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A NOTE ON WOODEN LADDERS

By J. J. Mack, Timber Structures Group

This Note originally appeared in Newsletter No. 309, July 1964. It is now republished, with some slight changes, to coincide with the issue by the Standards Association of Australia of the revised Standard Specification for Portable Timber Ladders (AS A90–1971) and Standard Code of Recommended Practice for the Use and Maintenance of Portable Timber Ladders (AS CA29–1971).

At a conservative estimate, some 30,000 extension ladders are currently in service in Australia. Considering the very wide range of conditions of use, differences in quality of manufacture, and the varying periods of service, it is perhaps only to be expected that a few ladders will fail each year. Because of the very nature of a ladder and its use, its failure may result in serious personal injury and occasionally in loss of life. Thus, even if only one ladder in every 1000 were to fail in any 12 months, apart from the personal cost in injury or worse, the cost of accident compensation would be heavy and of considerable concern to the employer.

The basic question is: should failure occur in even as few as 1 in 1000 ladders? Must such a failure rate be accepted as reasonable in a fabricated structure that has been designed to be as light as practicable, and in the use of which there is always some small element of danger? The answer is no! Given well-made ladders of good-quality timber, proper use, care in handling, and adequate maintenance, there should be no reason why the failure rate should not be as small as 1 in 30,000, or even less.

In a test made at the Division with a new 21-ft extension ladder supported against a wall at the recommended 70° angle, a load of 450 lb at mid height was sustained without any sign of failure. This load is equivalent to a 16-stone man carrying 126 lb which, it will be agreed, is a most unlikely loading. The deflection at the centre of the ladder under this load of 450 lb was approximately 6 in., which is not considered severe. Several single sections of old extension ladders, the other sections of which had broken in service, were also tested and the breaking loads were so high that it was clear that some reason other than an inherent weakness of the timber was responsible for the failures.

AS CA29–1971 amply covers the scope conveyed by its title. However, from inspections of large numbers of ladders it is apparent that their treatment in service is often not up to the desired standard. There is evidence of ladders having been retained in service after damage resulting from falls, from incorrect carriage on vehicles, and even from being run over by a vehicle. Clearly, some form of regular inspection should have been carried out to ensure that such damaged ladders were discarded.

Occasionally, timber which should have been rejected has been used for manufacturing ladders. Although AS A90 limits sloping grain to 1 in 15, grain slopes of up to 1 in 12 have been observed in many finished ladders, and in some cases slopes were even steeper. Severe sloping grain reduces considerably the strength and stiffness of the wood and when present can seriously reduce and even eliminate a ladder's margin of safety.

Also, characteristically brittle types of Douglas fir, not allowed by AS A90, have been detected in some ladders; this material can usually be recognized by inserting the point of a knife into the wood and lifting out a small splinter. If the splinter is short and brittle in appearance, then probably the piece of wood is generally brittle and should be rejected as unsuitable for ladder construction. It is known that very fast- and very slow-grown Douglas fir have markedly inferior strength properties to timber of medium growth rate. Thus it is advisable to select this timber for ladder stiles only if it has more than about 8 and less than about 30 rings per inch.

It is common practice to insert a steel wire of about 10 gauge into a groove on the underside of each stile. The purpose supposedly is to hold the ladder together for a sufficient time, in the event of failure of the timber, to allow the user to jump clear. Some, however, mistakenly consider that the wire adds to the ladder's strength and stiffness. Tests made by the Division on matched stiles with and without the wire have shown positively that as normally fitted the wire in no way improves either property. In fact, the fixing is generally so ineffective that after a few severe flexings of the ladder the wire becomes quite loose.

AS A90 specifies that wire-reinforced ladders are not suitable where electrical hazards exist. Also, as no increase of stile size is suggested when a wire is not used, the Standard implies the ineffectiveness of the wire on the strength and stiffness of the ladder. However, an interesting development has been the attempts by several ladder manufacturers to increase these properties by gluing fibreglass cord into the groove in place of the steel wire. Tests conducted on some experimental stiles indicate that, although no appreciable increase in stiffness has been achieved, the fibreglass has slightly improved the strength. It is quite probable that with correct gluing technique and cord size a significant improvement in properties could result. AS A90 now recognizes this use of fibreglass reinforcement but no allowance is made in stile size.

Despite any such improvements in timber ladder design, the fact still remains that ladders, particularly long ladders, are really delicate structures compared to other forms of construction. If properly made they should have an ample margin of safety. When improperly used and badly cared for they are potentially dangerous. Complacency with this state of affairs can only lead to trouble. Almost invariably, the blame for a ladder failure is placed on the quality of the timber, but more often than not the fault lies with the user.

Do You turn a Deaf Ear to Your Family?

By W. A. Davern, Architectural Acoustics Section

If you have difficulty in hearing clearly (when you are listening) what your family has to say to you when you come home from work, it is possible that the level of noise in your working environment is too high and your hearing is being impaired.

High levels of noise are becoming an increasing health hazard in our every-day lives. In industry, we can be subjected to these high levels and we can also be subjected to them in our leisure activities, e.g. motoring, travelling, lawn-mowing (could this be used as an excuse?), participation in noisy spectator sports and some forms of music and similar entertainments. Thus these health hazards may be prolonged after normal working hours.

Noise-induced deafness is irreversible and prevention is the only solution. Hence, it is important that a person is not subjected to levels of noise that will bring about this irreversible change in his hearing ability. This is believed to be most important early in an individual's noise-exposure history.

The noise hazard cannot be eliminated from today's industrial processes, so the compromise in practice is to reduce it to acceptable levels at acceptable cost. It is at the design stage in the production of equipment and in its mode of operation that potential noise problems may be most effectively eliminated, since, almost exclusively, noise as it affects the community today is a by-product of the use of machines. Hence the noise produced by a machine should be an important consideration when purchasing new equipment.

Hearing sensitivity to noise damage is a human problem, the sensitivity varying greatly from one person to another. Thus any attempt to lay down a maximum permissible noise level must be made on a statistical basis, i.e. find what the average sensitivity is and look at the spread around this sensitivity. Such a level applies only to the healthy ear. For such an analysis a representative number of subjects is required, and results of measurements of temporary deafness, where the subjects experience high noise levels for brief periods of time, are used. Under these conditions hearing will return to pre-exposure levels within a certain period of time. Comparisons of the similarity of effects in both temporary and permanent hearing damage justify such a procedure.

Noise is measured in a logarithmic unit, the decibel (dB), to cope with the large range of sound levels we can hear. The ear handles a pressure range of more than 1 to 1,000,000 which corresponds to 0 to 120 dB. The sound pressure level in decibels is measured by means of an instrument called a sound level meter and its A-weighting network is used to assess hearing damage levels, as the sensitivity of the instrument on A-weighting approximates the sensitivity to damage of the ear. Thus the level of normal conversational speech is 65 to 70 dBA.

Where broad-band noise is concerned, when a sound level is measured in excess of 85 dBA the institution of a hearing conservation programme is considered essential. At such a level conversation in a normal voice is impossible, and at a distance of 3 ft a person must shout to be heard. A person subjected to a level of 85 dBA for 40 hr per week could suffer permanent hearing damage. At this level, then, a person should take steps to protect his hearing.

For levels of sound higher than 85 dBA the allowable exposure time per week should be reduced accordingly.

85 dBA for 40 hr	100 dBA for 70 min
90 dBA for 12 hr	105 dBA for 30 min
95 dBA for 4 hr	110 dBA for <10 min

An approximate rule-of-thumb for assessing the level of noise without using a sound level meter can be given.

- At 90 dBA a person must shout to be heard at 2 ft.
- At 100 dBA a person can communicate only with great difficulty at 2 ft.
- At 105 dBA communication is practically impossible with maximum vocal effort.

As mentioned above, these "rules" apply to the average sensitivity of a normal healthy ear and will not protect the over-sensitive. Two further rules might help to protect them as well as the average person:

- If a person suffers "ringing" in the ears after exposure to noise a critical level has been reached.
- If a person experiences some temporary deafness, e.g. at home after work, the noise level is critical.

The levels discussed above apply to broad-band noise but when it is tonal in quality (e.g. a siren) lower levels of noise are critical—approximately 10 dB lower. Impulsive noises come into a different category and research on criteria for this type of noise is still being done.

In the timber industry the following machines produce high levels of noise.

Noise source	Sound pressure level (dBA)
Band saw	95–103
Circular saw	97–110
Docking saw	113–118
Gang saw	98–101
Grinder	92–110
Moulder	97–109
Thicknesser	94–103
Twin edger	101–104

Some of these sources produce noises that are tonal in quality and hence 75 dBA would be the critical level to be considered. All of them are in the category where exposure times of the operators should be examined.

The problem of what to do when excessive noise is present is not easy to solve. However, the following measures should normally be taken.

Immediate Steps

- Remove personnel from the area.
- If removal is impossible supply personnel with ear protection (ear plugs or ear muffs).
- Set up an audiometric programme for assessing hearing ability if the situation is to continue.

Long-term Steps

- Completely examine the noise situation.

Can the equipment be modified to reduce the level of noise produced? If not, can some form of enclosure be designed to reduce the amount of noise reaching the ears of the operator?

