NATIONAL TRUST

WOOD DETERIORATION IN BUILDINGS

TECHNICAL BULLETIN 7.1

AUSTRALIAN COUNCIL OF NATIONAL TRUSTS

COVER
Decayed house flooring with the imprint of the rubber carpet underlay reproduced in the mycelial mat. Note the excessive shrinkage at the ends of the boards near the heater.

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WOOD DETERIORATION IN BUILDINGS

A GUIDE TO THE IDENTIFICATION AND TREATMENT OF WOOD DETERIOGENS

by John Beesley

B.Sc.For. (Sydney), M.Sc.For. (Melbourne), Dip.For. (Canberra).

Retired from C.S.I.R.O. after more than thirty years service
specialising in the many aspects of wood preservation

Technical Bulletin 7.1

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FOREWORD

The National Trust is pleased to present this Technical Bulletin, entitled **Wood Deterioration in Buildings. A Guide to the Identification and Treatment of Wood Deteriogens.**

This new Bulletin has been produced by the National Trust, with the assistance of a grant through the National Estate program. We have been able to collaborate in this project with the Commonwealth Scientific and Industrial Research Organization, particularly its Building Research Division. This is our second such joint venture with the C.S.I.R.O., the first being our Technical Bulletin 5.1 **Damage to Buildings on Clay Soils**. We look forward to continuing this fruitful co-operation.

I know you will find this new Bulletin on Wood Deterioration in Buildings a very practical guide to the subject. In recent years there has been a burgeoning interest in old timber buildings, and in the repair and restoration problems peculiar to them. This Bulletin deals comprehensively with issues such as decay from damp, insect attack and fungus, and treatment using commercial preservatives and home-use remedies. The author of the Bulletin, Mr. John Beesley has provided us with the benefit of his thirty years' professional experience in wood preservation.

I commend our new Bulletin to you.

S. R. Molesworth
Chairman
National Trust of Australia (Victoria)

ACKNOWLEDGEMENTS

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INTRODUCTION

Most countries can boast of buildings and other structures of very considerable antiquity in which wood is an important component. In these structures the wood is, today, every bit as good as when it was first placed anything from a few decades to several hundred years ago. Equally, many people will be aware of examples of wooden structures failing very much sooner than was to have been expected. Why the difference?

Because of its ready availability and the ease with which it can be worked with simple tools and by unskilled labour, wood is often chosen as a medium of construction irrespective of its suitability for the purpose. With proper selection of materials, appropriate design and methods of construction and an understanding of the hazards to which the timber might be subjected during the whole of its expected service life, wooden structures can be expected to give many years of satisfactory service — often with very little maintenance.

As with any other material of construction, best results will be obtained from timber structures when the user understands the nature and natural properties of the wood, can appreciate and anticipate the possible hazards to which it might be exposed during the whole life of the structure and can adopt designs and construction methods to eliminate the avoidable ones and to ameliorate those that are unavoidable. An important element in extending the service life of a structure is the type, amount and frequency of maintenance it will receive. However use and or ownership may change and with each change will come different "levels" of maintenance.

In this bulletin, these questions will be addressed in sufficient detail to alert the designer or restorer to aspects of his task which, if neglected, could result in continuing and costly maintenance, repairs and replacements.

WOOD — THE MATERIAL

General description. Wood is a complex and variable natural plant product with each tree species producing its own, characteristic wood. Under a microscope, wood has a cellular structure with the cells of softwood or coniferous timbers being distinctively different from those of hardwood or 'broad-leaved' species. The distinctive 'annual rings' frequently present in deciduous trees of the temperate regions are often missing from the timbers of the evergreen, tropical forests. An experienced wood technologist can usually recognise a timber species from a small piece of sound heartwood, although he may need a hand-lens (10 x magnification) or even a microscope to confirm his identification. This is only possible because each timber species has a characteristic arrangement of its cells and tissues.

All wood is hygroscopic and will change in dimensions with changes in moisture content. This shrinkage or swelling is not uniform in all directions because of the cells of the wood are not isometric. As a rule, shrinkage (or swelling) parallel to the long axis of the log or tree is appreciably less than that which occurs radially (from the outside or bark to the centre of the log) and this, in turn, tends to be substantially less than that which can occur in a tangential or circumferential direction. These relative differences account for the checking which is common in round timbers and contribute to the warping, twisting or cupping which can be see in sawn timbers.

In addition to its effect on dimensional stability, moisture content also affects the strength and elasticity of timber. Within ordinary limits, the drier the wood the greater its strength and the less its elasticity (i.e. capacity to bend without cracking or breaking). In fact, when wood is to be bent or moulded it is steamed to increase both moisture content and elasticity, as well as plasticity which is affected by heat.

Natural durability. Wood is a material which is chemically stable and which does not deteriorate through age alone. Chemically, wood may be regarded as consisting of "celluloses" — which are hygroscopic; lignin which contributes to strength and density; and "extractives" which are mainly responsible for the darker colours in wood and wood's "durability" or natural resistance to wood-invading organisms.

The natural durability of wood which, by definition (AS 1604 — 1980), refers to the natural resistance of *untreated heartwood of commercial quality used in ground contact under climatic conditions approximating the average of Australian capital cities* seldom bears any relationship to the **induced** durability achieved by the use of appropriate chemical preservative treatments.

Within the tree or log, there may be considerable variation in the natural durability of the timber from different zones. For example, the sapwood (i.e. the layers of wood on the outside of the log and immediately under the bark) should never be regarded as durable when exposed to the weather or used in ground contact. In addition, the sapwood of some hardwood timbers is susceptible to infestation by wood-boring beetles, while that of other species is naturally immune from such attack.

Provided due allowance has been made for the risk of damage by wood-boring beetles which infest seasoned sapwood — either by eliminating it or by applying to it an appropriate preservative treatment — sapwood has virtually the same strength and other physical properties as the heartwood of the same log. It may be used with confidence where it is fully protected from the weather, as in furniture and interior fittings.

The width of the sapwood, measured radially, from the centre of the tree, may vary from a few millimeters to many centimeters, depending upon timber species and conditions of growth.

The most durable part of the tree or log is the outer heartwood which lies immediately beneath the sapwood. Heartwood is generally darker in colour than sapwood, because of the presence of extractives. The durability of the heartwood tends to decrease as the centre of the log is approached. With most species, the centre part of the log, which is often defective, is eliminated in the sawing process. However, when timbers are used in the round, as poles and piles, the user should be aware that defects can be present in the heart, or centre, with little external evidence of their presence.

The Appendix D of Australian Standard AS 1604 — 1980 sets out the durability ratings assigned to the heartwood of the principal timbers used in the Australian building industry. Should an authoritative statement be required for a species not so listed, the local State Forest Service, or the CSIRO Division of Chemical and Wood Technology should be able to advise. It should be noted that the Australian Standard uses four durability classes, with Durability Class 1, as the most durable, and emphasises that sapwood should always be regarded as 'non-durable'.

Permeability. Permeability is relevant only when timbers are being considered for chemical preservative treatment. Only in very few Australian building timbers is the **heartwood** permeable. Hence treatment of the heartwood, by most common commercial methods, achieves little more penetration than can be obtained from brushing (painting).

The sapwood of most of the timber species used in Australia is permeable and will benefit from preservative treatment. The thicker the sapwood (measured radially) the better the potential for penetration of chemical preservative and, consequently, the better the protection afforded.

Faults and defects. Knots, gum veins, brittle wood and sloping grain occur naturally in many trees and will affect the strength of the timber containing them. However, these do not spread or increase in sawn timber. If a timber containing such defects was considered to be sufficient for the purpose at the time of erection and there is no evidence of structural failure after years of service what reason is there to condemn or replace such a piece? Unless significant changes in the amount or distribution of the loading is anticipated, there can be little justification for strengthening or replacing a framing timber with an in-grown fault, which has had many years of service.

In older buildings, some timbers may not conform to modern codes for size or spacing. Again, if the timbers are sound and in good order, is there any need to supplement or replace them if no change in the type of service is anticipated? When old, well-seasoned timbers are replaced with wood which is improperly seasoned and in which further drying and shrinkage is to be expected, special precautions must be taken to ensure that the replacement timber will carry its share of the load *after it has become fully seasoned.*

Two common faults which occur in the conversion of logs to sawn timber are "want" — where the piece is sawn undersize — and 'wane'. Wane is defined as: "the presence of the original underbark surface with or without bark, on any face or edge of a piece of timber" (AS 01 — 1964).

Seasoning. Timber is an hygroscopic material which changes in dimension with changes in moisture content. In some trees, the moisture content of the green wood might exceed 100 per cent — on an oven-dry basis (i.e. the weight of moisture in the wood could be more than twice the oven-dry weight of the wood).

As the wood dries, no change in dimension will occur until the moisture content of the wood approaches 30 per cent (on an oven-dry basis). As moisture content falls below this level shrinkage will occur, more or less uniformly, until the wood is "oven-dry". Conversely, as moisture content is increased from oven-dry, swelling will occur.

Timber is said to be **seasoned** when it is in equilibrium with the relative humidity of the environment in which it is to be used, that is when, on the average, it neither gains moisture from, nor loses it to, the surrounding atmosphere. In practice, this concept needs some modification because moisture migrates slowly through wood which has started to dry. Hence, a large piece of timber will appear to be less responsive to changes in relative humidity than a small piece. Normal building scantlings show very little response to diurnal changes in relative humidity and may vary by no more than three or four per cent in moisture content between summer and winter in most of south-eastern Australia. On the other hand, it can be shown that thin veneers will respond to changes in relative humidity within a few minutes.

Seasoning has the effect of strengthening and stiffening a piece of timber and stabilising it dimensionally. In most of south-eastern Australia, seasoned timber would have a moisture content within the range of about 11 per cent (oven-dry basis) in summer and 14-15 per cent in winter.

Collapse (and Reconditioning). Many south-eastern Australian eucalypt (hardwood) building timbers are prone to "collapse" while drying. This term is used to describe the excessive shrinkage which takes place when, at a certain state in the drying or seasoning process, the walls of the cells in the wood lose their shape and crumple. Under the mocroscope, a 'collapsed' wood cell has very much the appearance of a sealed milk carton which has been fully evacuated without allowing the entry of replacement air.

"Reconditioning" is the controlled, commercial process rectifying collapse. Essentially, it consists of subjecting the collapsed timber to live steam for an appropriate period. The heat and moisture restore the resilience of the cell walls, which then resume their natural shape. Under controlled conditions, drying may then be resumed until equilibrium is reached. For all practical purposes, kiln-dried and reconditioned timbers (KD&R) can be processed and used without making any allowances for the phenonomen of collapse. In other words, the problem of collapse is dealt with during the conversion and processing of the timber and requires no action from the ultimate user.

