at Port Moresby.

TOPIC 3A - TIMBER FOR CONSTRUCTION - STRUCTURES

RECOMMENDATION 1

The Conference recommends urgent evaluation, using existing data and known physical relationships, of the parameters governing the incidence of condensation on wood in buildings, with special reference to condensation on flooring and within the wall cavity of wood framed houses. This is required in selecting the critical parameter for future experiments or surveys, and in choosing among recommendations for ventilation in various situations.

Relevant Work

Adoption of this recommendation has been delayed by staff absences and changes of work which have particularly affected Mr Da Costa who was to co-ordinate this research. As initial steps an up-dated Newsletter article on sub-floor ventilation, an informal survey of opinion on causes of condensation leading to mould growth in houses, and a preliminary theoretical quantitative evaluation of ventilating effectiveness of current recommendations have been prepared. Further work has been deferred pending the move to Highett when co-operation with other interested groups can be more readily organized.

RECOMMENDATION 2

That the CSIRO Division of Building Research set up a Techno-Economic Development team to take these and other projects of a like nature to a total design stage whence they are capable of ready assimilation by industry. It was further recommended that industry should be approached for funds to finance this work.*

(panel type construction and rationalised foundation and framing systems)*

Relevant Work

Although work in panel type construction and rationalised framing systems has continued, the Division of Building Research has, so far, not felt able to accept the recommendation that a Techno-Economic Development team be set up to carry this work to the stage of commercial development. However, discussion on this is proceeding with the Victorian Timber Promotion Council.

TOPIC 3B - TIMBER FOR CONSTRUCTION - WOOD PRESERVATION

RECOMMENDATION 1

It is recommended that DER and the State Forest Services should regard as urgent the development of a stabilising organic solvent preservative pressure treatment for exterior building timbers and pre-machined timbers and should co-operate closely with industry in this development.

Relevant Work

The basic work leading to the recommendation to industry that a Rueping treatment be used (employment of initial air pressure to obtain very low solvent retentions) was completed soon after the last Conference. It is now accepted as the basis for development of commercial organic solvent treatments in Australia. There is much other work to be done in this field (as summarised in a paper to be given later in this Conference) but priority has had to be given to other projects of equal or greater urgency. However, some work has been commenced to compare the effectiveness of different candidate fungicides including TBTO/PCP mixtures.

RECOMMENDATION 2

It is recommended that screening work on new preservatives and coatings for marine timbers which is already progressing, should be given high priority on the widest possible basis.

Relevant Work

Tests of a number of new treatments - mainly organic toxicants - were installed at Sydney, Port Stephens and Cairns in late 1973. Further tests of double treatment with CCA and creosote and of arsenical creosotes applied to P radiata, E maculata and E pilularis were installed in the same ports in 1974. Specimens are now being prepared for tests of a much larger number of toxicants to be applied as superficial treatments or in toxified coatings, to wood already pressure treated with CCA or creosote.

A joint investigation by the Department of Forestry (ANU) and the Division of Building Research is in progress to determine factors responsible for the marine durability of turpentine (Syncarpia glomulifera)

Resolution (As only 2 recommendations were permitted under topic 3B, a resolution was submitted to the Conference as follows)

In view of the significance of rail sleeper fastenings on the service life of wooden sleepers, it is resolved that this matter should be given urgent attention in co-operation with railway authorities.

Relevant Work

Since the last Conference the subject of rail fastenings has been discussed in a paper prepared for the first International Rail Sleeper Conference held in Sydney in August 1973. Follow up meetings since this Conference have resulted in the formation of the Rail Sleeper Association (Australia). This Association is anxious to co-operate in tests of new fastenings and this work will commence as soon as possible. We have judged that the delay in commencing these tests is justified by the closer personal co-operation of senior railway engineers which has now developed through the Association.

TOPIC 3C - TIMBER FOR CONSTRUCTION - BIODETERIORATION

RECOMMENDATION 1

This Conference recommends urgent investigations on the problem of severe soft rot in treated eucalypts and other hardwoods, including:

(a) biological and chemical research
(b) immediate evaluation of remedial treatments for infected poles
(c) development of more effective initial pole treatments

Relevant Work

Since the last Conference high priority has been given to the problem of soft rot in treated hardwood timbers. Progress has been slow because of the inherent difficulty of the problem as indicated by our field tests in Queensland and Papua New Guinea where no preservative treatment has given satisfactory long term protection of eucalypt sapwood in ground contact. We are therefore faced with the problem of developing new preservative treatments for tropical ground contact use and of establishing methods for remedial treatment of timbers attacked in service.

Our work, and that of others, has indicated that in conventional CCA treatments, the preservative components do not effectively penetrate the cell wall of eucalypts and that this lack of penetration is probably the basic factor limiting the effectiveness of most preservatives against soft rot. To study this problem of cell wall penetration in hardwoods we have spent almost $90,000 on the purchase of a Cambridge scanning electron microscope (SEM) which will enable us to relate the micro distribution of preservative in the wood to soft rot susceptibility and to examine methods for achieving better penetration. This fundamental work is now commencing.

In the development of remedial treatments a number of potential fungicides are being tested against soft rot in the laboratory. The best of these will be tested in pole bandages with the object of using this type of treatment to arrest soft rot in CCA-treated poles in Queensland. These bandage tests are almost ready for installation.

RECOMMENDATION 2

Recognising the potential hazard of centre rots in treated transmission poles of durability class 3, this Conference recommends immediate surveys of the incidence of these defects, the development of methods for the treatment of standing poles, and the evaluation of the use of diffusible preservatives in the initial treatment of these poles.