Again, it cannot be stressed enough that noise-induced deafness is a significant health problem that should be brought to the attention of management and staff. It is possible to take the view that all we have to do is to get used to it. The human organism is certainly very adaptable, though in this respect as in all others connected with response to noise individuals vary widely. Many industrial workers are unconcerned by high noise levels that seem highly offensive to a visitor, and although such levels may be quite dangerous the worker finds this out only after the damage is done—when hearing has been impaired.

People should know of this danger to their health and management should use every means to protect staff and to make them more aware of this problem so that they can protect themselves at work and in their leisure time.

Case Histories of the Dry Rot Fungus *Serpula lacrymans* Gray

By N. E. M. Walters, Preservation Section

The term "dry rot" is often used loosely to describe dry powdery brown rots which occur in both buildings and bush. These decays are distinguished by cracks that develop along and across the grain to break up the wood into elongated cubical lumps. Since the term will be shown presently to be a misnomer, it is better to restrict it to at most two or three house fungi, chief of which is *Serpula lacrymans* Gray (also referred to as *Merulius lacrymans*). In spite of its notoriety overseas, the unique characteristics of this fungus shown here reveal weaknesses that greatly simplify its control. The salient features of five recent cases, selected to cover all these characters, show the importance of speedy diagnosis and action. Attack by *Serpula* above skirting level, seen in three of the cases, is, however, very rare.

Unique Characteristics

Domestication.—*Serpula* alone of all our house fungi is almost unknown outdoors, although it has close relatives there. The fungus possibly reached Australia about a century ago and is still found only in restricted localities, chiefly the older suburbs of Melbourne. Time may show that some mines here would also suit it. It will presently be seen that its sensitivity to climatic factors has limited the type of building it favours and its ability to spread.

Low heat tolerance.—*Serpula* is killed at about 80°F. For other house fungi this lethal temperature, although variable, is closer to 100°F.

Water management.—Ahead of and among

delicate papery hyphal fans that attack wet* timber rapidly in air above 90% R.H., run strands of tougher specialized hyphae (rhizomorphs). These penetrate brickwork and soil as well as wood, to carry water from a wet focal point to drier wood (hence "dry rot"). With poor aeration such wood and the air nearby soon become wet enough for further attack. *Serpula* can augment its water in such a place by the chemical breakdown of the wood cellulose it feeds on. The fungus uses these two water supplies so efficiently that it has to rid itself of extensive surpluses as droplets or tears—hence the name "lacrymans" or "weeping". Despite this efficiency, good ventilation halts it completely.

Fast growth.—It is unquestionably our fastest-growing house fungus and in favourable conditions can destroy a new pine floor, of hundreds of square feet, in a year or so.

Wide cracks.—These are due to severe shrinkage of the wood. Early in the attack these cracks become spacious passages to let floating spores pass through the floor to the rooms above. Other house fungi, slower in attack, cause much less shrinkage and have cracks that usually stop short at a skin of sound wood adjacent to the living rooms.

Spores.—A copious rust-coloured spore deposit is nearly always conspicuous to the housewife in rooms above the attack on all horizontal surfaces and reflects the two previous characters as well as *Serpula*'s copious spore production. The colour of the spores is not unique but their abundance and location are. Other house fungi with brown spores produce so few by comparison that a housewife would not see them, even when, as often, the floor has numerous natural cracks. This tell-tale spore deposit was conspicuous in all the cases cited but especially in the last.

Appearance of the fungus fruit.—This forms as a thin layer closely adhering to the under or vertical sides of the structure, growing out like a shelf. It consists of a felt-like chrome yellow layer of tissue against the wood that is overlain with a honeycombed or buckled rust brown gelatinous layer up to ¼ in. thick. The fruit is generally surrounded by damp soft papery sheets (or hanging curtains) of dirty white to mauve material with a strong mushroom odour, brightened by a few patches of lemon yellow and deeper mauve. Bright rust red spore deposits all around and especially on cobwebs, together with copious droplets of amber fluid hanging from every part of the fungus, complete a colourful sight. Embedded in the sheets, rarely conspicuous, are the rhizomorphs.

* "Wet" wood in this context means wood with a moisture content between 30 and 40% of its oven-dry weight. Compare "dry" wood at about 12%.

Conditions favouring Growth

All fungi have four principal growth needs: a suitable food supply (for *Serpula* non-durable timbers, preferably softwoods); adequate water; oxygen (never a problem in houses); and a suitable temperature. Light does not affect *Serpula*. *Serpula*'s unusual temperature range, however, raises the question, "How can such a vulnerable fungus survive the Australian summer?" There appear to be three ways in which suitable conditions may be maintained in buildings:

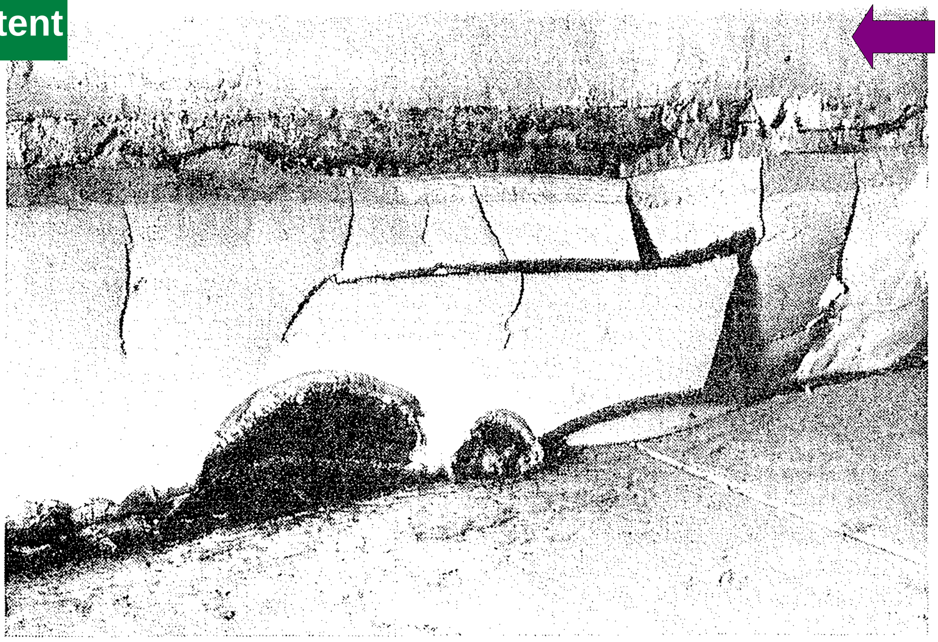
(1) By heavy insulation of masonry. This is the most important because it is common to all outbreaks. Masonry, soil, and heavy timbers also protect the fungus by impeding builders' access and by resisting penetration of heat, air, and chemicals.

(2) By air-conditioning.

(3) Well-insulated (masonry) buildings with very high ceilings, such as halls and churches, exhibit temperature stratification from extremely hot at ceiling level to cool near the floor. These and some other tall buildings, especially those with an open stairwell, may encourage *Serpula* well above the floor because moist air also sinks. Damp wood, such as a wetted door post at floor level, will not dry out there if aeration is poor—clearly measured by the height to which decay rises up the post.

Case Histories

Case 1.—A well-drained site with a 3-year-old, 2-storey brick house of very large floor area had an air-conditioning system which impeded through draughts by bulky ducts under the wooden floor; maintained temperatures well below 80°F everywhere in the



Serpula lacrymans *attacking skirting board in Case 2. Note severe shrinkage, wide cracks, and fruit body extending onto the concrete floor. Three months before, there had been no apparent attack.*

building; and swept bathroom moisture through the house to the central exhaust duct. *S. lacrymans* flourished round the bathroom door, especially near floor level; inside the bathroom in the wooden framework of a tile-clad wall, to near ceiling level; and (slightly) under neighbouring floors, which, having a large area, needed extra ventilators but actually had fewer and less efficient tile vents. The builder had undoubtedly precipitated the attack by embedding unprotected timbers in the new concrete of the bathroom floor.

Case 2.—A high-ceilinged church hall, closed up most of the week, was only opened to admit large congregations at weekends or in the evening. The people, of course, would provide a further source of water vapour for this efficient "moisture trap". *S. lacrymans* flourished up to the tops of the door posts. The case was the last of several outbreaks, the later ones encouraged by replacing decayed wooden floors with concrete. This not only cut off subfloor ventilation routes, it also provided a supplementary source of moisture for the air in the hall. Moisture from concrete continues to evolve slowly for up to 15 months after laying. Should it lack a waterproof barrier the position is worse: it can transmit soil moisture by capillarity indefinitely.

Case 3.—A house near the beach with a subfloor space deeply excavated into the sandy soil to within inches of the water-table. Cellar conditions like this are difficult to ventilate because the space is chiefly below both damp course and soil level, a perfectly insulated pool of cool, damp air. It requires efficient ventilation to keep this dense air moving. Ventilators were good but the draught route inside led sinuously from a fully enclosed narrow courtyard on one side of the house to another narrow one on the other side that was nearly enclosed. Front-to-back ventilation was negligible as a result of concrete verandahs and house additions. The fungus had destroyed much of the year-old pine floor in two rooms. Water also rose up to the brickwork through a bridging pile of rubble fallen from an old disused fireplace, and this wet pile, covered with a dense weft of fungus mycelium, seemed to be the focus of attack.