It should be noted, however, that timbers which are prone to collapse may do so if allowed to dry naturally and the distortion so produced will remain evident permanently. Often, it is most obvious as wood with concave sides (and edges) which may also be "out of square".

Additions and alterations. The modern tendency to alter, add to or refurbish an existing building can have far-reaching effects which may be as unexpected as they are unwanted.

The addition of an extra storey will, of course, increase the load on the foundations and the lower-storey walls. In part this may be compensated for by replacing a heavy tile roof, with a sheet metal roof NEVERTHELESS, THERE IS LIKELY TO BE A CHANGE IN THE NATURE AND DISTRIBUTION OF THE LOADS IMPOSED and adequate precautions should be taken against failure.

The installation of a solid (concrete) floor, in place of an existing suspended timber floor could interfere with sub-floor ventilation and accelerate the development of decay. The same effect could occur from the addition of a patio or an additional room. These additions might also nullify the efficacy of any precautions taken against the entry of subterranean termites.

Creep. This term is used to describe the gradual deformation which occurs in timbers loaded beyond their safe working capacity. It is commonly observed in the ridge-line of the roof or in roof purlins when rafters are too widely spaced. It may also occur in suspended timber floors.

Whenever such irregularities are observed, they should be examined critically to ensure that the deformation is due to creep (excessive, long-term loading) and that no other form of deterioration has contributed to the condition.

AGENCIES OF DETERIORATION and SOME REMEDIES

General. In service, all structural materials are likely to be adversely affected by destructive forces of one sort or another but may vary widely in their resistance to these forces. Timber differs from most other structural materials in that it is the product of a living organism subject to the natural forces of growth and decay — decay by biological deteriogens.

The designer or restorer of buildings needs to be able to recognise and classify the various destructive agencies likely to affect the building and to understand the conditions under which they operate in order to minimise the risk of premature failure and excessive maintenance. He may choose to ameliorate the destructive potential of these forces by choice and selection of materials, by attention to detailing and fixings, by the use of protective coatings or by the proper use of chemical preservatives.

Modern wood preserving chemicals and timber preservation treatments are effective in protecting timber and timber structures against certain forms of deterioration but these should never be used until alternative methods of construction or design have been considered. The following classification of non-biological causes of deterioration in timber can be used as a guide to practical, low-cost remedies.

Non-biological deterioration

Mechanical damage. Common forms of mechanical damage include bending and fracture from overloading; loss of section from abrasion or wear; the "brooming" or "mushrooming" of the end-grain of a stake, post or pile subjected to repeated impact (as from a drop-hammer); splitting often associated with improperly designed fastenings. It should be noted that timber does have good resistance to abrasive forces and is often chosen as a lining for chutes in the mining industries and for mine guides. It is also a preferred material for bearings — especially for the propellor shafts of marine craft.

Remedial Measures: With timber structures, remedies against mechanical damage are usually self-evident. Replace with a member that is harder, stronger or heavier; protect the structural member with an expendable wearing surface, anti-brooming collar or energy-absorbing dolly; or, as with timber railway sleepers, spread the load by inserting a steel plate between the rail and the sleeper.

Chemical attack. Most timbers have good natural resistance to the action of dilute chemicals and are, generally, more resistant to the action of strong acids than to that of strong alkalis or caustics. Traditionally, wooden vats have been used in the dyeing industry, the brewing industry, the tanning industry and many others. Conversely, the sophisticated chemical procedures used in the pulping and paper-making industries confirm wood's natural resistance to chemical deterioration!

Remedial Measures: Where exposure to chemical attack is unavoidable, timber may be protected from attack by an appropriate coating or sheathing. In special cases, it may be appropriate to impregnate the timber with a resistant preparation such as a wax, an oil or a polymer (e.g. methyl methacrylate).

Physical damage. Prolonged exposure to elevated temperatures or to high humidities will affect timber properties — including those of dimension and surface finish.

Unlike metals and glass which soften upon exposure to elevated temperatures, timber chars or burns from the outside surface inwards, usually, at a relatively slow rate. Thus timbers of large cross-sectional area tend to perform better in fire than the equivalent member in other structural materials. Often, timbers which have survived a fire are re-useable, although they might be a little burnt around the edge. A well engineered timber structure will have poorer fire-resistance than one which is less efficiently engineered and contains members larger than the minimum necessary.

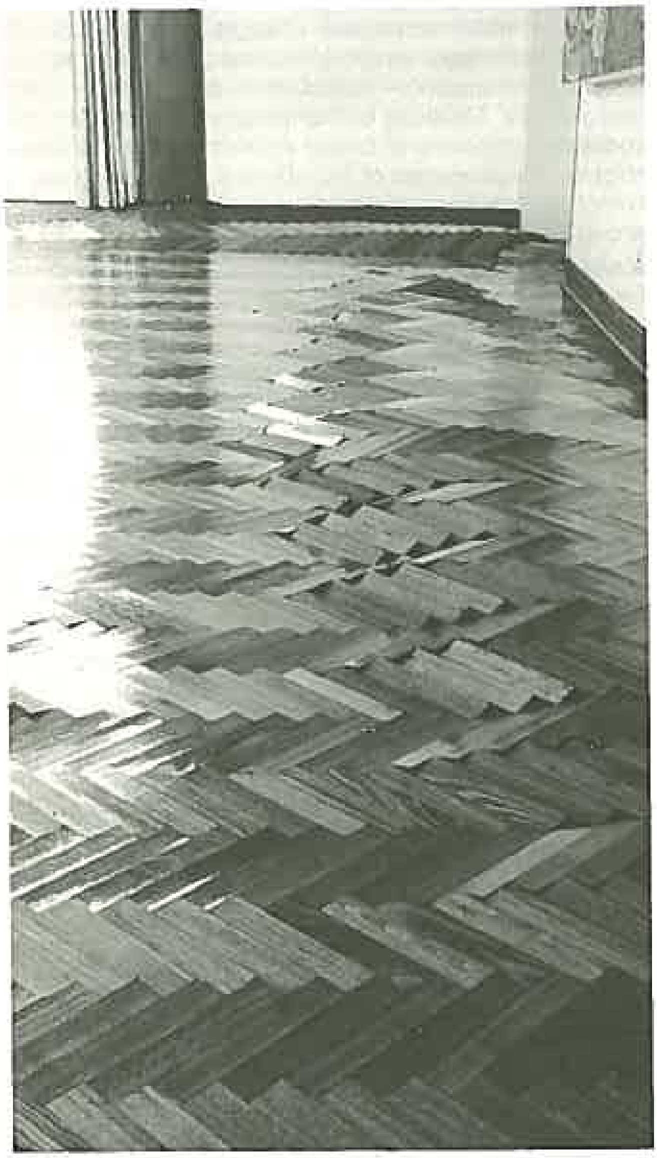
Prolonged exposure to an atmosphere of high relative humidity, or direct wetting, will cause timber to absorb moisture and swell. These changes in dimension which accompany changes in moisture content can impose very high stresses on joints and fastenings in timber — especially if the joint is non-yielding. Crushing and splitting are the most common two forms of failure which result from these stresses. Replacement of the affected pieces, without correctly diagnosing the true cause of failure, may not prevent the problem from recurring.

Remedial Measures: Where practicable, any hazard from fire may be minimised by removing the source of heat and reducing the fuel load in the proximity of the timber. For example, in country areas where timber culverts and bridges are frequently used, the removal of any debris accumulating around the structure will greatly increase its chances of surviving fire (purposely lit, or otherwise). Alternatively, in buildings, the integrity of the structure may be protected by the use heat barriers between the sources of heat and any timber of the structure. Building regulations provide stringent rules for the installation of 'pot-bellied' stoves in dwellings.

Where neither of these remedies is appropriate, timbers of large cross-sectional area, with planed surfaces will be slower to ignite and burn more slowly than timbers of smaller sectional area. Loss of strength will be proportional to loss of sectional area so collapse of a loaded member is unlikely in the early stages of a fire. It should be noted that some timber species are more resistant to damage by fire than others (Beesley ***et al*** 1974; *Moulen & Grubbits 1980).*

Wetting. Where dimensional changes due to changes in moisture content are to be expected, appropriate allowances should be made for this movement. Timbers with a large width or depth are more likely to be affected than timbers of smaller section. Because of the big differences which can occur between longitudinal and transverse (radial or tangential) shrinkage, special care is needed where timber members meet at right-angles and when such members are fixed to unyielding materials (e.g. steel gusset plates etc). Remedies to prevent joint failure under such circumstances include the use of slotted bolt holes; "halving" (or splitting) the end of a large member to localize shrinkage around groups of fastenings and to contain shrinkage within predetermined planes.

Where conditions of high humidity are likely to persist for prolonged periods the risk of biological attack will be increased and the physical and mechanical properties of the timber will deteriorate as its moisture content changes from "seasoned" to the "green" condition. Green timber has lower strength and stiffness than seasoned timber and allowances for these differences can be made in the design of a structure. However, if conditions are such that biological attack can be initiated, deterioration will be permanent and may persist until the structure becomes unserviceable — unless appropriate remedial measures are instituted.



Parquetry floor which has been allowed to become damp, has swelled and lifted.

Weathering. Freely exposed to the weather, the surface of timber will deteriorate due to "silvering" and surface checking. This surface checking is due to the repeated cycles of wetting and drying, heating and cooling which are a normal feature of our climate. The "silvering" is due to the effect of ultra-violet light on the lignin and other components of the wood, accompanied by a certain amount of leaching from wetting.

Remedial Measures: Resurfacing, by sanding, scraping or planing, will restore the colour of the affected wood, since "silvering" affects only the surface layers, but will not prevent recurrence with subsequent exposure.

A good quality, heavy-bodied paint gives the best protection against weathering, provided it is well maintained. Pigmented, water-repellent preservative stains are cheaper to apply and maintain than paint systems and will usually give very satisfactory protection. In certain cases, and especially with the more permeable timber species, impregnation with a preservative oil, or oil-borne preservative, will be very effective and may prove to be almost maintenance-free. The recently-introduced, commercial, light organic solvent preservatives (LOSP) provide but a partial remedy against this form of deterioration because their effectiveness persists for only few months unless they are protected from the 'weather' by an effective paint system.

BIOLOGICAL DETERIOGENS

(Living organisms which use wood for food or shelter).