Relevant Work

Further statistics have been obtained on the occurrence of centre rots in creosoted poles in the Melbourne metropolitan area. A joint survey with the SEC (Victoria) was made in which inspection records were analysed for a random sample of 3418 treated class 3 poles (mainly E obliqua and E cypellocarpa) installed in the period 1958-72. Results for poles still in service when inspected in 1972-74 indicated that:

about 2% ofthe 1958/62 poles would fail (all causes) within 19 years of installation
about 0.4% of the 1963/67 poles would fail (all causes) within 14 years of installation
about 0.03% of the 1968/74 poles were beginning to fail

As no records were available of failures before the 1972-74 inspection the 2% figure is too low by an unknown amount but the other figures should be little affected.

The SEC(Victoria) is now planning to treat the heartwood of all new poles with a diffusible preservative applied in bored holes in the critical area near to ground line. We are co-operating in the work which involves field and laboratory tests of various diffusible preservatives including a copper-fluorine-boron complex developed by Mr Johanson for which patent application has been lodged. A preliminary test has been done to determine diffusion patterns for about 19 formulations based mainly on copper, fluorine and boron compounds applied in holes bored in the heartwood of green E regnans rounds. Longitudinal diffusion for distances of over 250 mm were obtained in 100 days for some formulations. A recommendation on the most suitable formulation has not yet been made.

TOPIC 4 - RESIDUE DISPOSAL AND UTILIZATION

RECOMMENDATION 1

FPL should make, in collaboration with the appropriate industry organizations, forest services and State departments, a more detailed survey of the location, quantities and type of forest products residues with the objective of offering advice on the most appropriate method for their utilization. Such a survey would provide useful outlets for current FPL research on residue utilization.

Relevant Work

Work has continued on the development and application of tannin adhesives from P radiata bark. We are actively co-operating with industry in the development of processes for tannin extraction and its use in adhesives for plywood, particle board and laminated beams. Work in progress includes a study of the quality and yield of tannin from radiata pine trees of various ages and localities; the formulation of a radio frequency cured adhesives for laminated beams; and the use of tannin formaldehyde resins for imparting water resistance to various paper products. The mechanism of adhesion to wood surfaces is also being studied as part of the fundamental background to our programme.

In accordance with the recommendation a survey of the location, quantities and types of forest products residues has been undertaken. A questionnaire which is a modified version of one originally prepared by NSW has been circulated to Forest Departments but as yet no replies have been received.

The possibility of producing from cypress pine residues a termite toxicant or repellant which is not environmentally hazardous is being investigated. Even if residues are inadequate for commercial extraction, a better knowledge of the structures of the active compounds may indicate ways to prepare synthetic compounds with equal or improved properties.

RECOMMENDATION 2

FPL and particularly the Division of Applied Chemistry, should give high priority and devote substantial effort to developing useful composites from mill residues in the short term and from primary resources in the long term in order to maintain a place for wood-based materials in the markets of the future. Such a programme involves research in adhesives and adhesion, surface finishes and protection, comminution, defibration and the role of particle geometry.

Relevant Work

In the Division of Chemical Technology, hardboard type composites have been prepared from P radiata sawdust and finely divided bark by heating with formaldehyde. Systematic data have been collected on dimensional response to liquid water and high humidity and on mechanical properties. At this stage work on lignocellulose fibre-polymer composites has been confined to primary resources rather than mill residues because of the need to work with well characterised and reproducible systems and because use of paper sheets and polymer films has overcome problems of mixing large amounts of fibre with small amounts of polymer. Particular attention is being given to the loss of stiffness of cellulosic composites on exposure to water. This is considered to be the most important impediment to their commercial situation.

In the Division of Building Research work is in progress on possible methods for utilizing fibrous eucalypt bark. Special attention is being given to the possibility of producing a cement-bonded bark board for use as exterior panels. Means of defibrating this type of bark are also being investigated.

RESOLUTIONS

Five other resolutions were also carried as follows:

Resolution 1 - Proposed by Mr Foxton

1. To assist DBR, DAC and the Forest Products Research Branches of the State services in assessing priorities, expenditure of the funds and the direction of research, and more especially development, in projects involving forest products, this Conference recommends that market research techniques be utilised where appropriate.

It recognises that the Divisions are not constituted to exercise this function and consequently also recommends that the assistance of industry and industry associations be enlisted to provide such data either from their own establishments or by the provision of funds to enable collaboration of professional personnel attached to the Divisions for this purpose.

Comment

This resolution is acceptable where it is appropriate, but we do not consider it applicable as a general principle to all areas of research. However, current work by Mr Wymond on the market acceptability of timber and timber products falls closely within the scope of this resolution.

Resolution 2 - Proposed by Dr Higgins

In view of the environmental benefits of chipping or other forms of using small residues as outlined during this Conference, it is recommended that the Forest Departments and Governments should give consideration to encouraging the extension of appropriate facilities at sawmills.

Comment

Action by the Divisions of Building Research and Chemical Technology is not implicit in this resolution.

Resolution 3 - Proposed by Mr Sutherland

That, having regard to the importance of establishing close contact between research workers and industry, this Conference requests all research organisations to establish a system whereby research personnel could be seconded to

industry companies to work on specific problems referred by such companies through industry organizations to the research body concerned.

Comment

As far as can be ascertained, no requests from Australian industry for secondment of a CSIRO officer have been received since the last Conference. However, officers have continued to visit industry, to advise on specific problems, and, if warranted, to undertake research in co-operation with industry.

Resolution 4 - Proposed by Mr Tamblyn

Recommendations for research or other work accepted at the previous Conference should be summarised in a pre-print together with a brief statement of the action taken.

Comment

In accordance with this resolution, the present document has been prepared.

Resolution 5 - Proposed by Mr Martin

That a study of the effectiveness of existing methods of disseminating the information from research bodies be undertaken by officers of the CSIRO Division of Building Research and Applied Chemistry, in conjunction with industrial promotional bodies and representatives of industries generally.

Comment

Although no systematic study has been made, a great deal of consideration has been given to improvement in methods of disseminating information. More specific comment from industry would be helpful in securing further improvements.