Case 4.—A large new extension room with a concrete floor was built two years before on the uphill side of a solid brick house. Deep filling under the concrete had bridged the damp course of the old section of the house and also held water that seeped downhill into it. Fungus attack, however, became inevitable with the choice of internal lining for the new room. This consisted of decorative plastic sheeting over a backing of untreated pine boards laid directly against the damp bricks. Once in the pine backing boards, the water could not escape through the impervious wall sheets. *Serpula* attack had reached within two feet of the ceiling. It had also fanned out briefly under the older (wooden) floor, now deprived of adequate ventilation by the new concrete, with the sheathed wall as its focus.

Case 5.—A large city building had had earlier floor attacks, each resulting in successive infillings with concrete until finally the stairwell had all subfloor ventilation cut off. The attack there was severe and copious spores settled on every horizontal surface on the ground floor above, despite daily cleaning. The only remaining wood floors had ventilators emerging into fully enclosed room extensions at the rear, that is, into areas too stagnant to allow any draught. Leaking downpipes had precipitated the latest attack.

Summary of Building Mistakes Cited

- Use of less efficient terracotta ventilators instead of woven wire types.
- Infilling with concrete regardless of obstruction to ventilation or of the water source added.
- Failure to provide extra ventilation for large floor areas.
- Failure to ventilate high-ceilinged halls when not in use.
- Failure to clear out debris under buildings, or to provide adequate floor clearance. (A suspended wooden floor should, if possible, be 18 in. above soil level.)
- Use of cladding impervious to water vapour over untreated timber in contact with damp bricks.
- Providing through draught only along tortuous routes or routes which emerge at either or both ends into a sheltered area, such as an enclosed courtyard or new room extension.
- Failure to ensure perfect ventilation in a cellar-like subfloor or above a shallow water-table.
- Bridging old damp courses with soil, concrete, or rubble.
- Using soil filling up to or near the bearers.
- Embedding timber in wet concrete, especially if no vapour barrier protects it.
- Allowing moist air to be evacuated through the house by an air-conditioning system.
- Inadequate soil drainage on the uphill sides of the house.
- Neglect of normal plumbing maintenance.
- Failure to investigate fully on the first appearance of the fungus.

Control

In theory, control is simple, deduced readily from these case histories; but action must be speedy. In practice, *Serpula*'s association with heavy masonry and concrete floors can make correction costly.

(1) Open up the site thoroughly and remove and destroy all infected material at once.

(2) Exclude all water sources and introduce copious air by efficient ventilation. Hot, dry summer air is ideal. Most important is efficient ventilation to reduce relative humidity. Bushes and fences outside that may impede air movement must be allowed for.

Good drainage should divert both surface run-off and subsoil water round the house to the downhill side.

If the subsoil is too low to dry further with conventional drains, a layer of waterproof sheeting such as polyethylene will reduce humidity to safer levels.

Check that the damp course is efficient, not bridged by soil, concrete, rubble, etc.

Waterproof cladding should not be used over untreated wood (e.g. in walls or floors) if this wood cannot "breathe" from one of its other faces. A backing of damp bricks cut off from ventilation, or even a complete coat of priming behind the wood, may precipitate fungus attack. Similarly, poor subfloor ventilation is made worse by the use of waterproof floor coverings.

Plumbing leaks and spillages must, of course, be cured.

(3) If initial construction or later alterations have made these steps difficult, all attacked or threatened timbers must be replaced with treated wood or perhaps by durable hardwoods, since softwoods unless treated are preferred by *Serpula*. While the fungus is sensitive to all wood preservatives, their use is often unnecessary, so vulnerable is *Serpula* to dry air (and heat).

Most attacks by *S. lacrymans* pose the same question: "How did the infection get here?" Its origin can only be guessed but it probably came as spores rather than infected wood; but spores are usually produced in summer and are then more vulnerable to outside conditions. (In no season do they germinate readily in the laboratory.) It is reasonable to suspect footwear and that motor-cars are involved in more remote outbreaks. The chief blame, however, must lie with the householder or builder who allows a wet spot to develop and so favour an infection.

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IUFRO

By W. E. Hillis, Officer-in-Charge, Wood and Forest Science Section,

Division of Applied Chemistry

In 1891 a committee of European foresters provided a proposal for their Governments to establish a National Union of Forestry Research Stations. This led to the formation in 1892 of the International Union of Forestry Research Organizations, popularly referred to as IUFRO, which has grown to 233 member organizations from 70 countries in 1971. IUFRO has been reorganized in 1929, 1948, and 1971. Congresses have been held recently at approximately 5-yearly intervals, the previous two being in Florida, U.S.A., in 1971 and Munich, Germany, in 1967. There are sometimes meetings of sections of IUFRO in between these main Congresses, such as the one on Forest Products held in Melbourne in October 1965. Australians have played an active part in IUFRO for several years. Currently, Dr. D. A. N. Cromer, Director-General of the Forestry and Timber Bureau, Canberra, is the regional member of the Executive Board.

The general public is giving increasing attention to aspects concerned with the maintenance and improvement of environment and all that it means to the quality of life. Forestry is a most important part of the environment. However, it is sometimes not recognized that properly managed forests provide one of the most valuable renewable resources of raw material in the world. It may be of interest to summarize the activities of IUFRO and its attempts to make the best use of the world's heritage of forests.

The main aims of the Union are to promote international cooperation in scientific studies embracing the whole field of research related to forestry, including forestry operations and forest products, through the following kinds of activities: (*a*) improvement of forestry concepts and of research methods; (*b*) promotion of high-priority forestry research on an international scale; (*c*) collaboration with other international organizations to supply scientific advice and guidance on forestry problems; (*d*) establishment of close personal relations among forestry research workers of all countries; (*e*) promotion of informal exchange of ideas and experiences, especially within the individual working groups of the Union; (*f*) preparation of a world-wide uniform classification system for forestry literature; (*g*) development of standard references for forestry terminology.

At the Florida IUFRO Conference a number of the main papers directed attention to existing forest resources, the future purpose of forests, forest products and their utilization, productivity, profitability, intensive cultivation, ecological and environment considerations, and disease and insect resistance. There were also many research papers and discussions concerned with detailed aspects of these and other topics.

Following the recent reorganization of IUFRO, it is now made up of the following Divisions.

Division 1—Site, Silviculture, and Growth and Yield. The subject groups of this Division include those concerned with forest ecosystems, site research, and site classification; soil and water management; stand establishment and treatment (including fertilization); tropical silviculture; studies of growth and yield; wildlife habitat management; forest fire prevention, control, and use as a cultural tool; and problems related to coppice treatments.

Division 2—Forest Plants and Forest Protection. This Division includes forest botany (including physiology, taxonomy, and dendrology), genetics and tree breeding, provenance studies and trials; forest pathology; forest entomology; and protection of forests from vertebrate pests.

Division 3—Forest Operations and Techniques. This Division embraces forest engineering, including building, construction, machinery, and operational methods in all forestry practices; ergonomics; operational planning and control; work study, payment, and labour productivity.

Division 4—Planning, Economics, Management, and Policy. This includes studies on forest inventory as a basis for planning and policy formation; economics of the forestry enterprise; economics at national and international levels; and forest policy.

Division 5—Forest Products. This Division includes research on the fundamental nature of wood and other forest products, and their utilization. These studies include their microscopic and macroscopic properties; engineering properties and structural utilization; protection in storage and use; and their physics, drying, conversion, and performance in use.

Division 6—General Subjects. This Division includes research that is generally in support of studies in a broad range of technical areas and includes statistical methods, mathematics, and computer technology; information systems; terminology; forest education; research organization; forest history; and remote sensing. The Division also includes forest recreation and landscape management (including interrelations with other forest resource management activities) and research and development management.

With regard to Division 5, Forest Products, recent elections resulted in the following appointments. Division Co-ordinator: H. O. Fleischer, U.S.A.; Deputy: B. Thunell, Sweden. The appointments to the four subject groups were as follows. Wood Quality: Chairman, W. Knigge, West Germany; Deputy, W. E. Hillis, Forest Products Laboratory, CSIRO, Australia. Wood Engineering: Chairman, J. Sunley, England; Deputy, D. Kennedy, Canada. Wood Protection: Chairman, G. Becker, West Germany; Deputy, M. Fougerousse, France. Wood Processing: Chairman, B. Thunell, Sweden; Deputy, R. Hann, U.S.A. Groups with a more limited tenure or with more specifically defined tasks to perform are listed as project groups. One is devoted to Properties and Utilization of Tropical Woods, with D. Noack, West Germany, as Chairman and J. Yavorsky, U.S.A., Deputy; and the other to Terminology, with F. Dickinson, U.S.A., as Chairman.

The Wood Quality Group contains several working parties concerned with fibre characteristics, heartwood formation, specific gravity, spiral grain (J. W. P. Nicholls, Forest Products Laboratory, CSIRO, is convenor), surface characteristics and internal properties, pruning effects on wood quality, growth stresses, and quality requirements for end use. A working party concerned with the properties of fast-grown eucalypts is being organized. W. M. McKenzie, Forest Products Laboratory, CSIRO, is convenor of the working party "Basic Cutting Studies" of the Wood Processing Subject Group.

