AUSTRALIAN TIMBER HANDBOOK

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NORMAN K. WALLIS

Sponsored by The Timber Development Associations

PREFACE

The *Australian Timber Handbook* is designed to assist producers and users of timber by submitting, in precise and practical form, the more important features affecting timber in its various stages of manufacture and use. Originally written by an experienced Australian timber man, Norman K. Wallis, with the special object of describing Australian timber practice, the *Handbook* was first published in 1956.

In that edition, acknowledgement of the co-operation of the C.S.I.R.O., Division of Forest Products, the New South Wales Forestry Commission, Division of Wood Technology and the Timber Research and Development Association, London was recorded. Special mention was also made of Mr. C. A. Lembke, Editor of *The Australian Timber Journal,* who was responsible for the checking of proofs, the setting up and the format of the volume.

A new revised edition, considerably enlarged to cover later developments in timber processing both in Australian States and overseas, was published in 1963.

Appreciation was there recorded for the assistance of Mr. John Moss, of Hicksons Timber Impregnation Co. (Aust.) Ltd., and Mr. Albert Cameron, of Lewis Berger & Sons (Aust.) Pty. Ltd., as well as those authorities mentioned in the Introduction, in the compiling of the original *Handbook.*

There has been an increasing demand for copies since that time, and the stage was reached where it became impossible to obtain a copy anywhere in Australia.

The untimely death of the original author at the height of his career in 1965 has left a serious gap in the ranks of professional men willing to devote the better part of their lives to the study of timber and its best application to the service of man.

Born in 1900 in Sydney, Norman Arthur Kingsbury Wallis received his initial education at All Saints College, Bathurst, and studied Arts and Economics at Sydney University.

His earliest association with the timber industry began in his father's business at Pyrmont. The business was originally founded by Norman's great-grandfather in the early nineteenth century.

Prior to the Second World War, he was a heavy cruiser yachtsman and owned the well-known yacht *Wanderer.* During the war he was a seagoing Lieutenant Commander and finished the war on corvettes and frigates.

On cessation of hostilities, Norman Wallis established new sources of timber supply in Malaya, Borneo and Sarawak on behalf of the timber industry. In the late 1940s he went to the Solomon Islands for the same reason.

He was a foundation councillor and life member of T.D.A. and was President on five occasions. At the time of his death, Norman Wallis was Chairman of the Timber Industry's Standards Committee.

In order to continue to meet the needs of those requiring a basic knowledge of the properties and utilisation of timbers in Australia, the Timber Development Associations decided that urgent publication of an up-to-date third edition of the Handbook was necessary, and they have been responsible for a major portion of the effort in compiling this edition. The task of editing was entrusted to Charles J. J. Watson, formerly of the Queensland Department of Forestry, an early Australian member of the International Association of Wood Anatomists, and well-known in the timber field.

The Associations again express their thanks to those Authorities who have given generous help toward the success of this new Handbook and to those who were acknowledged in earlier editions. Special mention is made of the technical officers of the Division of Forest Products, C.S.I.R.O., Melbourne, and of the Division of Wood Technology, New South Wales Forestry Commission, Sydney. Other essential material was supplied by the Director-General, Forestry and Timber Bureau, Canberra, and the Conservators of Forests in other States. The assistance of Mr. P. E. Marshall, B.Sc, formerly Officer in Charge of Seasoning, Division of Wood Technology, New South Wales Forestry Commission is also acknowledged.

The assistance of Mr. David Bubb, Director of the Timber Development Association (Queensland) and Mr. D. S. Jones, Development Engineer, Queensland Timber Board, is recorded with appreciation.

N. K. GIRDLER, Director,
Timber Development Association (New South Wales) Limited.

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Introduction

THE WONDER OF WOOD

"GIFT OF GOD AND FRIEND OF MAN"

From a seed, which in the autumn falls, a tree is born. Nursed in the soil and blanketed by winter's falling leaves, the seed becomes conditioned for the marvel of its growth. Soon, spring will bring it warmth and moisture, awakening it to life. Its roots will thrust down into Mother Earth; its first tiny shoot will reach for the light. There, where the seed fell, or where the seedling is planted, for better or for worse, the tree will pass its life, enduring hazards of tempest, drought, and fire, to survive or to succumb in the face of nature's torments.