Perspective. A growing green plant, such as a tree, stores solar energy which can be used by predators and parasites which themselves lack the capacity of utilising solar energy directly. The various tissues of a living tree supply food and shelter to a vast array of life forms — birds, animals, insects and spiders etc. etc. Of course, these may change or vary with the different stages in the life-cycle of the tree.

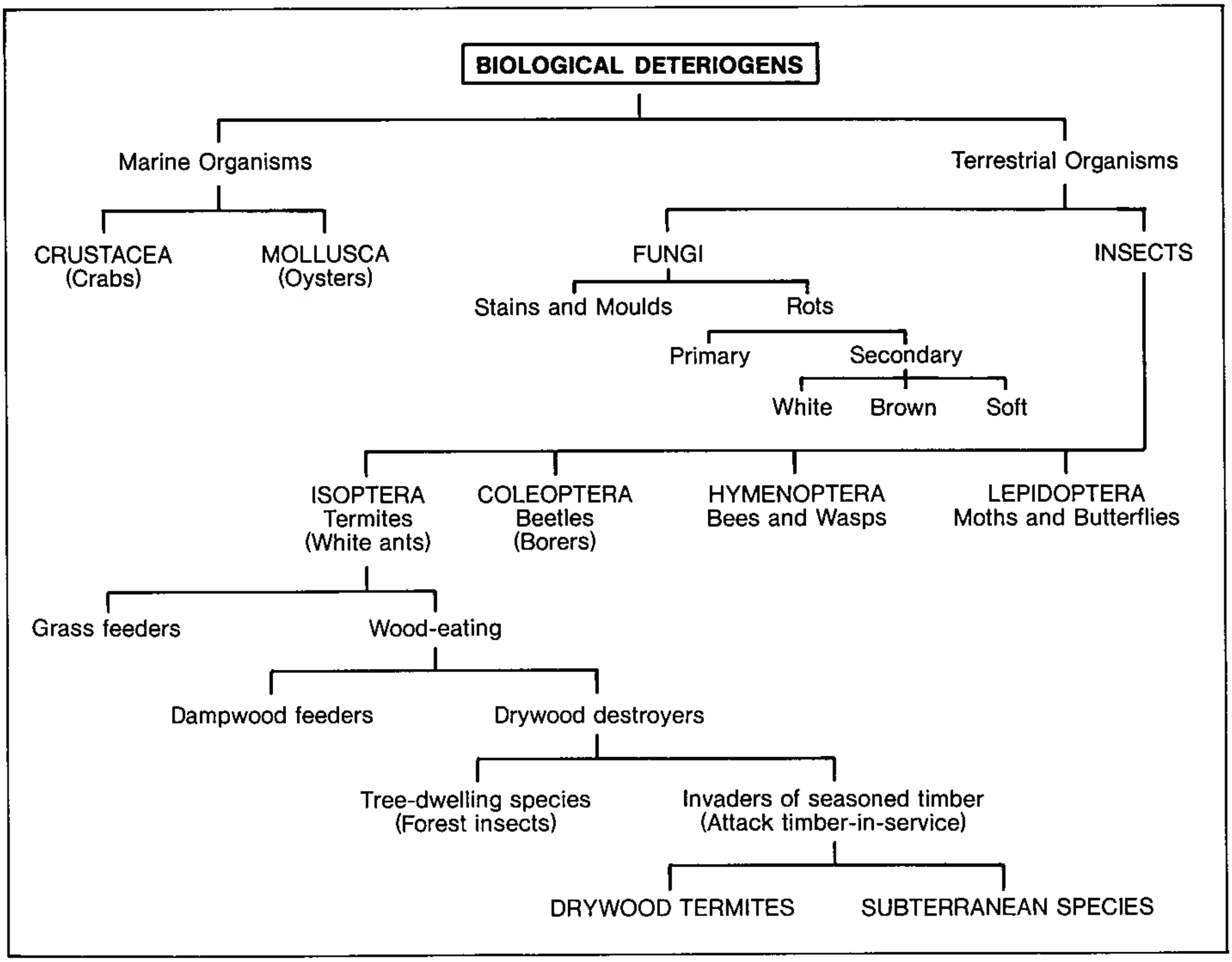
When a tree, or any part of it dies, there is a natural cycle of plant and animal (including insect) life which reduces the tree's tissues to their elements and re-cycles them. Whether the dead plant tissue lies upon the surface of the ground, becomes embedded in the soil or is carried down rivers and deposited in the sea, it will with time be reduced to its elements and re-cycled.

When man uses the trunk of a tree, either as a log or as sawn timber, these organisms which, in nature are beneficial and reduce the dead matter to something useful, become "pests" to be controlled or eliminated. The more complete our understanding of the habits and environmental requirements of these organisms, the easier it becomes to design and develop methods for their control. In nature each of these organisms occupies its own niche, with very specific parameters. Any alteration to a critical parameter will interfere with the activity of that organism. Hence, by judicious choice of materials and attention to detail in design, it is often possible to minimise, if not eliminate, many of the biological hazards to which timber in service might be exposed.

With living organisms, an incorrect diagnosis or identification is almost certain to lead to incorrect (and ineffective) measures for their control.

Decay *(Fungal Deterioration).* Unlike green plants, fungi lack chlorophyll and do not have the capacity of synthesizing nutrients from air and water in the presence of light, Hence, they must derive their nourishment from an organic substrate. Some fungi are able to thrive on a wide range of substrates, others are much more specific in their host requirements.

Fungi affect wood in a number of different ways. **Moulds** can occur on freshly-sawn green wood, particularly when sapwood is present. They perish when the timber dries and the discoloration they cause is only "skin deep" and easily removed by sanding or planing. **Stains** affect the sapwood of many species and the heartwood of some. They can penetrate quite deeply and quickly and are not easily



disguised. Fortunately, they have little adverse effect on mechanical properties but will down-grade "appearance" grades of timber. **Rots,** on the other hand, may not always be conspicuous but do affect the strength of timber. Specialists are able to recognise and identify many wood-destroying fungi but, for practical purposes, the simple classification of 'white rots', 'brown rots' and 'soft rots' is usually sufficient.

White Rots are able to attack and destroy both the lignin and the celluloses of the cell wall. Removal of the lignin accounts for the bleached (hence 'white') appearance of the affected wood. Some white rot fungi are able to destroy wood almost completely reducing its original weight by more than 90 per cent. Wood affected by white rots often has a 'stringy' appearance when the surface is broken. In the early stages of attack mechanical strength could be seriously reduced with little visible evidence of the incipient rot. Resistance to impact is likely to be affected first but the decayed wood can usually be detected by probing with an awl or ice-pick or even a small screwdriver.

Brown Rots attack the celluloses of the cell wall but are unable to destroy the lignin, which forms a major part of the wall substance. Since most of the strength of wood rests in the cellulosic fibrils, a brown rot fungus will still destroy the wood. In fact, by the time the wood has lost about one-half of its original weight through decay by brown rot fungus, it can usually be reduced to a fine powder by rubbing between the fingers. Wood affected by brown rots becomes darkened and soft and breaks with a definite brash or carroty fracture; on drying, it shrinks abnormally and checks both along and across the grain to form a typical 'cubical' pattern.

Soft Rots darken the wood much like a brown (cubical) rot but the decayed wood might be quite hard and show little change on drying out. Timber affected by soft rots has a very low impact strength and may not be detected until decay has progressed to an advanced stage. Severe soft rot in building timbers will usually be confined to pieces which can be more or less continuously wet, such as stumps and bearers resting on the ground. They are also a major cause of deterioration in the timber components of cooling towers and cold rooms. Other classifications for rots, such a "dry rot", "wet rot", "primary rot" and "secondary rot" are non-specific and need not be used.

The sapwood (i.e. the outer layers of wood, immediately under the bark) of practically all timber species is susceptible to decay and may be seriously damaged within a comparatively short period if exposed to conditions conducive to decay. Under such conditions it should always be regarded as expendable of "perishable". Because of the presence of toxic extractives, density and other factors, the heartwood of some timber species is much more resistant to decay than that of others. Most Australian timbers of

Dense mycelium mat of Serpula lacrymans *beneath a poorly ventilated and badly decayed floor.*

commercial importance have already been classified for natural durability in ground contact (see Appendix D of Australian Standard AS 1604 — 1980:).

Conditions Conducive to Decay. No fungal infection can develop unless five basic conditions have been met. These are:

- *A source of infection — Fungi procreate by producting vast numbers of microscopic spores which may float in the air for long periods and be blown considerable distances. An absence of infecting spores is unlikely ever to be the reason why some timbers do not rot.*
- *A non-resistant, organic substrate upon which they might grow and from which they can derive nourishment.*
- *An adequate supply of air or oxygen. Vacuums do not occur in nature, but timber stored under freshwater will remain free from decay because of the absence of oxygen. This is not true of cooling towers and other situations where the water is highly aerated.*
- *Suitable temperatures. All fungi have an optimum at which growth is fastest; as the temperature departs from the optimum the rate of growth will slow. Fungi are generally more tolerant of low temperatures than of high ones.*
- *An adequate supply of moisture. "Adequacy" refers to both quantity and time or duration of dampness.*

Wood that is dry and kept dry will not rot! Wood that becomes damp and is allowed to remain so might rot. In cool climates, fungal spores may take several days to germinate and commence growing. In humid tropical climates germination will be much sooner.

Once wood has started to rot, the decayed wood will absorb water quicker, hold more water and retain it longer than equivalent undecayed wood. As successive cycles of wetting and drying are repeated, the period during which the wood remains damp enough to support fungal growth may be extended until it is continuous.

Remedial Measures. The principles are simple but their implementation may call for considerable ingenuity. *The principle is to keep the wood dry or, at the least, to prevent it from remaining damp for prolonged periods.*

Wood that is allowed to remain damp can be expected to decay or rot. When circumstances prevent the wood from being kept dry or the timber is to be used in ground contact, only species with a high natural durability (Durability Classes 1 and 2) should be used, unless timbers properly treated with a suitable chemical preservative can be obtained. The alternative is, of course, to substitute other materials which will not be adversely affected by the conditions of service.

In buildings, the commonest sources of moisture causing decay are:

Stormwater collection and disposal.
Water supply and waste-water system leakages.
Ineffective, incomplete (or missing) damp-proof courses.

Condensation. Moisture, in a humid atmosphere will condense on the coldest surface. In dwellings with suspended timber floors, the 'coldest surface' is, often, the underside of the floor. If the upper surface is sealed with an impervious covering (e.g. vinyl, lino or rubber) the floor timbers will soon become damp if sub-floor ventilation is insufficient.