In preparation for future activities and to indicate changing needs, W. E. Hillis, as Deputy Chairman of the Wood Quality Subject Group, prepared a review into aspects of wood quality. This has been circulated to working party convenors and others. An adaptation of the review is presented here for the interest of those people in Australia engaged in these aspects of forest products. Comments are invited.

Review of Current Situation of Research into Wood Quality

Environment and Forest Products

The general population in many industrialized countries is becoming increasingly aware of the importance of the environment, the dangers of pollution, and the limited availability of a number of the world's resources. The essential contribution of forests to the oxygen-carbon dioxide balance, the terrestrial heat balance, soil stabilization, water collection, recreation, etc. is being realized. Wood utilization from these forests is a necessary part of the efficient utilization of a renewable resource of the rural environment. Some of the less-developed countries are becoming involved in the increasing international trade of forest products. As a result they are gaining finance for their economies and gainful employment for their increasing populations. Most forests are under the control of public bodies and most of the research and development is dependent on Government funds. These funds are needed to ensure the use of forests for the best long-term advantage of people.

The Expected Demand for Forest Products

There is an uneven consumption of forest products in the world. With an increasing standard of living in low-consumption countries and with increasing populations in most countries the demand for forest products will increase. A threefold increase over the next 30 years has been estimated. The exploitation of new forests containing new timbers, with unknown or different or lower quality, is proceeding rapidly in order to meet the increasing demand. Some consumers of wood from these sources have found it necessary to adjust their procedures to accommodate different or changing standards of wood quality. The current market for forest products is of enormous size. For example, in the U.S.A. the tonnage of wood harvested is similar to the production of plastics, aluminium, portland cement, and steel combined. However, we cannot be complacent about the future. In the past, the demand for some other natural products has decreased suddenly.

Possible Changes in Demand

There are situations developing that will affect simple projections of consumption and production of wood. Conservationist bodies in industrialized countries will place constraints on efficient management of some forests for wood and the activities of forest product industries causing pollution. The rising labour costs in tne labour-intensive forest products industry will affect the use of different products, particularly where there is a lack of uniformity of quality. The use of monetary reserves for importing forest products could change present patterns of consumption. For a number of uses, metals, plastics, ceramics, and concrete are replacing forest products, and lost markets will be difficult to regain, even with improved products. These changing patterns in the use of basic materials will take place mainly in industrial regions but will influence the consumption of forest products throughout the world.

Improvements Required to Maintain Demand

Forests, and in particular multi-purpose forests, are an indispensable part of the rural environment. For forest products to maintain their present importance nationally and internationally, it will be necessary to ensure that their quality is the optimum for projected needs and that they are the most suitable and economical material available. The criteria of quality will alter with the development of technology in different countries, and for maximum utilization the quality of the wood used in each product should not be better than necessary. Now that the properties of many woods have been established, more attention can be given to the selection of the most appropriate aspects of wood quality. International standards concerning quality requirements will need to be developed. Wood will need to maintain or improve its favourable cost structure. More attention will have to be given to the quality of the unused portions of the log (about 50%) so that they can be fully utilized, and thus improve the efficiency of the conversion process and reduce production costs.

Ways to Improve Effectiveness of Research Funds

IUFRO has done much to bring together specialists who work in relative isolation in their own countries because of the nature of their studies. Because growing conditions, species, management practices, etc. differ from one country to another, problems assume different dimensions in the various regions. Clarification of different aspects has taken place through the interchange of information. Because no country has the financial resources to study comprehensively all aspects concerning forest products, this free exchange of information can only result in improved efficiency in world forestry. Moreover, with the restriction of research funds in some countries, the increasing participation of less-developed countries in the forest products trade, and the growing competition from substitutes, it is necessary to strengthen past cooperation and clarify our mutual objectives and selection of priorities.

The emphasis in these objectives will differ between countries. A country starting to use its forest resources for immediate social or economic gain will have different priorities from one developing new sophisticated uses for its forest products and growing forests best suited for these uses. The greatest challenges reside in those studies attempting to exploit fully the inherent properties of wood and to adapt them to present-day needs.

Future Action

Continued increasing use of forest products will depend on the availability of materials at competitive prices and with optimum quality to meet changing needs. The activities covered by IUFRO Division 5, Forest Products, could be intensified to help achieve this requirement. The attention of the other subject groups in Division 5 is more directly concerned with the improved fabrication and utilization of well-known species from mature forests for primary uses. The attention of the project group concerned with the "Properties and Utilization of Tropical Woods" is directed to the definition of the properties of little-known species exported from less-developed countries. A fuller understanding of these species will assist the selection of the most important criteria of wood quality.

Most of the activities of the Wood Quality Subject Group are concerned with the improvement of the quality of wood from recently established forests for use as solid wood, in reconstituted wood and bark products, in pulp and paper, etc.

Consideration of the present working parties on quality requirements indicates that others could be formed to meet changing needs in an industry that is improving present products or developing new ones. A greater knowledge of the wood properties desired for each use is required.

A number of working parties are concerned with the wide variations in properties that can be found within and between trees. Departures from uniformity in wood quality affect large-scale utilization of wood. However, no party has been assigned to the study of defects found in a log that had been formed in the tree as a result of microbiological (e.g. heart rot) or mechanical (e.g. kino or resin veins) damage. These defects will probably become more important with certain forestry practices. The attention given to spiral grain by IUFRO has greatly aided its understanding and control. An extension of interest of this party to interlocked grain would be worth while. Growth stresses require intensified attention because of the extent to which they are affecting the utilization of fast-grown eucalypts. The increasing use of wood from fast-grown plantations of short-term rotations and of coppice material and the economic advantages in such materials necessitate much more attention to the properties of juvenile wood.

With the rapidly increasing amounts of reconstituted wood being manufactured a greater knowledge of the surface and other criteria of wood quality affecting adhesion is required. Specific attention is not being given to those factors controlling penetration of wood and the effect these have on the properties of some woods for preservative processes and plastics impregnation or for some pulping methods. Under present conditions wood can be produced appreciably more cheaply than plastic–fibre composites. However, its fabrication is more labour-intensive than plastics, so that the final product loses some of its price advantage. This could be partly overcome if wood could be made more mouldable by processes similar to the ammonia treatment. Also, it is less dimensionally stable than other structural materials. Both these aspects require further attention.

In summary, it is important that forest products should be utilized in the most efficient way because forests are environmentally essential and are one of the few renewable resources in the world. Forest products are valuable in the internal economy of many countries as well as being an important international commodity. Consequently, improved utilization is of considerable international importance.

Probably the cheapest, quickest, and surest way to ensure that forest products keep their major markets is to have the close cooperation of specialists of different countries in working parties and the free exchange of information. The parties can assist each other and alert wood producers to improvements in the quality criteria most relevant to particular end uses and in the establishment of international standards regarding different aspects of wood quality. Also, we can direct attention to the development of new uses for wood which will utilize it fully as a source of low-cost fibre or solid material for fabrication.

IUFRO provides an established body for specialists to engage in international exchange and cooperation to achieve these ends. Any improvement in its effectiveness will be to everyone's advantage and suggestions are welcome.

Application of Gluing Pressure by Nails or Staples

By K. Hirst, Forest Conversion Engineering Group

Frequently gluing must be carried out where the use of clamps or presses is uneconomical, inconvenient, or impractical. In some cases it will be possible to use glues that do not require pressure, such as contact adhesives, panel glues, etc. However, often pressure will be essential for gluing and here screws, toms, nails, or staples may be used.

The insertion of screws is relatively slow, making it difficult to apply pressure within a specified assembly time of the glue, and increasing costs. Toms, which have the advantage of not damaging the surface, may be convenient in some specialized instances. Nails or staples are often chosen because they are fast, versatile, simple, and inexpensive to use.

The action of nails differs from most other methods of pressure application. Presses and cramps in combination with cauls will apply pressure evenly over the whole gluing area. With nail gluing pressure is exerted at discrete points and decreases with increasing distance from the nails, the rate of decrease depending largely on the thickness of the timber. Also, the timber distorts because it absorbs water from the glue. Between the nails this may be beneficial; outside the nail group it will increase the gap between the two parts. Therefore, the thickness and consequently the quality of the glue lines of nailed glued joints will be uneven, with bond strength sometimes decreasing with increasing distance from the nails (Fig. 1). Under optimum conditions nail gluing may give similar joint strength to orthodox pressure application. However, the quality of the bond generally is likely to be more variable.

It is often argued that screws, nails, or staples add to the strength of the joint. However, owing to their lower stiffness, they act only after the glue has failed. Also, nails or screws necessary for pressure application usually have only a small portion of the joint strength required.