Growing from seedling to sapling and finally coming of age, the normal life span of the mature tree will vary according to its species. It may be a matter of twenty years or so, as in the case of our acacias, or it may amount to as much as 3,000 to 4,000 years, the age giant sequoias are estimated to attain.

Whatever its life cycle, and however and wherever it grows, the tree will join those others which together clothe some three-fifths of the world's land surface, making it habitable for man. It will help to sweeten the air, adorn the fields, temper the wind, shelter the birds, lay the dust, conserve moisture and protect the soil. And it will increase and multiply—a perpetual source of pleasure and profit to man—if man so wills.

Each kind, or species, of tree has developed, so to speak, its own racial characteristics, expressed in the form and contour of the tree, in the physical nature of leaves, bark, branches, flowers, fruit and so forth, and also in the nature of its woody substance. And so, as may be expected, the wood of each species has definite qualities by which it may be clearly distinguished from that of other species.

But each tree is also an individual, possessing personality, and in the course of its life many things affect its growth and nature—the cycle of the seasons, the nature of soil and climate, latitude and altitude, times of drought and plenty. These factors materially affect the tree's substance—wood—and into the grain of its wood is verily written the life story of the tree. And so, when axe and saw lay bare the hidden beauty of its heart, the technologist can read

there at least part of its history: whether it dwelt in temperate or tropical regions, in good soil or bad; whether, in lonely vigil, it grew bent and twisted on some windy rise, or, in forest association with its fellows, rose straight and true, seeking the sky.

These distinguishing qualities of the various species and the variety of grain in individual boards, give to wood such a wide range of usefulness and beauty that it truly becomes the most valuable and most versatile of all the natural substances available to man. Small wonder then, that from his very beginning, wood has been man's best and oldest friend.

Among the first acts which shaped his course towards civilisation, wood played a major part. It was of wood that he made his first fires, fashioned his first implements and weapons, erected his first rude shelters. It was a red letter day in the history of man when a floating log first bore him across a stream. With awakening understanding he wrought from the log a canoe. And thus, in his first tiny wooden craft he searched for and found new hunting grounds and new peoples.

He came to understand the pulse of ocean and the way of the wind. His canoes grew to caravels, to clippers, to ships of the line. In them he ventured beyond the horizon's rim, and the seaways and the havens of the world came to know the form of timbered hulls and the spread of wooden spars. Wood alone made it possible for man to explore and conquer, to merge and mingle, to trade treasure and exchange ideas, with lands and peoples across the sea.

So too, when he first built for himself a shelter, man turned to wood. Whether of plaited boughs or of stout logs, wood protected him from the elements and from his enemies. As he became civilised he expressed much of his culture and his concepts in the form of buildings of wood, many of which have survived the passing of centuries. In Oslo recently there was celebrated the 1300th anniversary of a church of timber construction even to the pegs holding the building together. In Japan, religious ceremonies are still held in a temple 1100 years old. The timbered walls of the church at Chipping Ongar, Essex, were erected in 841 A.D.

As O. D. A. Oberg, C.M.G., a great lover of timber, has said: "Timber is the stuff of history. Timber kept us warm for a thousand centuries, saved Noah, built King Solomon's temple, sacked Troy, symbolised* our hopes of Heaven, discovered America and Australia, made Britain mistress of the seas, and keeps the flag flying still."

Touch a piece of wood, feel its friendly texture, as so often a craftsman will, observe the beauty of its grain, know the fragrance of its scent. It is apparent at once that it is different from all other materials. It is warm, has a character and vitality of its own. Perhaps this is because it is an organic substance, created by the processes of life itself, and formed of the same such stuff as all living things—including you and me.

With the help of modern research, the range of uses of wood is being continually extended. Today wood fulfils for us innumerable tasks, supplies our countless needs. Wherever we turn, the product of the living tree is our con-

* Col. 1:20.

stant servant and companion. Say, if you like, it has no thoughts, nor tongue to speak, but at this very moment it bears the message you are reading.