REPORT OF THE WOOD PRESERVATION COMMITTEE (1973-75)

Prepared by N. Tamblyn (Convener)

1. General

Since the last Forest Products Research Conference there have been four meetings of the Wood Preservation Committee at approximately 6-monthly intervals with a venue alternating between Brisbane and Sydney. At each meeting one day has been devoted to a session restricted to members of Government Departments and a further 2 days to a joint meeting with members of the Technical Committee of the Timber Preservers' Association of Australia (TPAA). The meetings have been frank and harmonious and all members of both Committees have made valuable contributions and expressed their satisfaction that the purpose of the meetings is being well achieved. The Wood Preservation Committee (Government members) is particularly appreciative of the time and effort given by members of the TPAA Technical Committee in attending the joint sessions and in freely giving their counsel on many matters. Except for one apology, all meetings have been fully attended.

2. Membership

The Committees have been enlarged by the nomination and acceptance of Mr. Colin Levy representing the Department of Forests, Papua New Guinea, and Mr. Bruce Rumball representing both the Radiata Pine and the Timber Preservers' Association. The full strength of the Committees is now 10 members, as follows:-

Government Departments (Wood Preservation Committee) -

Messrs. W. Clifford, E. Da Costa, R. Johnstone, C. Levy, N. Tamblyn, K. Cokley

Timber Preservers' Association (Technical Committee) -

Messrs. J. Foxton, D. Price, S. Retter, B. Rumball.

Although further enlargement of the Committees is not at present proposed, we have, at times, adopted the approach of inviting participation of others in the discussion on particular items.

3. Work of the Committees

In the 4 meetings since the last Forest Products Research Conference, the Committees have spent 4 days in the restricted sessions discussing about 65 agenda items, and 8 days in the joint sessions for which almost 150 items have been listed for attention. As there has been no restriction on topics which may be raised, discussion has ranged over the whole field of wood preservation from current research to problems of industry. As far as possible discussion on current research has been supported by brief papers summarising results as they become available. In this way the joint committee has been kept well informed and it has been left to the discretion of the TPAA Technical Committee to disseminate non-confidential information to industry.

It is not possible in this report to review the numerous items discussed. The main topics are however listed as an indication of the scope of our discussions in the joint meetings.

4. Main Topics Discussed

1. Protection of rail sleepers in the Pilbara (W. Australia) against Mastotermes
2. Results of current rail sleeper tests in various States
3. Development of better methods for incising rail sleepers
4. Centre rots in treated eucalypt poles (problem in Victoria, results of survey and use of diffusible preservatives)
5. Soft rot in CCA-treated hardwood poles in Queensland and PNG (development of new treatments, use of bandages for remedial treatment)
6. Tests of pole stubs treated against soft rot in Queensland
7. Loss of creosote by drainage or volatilization from treated round eucalypts
8. Methods of determining creosote retention in poles and significance of time of sampling in relation to approval under State legislation
9. Restrictions on use of CCA treatments for hardwoods in tropical and sub-tropical ground contact use
10. Effect of high temperature drying on CCA preservative treatments in pine
11. Organic solvent preservative treatments for pine and other timbers
12. Use of TBTO and mixtures of TBTO/PCP in organic solvent treatments
13. Glue additives for plywood (progress of research by DBR, laboratory termite tests of plywood containing heptachlor)
14. Preservative shortages and possible future bans
15. Reduction in boron retention for Lyctus immunization - planning of new tests to re-examine toxic thresholds
16. Lyctus susceptibility ratings - preparation and issue of common list
17. Marine borers - results of current tests, planning and installation of new tests to re-examine toxic thresholds
18. Health hazards from CCA-treated timber in children's playgrounds
19. Corrosion in kilns from high temperature drying of treated and untreated timber
20. Import into Australia of diffusion treated timber from PNG
21. Treatments desirable for termite protection of timber used in re-building of Darwin.
22. Market requirements for various treated timbers
23. Need for redrafting of existing wood preservation standards and for preparation of new standards
24. Branding of preservative treated timber

REPORT OF WORKING GROUP ON TOPIC 1 - MECHANICAL PROCESSING AND APPLICATIONS

The group discussed various aspects of safety in the timber industry, with special reference to current work on noise suppression and the effects of recent change in Workers Compensation premiums. It was suggested that in visiting timber conversion plants, Mr. Lhuede and any others engaged in research in this area keep in mind other problems of safety which may require some investigation.

There was considerable discussion on various aspects of residue utilization, particularly in regard to bark and sawdust. It was suggested that further work on bark, especially in regard to barking in the forest, be carried out in collaboration with the Division of Forest Research, C.S.I.R.O. There was concern that moves to utilize a greater proportion of the tree, especially limbs and tops, could give rise to nutritional problems. This resulted in the framing of Recommendation 1.

On the question of a committee to coordinate work on residues, it was felt that this was unnecessary as an industry committee - T.I.R.C. - Timber Industry Residues Committee already exists. It was agreed that since T.I.R.C. has wide representation and is functioning smoothly, that liaison be maintained with that committee.

In the field of timber seasoning, attention was focussed on two main aspects, high temperature drying and the need for a seasoning committee. In addition to the need for fundamental research into various aspects of the high temperature process, it was felt that there is also a critical need for more and better information on materials for kiln construction which would withstand the conditions imposed by the process. Considerable discussion on this topic led to the framing of recommendations 2 and 3. In support of the recommendation to establish a seasoning committee, the group felt that there is need for such a committee to coordinate work on high temperature drying, and to obtain feedback from industry, especially in relation to performance of materials. In this regard it was suggested that other avenues of expertise be exposed, for example, other groups within D.B.R., in order to find solutions to some of the pressing problems which are already being encountered.