Choice of Glue

Normally, glues for nail gluing are chosen on similar principles to those for other gluing

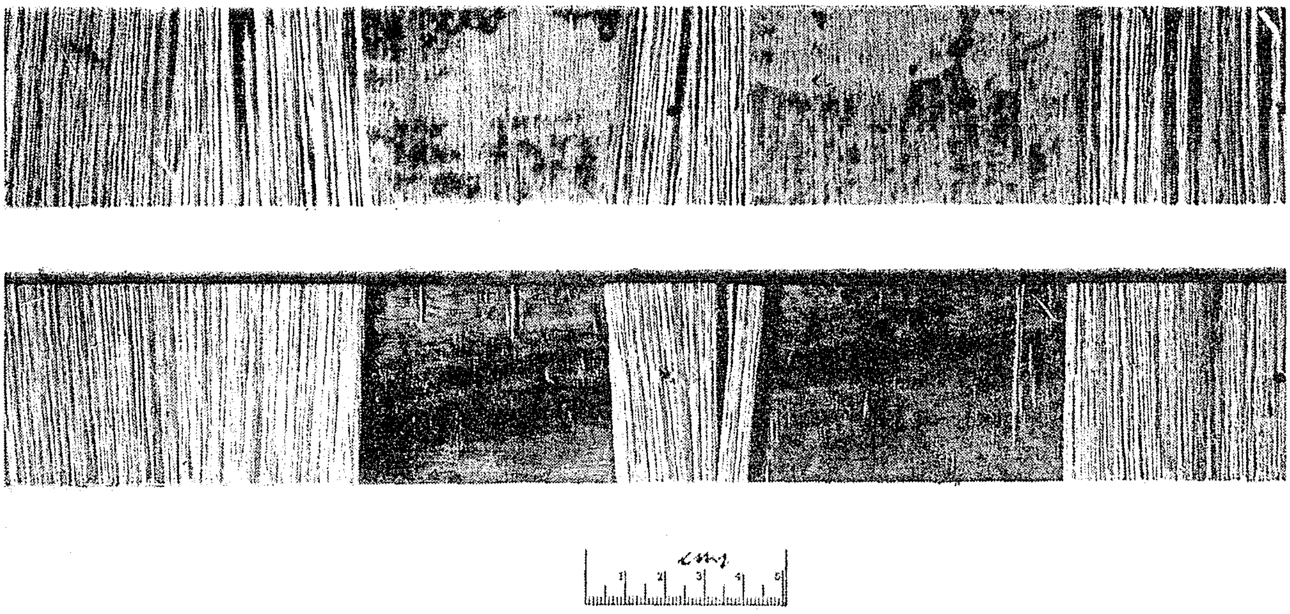

Fig. 1.—Plywood glued to hardwood stud with excessive nail distance, showing unsatisfactory bond between nails.

operations.* However, because glue lines will be generally thicker, gap filling glues must be used. For interior structural applications casein glues are usually recommended. PVA glues are suitable where water resistance and creep resistance are not necessary, while resorcinol formaldehyde or resorcinol phenol formaldehyde glues are normally used where water and weather resistance are needed.

In nail gluing, assembly often takes longer than in normal gluing operations, and it is important to anticipate the time needed for the nailing to be completed in order to choose glue and gluing conditions to give an adequate assembly time. Assembly will decrease with more reactive glues, higher temperatures, and lower glue spreads; old raw materials and old mixes may also materially decrease it. In case of doubt the glue manufacturer should be consulted.

Gluing Techniques

Joint preparation, timber moisture content, mixing, and gluing procedures in nail gluing vary only little from orthodox procedures, and manufacturers' instructions should be strictly followed.

As there will often be gaps between the adherents it is necessary to provide sufficient glue to fill them. Therefore, glue spreads must generally be heavier than normal, and spreads of 350–500 g/m² (70–100 lb/1000 ft²) of glue line are recommended.

Usually the glue is spread only on one surface. For critical and structural application the glue should be spread on both surfaces of the glue line to ensure complete wetting.

Pressure Application

In gluing operations pressure is needed to:

- locate correctly the members relative to each other, and in curved joints to form the necessary shape;
- flatten the bonding surfaces and bring them in close contact;
- induce flow of the adhesive so that the adherends are fully wetted, the gaps completely filled in, and, if necessary, the surfaces penetrated and so reinforced;
- maintain components in position until glue has set sufficiently to hold the joint.

The pressure required will vary with the type of adhesive, its viscosity, the glue spread, the strength properties of the wood,

* Further information on properties of adhesives is contained in Forest Products Technical Note No. 8, Wood Adhesives—A Summary of their Properties and Uses.

and the straightness and smoothness of the gluing surface, higher pressure being required for rougher surfaces, stronger species, thinner spreads, and higher-viscosity glues.

In order to obtain adequate gluing pressure, nail distances should be reasonably close and their diameters and lengths adequate for the purpose. Suitable nail sizes and distances given in literature have been collated in Figure 2. Where the suggested nail length exceeds the total thickness of the assembly, a dummy board is placed below it into which the excess length is driven. Values given are for straight smooth components. For rough twisted material and for curved components the distances may have to be decreased materially. However, when the pitch is decreased care must be taken that the timber is not split by the nails and, if possible, they should be offset. Across the grain the distance between the nails should be no more than 20 diameters and nails should be no more than 7 diameters from the edge of the component. If staples are used their surface area should be at least equal to that of the nails suggested. Nails may be driven by hammer or by gun; staples are always gun-driven.

Generally, smooth nails are used, though grooved nails have higher holding power. When, for exterior application, nails are not withdrawn after the glue is set, galvanized, brass, or monel nails should be used. Where appearance of nails in the finished article is objectionable, they may be punched in and puttied, or double-headed nails may be used which are easily withdrawn after cure of the glue. Alternatively, nailing through cover strips will facilitate removal of the nails. These strips may be of veneer, thin plywood, or stiff leather belting approximately 9 mm ($\frac{1}{4}$ in.) thick for curved assemblies, or of timber approximately 20 mm ($\frac{3}{4}$ in.) thick for straight assemblies. Cover strips will also materially aid in applying more uniform gluing pressure, and therefore

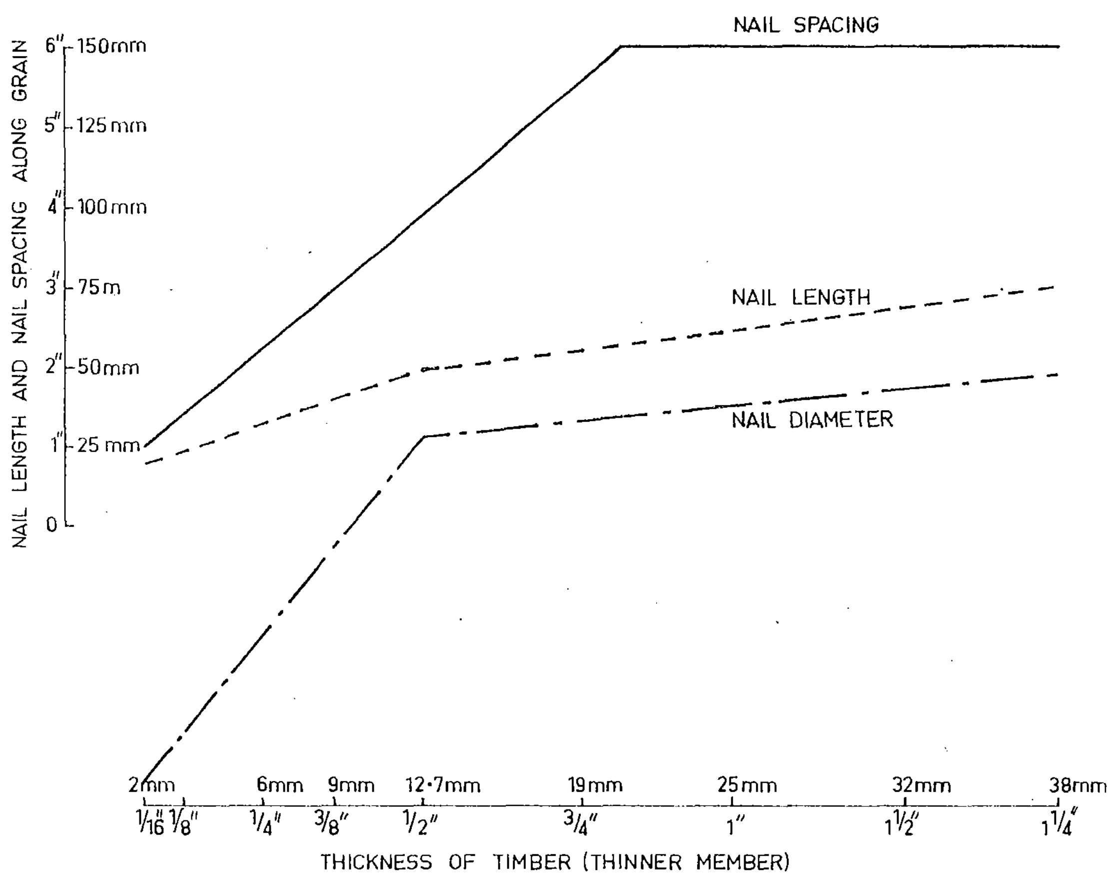

Fig. 2.—Suggested nail distances, nail lengths, and nail diameters for nail gluing.

should always be used when very flexible material is glued.