Wood frames and sheathes our homes, furnishes the rooms, forms the fence, provides the gate. It spans the stream, supports the railroad, crates the goods, lifts the loads, carries the cargoes. It is the door of the house, the heat of the hearth, the board of the table, the frame of the bed, the wood of the cradle and the shell of the coffin. It is the gift of God and friend of man.

Part One

AUSTRALIAN TIMBERS
AND THEIR CONVERSION

I

THE AUSTRALIAN TIMBER INDUSTRY

Compared with the principal timber-producing countries in the world, Australia has one of the lowest percentages of forest area to total area, namely 4.0 per cent. Others low in the scale are the Republic of South Africa and Great Britain with 3 . 3 per cent and 7 . 2 per cent respectively. On the other hand, Finland with 69 . 0 per cent has the greatest proportion of forest land.

Table 1 shows the relative percentages of forested areas to total areas of Australia and some other countries.

TABLE 1

Country	Forest Area {Per cent of total area)
Finland	69.0
Canada	45.0
Soviet Union	34.0
United States of America	32 . 0
Great Britain	7.2
Australia	4.0
Republic of South Africa	3 .3

Table 2 sets out the areas of State Forests and Timber Reserves in the various Australian States as at 31 March 1967.

It has been estimated that the exploitable and potentially exploitable forests in Australia amount in total to approximately 40 million acres. This figure, however, includes an allowance for unreserved Crown lands and private property of which the actual extent of the resources has not yet been determined.

Forested land of inferior quality has been estimated to cover a further 55 million acres, but little of this will provide more than fuel and minor products.

Of the total forested land 93•8 per cent is estimated to consist of eucalypts, 3 .3 per cent of rain forests, 2•5 per cent of cypress pine and 0•4 per cent of coniferous plantations.

The bulk of the present local timber supply comes from the thick forest areas in the 30-inch and over rainfall belt south of the tropics and the 70-inch

TABLE 2

FOREST AREAS OF THE COMMONWEALTH*

(Government Owned)

	N.S.W.	Vic.	QldS*	S.A.	W.A.	Tas.	ACT	N.T.	Total (000 acres)
Production Reserves[a]									
Productive	6937	4108	8664	248	4083	1917	29	11	25,997
Unproductive	—	1382	—	23	—	1389	—	—	2,794
Unstocked	—	114	—	—	708	—	20	—	842
TOTAL	6937	5604	8664	271	4791	3306	49	11	29,633
Protection Reserves[b]									
Productive	20	—	—	—	33	233	13		299
Unproductive	—	500	2268	17	—	—	97		2,882
Unstocked	—	—	—	—	28	1	—		29
TOTAL	20	500	2268	17	61	234	110		3,210
All other Reserves									
Productive	—	—	—	—	—	—	—		
Unproductive and Unstocked	—	151	—	—	—	—	—	2394	2,545
TOTAL	—	151	—	—	—	—	—	2394	2,545
Total area all Reserves	6957	6255	10,932[e]	288	4852	3540	159	2405	35,388

(a) Forest lands reserved by law for the production of logs, pulpwood, pit props, poles, posts and fuelwood for commercial purposes.

(b) Reserved lands, the management of which is principally aimed at the protection of natural resources of fauna and flora, or at other purposes not directly related to the production of timber (e.g. parks, watersheds, soil conservation etc.). Industrial cutting may or may not be allowed in these protection reserves.

(c) As at 30 June 1967.

(d) National Parks.

(e) Excludes Scenic Areas of 39,000 acres.

  *As at 31 March 1967; Forestry and Timber Bureau.

AREAS OF PRODUCTIVE FOREST, IN FOREST LANDS PERMANENTLY
DEDICATED BY LAW, AS AT MARCH 31 1968

		000's *Acres*	*Percentage of Total*
Eucalypt		21,302	81.9
Rain Forest		1,490	5.7
Native Conifer	(a)	2,392	9.2
Plantation Conifers		813	3.2
TOTAL		25,997	100.0

(a) Chiefly Cypress Pine.

and over rainfall belt within the tropics. The total forest area included in these divisions is comparatively small and is confined to the following regions:

1. The coastal belt in the extreme south-west of Western Australia, from a point just north of Perth to Albany in the south.