Condensation can be prevented by providing for a good flow of air under all parts of all suspended timber floors. Similarly, the development of moulds on the walls and ceilings of bathrooms, laundries and bedrooms can be controlled by ensuring that the room is well ventilated by opening doors and windows to ensure a 'through draft'. *(Bowers, 1985).*

Wherever, the joints in joinery are exposed to the weather, or other wetting, they should be made tight and well sealed with paint or preservative to prevent the entry of water. Where this is not practicable, as with patios and other exterior structures, provision should be made for drainage of all joints likely to get wet.

Alternatively, the decay-resistance of the joint can be enhanced by inserting a shim of felt, radiata pine or other soft, permeable wood, inpregnated with creosote oil (or other non-drying preservative). This reservoir of preservative will 'coat' the contact or bearing faces of the timbers in the joints and inhibit decay.

When these measures are inappropriate or appear to be inadequate, only timbers of high natural durability or timbers which have been given proper preservative impregnation treatment should be used. Under some circumstances, the question of whether timber should be used at all, must be asked.

Insect attack. Under natural conditions, the tree is host, home and food supply to a vast array of insect predators. The timber user need be concerned only with those insects which can cause permanent damage to the wood, either in the tree, in log form or, later, during its service life. Insects are very specific in what wood they will invade, the condition of the wood when they invade it, the manner in which they attack it and the appearance and consequences of the damage they cause.

Some insects can attack timber only when the moisture content is high but are quite unable to survive in dry wood; however, the damage they cause might remain visible in the dry wood. Other insects never invade timber until the moisture content has dropped below fibre saturation point (i.e. the moisture content at which free water has been removed from the cell cavities but the cell walls are still saturated) but may persist in very dry wood.

Others, again, are less restricted in their dependence on the moisture content of the wood. In all cases of insect damage to timber, it is essential to be able to recognise the damage caused by the different groups of insects in order to be able to apply the appropriate remedial measures.

The insects which invade wood may be divided into two groups — the primary invaders and the secondary invaders. These terms can be used to distinguish between those insects which are able to initiate their attack in wood which has not been 'pre-conditioned' by decay — hence, the term "primary invader" — and those for which pre-conditioning by decay is essential.

Because pre-conditioning by decay is an essential pre-requisite for attack by the secondary invaders, control is usually confined to rectifying the conditions which permitted the decay to occur, supplemented by any necessary replacement of severely affected timbers.

Of the several groups or orders of insect which are able to damage wood as **primary invaders** the two which are of the greatest commercial consequence are the *Isoptera* "termites" or "white ants" and the *Coleoptera* The Beetles or "borers". These two groups of insects are so very different in their life-cycles and habits and in the way in which they attack timber that it is convenient to consider them quite separately.

Subterranean termite (White Ants) reach susceptible timber in a building by constructing mud-covered shelter tubes to connect their nest with their source of food.

***Isoptera* Termite or White Ants.** Australia has a rich fauna of termites or 'white ants' — which are neither white nor ants. While the classification and habits of these three hundred-odd species of insect are of very considerable interest to the specialist, the builder or renovator or house-owner need be concerned only with their effect on the timber he uses and the houses he builds.

Termite damage can occur in the tree while it is growing and remain active after the tree has been felled and while it is in use as a pole or pile (a natural round timber). Termite attack may be initiated at any time during the life of timber in service.

In round timbers, termite damage often takes the form of a series of concentric galleries concentrated towards the centre of the log, pole or pile. These galleries may extend for many meters parallel with the long axis of the timber, have smooth rounded margins and be irregular in outline.

In sawn timbers, the concentric pattern may be less evident but the interior of the piece might be completely excavated, leaving only a paper-thin skin covering the extensive interior damage.

Timber so affected will have a "papery" sound if lightly tapped and is unlikely to look "smooth, hard and flat".

Termites are able to move freely throughout their gallery systems and, if disturbed, may migrate from one foraging area to another. Active or occupied termite galleries are never packed with 'frass' (mud, excreta etc.) although some 'peppering' or 'speckling' of the walls may be observed.

Termite attack may, or may not, be associated with decay.

Detailed descriptions of termites, their life histories and habits have been published in many places, so only the barest outlines need be repeated here. *(See McKeown, 1942; "Insects of Australia" 1972 and "Supplement", 1974; CSIRO DBR Info Sheet 10-66, 1978; Beesley, 1978; Beesley, 1979).*

Termites are creamy-coloured, soft-bodied social insects which live in well-organised colonies which may contain several million individuals. Each colony is a discrete unit, which may have a life-span limited to that of the founding pair of reproductives or, in those species which have more than one pair of reproductives, may have an indefinite life of several decades or more.

The population of each colony may be divided into a number of distinct 'castes' — each of which fulfills a specific function — as well as 'nymphs' or juvenile forms. Unlike beetles, for example, which have a hard, waterproof exterior, the termite exterior or *exoskeleton* is quite pervious. Hence, when exposed to an unsaturated atmosphere, the insects lose moisture and desiccate. Consequently, they do not normally move about outside their enclosed gallery systems and tend to avoid light when exposed.

Termites live in colonies and all foraging is centred around the colony, nest or *Termitarium*. Most large colonies have several foraging sites within a radius of 200-300 meters from the nest, which may be in a living tree, an old stump, a service pole or other large piece of timber buried in the ground. In nature, the foraging areas of several colonies may overlap, and foraging galleries interlace but the gallery systems of two colonies, even of the same species, **Never** inter-connect. Hence, when termite attack is discovered, it is advisable to assume that more than one colony is active in the building.

The Australian termite fauna may be divided into several groups of species, only a few of which need be of concern to the user of timber.

• ***Tree-Dwelling Species*** are forest insect which infest growing trees and seldom invade seasoned timber in service. Their colonies may persist for several years in round timbers used as poles, posts or piles. In sawn timber, the damage they cause is usually culled by the sawmiller so that little of it appears in timber offered for sale. However, occasionally, small pockets of termite damaged wood may be present in parcels of freshly sawn scantlings and these may even contain a few live insects.

• ***Treatment:*** Leave the infested sawn timber freely exposed to the weather for a few days with plenty of space between each piece. If the insects do not die from desiccation, birds will happily eat them. The damage will **NOT** extend in the drying or dry timber. Due allowance should be made for any existing weakening.

• ***Drywood Termites*** are more or less confined to humid tropical areas. Although their colonies are not usually very populous, in regions where they are prevalent, drywood termite colonies might be very numerous and, thereby, responsible for considerable commercial damage. Drywood termites are so called because they do not require contact with the soil or other obvious source of moisture. They are able to derive all the moisture they need from the atmosphere. Characteristically, an active drywood termite colony will eject noticeable piles of faecal pellets from their workings as well as storing them within their excavated gallery systems.

• ***Treatment:*** The amateur is seldom equipped or competent to deal effectively with an infestation of drywood termites. Therefore, when drywood termite attack is suspected —
Cause a minimum of disturbance to the pests
SEEK PROFESSIONAL ADVICE AND ASSISTANCE

• ***Subterranean Termites.*** These are, by far, the most common and widespread termites in Australia. They are likely to be a problem in all parts of every State, except Tasmania from where they are absent.

Typically, their colonies are in the soil, from which all attack (foraging) originates. Their colonies may be large, with very numerous inhabitants, and persist for many years. In fact, so ubiquitous and commercially important is the problem of subterranean termite control that the Standards Association of Australia has published three Australian Standards dealing with the problem, namely AS 1694 — 1974; AS 2057 — 1977; AS 2178 — 1978.

• ***Remedial Measures*** — **Prevention.** In most parts of mainland Australia, attack by subterranean termites must be regarded as a normal hazard of the environment. Therefore, unless there is good evidence to the contrary, precautions should be taken to protect all structures of timber from damage by these pests.

Since practically all damage originates from the nest in the soil protection measures are usually concentrated around the foundations and footings of the structure. In principle, if the termites are unable to reach the superstructure of a building, because of appropriate barriers, there need be no restriction placed on the choice of materials used above the barriers.

Unless effective precautions have been taken, the fact that the materials of construction in a building are immune from damage by termites is no guarantee that subterranean termites will not damage the contents of that building. Appropriate precautions, recommended by the Standards Association are of two types:

(i) ***Impervious Foundations.*** *(See AS 1694 — 1974).* Footings and foundations of impervious materials through which termites cannot excavate galleries will force the insects to construct mud-covered 'shelter-tubes' over exposed surfaces. These foundations should be topped with metal caps or shields fitted in accordance with the Standard.

The long-term efficacy of this method of protection will depend, very much, upon the frequency and thoroughness of the periodic inspections demanded by the Standard.

It should be noted that termites have a propensity for discovering cracks and crevices which are not readily accessible for inspection and of utilising these for gaining access to susceptible materials.

(ii) ***Treated Soil Barriers.*** *(See AS 2057 — 1977).* Barriers of chemically-treated soil completely surrounding foundations of concrete or other impervious materials will ensure long-term protection against the attack of subterranean termites **provided** that these barriers are not breached by subsequent excavations or earthworks which either displace them or cover them over with untreated soil.

Effective chemical barriers can be bridged by the addition of patios, carports or other extensions making contact with the superstructure of the building. These additions should also be protected by a chemical barrier or other means so as to preclude the possibility of an unprotected pathway into the building being possible.

Chemically-treated soil barriers have been widely used in the building industry in Australia for the last 25 years or so and have proved entirely effective. When failures have occurred, there has always been an obvious explanation — either an incomplete barrier or a breached barrier.

The chemicals used in forming treated-soil barriers are persistent poisons and the abovementioned code gives sufficient detail for the owner-builder to establish an effective barrier. However, in cities and most larger towns, most people will prefer to engage the service of an experienced, professional contractor *who will have the right equipment and who is trained in the handling of poisonous chemicals.

In most States, government regulations require pest control operators to be registered. Most of those who register will also be members of the state Pest and Weed Control Association.

Untrained persons intending to establish treated soil barriers on a Do-It-Yourself basis are warned to familiarise themselves thoroughly with the safety precautions applicable to the poisons AND TO OBSERVE THOSE PRECAUTIONS SCRUPULOUSLY.

• *Remedial Measures* — **Eradication.** Unquestionably, the prevention of subterranean termite attack is cheaper, simpler and more reliable than the eradication of an infestation in a building. When such attack is detected in a building, the first reaction is to remove and burn the infested wood. When this has been done, replacement becomes urgent and then, and only then, is advice sought on methods of preventing re-infestation. This knee-jerk reaction makes proper treatment much more difficult than would be the case if advice were to be obtained **before** interfering with the termites in any way.