Testing

In structural applications, or where the glue lines are likely to be severely stressed in shear or bending, the assembly should be tested by making it at least 2 in. longer at each end and by parting the glue lines of the surplus material with a chisel. The test pieces should in all cases contain material glued at maximum distance from the nails. The resulting failure should be predominantly in the wood.

For exterior joints vacuum-pressure cycling, as described in Appendix C of the proposed Standard for Manufacture of Glued Laminated Timber (AS O 131) may be necessary.

Conclusion

Nail gluing will be economical in applications where it is difficult or impracticable to use other pressure media. With necessary care the bond will be satisfactory, but greater variation of bond strength may be expected. For large-quantity production orthodox methods of applying pressure will usually be found to be less costly.

Shrinkage and Density of Spotted Gum *(Eucalyptus maculata)*

Data additional to those already published in 1961 for spotted gum (Div. For. Prod. Technol. Pap. No. 13) are given. They should be interpreted as indicated in the instructions given on page 8 of that paper. The additional data include green density and moisture content as well as radial and tangential intersection point.

TABLE 1

(Replacement data, p. 27)

Species	Density				Shrinkage			
	Unit	Basic	Air-dry B.R.	Air-dry A.R.		Green to 12% B.R.	Green to 12% A.R.	Unit A.R.
Eucalyptus maculata N.S.W. Qld. Vic.	lb/cu ft	**48·1** 59 0·62 36·4–53·2	**60·6** 67 0·63 47·1–67·9	**59·3** 67 0·63 45·8–66·7	T	**6·4** 59 0·17 4·1–9·6	**5·2** 59 0·15 3·4–8·4	**0·38** 25 0·005 0·29–0·45
	kg/m^3	**770** 59 9·9 583–852	**971** 67 10·1 754–1088	**950** 67 10·1 734–1068	R	**4·5** 59 0·12 2·4–6·8	**3·8** 59 0·10 2·3–6·1	**0·31** 25 0·005 0·23–0·38
Additional information								
		Green Density	Green M.C.			Intersection Point		
	lb/cu ft	**73·5** 43 60·2–81·2*	**48** 43 30–88*		T	26·2 16		
	kg/m^3	**117** 43 964–1305*			R	23·8 16		

* Actual range of material tested.

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1972##389

Possible Methods of Transport for Wood Chips

By B. T. Hawkins, Division of Building Research, Highett

The nature of wood chip use is such that large quantities of chips are required at a small number of selected locations. This applies whether the chips are for local processing or for export to other countries. In the latter case, large quantities are required at suitable ports for bulk loading into special chip-carrying vessels. Chips already are transported some distance to at least one processing centre, and it is reasonable to assume this situation will apply more generally in future, and the distances over which chips must be carried will increase as the value of wood fibre increases.

In Australia it is not uncommon for the source of chip supply to be near the coast but not necessarily near a port. Thus, it has been suggested that it might be possible to transport the chips by loading them into some sort of plastic or rubber container, launching this container into the ocean, and towing it to the processing or exporting centre. It is envisaged that a number of these containers could be strapped together and all towed by one vessel. It is thought that around 2000 tons per week might be available for transport by such a method.

Some possible modes of operation are discussed below together with some of the likely costs. It must be emphasized, however, that details are likely to vary considerably from place to place and the costs are merely meant as a general guide.

Size and Shape of Container.—One concept envisages a container that might be about 10 ft in diameter and 100 ft long. It is expected that hardwood chips would occupy approximately 85 ft^3 per green ton, so that for a 10-ft-diameter container there is approximately 1 ton for every foot of length. It is suggested that units approximately 10 ft long would have fewer handling problems at both the loading and unloading stages and also in being launched. It is expected such a container could be handled by mobile cranes and fork lifts.

Cost considerations for the container are discussed later.

Method of Launching Container.—Three possible means of launching are suggested. Local conditions will determine which of these, or any other method, is most suitable.

(1) Establishment of a very short jetty to enable a vehicle such as a fork-lift truck or mobile crane to drop or lower the container into sufficient depth of water to float it;

(2) Use of a "duck"-type vehicle which is loaded at a beach station and then takes the containers to an area in the water where they are prepared for towing;

(3) Use of a type of dry-dock in which the containers could be placed by a land-based vehicle. This would perhaps be the most useful method if very large containers are found to be the most suitable.

Towing Costs.—There are a wide variety of circumstances that will affect the cost incurred when using a towing vessel. These include the location of the towing task relative to the vessel's home port, whether the vessel is hired for a short or long period, and, of course, the total distance of towing and size of vessel involved. However, it appears the likely hiring cost of a towing vessel might be around $135 per hour, or around $1600 per day for daily hire. On this basis, if it is assumed that for hauls up to about 50 miles the hiring rate will be based on hourly hire and that 2000 tons of chips are involved each trip, then the cost per ton mile is around 1·8 to 2·0 cents. For longer hauls the more favourable daily hire rate is likely to apply, and in these circumstances the cost per ton mile for a 2000-ton haul is around 0·9 to 1·0 cent. It has been assumed that the non-towing journey involved is about equal to the towing journey in both cases and the average speed for the whole journey is approximately 7 knots. As the cost of operating a towing vessel is not likely to drop appreciably if the quantity towed is reduced, the cost per ton mile would double if only 1000 tons were involved in the tow.

Container Cost.—The present cost of road transport of chips appears to be around 5½ cents per ton mile for relatively short hauls (about 35 miles) and a little less than 4 cents per ton mile for hauls up to 140 miles. Assuming there is a cost of about 0·5 cent per ton mile due to incidental expenses associated with both the loading and unloading of the sea-transported chips, then the cost due to the container itself should not exceed the equivalent of 2 cents per ton mile if the sea transport proposition is to be economical.

The present cost of rubber containers used for carting liquids suggests that a similar container for wood chips capable of withstanding towing loads with a capacity of 10 tons would be well over $2000. On the other hand, a container which does not itself have to carry the towing load but is placed in a towing net or some other secondary towing device might well cost less than $1000. On this basis, after allowance for interest, etc., and assuming the container is used every second week for an average trip of 200 miles, then it would need to last about 2¼ years if the component of transport cost due to the container is not to exceed 2 cents per ton mile. The expected life of the present containers used on road transport for carting liquids is greater than 5 years. While the treatment received by the chip containers may be rougher than that of the liquid containers, an average life greater than 2¼ years seems quite possible. It should be noted, however, that at $1000 per container at least $400,000 capital would be needed for containers if 2000 tons of chips per week are to be transported.

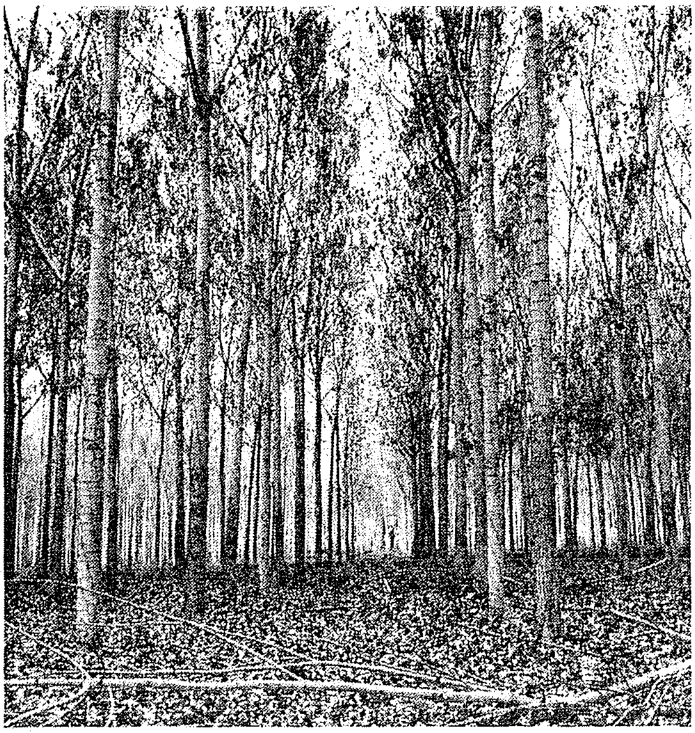
Other Possibilities.—Perhaps a more attractive proposition under some circumstances would be the use of large barges in place of the floatable containers. It is also possible that instead of the one pick-up point, as suggested, a system might be established involving picking up a number of smaller quantities at several different points during the trip to the receiving location. In particular, it may be feasible to leave barges in sheltered bays or rivers convenient to mills producing chips. The towing vessel might then call as required, perhaps more economical towing loads of up to 4000 or more tons being involved by shipping only as required, be it once a week, once every two weeks, or once a month.

Conclusion.—Where chips are available close to the shoreline and they are to be transported to a location also close to the shoreline, a system involving the towing of chips in containers seems economically feasible for quantities around 2000 tons per week, especially for distances greater than 100 miles. If, however, the quantity available from a particular location is only around 1000 tons per week, the viability of this method of transport may depend on the development of a cheap container.