2. The pine plantations in the south-east of South Australia.

3. The Otway country in the south of Victoria and the whole of the south-eastern portion of that State.

4. The mountain forests of Victoria and New South Wales.

5. The coastal districts of New South Wales and Queensland.

6. The north east, north west and south of Tasmania.

7. The red gum forests along the Murray River and its main tributaries.

8. The inland cypress pine belt, from the Murray River northward into south-western Queensland.

Australia possesses a predominance of hardwoods and is deficient in softwood. This deficiency has been reduced rapidly in recent years by greatly increased plantings of selected exotic pines in all States, in addition to hoop pine in Queensland. In most other countries the reverse applies. Over 90 per cent of the timber trees of Australia consists of hardwoods, mainly of the genus *Eucalyptus.* Including the mallees, over 600 species are now recognised, but the chief commercial varieties are confined to about 40 species (see page 141).

In addition to the hardwood forests and the inland cypress pine belt, the coastal strip in Queensland and northern New South Wales provides tropical and semi-tropical "rain" or "brush" (scrubwood) forests. These tropical forests have hoop pine (Australia's utility softwood), and a wide variety of cabinet timbers, such as black bean, Queensland walnut and maple, silkwood etc. In Tasmania there are considerable areas of temperate rain forests.

The areas of State Forests already reserved in perpetuity amounts to more than 90 per cent" of the area considered capable of permanent reservation in Australia. A considerable proportion of the area reserved consists of inaccessible mountain country and cut over lands. The foresters of Australia are therefore faced with a difficult task in improving and preserving the existing

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forests, and in securing the reservation of sufficient suitable forest country to ensure a permanent supply of timber for the requirements of the Commonwealth. Substantial progress has been made in the establishment of coniferous plantations in Australia as shown in Table 3.

Australian sawmills are generally small units. With the exception of some jarrah and karri mills in Western Australia, some hoop pine mills in Queensland, and four radiata pine mills in the south east of South Australia, few sawmills have an annual output exceeding 5,000,000 super feet of sawn timber. The low volume of timber per acre in the indigenous forests largely determines the size of mills.

The tables on pages 17-22 give pre-war and post-war figures covering Australian production, imports and exports of timber.

In addition to timber and plywood, as covered by these figures, Australian forests supply mining timber, poles, firewood, etc. and wood derivatives such as tannin extracts, wallboard, rayon products and so on. In Victoria and Tasmania the paper pulp industry has grown to one of major importance.

Only Western Australia and Tasmania produce timber in excess of their internal requirements. They export to the other States and overseas.

The nature of timber production in the various Australian States is indicated as follows.

QUEENSLAND

In South Queensland a good range of softwoods is being produced. Sawn hardwoods of the genus *Eucalyptus* include blackbutt, spotted gum, forest red gum, rose gum, grey gum and scribbly gum, white stringybark, red and white mahogany, grey and red ironbark, with small quantities of Gympie messmate and grey box.

Other timbers sold as hardwoods include the botanically related brush box, turpentine and satinay, the last species almost confined to Fraser Island and supplied through Maryborough sawmills. Brush box and satinay are most popular for seasoned internal polished flooring and exterior dressed weatherboards, better known in Queensland as "chamfer boards". Preservative treated tulip oak is assisting hardwood supply for internal building framing and flooring.

The softwoods are represented by hoop pine in the main and the increasing yields from Forestry Department plantations have for some years considerably exceeded the supply from virgin forests. This is augmented by cypress pine mostly from reserved areas west of the Great Dividing Range. Considerable quantities of useful softwood are now marketed from large plantations of maturing exotic pines *(Pinus spp.).*

There is also a small quantity of plantation-grown bunya and southern kauri pines together with some brown pine from the original rainforests remaining. Some small supplies of a number of other rainforest timbers are still coming in, including the satinashes and yellow carabeen. The latter is used as a softwood substitute.