Discussion on the topics grouped under the general heading of "Structural" indicated considerable interest in the work being done on adhesives, and on possible developments in the field of glued laminated structural members. It was also noted that the Building Research Association of New Zealand - B.R.A.N.Z. - is working in a number of fields directly related to the structural application of timber and wood products and the group suggests that B.R.A.N.Z. be invited to send a representative to the next Conference.

Finally the industry members of the group paid a tribute to the assistance in kiln design work provided over many years by Mr. Leo Brennan of D.B.R. and recorded its wishes for his long and happy retirement.

REPORT OF WORKING GROUP

on

Topic 2A - Wood Biology

Working Party:- W.E. Hillis (Chairman), R. Stokes, Mrs. E. Bolza, G. Waugh, W.J. Smith, R.E. Palmer, K.F. Plomley, J.P. Wright, Y. Yazaki, N.B. Lewis, C.M. Stewart, P. Eddowes.

The following 26 papers were discussed from the viewpoint of the aims of the Conference, namely, assess research effort, identify research priorities, and coordinate research planning:-

Papers 2/1 - 2/12, 2/1c - 2/9c, 2/17c, 2/18c, 2/20c, 2/21c, 3/11, 3/1c, 3/4c.

1. Research Effort

The papers were considered in three groups.

1.10 Primary quality and biological characteristics of -

1.11 Eucalypts

1.12 Conifers

1.20 Secondary quality and biological characteristics

1.21 Extractives

1.22 Durability

1.23 Sapwood - heartwood

1.30 Bark characteristics

The most significant aspects of the discussion were -

1.11 Eucalypts

Attention was drawn to the effects of growing species in off-site areas, or outside the normal range of growth conditions. Good growth may be obtained but the physiological stress may result in variations in tree characteristics and wood quality such as growth stress, brittle heart, kino, drying problems etc. Growth on off-site areas appears a more likely cause of these characteristics than fast growth rate.

Because of these changing conditions a need was expressed for more information on physical, mechanical and anatomical characteristics of the wood and bark of the more important eucalypt species in natural or plantation type regrowth forests.

Also there is a need for the evaluation of the properties of other fast grown species such as Acacia.

1.12 Conifers

Knots have the most degrading influence on quality and the subject has been neglected. Attention was given to the economic aspects of pruning, silvicultural methods to reduce the incidence of "rotten" or loose knots and to technological methods to overcome these effects in the large amount of existing wood.

It was considered that increased effort on the study of the effect of selection for vigour and straightness on wood quality parameters would be worthwhile.

1.21 Extractives

In view of the influence and potential of extractives in some applications it was considered worthwhile that work on the quantity, chemical nature and influence of extractives on the utilisation of wood and bark be continued and extended.

It is considered the incidence of resin pockets in exotic pines is not fully realised and that the pockets could be caused by physiological factors.

It is hoped that work on the resinification of radiata pine continues with particular attention being given to the selection of non-hazardous stimulants.

1.22 Durability

In view of the need for long lasting marine timbers, particularly for tropical waters, encouragement was given to the study of the causes of extended marine durability so that selection of suitable woods be facilitated.

The few cases of allergies caused by cypress pine should not hinder the current search for environmentally non-hazardous preservatives from cypress pine residues.

1.30 Bark characteristics

In view of the unexpected nature of recent results and the general lack of information about bark, it was urged that increased attention (even to the extent of establishing a Working Party) be given to the basic properties of bark with the view to developing specific end-uses other than those for horticulture.

2. Research Priorities

2.1 The Working Party is concerned with the scarcity of information on the quality of wood from regrowth eucalypts and RECOMMENDS that attention should be given to "Evaluation of the properties of wood and bark of the more important eucalypt species of regrowth forests with regard to end-use requirements".

2.2 The Working Party recognises that knots, and particularly dead knots, are a major defect in conifers and it was resolved that this matter should be brought to the attention of the Standing Committee of the Australian Forestry Council so that it can consider recommending to the Silvicultural Working Groups 4 and 5 to consider ways to keep them to a

minimum. Also it was resolved that relevant members of this Conference should evaluate the effects of these defects on utilisation with a view to ameliorating other effects through technical application.

3. Coordination of Research Planning

3.1 To facilitate coordination and to give attention to matters considered to have the highest priorities, the Working Party RECOMMENDS -

The establishment of a Working Group concerned with Wood Quality Evaluation to operate between Forest Products Conferences and that steps be taken to have its activities incorporated within the Research Working Group system of the Australian Forestry Council.

3.2 Furthermore the Working Party, recognising the potential of certain eucalypts in regrowth forests and the complexities of matching appropriate species, sites, silvicultural treatments with wood characteristics, conversion techniques, and the appropriate utilisation, accordingly RECOMMENDS the formation of a multidisciplinary Project Team to advise in the coordination of the planning of relevant research into Regrowth Eucalypt Forests for Wood.

3.3 The meeting unanimously elected the Working Party chairman as convenor of any such Groups or Teams to be formed.

It is suggested that if the same format is followed for the next conference that a more suitable title for this working group should be "Wood Biology and Tree and Wood Quality".

REPORT OF WORKING GROUP ON TOPIC 2B - WOOD PRESERVATION

The working group adopted the following program.

1. A quick review of the Resolutions and Recommendations of the previous conference.
2. Discussion of areas of major concern.
3. A quick look at the questions received in response to the contributed papers.
4. Framing of recommendations.

Previous Recommendations and Resolutions

It was generally felt that the work in progress in the areas of the recommendations and resolutions was most satisfactory.

With regard to rail sleeper fastenings it was considered that the state of the wood around the hole should be studied and the S.E.M. appeared to be a logical tool for this work.

Discussion on Areas of Major Concern

The following topics were suggested by the group for discussion:

1. Organic Solvent Preservatives
2. Microdistribution of preservatives in timber
3. Health hazards both in the treatment plant and in the utilization of treated wood
4. Quality control in timber treatment
5. Surface finishes for timber
6. Plywood preservation
7. Decay in existing buildings
8. Fire retardant treatments
9. Compilation and collation of service histories of timber.