The less the interference and disturbance of an active termite infestation in a building, the easier will be the treatment by a qualified pest eradicator and the better will be the prospect of complete success. In practice, this means that once an active termite infestation has been detected in a building NO FURTHER EXPLORATION OR REMOVAL OF INFESTED TIMBER SHOULD BE UNDERTAKEN until a proper plan of eradication, under the guidance of a qualified eradicator has been prepared.

By the time a subterranean termite colony has damaged a building to such an extent that the attack becomes obvious to an amateur, the attack will have been proceeding for several weeks, or even months. A further delay of a week or so will make little difference to the extent of attack. One of the cheapest and most effective methods of eradicating an active termite colony is to use arsenic dust. The supply of this poison is strictly regulated so that it is virtually unobtainable by an unlicensed person.

The theory behind the use of arsenic dust is fully described in the Australian Standard, AS 2178 — 1978. This code has been prepared, primarily, for use by professional pest control operators but could also serve as a guide for owners and others seeking or specifying such service.

Because of the many factors which have a bearing on successful termite eradication, no single method of treatment will necessarily be successful in all circumstances. Before complete control is established some treatments may need to be repeated several times or several different treatments may need to be used, together or successively.

While many amateurs may have successfully eradicated termites from their homes, experienced operators who are familiar with the habits of termites and conversant with a variety of methods of treatment are most likely to be able to achieve success at a reasonable cost. Further, licensed pest control operators will be familiar with the precautions to be observed when handling the poisons used. In addition to which they will, of coure, have access to them!

• *Remedial Measures* — **Making good.** Subsequent to the successful eradication of subterranean termite attack, there will be a need to replace badly damaged timbers. If the eradicative treatment has included the installation of precautions against further infestation, as is specified in the code, no restriction need be placed upon the class of timber used in replacement. The barriers should prevent any further termite infestation from reaching the superstructure of the building.

When such barriers cannot be effectively installed and there is some risk of future infestation, replacement timber should be either those of high natural durability which are known to be resistant to termite attack or else timbers treated with preservative chemicals in compliance with the applicable provisions of Australian Standard AS 1604 — 1980.

• ***Remedial Measures — Porotermes adamsoni.*** *(See Beesley, 1978).* This termite species is fairly common in forested areas in south-eastern Australia where it often occurs in growing trees. However, it does have the capacity of invading decayed wood, such as old house stumps, piles and rotting bridge timbers. Once well established in such timber, the colony may extend its foraging into adjacent sound timber and cause some damage to sub-floor timber, flooring and framing.

The colonies of this species are usually relatively small and confined to a single piece of wood — and those adjacent to it. Removal and replacement of the decayed stump will usually cause such disruption to the colony organisation that it will not survive, even if it is not totally removed in the replacement process. Correct identification is essential.

• ***COLEOPTERA*** *Beetles, Borers.* Beetles have been described as one of the most successful life-forms on earth, and many thousands of species have been described.

Unlike the termites, where the nymphs (juvenile stages) resemble the adults, beetles undergo a complete metamorphosis of four states: **Egg** — laid by the fertilized female, sometimes singly, sometimes in large numbers; **Larva** or "grub"

(NOT 'caterpillar') — for most wood-boring beetle species, this is the feeding stage during which damage occurs in the form of galleries or tunnels in the wood.

These may or may not be filled with **'frass'** or excrement. A **Pupal** stage — which is non-feeding and, basically, non-motile although the pupa may perform a considerable number of gyrations before the adult or **Imago** emerges.

The pupa is encased in an impermeable, flexible membrane which enables it to survive vacuum/ pressure impregnation in waterborne preservative chemical solutions. If the adult is non-feeding, as with most wood-boring species, it is able to tunnel its way out of the treated wood without ingesting any.

The commoner wood borer which damage timber in Australia can be divided into two classes, those which initiate their attack in green wood and are unable to do so in dry or seasoned wood, and those which initiate and extend their attack in seasoned timber. This division is convenient for descriptive purposes but not strictly factual *(Beesley 1977).*

• ***Pinhole Borers.*** So called because the damage they cause takes the form of small galleries (pinholes), across the grain of the wood, fairly straight or gently curving into which an ordinary needlework pin is easily inserted.

The galleries generally contain no frass, but may show dark staining around their margins. In cross-section these galleries are round, and less than about 2mm in diameter. Attack can be initiated only in green timber with a high moisture content and the galleries will penetrate through the sapwood well into the heartwood.

The galleries may be few and widely spaced or numerous and quite close together. In the latter case, pinhole-borer attack may be associated with brittleness and low resistance to impact.

A crude, but effective way of checking affected building scantlings when there is a possibility that strength is affected is to support the ends of the piece and then to stand on the middle.

• ***Treatment.*** Pinhole borer cannot survive in seasoned or dry timber. All the damage they cause occurs in the green wood and will not extend in dry timber. If appearance is of no consequence and strength has not been impaired, *Pinhole borer attack in scantlings may be ignored.*

• ***Longicorn and Jewel Beetles.*** All these beetles are somewhat larger than the pinhole borers. The female lays her eggs, in clusters, in cracks and crevices of the bark of decaying and dying trees, or freshly felled logs. Upon hatching, the larvae feed in the cambial zone (i.e. between the bark and the sapwood) until fully fed. They then tunnel towards the centre of the log to pupate. After pupation, the adult emerges by cutting through the bark — if it is still adhering. Depending upon locality and species, the life cycle of these insects can range between a few months and several years. In sawn timber, the galleries formed by these pests are oval in cross-section, with a major axis of almost 10 mm, but may be much smaller. Frass is usually absent, but if present tends to be coarse and stringy.

Attack is initiated in timber with a high moisture content but the insects are able to survive and complete their life-cycle in timber which has been allowed to dry naturally. In new buildings, they may emerge several months after the building has been completed and occupied.

Larval galleries of the Longicorn Borer radiating from a slit in the bark where the eggs were laid.

• ***Treatment.*** Longicorn and Jewel beetles cannot initiate attack in dry wood but may emerge through most of the commoner lining materials several months after a building has been occupied. Even when two or three large oval holes appear through a sheet of lining material, there is no possibility of the whole house collapsing. Probably, what will have happened is that a single stud has contained a few of these beetles which have completed their life-cycle and emerged. Cosmetic treatment of the emergence holes is all that is necessary.

Longicorn borer holes in scantlings seldom cause structural weakening but affected pieces should be examined critically before being used.

• ***Powderpost Borers (Lyctids, Auger Beetles).*** Hardwood timbers are used in a high proportion of the buildings in Australia. By far, the commonest borer affecting these timbers are the ***LYCTID*** or powderpost borers. They are very common and it may fairly be said that any unprotected wood which does not show evidence of attack within the first couple of summers in service is probably immune from attack *(Beesley, 1956).*

Typically, powderpost borers attack only the sapwood of certain hardwood timber species. Attack is restricted to hardwoods because only some species have pores of vessels (microscopic tissues) of sufficient diameter to accommodate the egg-laying tube of the female beetle. The grain of softwoods is never coarse enough for this and many fine-grained hardwoods are also immune for this reason. Powderpost beetle attack is restricted to the sapwood of certain species because it is only in the sapwood that sufficient starch is stored to nourish the growing larvae. A timber species may have natural immunity from attack either because of pore-size or because of absence of starch, or both.

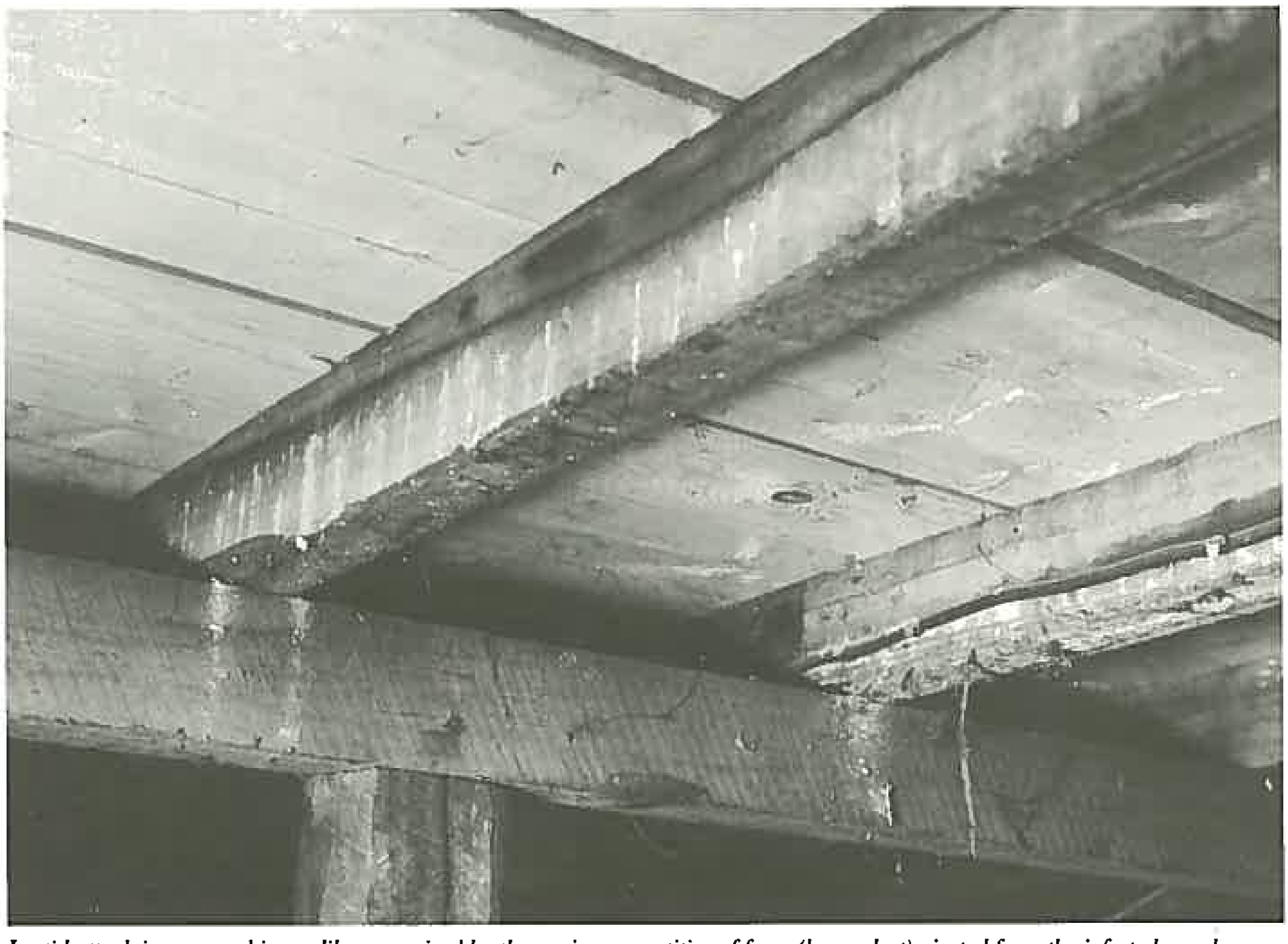
Powderpost borers are able to initiate and extend their attack in seasoned timber, provided the pores are large enough and starch is present. In fact, the susceptibility of the sapwood of a hardwood timber is usually estimated by a simple chemical test for the presence of starch *(Beesley, 1956).*

Powderpost borer damage is quite distinctive and easily recognised. First, it is restricted to the sapwood of hardwood timber species which are drying or have dried. Emergence holes, if present, are numerous, small (less than 3mm in diameter), round and unstained around the margins.