The hardwoods are used for general building work and engineering structures such as preservative-treated piles and poles, bridges and wharves, and

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TABLE 3

AREA OF CONIFEROUS PLANTATIONS BY STATES*

(Acres)

State/Territory	Government Owned			Private Property			Govt. Plus Private
	Pinus radiata	Other species	Total	Pinus radiata	Other species	Total	
NEW SOUTH WALES	112,192	19,319	131,511	7,804	16,381	24,185	155,696
VICTORIA	68,868	9,668	78,536	98,681	3,052	101,733	180,269
QUEENSLAND	3,448	130,068	133,516	840	27,550	28,390	161,906
SOUTH AUSTRALIA	130,958	12,808	143,766	40,500[b]	—	40,500	184,266
WEST AUSTRALIA[a]	21,799	31,177	52,976	1,888	188	2,076	55,052
TASMANIA	31,135	419	31,554	13,113	3	13,116	44,670
A.C.T.	27,400[b]	2,600[b]	30,000[b]	—	—	—	30,000
NORTHERN TERRITORY	—	1,500[b]	1,500[b]	—	50	50	1,550
Total	395,800	207,559	603,359	162,826	47,224	210,050	813,409

(a) South west zone only.

(b) Estimated.

*As at March 31, 1968; Forestry and Timber Bureau.

for framing of heavy vehicles and small ships. A number of species are used for the manufacture of high-density wall boards.

Cypress pine is used in home building, mostly in flooring and light framing. Hoop pine is used for plywood, particle board, furniture and cabinet work, joinery, internal house framing and flooring, boat and caravan building, boxes, brush stocks and other small machined work. Most of the plywood is exported to other States.

To meet future timber demands the Department of Forestry is extensively planting hoop pine, principally on better soils and mountain slopes within a radius of about one hundred and twenty miles from Brisbane. In addition, some American pines have been established in large plantations, *Pinus radiata* on highlands south and north of Toowoomba and slash and loblolly pines on low coastal areas between Brisbane and Maryborough. The total area in Queensland under softwood plantations exceeded 133,024 acres on 30 June 1968.

At the same time the best hardwood and cypress pine forests are being protected against fire, and silvically managed by selective thinning of trees of poor form and unwanted species to attain the maximum growth of good timber by natural regeneration.

North Queensland is poorly endowed with hardwood supplies of the most durable species, with the result that so-called "southern hardwoods" mostly spotted gum, forest red gum, blackbutt and satinay, find their way into buildings and other structures well to the north of the Tropic. On the other hand, the high rainfall coastal forests from Mackay to Cairns and further north lead the Commonwealth in quantity and quality of good working cabinet timber in a wide range of both figured and plain timbers.

The best known hardwoods are Johnstone River hardwood, rose gum, poplar gum, cadaga and white stringybark, with two very hard species of penda. All of these find place in general building and engineering work. There are also small supplies of Gympie messmate, known locally as "dead finish", lemon-scented gum, red mahogany and turpentine which is preferred for marine piling when in suitable lengths.

Limited supplies of North Queensland kauri, with some brown pine and softer black pine, are available. Some hoop pine is being sold from Forestry Department plantations. Cypress pine from over the Dividing Range on the Gulf of Carpentaria fall comes to the coast for use in house piers and fence posts. Trial plantations of exotic *Pinus spp.* are being established on the coast north of the Tropic which, it is hoped, will yield useful supplies of softwood for North Queensland in the future.

The most valuable cabinet timbers, used primarily in veneered panels, plywood, joinery and furniture are Queensland maple, northern silky oak, red tulip oak, northern and yellow walnut, black bean, silver ash, blush and rose alder, rose butternut, bolly silkwood and quandong in several species.

A number of good working, durable and close textured satinashes respond well to a variety of stained finishes and are available in large quantities. They can be used for both internal panelling and external joinery and sheeting in

the same way as the softer "ash" eucalypts in southern states provided that equal care is given to seasoning.

A statement* prepared for the Ninth Commonwealth Forestry Conference, 1968, records that about one hundred and thirty-five North Queensland rainforest species have been milled at one time or another and about fifty are readily acceptable to the trade, but most of them do not occur in quantity. Fourteen species are listed which are frequently peeled or sliced into veneers. About sixty sawmills and plymills obtain log supplies from the rainforests and of these four mills have an annual log quota in excess of six million super feet.