Organic Solvent Preservatives

This topic evoked a lot of discussion and a recommendation to the Conference for more work in this field. The aspects requiring some resolution were considered to be:-

(a) bleeding of resin and solvent from the heartwood of pine timbers (P. radiata in particular) affecting painting etc.

(b) the question of what pine heartwood was penetrated by O.S.P.s and what was not

(c) suitable preservatives

(d) suitable solvents

(e) economics generally but particularly those of solvent recovery

(f) fire and health aspects

Microdistribution of Preservatives

Mr. H. Greaves was asked to explain the capabilities of CSIRO's newly acquired scanning electron microscope with particular reference to its use in the determination of the microdistribution of the preservatives in wood.

His outline received an enthusiastic and unanimous response from the group.

It was felt that it was critical that this work should proceed and knowledge obtained as answers were urgently required in the soft rot field and the field of surface treatments in particular as well as other areas. The use of this machine in tracing preservatives in insects, fungi and bacteria should prove particularly useful.

Health Hazards

This subject was well ventilated under three broad headings -

Treatment plant hygiene
Disposal of shavings, offcuts, etc.
Final disposal of treated timber

It was generally agreed that the problems were largely a matter for education and the TPAA representatives indicated that their Association plans to print a small manual for treaters and a handout for distribution by retailers warning that treated wood contains toxic chemicals.

The discussion turned to the reaction of Health etc. Authorities to preservatives such as Arsenic and Dieldrin. It was felt that their reactions were generally over-reactions and a plea was made for a sensible approach on the part of the Authorities. At the same time the Working Group felt that the climate was such that a spur should be applied to the search for preservatives of low health and environmental hazard.

Decay in Buildings

A suggestion was made that a survey of decay in existing buildings should be made as this could reveal the need for the development of palliative measures which in turn could lead to economies. It was felt that the causes of decay in buildings were well known and despite this people still made the same mistakes although new building methods had created some new situations. Education of designers, builders, regulatory bodies and their executives was considered the best line of attack to the problem.

Fire Retardants

The Group, conscious of the vast amount of fundamental work needed in this area, felt that with present resources, all that could be done was to pick out small areas where a quick return was likely, or, at the most, a pilot project could be undertaken. It was felt that the subject was more appropriately the province of the Fire Retardant Committee of the FPRC.

Service Statistics

It was thought desirable that records of timber in service should be kept and collated to determine reasons for failure and success. The unresolved question was who should do the work.

ITEMS FROM QUESTIONS RECEIVED

The only item of interest not answered by the discussion was control of stain and discoloration in particle board. It was considered that this could be easily controlled by glue formulation.

Recommendations

The three recommendations below were put to the Conference on the final day and appear in amended form under the heading on Topic 2B - Wood Preservation on page 26 of these proceedings.

(i) It is recommended that fundamental research into the movement of liquids in wood be undertaken, including such areas as organic solvent preservatives, the penetration of refractory heartwood of pine, and treatment of eucalypt heartwood.

(ii) It is recommended that increased effort be applied to research into and development of new types of preservatives of improved efficacy and low health and environmental hazard.

(iii) It is recommended that fundamental work on surface treatments for timber should be carried out with emphasis on the wood/finish interfaces arising from the application of natural finishes.

REPORT OF WORKING GROUP ON TOPIC 3 - FIBRE UTILIZATION

1. Terms of Reference

In accordance with the aims of the Conference, the terms of reference of the Working Group were accepted as:

Assessment of the research effort in the field of fibre utilization
Identification of research priorities
Co-ordination of research planning

2. Background Material

It was considered that the papers put before the Conference could all serve as background material for the Group's discussions, particularly Invited Papers 2, 4 and 5, and the contributed papers and comments under Topic 3. A statement on the Residue Survey by Mr. Wymond was also made available to the Group.

3. Research Objectives

In response to a suggestion by Dr. Macmillan, a statement of the research philosophy and current programmes of the CSIRO Division of Chemical Technology was presented by Dr. Weiss.

4. Plantations

The work of the CSIRO Division of Chemical Technology on the assessment of species for plantations in tropical areas was reviewed. This work has been to a large extent financed by the PNG Department of Forests and any further work in this field in S.E. Asia can only be undertaken on a sponsored basis.

The major problem of site preparation for large scale plantations was posed, and there was a short discussion of the problem of nutrient depletion with successive crop harvests, which remove significant proportions of the available nutrient store in bark and leaves.

5. Residue Utilization

Considerable discussion took place on the question of residue utilization. It was considered that more effort was required in defining the nature and magnitude of the resources available, which might for example be considered by the Standing Committee of the Australian Forestry Council, in defining the necessary research in this field, and in partitioning the work done between state forestry departments, CSIRO and industry.

In general CSIRO undertakes such work only in situations which meet a national need, or where the development of new technology is involved. National needs may be defined within CSIRO itself, by federal or state authorities or by private industrial organizations which are not in a position to carry out the appropriate investigations themselves.

The effect of the utilization of forest residues on soil fertility was seen as an important problem which should be referred to the new CSIRO Division of Forest Research.

The question of bark utilization was discussed in some depth, in respect to direct pulping, pulping of young hardwoods with the bark on, and the inclusion of bark in particle board and hardboard.

6. Smoke Pollution

The Group took note of Dr. Vines' conclusion that bush fire smoke from prescribed burning did not represent an appreciable pollution hazard, and it was suggested that smoke from the incineration of mill residues might be similarly innocuous. Note was taken of the absorptive capacity of carbon particles and their possible role in cleansing the atmosphere. It was noted that ozone appears to be found only under high level inversions downwind from the fire.