In buildings, emergence will take place through most common lining materials, disfiguring the wall with a series of holes more or less delineating the timber from which the beetles are emerging. The presence of emergence holes is usually accompanied by the production of copious quantities of frass (borer dust) which feels smooth and floury when lightly rubbed between the fingers.

If the surface of infested timber is broken, the exposed galleries will be tightly packed with frass, be parallel to the grain of the wood, and in time, will result in the complete destruction of the susceptible wood.

External evidence of attack (i.e. emergence or flight holes) is seldom present until the susceptible timber has been in service for one summer.



Lyctid attack in sapwood is readily recognised by the copious quantities of frass (borer dust) ejected from the infested wood.

Generally attack will reach its maximum extent by the end of the second summer of service but will increase in intensity over several years until the susceptible sapwood has been totally destroyed.

• ***Treatment.*** Powderpost borer attack can be initiated in and will extend in seasoned timber. It is confined to the sapwood of susceptible hardwood species. The proportion of sapwood present in any sawn timber will depend upon the timber species, the rate of growth of the tree, the position in the tree from which the piece was sawn and, finally, the size of the member. Powderpost borers do not damage heartwood (except superficially).

Powderpost borer infestation may be **ignored** in building scantlings and other structural timbers where appearance is of no consequence AND the proportion of susceptible sapwood in the cross-section is small. In New South Wales and Queensland, state legislation permits up to *one-quarter of the perimeter of the piece to be in untreated, susceptible sapwood* otherwise other provisions apply.

The problem of powderpost borer infestation in furniture, flooring and other decorative and finishing timbers can be eliminated by avoiding the use of susceptible sapwood.

When powderpost borer attack is discovered in furniture or other decorative wood work — and the abundant frass, which accumulates in small piles under the infested wood is hard to overlook — a choice must be made between replacement of the piece with unsusceptible wood and *in situ* treatment. Replacement is a simple matter of carpentry, after selection of the right piece.

In situ treatment consists of saturating the infested wood with a persistent insecticide in a non-swelling solvent. After the solvent has had time to dry, the flight holes should be filled and the surface finish restored. Any fresh holes appearing subsequently should be similarly treated. When the holes are very numerous, the preservative solution may be applied with a brush, but when holes are few or scattered injection with a syringe or oil-can with a small metal spout will be effective.

Surplus solution should be wiped off before it affects the finish. Waterborne solutions should not be used for this purpose as they will cause the wood to swell, are likely to affect most finishes adversely, may cause glued joints to fail or have other unwanted effects.

Commercial or proprietary solutions suitable for this purpose are based on hydrocarbon solvents such as mineral turpentine, kerosene, or even alcohol.

"Immunized Timber" Some of the species in the rainforests of Queensland and New South Wales can have a band of sapwood susceptible to powderpost borer attack many centimeters in thickness, as can some important timbers.

This sapwood can be totally destroyed by powderpost borer attack. Until reliable "immunisation" treatments were developed, none of this timber could be used for any form of permanent construction.

With the introduction of suitable immunising treatments, this situation changed. The two States most affected, namely New South Wales and Queensland, have passed what has come to be known as Timber Marketing legislation which regulates the treatment of timber and the sale of timber susceptible to powderpost borer damage.

Details of this legislation will be well known to sawmillers and timber merchants in the two States in question, where it is policed by the state forest service.

In both States, timber which has been immunised in accordance with the legislation is required to be branded as such. Timber so treated can be used with confidence that the risk of powderpost borer damage has been eliminated. The amateur is unlikely to have access to the chemicals needed for checking this treatment but such a service should be readily available through the departmental authorities.

• ***The Anobiid Borers.*** Unlike the powderpost borers which attack only the sapwood of hardwood timbers when seasoned, the anobiid borers are able to damage both the sapwood and the heartwood of susceptible hardwoods and softwoods. Like the powderpost borers, attack by anobiid borers can result in the complete destruction of the infested wood *(Beesley, 1957).*

The external appearance of the damage by the two types of borer is very similar. Both make small (less than 3 mm in diameter), round flight holes, with no staining around the margins; both produce copious quantities of frass and both are pests of seasoned timber.

Unlike powderpost borer damage which usually becomes evident within the first couple of years of service, anobiid damage may take many years before it occurs. Anobiid borer damage is readily distinguished from that of the powderpost borers because:

It is more likely to occur in timbers which have been in service for many years than in timbers which are comparatively new:
Attack is more common in softwoods than in hardwoods;
Eucalypt timber are practically never attacked;
Initially, the borer galleries tend to follow the grain but, as the attack develops, the wood becomes 'honeycombed';
Once started, the infestation will continue to extend over a period of many years.
Anobiid frass, although very abundant, is loose and feels like fine table salt when lightly rubbed between the fingers.

• ***Treatment.*** Treatment, or replacement, is always necessary because the attack will continue to spread, even if only slowly, until all susceptible wood has been completely destroyed.

Bare (i.e. unpainted, unvarnished) woodwork which has not been so extensively damaged that replacement is mandatory, may be treated by saturating it with a persistent insecticide in a non-swelling solvent, as for powderpost borer attack.

If the timber cannot be dipped in the insecticidal solution it should be thoroughly soaked by applying several flowing brush coatings consecutively until no further absorption appears to be taking place — then an additional coating or two should be added.

The objective of this treatment is to apply sufficient preservative to penetrate through the whole cross-section of the infested wood. If drying is allowed to occur between successive coatings, a high concentration of insecticide will be formed in the penetrated wood but wood, and borer larvae, deeper down might be unaffected.

These beetles have an amazing capacity for emerging through preservative-treated wood.

After the initial treatment, the timber should be allowed to dry and then all visible flight holes should be filled, or otherwise marked, as by encircling with a pencil.

The treated, infested wood should then be inspected periodically, at least twice each year, to ensure that no fresh holes have been made. If any are observed, they should be retreated in a similar manner, with a brush or syringe.

Sealed (polished or painted) woodwork is a little more tedious to treat. Loose frass may be removed from the borer workings by vacuum-cleaner to facilitate penetration of insecticide, which is best applied by injection into individual flight holes.

If the attack is severe, before it is discovered, and the infested wood is a fixture which is not easily replaced, sanding of the surface finish may be desirable so that it may be treated by brushing.

After the liquid treatment has had time to dry, the flight holes should be filled and the surface finish renewed.

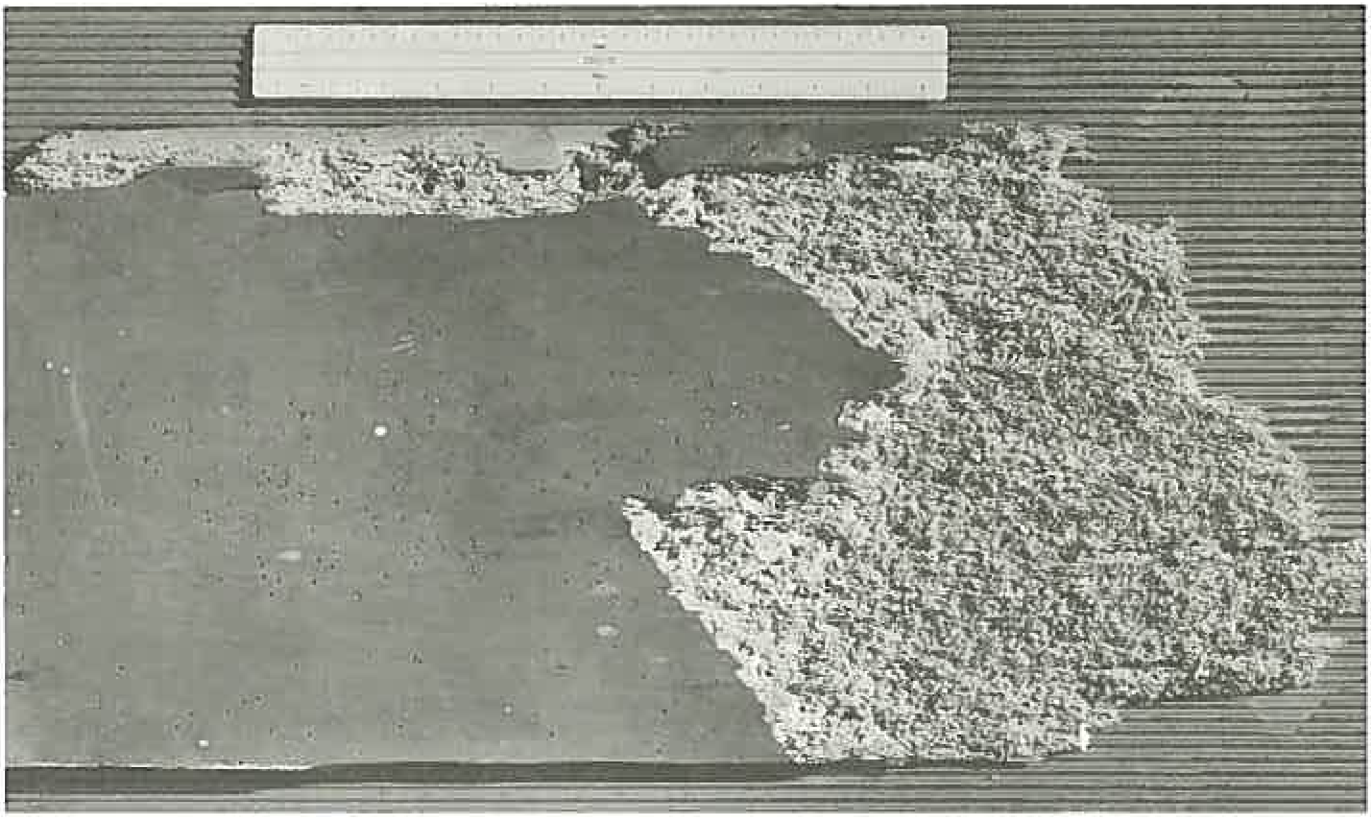
Moveable pieces of valuable furniture, such as pianos and upholstered suites, can be effectively and cheaply 'sterilized' by fumigation with toxic gases. This is a task for the professional because not all fumigant gases penetrate wood. No fumigation treatment confers any immunity from future attack on the wood.