The onset of the annual tropical wet season extending from about March to June is a severe handicap to northern sawmillers in maintaining sawn production, most of which is used in local building and engineering work. Only a small percentage of sawn timber production is exported while the greater proportion of veneers and plywood are sent to southern states and overseas markets.

Details of the properties and recommended uses of more than three hundred timbers used commercially in Queensland are supplied in Forestry Department trade publications, particularly those on joinery and building timbers.†

The total log timber processed by Queensland mills during the year 1967-8 was 418 million super feet which included 12 million super feet, or 3 per cent, of imported timbers chiefly for plywood and veneer.‡

Timber processed from native trees totalled 361 million super feet, or 86 per cent, and that from plantations was 45 million, almost all pine, and 11 per cent of the total.

The reserved forest areas and plantations under the control of the Department as at 30 June, 1968 were:

State Forests	6,972,517 acres
Timber Reserves	1,881,676 acres
National Parks and Scenic Reserves	2,323,617 acres
TOTAL	11,177,810 acres

NEW SOUTH WALES

The coastal area north of Newcastle is the principal region in New South Wales for supplying sawn timber and also hewn constructional timbers for bridges, wharves and railways. Timbers in plentiful supply in normal cut include blackbutt, grey gum, grey ironbark, white mahogany, tallowwood, spotted gum, Sydney blue gum, yellow carabeen, white birch, and sassafras.

In recent years greater attention has been given to the better utilisation of considerable quantities of the brown and blush tulip oaks, yellow carabeen and other rainforest timbers in the north coastal forests using modern advances

* Paper by H. E. Volck, Atherton Forest Research Station, North Queensland.
t Forestry Department Pamphlets Nos. 3, 4 and 5.
‡ *Bulletin* No. 65 of 1968 Bureau of Census and Statistics, Brisbane.

in preservative treatment and seasoning. These are now finding useful service in internal house construction. In limited supply are hoop pine, coachwood, brush mahogany and various other useful brushwoods. The hardwoods are used for general building work, shipbuilding and engineering structures.

The south coast of New South Wales also produces hardwoods, principally spotted gum, suitable for structural work and shipbuilding. In the inland regions cypress pine, a small tree seldom more than 12 inches in diameter at breast height, and the red gum of the southern Riverina, are the principal sawmill species.

Principal timbers exported are as follows: ironbark is used for bridge decking, piles, poles, girders, transoms, sleepers, heavy wagon framing and shipbuilding. It has also been used as an outer sheathing for craft operating in far northern regions—it is claimed to be the only timber known to satisfactorily resist the grinding effects of ice. Grey box is a valuable hardwood for all heavy constructional purposes, wharves, bridge decking, shipbuilding, sleepers and girders. Spotted gum is used for shipbuilding, wheel and wagon building, agricultural implements, handles, etc. Coachwood is used for rifle furniture, motor body work, shoe heels, turnery, joinery, furniture and aircraft plywood manufacture. Tallowwood is used for general building purposes, window sills, crossarms, sleepers, flooring, wagon framing and for all purposes exposed to weather. Turpentine is used for marine piles and underwater structures subject to action of sea water. Other export timbers include white mahogany (sleepers), grey gum (sleepers), blackbutt (sleepers and general construction), rosewood (cabinet work), forest oak (brush backs) and Murray River red gum (sleepers).

On the local market Sydney blue gum and rose gum are used for shipbuilding, flooring and general building and construction work, whilst cypress pine is used mainly for flooring, weatherboards, linings, building scantlings and so on. Other timbers have special uses, such as crow's ash or colonial teak (veranda floors exposed to weather, and shipbuilding), southern silver ash (furniture, interior joinery), bollywood (aircraft construction), and brush box (bridge decking and flooring). Also of growing importance is the wallboard industry which is consuming large quantities of New South Wales timbers.

The main avenues through which the Forestry Commission of New South Wales proposes to rehabilitate the forests of New South Wales are by forest management and silviculture, fire control, forest roading, wood technology and market extension. Extensive stand improvement operations are being undertaken in the various forests throughout the State to encourage further growth. In addition, hoop pine and exotic coniferous plantations have been established. About 6 per cent of total sawn timber production is exported.