7. Integrated Photosynthetic Process Industries (IPPI)

The possible application of the IPPI Concept in Southern Australia was mentioned by Dr. Gartside, and the Working Group considered that the potentialities in relation to hardboard and paper manufacture deserved further exploration.

8. Digestibility

There was a discussion on the work within the CSIRO Division of Chemical Technology on improving the digestibility of cellulosic wastes for use by ruminant animals. The question of the economic viability of such processes was raised.

9. Cypress pine

A discussion was held on the possible utilization of cypress pine for pulping, and hardboard and particle board manufacture. The point was raised that regeneration of cypress pine could be significant from the point of view of soil stabilization in inland areas.

10. Oleoresin Stimulation in *Pinus radiata*

The work in the CSIRO Division of Chemical Technology on the

stimulation of oleoresin production by paraquat application to *P. radiata* was discussed. The Group considered that it should be drawn to the attention of the Standing Committee of the Australian Forestry Council.

11. Defibration

Development of alternative means of defibration of wood to provide high yield fibre was discussed. Early results suggest that the gas explosive process could lead to more economical defibration than, for instance, the high power consuming refiner processes, or the high heat consuming steam explosion processes.

It is understood that the explosive defibration work of Dr. Mamers will be extended to provide larger samples for evaluation and for confirmation of the apparently favourable economics of gas compression versus other methods.

12. Composites

The Group discussed wood and wood fibre composites on a broad level, including novel composites based on lignocellulosic fibres within polymer matrices, and more traditional materials such as hardboard, particle board and plywood. It was considered that support should be given to the setting up of a working group on wood and wood fibre composites, and that this should include representatives of CSIRO, interested state forestry departments, the chemical industry and appropriate associations concerned with the manufacture of the various products and with waste paper utilization.

RECOMMENDATIONS ADOPTED

TOPIC 1 - MECHANICAL PROCESSING AND APPLICATIONS

(1) In view of the increasing intensity of utilization of the indigenous forest resource, it is recommended that increased attention be given to research into the long term effects of such intensive utilization, especially in relation to the depletion of nutrients which are necessary for perpetuating the forest resource, and that the content of this recommendation be conveyed to the Division of Forest Research, CSIRO.

(2) It is recommended that a Seasoning Committee of the Forest Products Research Conference be established. Mr. Rumball to be invited to convene a meeting to set up the Committee.

(3) In view of the lack of knowledge of the optimum requirements for the drying of both softwoods and hardwoods at temperatures over 100°C, it is recommended that (a) basic research be carried out into softening points, optimum schedules for each stage, distortion patterns and restraint methods, and such other factors as arise in the course of this work and (b) that information be collected and recommendations formulated on kiln design and materials for high temperature kilns and that these be made available by the research organizations to guide industry in the construction of such kilns.

TOPIC 2A - WOOD BIOLOGY

(1) It is recommended that a working group concerned with wood quality evaluation be established to operate between Forest Products Conferences and that steps be taken to incorporate such a working group within the research working group system of the Australian Forestry Council.

(2) In view of the potential of certain eucalypts in regrowth forest and the complexities of matching appropriate species, sites, silvicultural treatments with wood characteristics, conversion techniques, and the appropriate utilization, it is recommended that the formation of a multidisciplinary project team be undertaken to advise in the coordination of the planning of relevant research into regrowth eucalypt forests for wood production. Dr. W.E. Hillis to be the convenor.

TOPIC 2B - WOOD PRESERVATION

(1) It is recommended that fundamental research into the movement of liquids in wood be undertaken.

(2) It is recommended that increased effort be applied to research into and development of new types of preservatives of improved efficacy and of low health and environmental hazard.

(3) It is recommended that fundamental work on surface treatments for wood should be carried out with emphasis on the wood/finish interfaces.

TOPIC 3 - FIBRE UTILIZATION

(1) It is recommended that a working group be set up on wood and wood fibre composites, including novel composites based on lignocellulosic fibres within polymer matrices and more traditional materials such as hardboard, particle board and plywood. The working group should include representatives of CSIRO, interested State forestry departments, the chemical industry and the representatives of the appropriate associations concerned with the manufacture of the various products and with waste paper utilization.

(2) It is considered that more effort is required (a) in defining the nature and magnitude of the wood and forest residues available, which should be considered by the Standing Committee of the Australian Forestry Council, (b) in identifying the research necessary in this field and (c) in partitioning the work done between State forestry departments, CSIRO and industry.

REPLIES TO QUESTIONNAIRE

Total Replies: 56

Did Conference achieve its objectives, viz.:-

(1) to assess the research effort
(2) to identify research priorities
(3) to co-ordinate research planning

Yes:	- 36%
In part:	- 64%
Not at all:	- 0

Are these appropriate objectives:

Yes	- 91%
No	- 9%

Format

Good	- 70%
Reasonable	- 27%
Unsatisfactory	- 3%

Comments:

- Too much time on recommendations
- More time for working groups
- Some favourable comments on 5 min. presentation - one that it was too restrictive.
- More definite guidelines to working group leaders

Length of Conference

Shorter	- 7%
Longer	- 4%
Same	- 89%

Number of Subjects:

Fewer	- 35%
More	- 9%
Same	- 56%

17TH FOREST PRODUCTS RESEARCH CONFERENCE

List of Delegates:

Alexander, J.A.	APPITA
Algar, W.	APPITA
Anton, A.	Forestry Commission of N.S.W.
Armstrong, L.D.	CSIRO, Building Research
Bagnall, R.K.	New Zealand Forest Service
Balodis, V.	CSIRO, Chemical Technology
Barnacle, J.E.	CSIRO, Building Research
Beesley, J.	CSIRO, Building Research
Bland, Dr. D.E.	CSIRO, Chemical Technology
Bolza, Mrs. E.	CSIRO, Building Research
Bootle, K.	Forestry Commission of N.S.W.
Bowers, E.A.	CSIRO, Building Research
Bowie, A.	Timber Development Assoc. (N.S.W.) Ltd.
Boyd, Dr. J.D.	CSIRO, Building Research
Brabin, T.R.	Vic. Sawmillers Association
Brennan, L.J.	CSIRO, Building Research
Bryant, L.H.	Forestry Commission of N.S.W.
Campbell, G.S.	CSIRO, Building Research
Chelberg, R.W.	Timber Promotion Council
Chinner, J.	University of Melbourne
Christensen, Dr. G.N.	CSIRO, Building Research
Clifford, W.A.C.	Forests Commission of Vic.
Cokley, K.V.	Qld. Department of Forestry
Collett, Mrs. O.	CSIRO, Building Research
Collins, M.J.	New Zealand Forest Service
Collins, P.	CSIRO, Building Research
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Cowan, R.M.	S.A. Woods & Forests Department
Creffield, J.W.	CSIRO, Building Research
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Dale, F.A.	CSIRO, Building Research
Davies, G.	CSIRO, Chemical Technology
Ditchburne, Miss N.	CSIRO, Mathematics & Statistics
Eddowes, P.J.	Forest Products Research Centre, P.N.G.

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Gibbons, J.	CSIRO, Building Research
Gough, D.K.	Forestry Department, Fiji
Gray, H.J.	P.M.G.
Greaves, Dr. H.	CSIRO, Building Research
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Hergt, H.F.A.	CSIRO, Building Research
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Ironside, G.	Forestry Commission of N.S.W.
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Keating, W.G.	CSIRO, Building Research
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Leicester, Dr. R.H.	CSIRO, Building Research
Lembke, C.	Australian Forest Industries Journal
Lewis, N.B.	S.A. Woods & Forests Department
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McKitterick, D.J.	Forests Commission of Vic.
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Wymond, A.P.	CSIRO, Building Research

ADDENDA TO PREPRINT PAPERS

Addendum to Topic 1/22

CSIRO Continuous Kiln

Strength

Samples of radiata from Run 13, dried at 184°C, were compared with matched samples dried conventionally (90°C). There was no significant difference in either Crushing Strength or Modulus of Elasticity.

Gluability

Samples of radiata and slash, dried at 177°C were tested and found to have no significant strength degradation or change in gluing properties compared to standard values.

Details

(a) Strength

	Controls (90°C)	High Temp. (184°C)
Test MC ex 12% condition (%)	12.3	11.5
MCS at Test MC (MPa)	46.4	48.2
MCS corrected to 12% (MPa)	47.4	47.2
M of E at Test MC (MPa)	11800	12000
M of E corrected to 12% (MPa)	11900	11900

(b) Gluability

A random sample of high temperature dried slash and radiata pine boards was conditioned to 12 per cent emc. These boards were then thicknessed to 19 mm x 60 mm wide.

Soon after thicknessing they were spread with a commercial cold-setting resorcinol-formaldehyde adhesive, making up single glue line laminates. Spreading was to both surfaces at a rate of 390 g m^2. Curing was at 0.7 MPa for 8 hours at 20°C. After pressing laminates were conditioned for 5 days at 12 per cent emc at 33°C.

Ten shear blocks 50 x 50 cm were cut at random for the laminates. Five of each were dry tested for shear while the remaining five were given a vacuum pressure cycle test as described in AS 1328-1972. The results are as follows:-

Pinus radiata dry Av. shear 12.00 MPa wood failure 94 per cent

Pinus elliottii dry Av. shear 7.92 MPa wood failure 98 per cent

In the vacuum pressure cycle there was no delamination at all after the test.

Keith Fricke

TABLE I: RESULTS OF SPRAY TREATMENTS (FRAMES)

Replacing original Table I in Paper (2/27): Comparative tests of superficial coatings and dip-diffusion treatments for Lyctus immunisation of Victorian scantling timbers.

Spray	Spray Application	Timber [1] Species	Number of Lyctus beetles emerged [2]					
			Inoculated 4 weeks before spraying			Inoculated 8 weeks before spraying		
			at 9 months	at 19 months	at 38 months	at 9 months	at 19 months	at 38 months
½% Dieldrin Emulsion (with prosol)	THOROUGH [3]	M.S.	4	135	430	15	68	196
		M.G.G.	Nil	18	323	11	31	75
	CARELESS [4]	M.S.	Nil	67	177	27	84	268
		M.G.G.	4	270	324	29	143	239
½% Aldrin Emulsion (with prosol)	THOROUGH	M.S.	4	130	277	3	51	219
		M.G.G.	12	56	236	13	82	233
½% Aldrin emulsion (no prosol)	THOROUGH	M.S.	3	401	574	Nil	362	514
		M.G.G.	12	56	188	13	82	180
½% Aldrin in Mineral Turpentine (with prosol)	THOROUGH	M.S.	Nil	400	653	Nil	117	377
		M.G.G.	Nil	101	271	Nil	203	340
	CARELESS	M.S.	Nil	293	789	1	159	829
		M.G.G.	Nil	303	528	Nil	180	394
¾% Lindane Emulsion (with prosol)	THOROUGH	M.S.	16	60	219	35	54	196
		M.G.G.	6	33	82	34	41	146
	CARELESS	M.S.	10	24	180	65	93	301
		M.G.G.	8	25	198	17	112	249
2% Chlordane Emulsion (with prosol)	THOROUGH	M.S.	30	728	802	7	475	583
		M.G.G.	16	374	465	21	331	366
Control Emulsion (with prosol)	THOROUGH	M.S.	42	422	502	157	867	928
		M.G.G.	66	587	651	184	472	503
Control Mineral Turpentine (with prosol)	THOROUGH	M.S.	Nil	532	605	3	424	445
		M.G.G.	4	224	263	Nil	222	257
Control Water Only	THOROUGH	M.S.	30	194	236	125	341	416
		M.G.G.	91	570	615	180	486	525

[1] M.S. = Messmate stringybark; M.G.G. = Mountain grey gum; [2] Determined by counting emergence holes;

[3] All wood thoroughly coated and joints well jetted; [4] Bottom face of bottom board not sprayed, no special attention to joints.