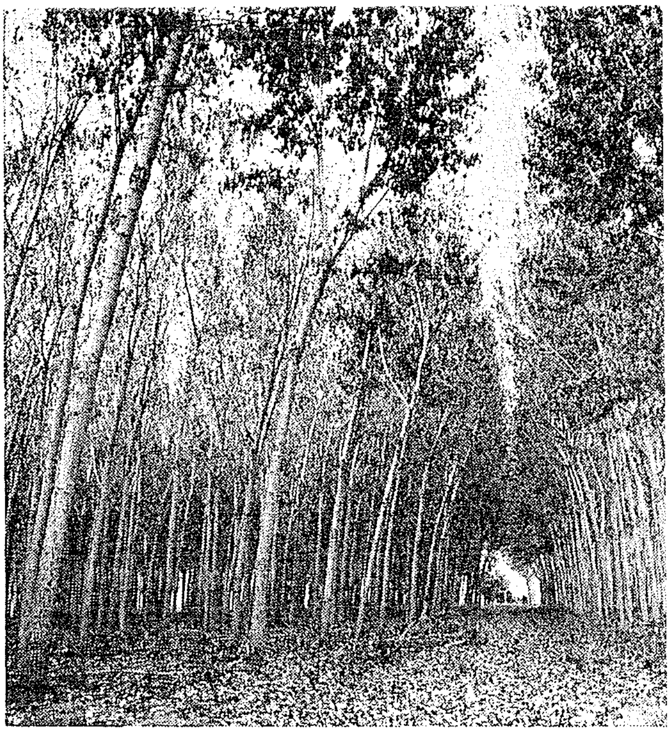
Acknowledgment.—Thanks are due to Mr. E. B. Huddleston, formerly Chief of the Division of Wood Technology, N.S.W. Forestry Commission, whose suggestion forms the basis of this article.

CORRECTION

On p. 8 of Newsletter No. 388, in Table 1 of the Shrinkage and Density of Spotted Gum, the species mean for green density should read 1177 kg/m^3. (*Please note.*—The metric units for density have been changed from gramme/cubic centimetre to kilogramme/cubic metre [kg/m^3].)



(*a*) *Even-spaced plantation.*



(*b*) *Border trees.*

Populus deltoides *Marsh. subsp.* angulata *Ait. Latitude 36°S. Individual stems show a marked sensitivity to light. Conditions of uneven light distribution will initiate an irregular crown development, resulting in a curved stem with high internal stresses.*

Growth Stresses—Genetic and Environmental Influences

By G. Waugh, Forest Conversion Engineering Group

The movement and distortion of wood during harvesting and subsequent conversion can be directly attributed to the relaxation of growth stresses existing within the wood prior to conversion. Growth stresses cannot be observed directly, but certain stress characteristics can be. Wood elongates when placed under a tensile stress and contracts when existing tensile stresses are released. This length change, termed "strain", provides a measurable parameter when studying stresses.

A green stem will maintain itself in a state of stress equilibrium between peripheral tensile and interior compression stresses. Disturbance of this stress equilibrium during conversion will result in the distortion of the component parts of the stem as they attain within themselves a new state of stress equilibrium. This distortion can lead to the production of an inferior product with a lower competitive appeal, as well as significantly contribute to wastage during conversion.

Much research work has been conducted in developing an understanding of the way in which growth stresses act in a green stem, although little is known of why and how these stresses originate in newly formed xylem cells. Newly developed sampling techniques which do not necessitate destructive sampling allow growth stresses in peripheral woody tissue in standing trees to be studied. This is achieved by measuring the magnitude of strain due to the release of these stresses in small sections.

A recent study employing these techniques has been carried out on eight clones of *Populus deltoides* Marsh. and its hybrid with *P. nigra* L., *P. × euramericana* (Dode) Guinier. This study was replicated in four localities ranging from inland Victoria to the north coast of New South Wales. Preliminary studies indicated that an optional sampling intensity could be achieved by carrying out five peripheral strain determinations, equally spaced around the one circumference of the standing stem, on each of three vertical stems (ramets*) for each clone on each locality.

There is an advantage in using poplars for this type of study. In commercial plantations poplars are reproduced vegetatively; therefore, the same genetic material is available over a wide locality range. Thus, differences between ramets of the one clone can be attributed entirely to environmental changes. The poplars studied are strongly demanding on the environment, and are quite sensitive to changes in environmental conditions.

The results of the field measurements were analysed for the effect of both locality and clone for both the mean strain value and the range of strains within each ramet. Analysis showed that for the mean strain value, on all localities there was a highly significant clonal effect, but in the overall analysis there was a highly significant interaction between clone and locality. This is an indication of the inconsistency of the behaviour of clones in different localities, i.e. not all clones will react in the same way to a particular change in environment.

Analysis of the ranges of strains proved to be quite interesting. The fact that ramets reacted similarly to similar environments was evident by small within-clone variances. At one locality only was there a significant difference (in range) between clones. In the overall analysis the interaction between clone and locality was not significant but the effect of locality on the range of strain measurements was highly significant.

The stems selected in this study were all chosen as being vertical but exhibited strain patterns normally associated with leaning trees, which may be due to a reaction to an external environmental factor. Wind and the effect of sunlight were closely studied. Examination of collected data indicated that in the southern areas stems which had been subjected to thinning produced the strains of highest magnitude, which would be expected to produce maximum distortion on conversion. The magnitude of the strains was such that distortion would have been a problem only in relatively few of the clones, and only in those which in their natural environment in the Northern Hemisphere grew at a much lower latitude. The effect of thinning may be that in opening up the canopy of the plantation the remaining stems become more susceptible to the effect of wind, and to the higher angle of incidence of the sun's rays due to the higher latitude. The same clones undergoing a similar silvicultural treatment at a latitude corresponding to that of their natural environment did not exhibit the same high strains.

Poplars, being more demanding on a site, are probably much more sensitive to the manipulation of the environment through silvicultural techniques than most other forest species.

In the growing of poplars in eastern Australia, it appears that the choice of particular clones at certain localities, along with currently adopted silvicultural techniques, is producing acceptable growth rates on selected stems. However, in some instances this is producing wood that will exhibit a high level of distortion on conversion, which is commercially undesirable.

It is probable that a more careful selection of genetic material for a particular locality based upon rate of growth, form, and a consideration of growth stresses, in addition to carefully applied silvicultural techniques, will substantially reduce this problem, leading to a higher recovery and an improved quality of end-product.

* A clone is a population of individuals (each termed a ramet) derived from a common parent by asexual reproduction.

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Timber—A Fire-resisting Material of Construction

By D. F. McCarthy, Preservation Section

THROUGHOUT HISTORY, wood has served mankind as both a fuel and a structural material. The spectacular nature of big fires like the burning of ancient Rome, and the great fires of London, San Francisco, Tokyo, and other cities have made a big impact on public opinion. Such disasters and the combustible nature of wood have led many people to assume that buildings constructed from non-combustible materials are necessarily safer than those containing a high wood content. It is further assumed that the "solid" shell can protect most of the contents of a building from fire. However, in many modern fire-resisting buildings, the more "solid" the construction the greater the damage in a fire.

Concrete construction can confine a fire to a particular compartment, but the structure acts as an oven and the temperature rise and damage to contents can be much more rapid than that caused by a fire in a wooden building. The concrete also tends to crack and distort at temperatures above 330°C and not to regain its strength on cooling. This effect would not be serious in a minor fire.

It is also a fallacy that steel is vastly superior to wood in resistance to fire. Steel softens near 540°C and distorts and yields rapidly when stress is placed upon it at the higher temperatures (1000°C and upwards) that can be reached in a fire. One has only to see the effect of a fire in a steel-framed hay shed or garage, commonly made with thin sheet or tube structural members, to appreciate this.

The futility of much so-called fireproof construction is amply illustrated by recent fires involving modern steel or concrete buildings, e.g. the Townsville sugar terminal (steel and iron) and the tragic multi-storey hotel fire at Seoul. These fires illustrate that the structure represents a small proportion of the fuel involved and rate of flame spread within the building contents is usually the critical factor in the early stages of a fire. Other spectacular fires such as the recent boarding house fire in Melbourne, when 27 men perished, and the frequent gutting of wood and wood–brick schools in Melbourne highlight the need for effective design, fire alarms, and fire protection systems rather than the elimination of wood.

Laboratory testing has shown that unprotected wood exposed to a fire on one face burns at the rate of about 1½ in. an hour with a superior load-carrying capacity to steel in the fire. Careful measurements taken in a fire that reached 600°C in about 5 min and 900°C in about 35 min showed that 4 in. x 2 in. softwood failed in approximately 25 min and mild steel in only about 6·5 min. The failure of the steel supports for a roof may also be compounded by strain on and collapse of the supporting walls. Obviously any increase in thickness of timber gives added fire protection.

It is frequently said by fire-fighting experts that there are a few critical minutes during the early stages of a fire. Thus, there is a vital need to curb or stop flame and smoke spread before the automatic or summoned fire-fighting equipment is in operation if life is to be saved and damage curtailed. This concept has led fire authorities to question how a material will perform in a fire rather than whether it is combustible or not. The realization that damage to non-combustibles may have more disastrous results than damage to wood construction in a well designed building applying modern fire-fighting techniques has paved the way for the introduction of fire-retardant treated wooden beams and trusses in large buildings.