VICTORIA

The principal items of produce from Victorian native hardwood forests include: mill logs for the production of sawn timber, pulpwood for paper and hardboard manufacture; telephone and power transmission poles, beams, bridge timbers and piles, railway sleepers, fencing timbers, mining timbers,

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and firewood. Victoria's softwood plantations produce logs for sawing, peeling, pulpwood used in the manufacture of paper and particle board, and fencing materials. Nearly all timber produced from Victoria's forests is for home consumption.

Between 20 and 30 eucalypt species and the exotic conifer, *Pinus radiata,* are in common commercial use in Victoria. These timbers have such a wide range of physical, mechanical and chemical properties that it is possible to obtain a timber suitable for every purpose.

In this chapter Victoria's commercially valuable forests have been grouped into the following five broad types:

1. The largest group of Victorian eucalypts, in respect of area and volume of commercial production, is the mixed species group. The main species are messmate, silvertop, various stringybarks, peppermint, mountain grey gum, manna gum and candlebark. The species grow in varying mixture over extensive areas in the foothills to the north and south of The Great Dividing Range, Otway Ranges and in the Strzelecki Ranges.

About two thirds of the sawn timber produced in Victoria is milled from logs of these species. They dominate the field of framing timber for light and heavy constructions of all kinds. Inferior produce and the leftovers from logging operations in mixed species forests produce pulpwood used for paper and hardboard manufacture. There is a demand for mixed species poles of all sizes if they have been treated with chemical preservatives. These preserved poles which are treated whole in large pressure cylinders have helped to ease the demand for the naturally durable species.

2. In the sub-alpine regions of Victoria the genus *Eucalyptus* attains its greatest stature in the mountain ash and alpine ash forests. Ash species grow in heavily timbered areas between 1,000 feet and 5,000 feet altitude on The Great Divide, the Otway and Strzelecki Ranges. They yield a high grade, even textured, light coloured wood. It is highly valued for the manufacture of veneers, furniture, flooring, weatherboards, joinery and a multiplicity of other purposes requiring a timber that can be easily worked and polished. Mountain and alpine ash are among the lightest in weight of the hardwoods. They are not naturally durable when in contact with the ground. They are valued for chemical wood pulp manufacture because of their relatively long fibres and good chemical recovery characteristics.

In 1939 catastrophic fires raged over extensive areas of prime ash forests. There are now 191,000 acres of ash forests which regenerated after the 1939 fires within 100 miles of Melbourne markets. Several stands are already being thinned for pulpwood and sawlogs. In future years these areas will produce large volumes of high grade timber.

3. Over 83,000 acres of forest land have been planted with exotic conifers, mainly radiata pine. Timber from Victoria's softwood plantations is used for furniture manufacture, flooring, linings and weatherboards. Large volumes are used in the packaging industry. Even larger amounts are cut for pulpwood to produce paper and particle board. Selected logs are used to produce top quality veneers. Round timber cut from thinnings in these plantations is

treated with chemical preservative and used for fencing materials and poles. Small amounts of softwood timber are now being kiln-dried and used for framing timber.

4. Red ironbark, various boxes, red gum and yellow stringybark are the principal species of durable timber. They are usually found on the lower foothills and savannah woodlands in the warmer northern half of the State and in the far east. River red gum is an exception and is more widespread. The more important river red gum forests are found on the flood plains of the Murray and Goulburn Rivers. Timber from these durable species finds its greatest use as railway sleepers, poles, bridge beams, house stumps and fencing timbers.

5. Wood from the various non-eucalypt varieties is used in small quantities for many special purposes such as ornamental veneers, tool handles and furniture. The two main commercial species are blackwood and myrtle beech.

Although there are large areas of Victoria's forest which still require considerable access development, the application of intensive management has made significant progress. Large blocks of forest are managed under working plans which will provide a sustained yield of timber for future generations. This management system is the main contributing factor to the improved stability which characterises forest industries today. With the improved management of hardwood forests and the increasing plantings of softwood varieties, Victoria can look forward to a future where it will be largely self-sufficient in its timber needs by the year 2000.

Government owned timber areas in the state of Victoria at the end of June 1968 consisted of 5,645,719 acres of reserved forest, in addition to 83,712 acres of coniferous plantations.