(To replace the supplement distributed at the Conference)

TOPIC 3/8

SAWMILL RESIDUE ESTIMATION - QUEENSLAND

by

D.M. GREVE
Queensland Department of Forestry, Brisbane

Further to the outline of our method of approach to sawmill residue estimation given in our presentation as Topic 3/8 in the Proceedings, the following estimates based on 1973/74 production have now been completed for the whole of Queensland. These will be broken down into zones and complete estimates made for all residue types by species groups when further survey information becomes available:

(a) Open Forest Hardwoods

Slabs and edgings		257,150 tonnes
Sawdust		72,690 "
Shavings	9625 tonnes(dry)	15,400 " (green equiv')
Dockage	2605 tonnes(dry)	4,170 " (" ")
Bark		30,020 "

(b) Rainforest Timbers

Slabs and edgings		57,570 tonnes
Sawdust		22,530 "
Shavings	4225 tonnes(dry)	6,750 " (green equiv')
Dockage	1143 tonnes(dry)	1,830 " (" ")
Bark		Not Yet Estimated

(c) Cypress Pine

Slabs and edgings	69,480 tonnes
Sawdust	24,290 "
Shavings) Dockage)	Not Yet Estimated
Bark	30,130

(d) Hoop, Bunya and Kauri Pines (Native)

Slabs and edgings	7,640 tonnes
Sawdust	4,800 "
Shavings) Dockage) Bark)	Not Yet Estimated

(e) Plantation Pines

Slabs and edgings	36,270 tonnes
Sawdust	14,730 "
Shavings) Dockage)	Not Yet Estimated
Bark	20,540 tonnes

(f) Total Estimated Queensland Sawmill Residue

Slabs and edgings	428,110 tonnes
Sawdust	139,040 "
Shavings	22,150+ "
Dockage	6,000+ "
Bark	80,690 + "
Total	675,990 + tonnes

Assumptions made:

(a) Open Forest Hardwoods

Slabs and edgings based on mills cutting over 300m^3 NHV per annum but excluding any species component of less than 150m^3 NHV.

Recovery: 65% NHV

Log defect allowance: 20-25% average

Conversion factor - green volume to weight: 360 s.ft/ton (0.836m^3/tonne)

Sawdust: 20% of net Hoppus log volume. 90% available.

20% of all production in the form of boards.

90% of all boards dressed.

90% of shavings and dockage reuseable.

Dressed material broken down into:

122 x 19mm chamferboards	5%
77 x 19mm "	35%
85 x 19mm T&G flooring)	35%
88 x 19mm shot edge flooring)	
60 x 19mm T&G flooring	25%
	100%

Green moisture content - 60%

Average air dry density - 930 kg/m^3

Dockage 10% of the dressed product

Bark volume 12% of gross true underbark volume

Bark density - 875 Kg/m^3 (green)

50% of bark available on slabs and edgings

(b) Rainforest Timbers

Slabs and edgings: as for (a)

Recovery:

Central Queensland)	62% NHV
North ")	
South "	60% NHV

Log defect allowance:

Central Queensland	4%
North "	3%
South "	8%

Conversion factor - green volume to weight: 400s.ft/ton (0.929 m^3/tonne)

Sawdust: as for (a)

Factors relating to dressed material: as for (a)

Green moisture content: 60%

Average air dry density 770 Kg/m^3

Dockage 10% of the dressed product

(c) Cypress Pine

Slabs and edgings - as for (a)

Recovery: 55% NHV

Log defect allowance - nil

Conversion factor - green volume to weight - 475 s.ft/ton (1.103m^3/tonne)

Sawdust - as for (a)

Bark volume 24% of underbark log volume

Bark density 830 kg/m^3 (green)

80% of bark available on slabs and edgings

(d) Hoop, Bunya and Kauri Pines (Native)

Slabs and edgings - as for (a)

Recovery 74% NHV

Log defect allowance - nil

Conversion factor - green volume to weight - 500 s.ft/ton (1.162 m^3/tonne)

Sawdust - as for (a)

(e) Plantation Pines

Slabs and edgings - as for (a)

Recovery 55% NHV

Log defect allowance - nil

Conversion factor - green volume to weight - 475 s.ft/ton (1.103 m^3/tonne)

Sawdust - as for (a)

Bark volume 27% of underbark log volume.

Bark density 830 Kg/m^3 (green)

80% of bark available

It is emphasized that these estimates do not take into consideration the quantities of residue already being utilized. It is hoped to also clarify this situation during the continuing survey.

It is believed CSIRO Division of Building Research is attempting to coordinate the estimation of sawmill residues at the national level, using a technique based on interviews between forest service district staff and the management of larger mills to complete prepared questionnaires.

There was a poor response to a similar type of survey carried out recently by the Queensland Timber Board in south-east Queensland. The CSIRO-type approach was tested on a small scale in conjunction with field work already in progress by the Queensland Department of Forestry, and it was found that in many cases timber producers do not possess information to provide the answers to many questions, or would sometimes provide a "guesstimate" which was not even reasonably reliable. The time involved was also considered prohibitive, especially in relation to the results achiveable.

It is considered that quick, low-labour-intensive, broadly based estimates made on bases similar to those used in the Queensland survey would be at least as reliable, and provide earlier information. This approach is particularly applicable and preferable in Queensland, where information on sawmill log intakes is available under the provisions of the State's Sawmills Licencing Act. In fact, this method has already been used to estimate slab and edging residues in one of the major production areas of Queensland with results remarkably similar to those obtained by a private consultant using data obtained from direct measurements of residues produced at several of the mills in the area.