The Burning of Wood

Wood is a poor conductor of heat and is therefore fairly difficult to ignite unless its surface area is large compared to its volume. Burning is not usually sustained or possible until temperatures in excess of 280°C are reached. The burning of wood proceeds in several stages which involve complex combinations of physical and chemical processes. In the preliminary stages of heating, wood loses weight due to loss of moisture and some non-combustible gases. Oxidation and exothermic reactions also occur, and above 280°C combustible gases that burn with a flame start to be evolved. The gases are usually ignited by an external flame source. At this stage heat transfer increases rapidly and the temperature of the burning wood continues to rise. At temperatures above 500°C evolved carbon monoxide and hydrogen commence to burn with a non-luminous flame. At these temperatures charcoal produced in the earlier stages of pyrolysis is consumed by a glowing and practically non-flaming type of combustion.

Fire Resistance of Wood

Since wood is consumed by flaming and glowing at different stages of combustion, both mechanisms of destruction must be curbed if added resistance to fire is to be obtained in situations where high heat transfer rates and ignition sources are available.

Several chemicals have been found to impart fire resistance to wood. As might be expected, different chemicals are required to control the flaming and glowing phenomena associated with the burning of wood. The basic concept in the use of fire-retarding chemicals is non-flammability. However, it is sometimes impossible, for the reasons mentioned earlier, to prevent wood from flaming, but it is possible to add sufficient antiflame chemicals to wood to ensure that it burns less readily and does not support combustion when the source of heat is removed. When burning continues and glow temperatures are reached, antiglow chemicals are necessary if the fire-retarding system is to have maximum efficiency.

Fire Retardants

Several combinations and ratios of chemicals have been used in imparting antiflame and antiglow characteristics to wood. Their efficiency varies somewhat and other factors such as leachability, deliquescence, corrosion, wood paintability and strength, compatibility with glues, as well as cost have to be considered.

Until fairly recently the most important fire-retardant chemicals suitable for wood treatment were boron compounds (boric acid and sodium borates) and phosphorus compounds (ammonium and sodium phosphates). As these salts are water soluble they are satisfactory fire retardants only if the treated wood is protected from rain and water leaching hazards.

Formulations containing boric acid or borates have the added advantage of imparting toxicity to insects and some fungi, and this may be increased by adding a small content of other water-soluble toxic compounds. These types of formulations, e.g. Pyrolith (Hickson's Timber Impregnation Co. (Aust.) Pty. Ltd.) and Celcure F (Celcure Australia Pty. Ltd.), are available in Australia.

Fire-retardant Treatments

Fire-retardant treatment of sawn and round timbers is usually accomplished by pressure impregnation with fairly strong aqueous solutions. The treating schedules are essentially the same as those used for injection of timber preservatives, and similarly aim for deep penetration of the wood. Timbers which are unsuitable for preservative treatment because of impermeability are generally unsuitable for pressure treatment with fire retardants.

When adequate penetration can be achieved it is reasonable to expect the failure time of a timber in a fire to be increased by at least 20%. It is perhaps appropriate to remark at this point that some untreated timbers, e.g. ironbark and jarrah, have considerable natural fire resistance and are relatively slow burning. It is, of course, necessary to emphasize that a sense of proportion in cross-sectional area and plane of erection must be considered in the use of such unprotected timber.

Another method of application of fire-retardant chemicals is the hot and cold bath treatment. This method sometimes allows the diffusion of protective chemicals into timber that is refractory to pressure treatment.

A third method in use is surface application of very strong solutions. Formulations may be applied by spraying, dipping, or brushing and may either partly diffuse into the wood or remain on the surface as a sealing coating. There is a danger with this type of superficial treatment that the coating may be overpainted for decorative reasons or easily damaged by mechanical means. However, properly applied continuous coatings can offer a useful degree of protection if a fire is of only limited duration. This type of protection is often applied to plywood, hardboard, and ceiling tiles. On these materials thermal insulation is usually provided by an intumescent or puffing and foaming material which produces a barrier to oxygen on the surface of the wood.

Action of Fire Retardants

The action of fire retardants is complex and not fully understood. The fire retardants may alter factors such as ignition temperature, flame spread, rate of charring, and heat transfer through the wood. The most serviceable fire-retardant multi-salt mixtures raise the temperature at which the various stages of combustion occur and simultaneously blanket the surface of the wood with an intumescent coating. The coating acts as both an oxygen barrier and a char binder if burning occurs before the insulating foam layer is fully formed.

Recent Developments

In recent years considerable efforts have been made to introduce non-leachable fire-retardant systems into wood. The treatments and formulations have usually been too costly or had detrimental effects on wood properties and were not widely used. An exception to this is the fire-retardant preservative 3S, for fence posts, developed by the Division. Considerable concern was evident in Australia in the sixties about the frequent burning of copper–chrome–arsenic-treated pine fence posts in grass fires on farm properties. CCA-treated fence posts do not catch fire readily and usually withstand a fire better than untreated posts, but once ignited they smoulder until destroyed. The propensity of CCA-treated fence posts for glowing and burning through after the surrounding grass had burnt out was due to the copper and chromium salts of the fixed waterborne preservative. In building timbers the loadings of CCA preservatives that would normally be used make little difference to the fire hazard.

It was found that preservative formulations containing zinc and phosphorus could be tailored to give satisfactory permanence and fire retardance at a reasonable cost. One formulation (3S) was particularly economic and acceptable to industry and is currently used to treat approximately 2 million posts per annum. The new formulation is a good example of a fire-retarding treatment holding or extending a market for a wood product.

Another interesting commercial development has occurred in the U.S.A. There a significant market for fire-resisting shingle roofs and wood cladding has existed for some years. The Division has also received enquiries from architects and the general public over the last few years indicating a demand for fire-retardant shingles in Australia.

The demand in the U.S.A. has been partly satisfied by the application of a new sophisticated *in situ* polymerization treatment technique developed by Koppers Ltd. A water-soluble resin-based system is pressure impregnated into wood and polymerized during kiln drying. The treatment does not unduly affect strength, hydroscopic properties, paintability, gluing, or other desirable properties of wood and has been increasingly adopted for timber used in exposed positions. The low cost treatment also confers decay protection and has widened the acceptance of wood in several American building codes.

Other competitive and similar type fire-retardant formulations and treatments that may also include fungicidal and termiticidal compounds have been developed in the U.S.A. and Canada, and are expected to become of commercial importance.

Conclusions

Undue emphasis is placed on the non-combustibility of materials of construction. Proper design and the curtailment of flame spread, early warning systems, and automatic sprinklers are more important requirements in minimizing fire damage. Wood, and more particularly fire-retardant treated wood, can contribute a significant degree of stability and insulation in a fire situation, and show less tendency to twist and collapse as will unprotected steel or to delaminate as with asbestos. These factors can be of vital importance in giving sufficient time for evacuation and fire fighting without risk to personnel.

The use of fire-retardant treatments, both water soluble and leach resistant, can expand the use of wood and regain markets lost to non-combustible products that lack stability and insulation in a fire situation. Some suggested uses for fire-retardant treated wood are roof systems, scaffolding, studs, bearers, joists and partitions, fence posts and shed poles, and other uses where alternative materials are subject to corrosion. A hidden saving in the use of fire-retardant treated timber in buildings is the ease of future maintenance or alterations.

The potential markets will not be gained and held, however, unless careful control is exercised in setting and adhering to precise treating specifications. It may be necessary often to insist that decay and/or insect resistance and leach resistance be incorporated in the treatment and that treated timber carry a brand and code to identify the fire rating and permanence of a particular process.

STANDARDS ASSOCIATION SEMINARS

As part of its Golden Jubilee celebrations the Standards Association of Australia is conducting a series of exhibitions and seminars in Melbourne and Sydney aimed at widening the awareness of its activities and the benefits of standards to industry and the community as a whole.

These exhibitions will provide a unique opportunity for Australian industry, including organizations engaged in research and development, to demonstrate some of the ways in which standard specifications, codes of practice, and methods of test contribute to quality, safety, and efficiency. The seminars which relate mainly to engineering subjects will be led by speakers who are specialists in their fields. Metric conversion, as might be expected, will feature in several sessions.

To those in the timber, building, and related industries, the full-day seminar on the Light Timber Framing Code to be held in Melbourne at the Chevron Hotel on Tuesday, 14 November will be of particular interest. This code is probably the most important timber standard to be prepared in recent years and provides the basic essentials for a uniform code of practice for the framing of domestic buildings. The topics for discussion relate to the preparation of the code, its technical content, its use, and the timber species and grades available.

The Standards Association also intends to repeat this particular seminar on the Light Timber Framing Code in Launceston, Hobart, Adelaide, and Perth during November, and probably in Brisbane during December. Further details may be obtained from the Standards Association office in each State.

7th World Forestry Congress

Dr. W. G. Kauman, Assistant Chief, CSIRO Division of Building Research, left Melbourne in September to attend the 7th World Forestry Congress being held in Buenos Aires from 4 to 18 October. In connection with the Congress he participated in study tours in Chile and Brazil.

The World Forestry Congress is held every six years and is the largest gathering of foresters, scientists, engineers, industry officers, and administrators connected with forestry and the forest industries. The Forest Products Laboratory submitted three invited general papers dealing with the utilization of multi-specific forests, economics of saw-milling, and pulping of tropical timbers.

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