Therefore, immediately after fumigation, steps should be taken to prevent re-infestation. The simplest of these is to seal all surfaces with a smooth coating of paint, varnish or lacquer which will fill any cracks or crevices into which the female beetle can lay her eggs.

Alternatively, a liberal coating of a persistent wood preservative or insecticidal solution will be beneficial.

Attack by anobiid borers tends to be initiated in the cooler parts of buildings, especially where there is a tendency for pockets of stagnant air to occur.

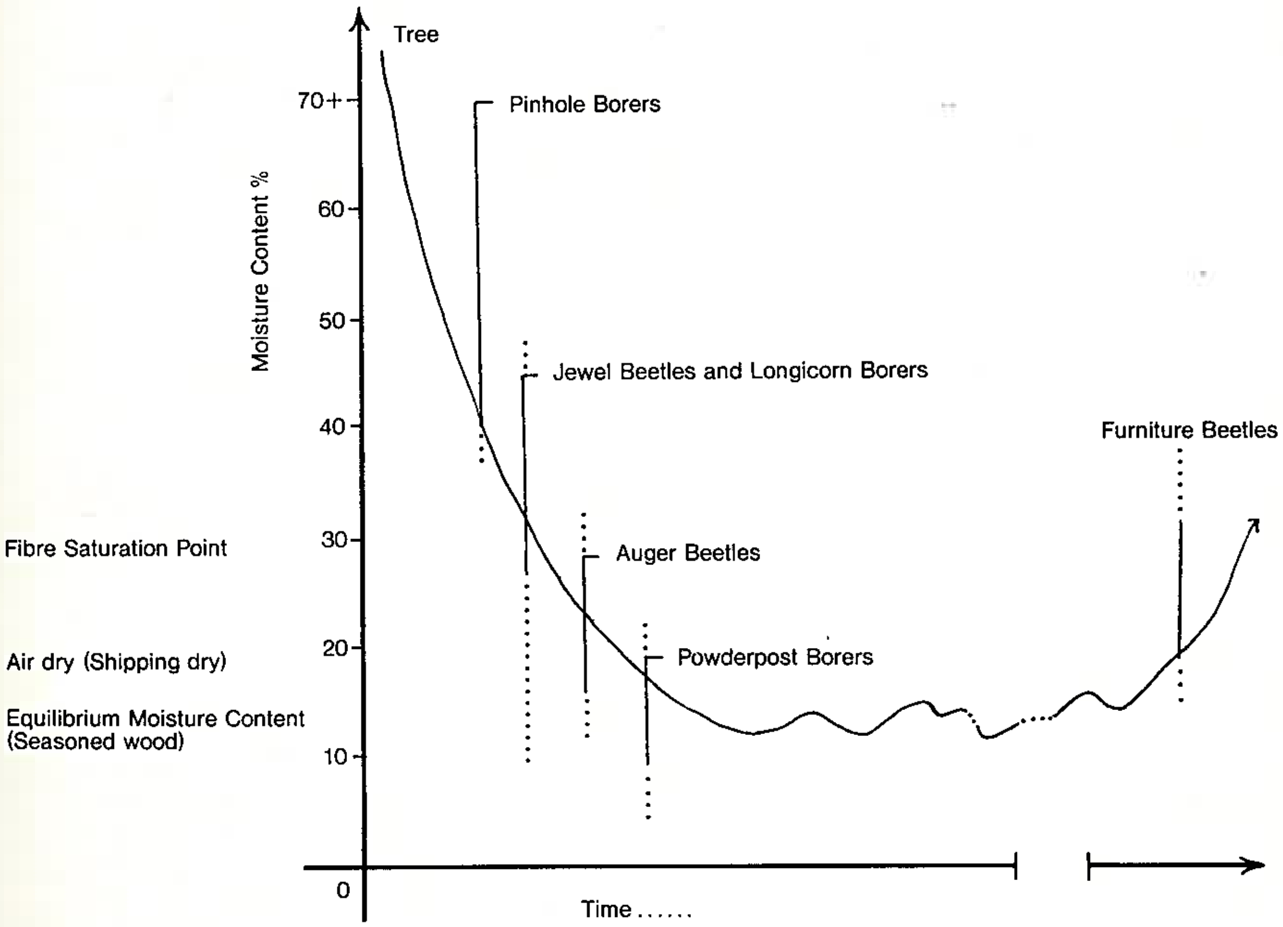
Thus, it is more likely to be found in the back of a sideboard, or in the angle-blocks used to fasten the top, than in the front; the interior of a piano is likely to become infested before the exterior; flooring under furniture which is seldom moved is



Sample of timber severely riddled by the Furniture Beetle. Flight holes in the surface give but a poor indication of the completeness of the tunnelling beneath.

more commonly attacked than that in the centre of the room or in doorways subjected to traffic and frequent air-movement. Therefore, attention to air-movement, especially during December in south-eastern Australia, which is the flight season for the adults, will reduce the risk of infestation.

Relationship between moisture content of wood and susceptibility to infestation of wood-boring beetles.



Moisture content is a major limitation on the susceptibility of wood to infestation by wood-boring beetles. The approximate limits of moisture content for each of the major groups of borers is shown diagramatically here plotting moisture content against time. In the growing tree, the wood may be at a moisture content well in excess of 100 per cent based on the oven-dry weight of the wood. Once the log is milled, and the timber commences to dry naturally its susceptibility to the different groups of borer will change. Above about 40 per cent moisture content, the wood is too wet for any borer infestation. At about 30 per cent, or fibre saturation point there will be little if any free water in the cell cavities of lumens and any further reduction in moisture content will be accompanied by some change in dimension as moisture is withdrawn from the cell walls. Wood with a moisture content of less than about 20 per cent is usually too dry for the development of any fungal infection and is often described as "air-dry" or "shipping dry". "Seasoned wood" is wood which, on the average neither gains nor loses moisture in its environment. The equilibrium moisture content of seasoned wood will vary with the average relative humidity of the seasons but is unlikely to be affected by diurnal changes — unless the wood is in the form of thin veneers. In a country as large as Australia, where the climate ranges from humid tropical to dry inland, the equilibrium moisture content of seasoned wood will range between about 10 per cent and 18-20 per cent according to locality of use. In the diagram, the range of moisture content indicted as preferred by each of the major groups of borers is only approximate and wood moisture content may not be the only factor limiting infestation.

DAMAGE IN THE MARINE (or Estuarine) ENVIRONMENT.

The submerged portion of any timber exposed in a marine or estuarine environment is likely to be invaded by 'marine borers' of one sort or another. The aerial portions of piers and jetties, as well as the upperworks of wooden boats may not be affected by these marine animals but will be liable to damage by decay and some wood-boring insects.

In particular, mention should be made of the frequency with which decay occurs in the cabins and under enclosed decks of "week-end" boats which are left at moorings during the week and used on some week-ends. These craft are often covered and sealed against the weather **BUT with insufficient allowance** for ventilation of the enclosed spaces. Temperatures in the voids under the covers may become quite high — far too high for human comfort.

Any moisture present, in the bilges etc. will vapourise and saturate the enclosed atmosphere. When the sun goes down and temperatures drop, condensation will occur on the coolest surfaces — usually the underside of the deck. Unless this has been sealed against the entry of **water vapour,** the moisture content of the timber will build up until it is high enough for decay to develop. THIS CAN BE PREVENTED BY PROVIDING FOR PROPER VENTILATION OF ALL ENCLOSED SPACES.

No timbers are entirely immune from damage by the animals which live in the sea, or in saline estuaries, and only a few have sufficient natural resistance to justify their use as marine piling for wharves and jetties.

Without special protective measures, only a few timber species are suitable for boat-building, when the craft is to be left permanently afloat and slipped only one or twice per year. On the other hand, the hazard to 'trailer boats', which are in the water for only a few hours at a time is very low and almost any timber may be ued in their construction.

Research workers studying the longevity of untreated timbers in the sea, often receive conflicting reports about the 'durability' of a particular species.

Usually, any conflict in data can be resolved by studying the animals which attack the timber. Quite often the absence of one species of marine borer from a locality and its presence in another will account for the differences in performance of the timber.

• ***Treatment.*** The prevention and control of marine borer attack on timber piling is a very specialised field and those needing to face such a problem should seek professional advice from harbour authorities and other specialists.

In some localities, radiata pine timber, heavily impregnated with a high retention of a fixed, waterborne preservative of the copper-chrome-arsenic type (q.v. next section) has given excellent service.

Elsewhere, round hardwood piles, impregnated with a high retention of creosote oil have shown excellent resistance against infestation.

It should be noted that the performance of the waterborne preservatives in hardwood timbers has not always given satisfactory results but the merits of 'double' treatment in the timbers, first with a waterborne preservative followed by a second impregnation with creosote oil deserves consideration.

WOOD PRESERVATIVES and PRESERVATIVE-TREATED WOOD

Wood preservation is a technology made up of several components. First, there is the technology of extending the useful life of timber in service by such means as proper selection and choice of materials, by adjustments to the environment (as by provision of adequate ventilation) or by attention to design and detailing.

Such techniques are seldom costly or require repetition and maintenance. They are not always practicable. When such straightforward methods are inappropriate and chemical wood preserving techniques are to be used, consideration must be given to the type of chemical preservative, the properties of the timber to be treated and the methods of application which will achieve the desired result.

This technology requires an understanding of the chemical and biological properties of potential wood preservative materials, an appreciation of the structure and properties of timbers and a knowledge of the physical and mechanical processes which will put the right amount of the best preservative for the purpose where it will perform effectively at a minimum of cost.

The science of wood preservation is becoming quite sophisticated, with preservatives being formulated to meet specific requirements.

Nevertheless, some principles appear to be more or less universal. The preservative chemical must be toxic, repellent or otherwise 'effective' against the target organism(s); it must have permanence, or longevity, compatible with the service-life of the treated timber; it must be so distributed within the treated wood such that no untreated (or inadequately treated) wood is exposed to invasion by the target organism(s); it must be present in sufficient quantity to deliver an effective dosage to an invading organism, at any time throughout the service life of the treated timber; finally, the cost of the preservative, and the treatment process must be within acceptable limits. Questions of distribution within the treated wood are generally considered under the heading of PENETRATION, while those of preservative quantity, can be considered as questions of **Retention**.

Australian Standard, 1604 — 1980: Preservative treatment for sawn timber, veneer and plywood:

> . . . *"is intended to have general application throughout Australia but in New South Wales the Timber Marketing Act, 1977 and in Queensland the Timber Users' Protection Act, 1949 — 1972, require prior approval of a preservative treatment and registration of a brand before timber offered for sale in either of those States can be described as preservative-treated."*

This document catalogues chemicals which may be used for commercial preservative treatments in Australia and sets limits to their composition. It also attempts to relate preservative retention and penetration to timber properties and severity of hazard. Appendices to the Standard provide for methods for sampling preservative liquids and preservative-treated wood, methods for determining the penetration of preservatives, tabulations of the natural durability of the heartwood of commercial timbers and a method for the detection of "lyctus-susceptible" (i.e. powderpost borer-susceptible) sapwood.

Whenever preservative-treated timber is to be purchased, reference should be made to the appropriate parts of this Standard in preparing the specification for such timber and the preservatives to be permitted.

Commercial Preservatives and Treatment. The autoclave facilities used in commercial vacuum-pressure impregnation processes for the preservative treatment of timber will seldom be available to those not engaged in the industry and other methods may have to be substituted when suitable treated timber cannot be purchased as such. Advice on such alternative procedures can be obtained through State forest services, agriculture departments and some Divisions of CSIRO.

Similarly, many of the preservatives used in commercial practice will not be available for 'individual' use because of prohibitions under State poisons regulations. Nevertheless, a few comments on the major classes of commercial wood preservatives would not be out of place.

- ***Creosote oil, Preservative oils.*** Creosote oils cannot be recommended for use indoors or where the public is likely to make direct contact with treated wood because it has a strong, persistent odour. Creosote-treated wood is difficult to paint but is ideal for use in transmission line poles, railway sleepers, bridge timbers and wharfage.

Preservative chemicals, such as pentachlorophenol, tri-butyl tin oxide and chlorinated hydro-carbon insecticides can be taken up in mineral oils to make effective preservative solutions. While the chemicals mentioned may be effective fungicides or insecticides, their persistence and/or longevity when exposed to the elements will depend upon the properties of the solvent or oil in which they are carried. As with creosote oil, which weathers well, the heavier the oil used, the better its resistance to weathering, but the 'dirtier' the treated wood is likely to be.

- ***Commercial Waterborne Preservatives.*** Most of the waterborne preservatives used commercially in Australia are of the "metal-chrome-arsenic" type, with copper, chromium and arsenic, (CCA) being the three metals most commonly present. These are prepared as dry powders or in paste form, are readily miscible with water to form true solutions in which the concentration of preservative salt can be accurately fixed. In commercial practice, the net dry salt retention of these preservatives in treated wood can be closely controlled.

Once the treated wood has commenced to dry, the preservative becomes fixed in the wood and will not readily leach out.

- ***Special-Purpose (Waterborne) Preservatives —* "Immunisation".** During the latter part of World War

Two, the CSIRO Division of Forest Products perfected a method of "immunising" the sapwood of hardwood timbers against damage by powderpost borers.

The process was cheap, effective and had minimal effect on the properties of the timber. In fact, the presence of the treatment chemicals can be detected only by sensitive indicators. Exhaustive tests had shown that very low concentrations of **fluorine** or **boron** would effectively protect timber against powderpost borer attack. Since salts of both of these are water-soluble, the treatment is unacceptable for timber which will be exposed to wetting or a leaching hazard.

In Queensland and New South Wales, much rainforest timber, with a wide sapwood susceptible to powderpost borer attack, has been commercially treated with one or other of these compounds since they were first introduced. The first intent of the timber marketing legislation in those two States was to regulate the "immunisation" processes based on boron and fluorine compounds.

• ***Light Organic-Solvent Preservatives (LOSP).*** In recent years, light organic-solvent preservatives (LOSP) have become quite fashionable. Originally, they were designed to protect finished joinery during the (comparatively) brief period between leaving the manufacturer and being painted after installation in a building. The present tendency is to advocate their use for purposes for which they have not, as yet, been proven to be satisfactory in Australian timbers and under local conditions of exposure to the weather. They are not designed for, and should never be recommended for use in ground contact.

LOSP preservatives can be formulated to meet specific needs. In general they should contain a persistent insecticide, to control wood insects, a fungicide or fungistat, to prevent the development of rots, water-repellent resins and waxes to reduce the penetration of moiture into joints in joinery, all carried in a volatile, non-swelling (organic) solvent.

Australian Standards 1606 — 1974 and 1607 — 1974 deal with the water-repellent treatment of timber and joinery and the composition of the water-repellent preservatives. It must be recognised that the recommended formulations can be modified and adapted to meet special needs.

In commercial practice, light organic solvent preservatives are usually applied by subjecting the timber to a period of reduced pressure in an enclosed autoclave and then flooding the vessel with the treatment solution without breaking the vacuum. The principle of the treatment is that the solution will replace the air that has escaped from the wood when it is under reduced pressure (vacuum).

• **Conclusion.** Out of doors and in ground contact, preservative-treated timber will, almost always, give better service than comparable untreated timber **but** some preservatives and treatment are not suitable for such service. When protected from the weather, and out of ground contact, preservative-treated timber will give better service than similar timber untreated **if** there is a hazard. The biological hazards of decay, borer and termite attack can almost always be eliminated from buildings without the use of chemical preservatives or preservative-treated wood.

Do-It-Yourself Wood Preservation. Except for the recommendations for the *in situ* treatment of borer damage with topical application of insecticidal solutions, the whole tenor of this document has been biased towards avoiding the application of wood preservatives personally.

There are wood preservation treatments which can be used effectively by the householder. Each will have its limitations but used judiciously might well extend indefinitely the useful life of infected or infested timber. The principles of good penetration and adequate retention apply as much to 'householder' preservation as to commercial operations. The preservatives and methods of application may be different, and the costs almost certainly will, but the objectives will be the same.

• **Simple Processes.** Wood preservatives may be applied topically with the simplest of equipment, namely, by brushing, spraying or injection. "Spraying with pressure" sounds impressive but will achieve less penetration than can be obtained with several flowing brush coatings. Spraying-with-pressure, usually results in a high proportion of the preservative solution "bouncing off". Brushing several flowing coats, consecutively will allow deeper penetration.

Small pieces of wood can be soaked in preservative, for several hours, and larger pieces may be dipped — even if the ends are dipped alternately. For example, when weatherboards, or timber siding, is being replaced, dipping the ends in water-repellent preservative will be beneficial and will inhibit decay at the joints. If the wood to be dipped or soaked can be given some preliminary heating and then "quenched" in cold solution the expanded air from the wood will be replaced by cold solution. This effect can be enhanced by heating the wood to be treated in the preservative solution and then allowing it to cool to ambient temperature.

N.B. Extreme care must be taken with this process when volatile, flammable preservative solutions are being used. *(See "Fencepost" Leaflet).*

• **Home-Use Preservatives.** Whether used commercially, or domestically, water-soluble preservatives in aqueous solution will cause wood to swell, and may cause glues to 'let go' and surface finishes to lift. When none of these will be detrimental, as when treating a building scantling for powderpost borer attack, waterborne preservatives, such as the CCA salts, or solutions of **borax** or **boracic,** or **sodium fluoride,** at a concentration of about 2.0 per cent (mass/mass) will give effective immunity against both powderpost and anobiid borer attack.

In furniture and seasoned, dressed finishing timbers, borer attack can best be controlled by using a persistent, chlorinated hydrocarbon insecticide, in a light mineral oil solvent that is volatile, such as mineral turpentine or kerosine. The treating solution should contain about 0.5 per cent (mass/volume) of aldrin, dieldrin or heptachlor, or about 1.0 per cent. (mass/volume) of chlordane. Suitable proprietary solutions are marketed and can often be purchased in hardware stores.

In a dwelling, decayed flooring cannot be "cured" by the topical application of chemicals. In all probability the decay will be due to poor sub-floor ventilation, defective damp-proof courses, or plumbing faults. When these have been rectified, the problem will probably have been solved — provided the ventilation is adequate under all parts of all the suspended timber floors.

Decay in weatherboards and siding, window sills and exterior joinery often occurs in pockets of limited extent such that replacement of the whole piece may not be justified. Provided the source of moisture which allowed the decay to develop can be traced and corrected, replacement of the decayed wood with a neat, tight-fitting patch will probably be sufficient, specially if the patch can be sealed with paint — or water-proof glue.

Thicker timbers, such as window sills, sometimes have quite deep pockets of decay which cannot be fully excised and, no matter how carefully patching is done, there still remains a strong possibility that some moisture will penetrate and allow the decay to continue to grow. In such cases, a generous 'smear' of a diffusing preservative beneath the patch will be very beneficial. These diffusing preservatives are designed to go into solution when (if) moisture enters the cavity and will then diffuse through the decayed wood to reach the growing tips of the fungus and kill them. When the wood dries, the preservative also dries but, should conditions again become damp, the preservative will re-dissolve and continue to diffuse through any damp wood.

A diffusing proprietary preservative, patented by CSIRO, specially designed for this sort of use is available from some hardware stores under the name of "DIMET BLUE — 7". This is usually supplied as a paste which can be brushed or smeared over decayed wood. It and some other diffusing preservatives have also been prepared in solid form on an experimental basis, to test the effectiveness of "rods" of preservative inserted into pre-drilled holes in timber as a method of controlling decay. Since these alternatives are not presently available for sale, technical advice should be obtained when their use is contemplated.

TECHNICAL ADVICE AND ASSISTANCE

Technical advice on all aspects of wood preservation and wood-preserving chemicals can be obtained from all State forest service headquarters as well as from most divisional offices. In CSIRO, the Division of Chemical and Wood Technology, Melbourne, has specialists in various aspects of wood preservation and publishes literature on the subject. Extension officers from departments of agriculture will have, or be able to obtain, advice on wood preservation. In some universities, there will be persons with considerable knowledge of this technology, but such persons may not be easy to reach. Members of sawmillers' associations, timber merchants' associations, timber promotion councils, the Timber Preservers' Association (T.P.A.A.) and licensed pest control operators will also be able to advise in at least some aspects of this technology.

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