SOUTH AUSTRALIA

The natural forest resources of South Australia must be rated as negligible and as long ago as 1870, the Government of the day, recognising this fact, took steps to provide legislative authority for the establishment of permanent State Forests.

Plantings commenced shortly after that date and have continued on a large scale practically without interruption since 1907 with the result that, as at 30 June 1965, approximately 179,000 acres of State Forests have been established with softwoods, of which about nine-tenths consist of radiata pine (a native of California), and the remainder of some twenty or thirty other varieties of exotic conifers. The greater proportion of the planted area is in the 30-inch rainfall belt in the south east of the State, within a 30-mile range of Mount Gambier.

In addition to State Forests, there are about 45,000 acres of privately-owned softwood plantations in the State, mostly owned by afforestation companies.

In the late 1920s a steady yield from these forests began to develop and since then many sawmills have been designed, constructed and operated, both by the State Government and private sawmilling firms, to handle the increasing volume of timber that has become available.

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The first large permanent sawmill, however, was established by the Government at Mount Burr and was followed by sawmills at Nangwarry in the heart of the Penola Forest, and Mount Gambier, centrally situated to handle yields from Myora, Caroline and Mount Gambier forests. The sawmills at Mount Burr and Nangwarry commenced production of timber in 1930 and 1940 respectively, and together are at present converting 1,250,000 super feet of log timber per week into sawn products. The Mount Gambier State Sawmill, officially opened on 19 May 1959, is designed to handle a log intake of 50 million super feet per year, bringing the annual Departmental milling intake to about 100 million super feet.

Private companies operate two large sawmills at Mount Gambier, as well as a number of smaller mills designed to cut flitch. Log supplies for these mills come from both State and private forests.

Altogether there are 11 sawmills, 4 timber preservation plants, 3 particle board factories, 1 veneer mill and 2 paper mills operating in the south-eastern region of the State; several sawmills in the Mount Lofty and Flinders Range areas; and a plywood factory in Adelaide.

A preservation plant of the vacuum cylinder type is included in the general set-up. Production is mainly railway sleepers, poles, fencing posts and so on.

Mount Burr Sawmill consists of a board mill, equipped with a log gang-saw line and a log bandsaw line and attendant equipment.

Nangwarry Sawmill produces boards and building timbers by a log band-saw and band resaw.

Yield from forest areas is still increasing and is expected to exceed 450 million super feet by the turn of the century. Present yield is over 300 million super feet per year, about one-third of which is from privately owned forests.

WESTERN AUSTRALIA

In Western Australia the sawmilling industry established in the south-west corner of the State has always catered for heavy structural requirements. A full range of general building sizes, flooring and weatherboards is produced also for consumption within the State and in South Australia and Victoria. Timbers in plentiful supply in normal cut include jarrah (general building purposes, flooring, furniture, wagon building, shipbuilding, sleepers, etc.) and karri (heavy constructional work, shipbuilding, wagon building) and plywood. Wandoo (heavy constructional work, wagon building, sleepers and cross-arms) is in limited supply. The general characteristics of Western Australian timbers are hardness, strength and durability.

The industry, which was largely based on an export trade in its earlier days (mining timbers, wharf timbers, railway wagon sections, cross-arms, sleepers, flooring, etc.), now finds most of its production absorbed by an increasing local population with exports down to about 20 per cent of production.

About two-thirds of this goes to the eastern states and one-third overseas. However, any considerable increase in the population of Western Australia will result in the whole of the permissible cut being absorbed by the State's own requirements. The development of pine plantations to supplement the

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State's indigenous forests will prolong the period of export availability of local hardwoods.

During recent years, great progress has been made by the Western Australian Forests Department in the rehabilitation of the jarrah and karri forests. Effective fire control methods involving considerable controlled burning in mild weather have been introduced, and a yield control plan established so that the cutting of these species is on a sustained yield basis. It will be possible to maintain supplies at the level of the present output in perpetuity.

Establishment of softwood plantations has been proceeding in Western Australia for many years, the area planted up to and including 1968 being some 60,000 acres. Current planting is at the rate of 6,000 acres per year with a target of 240,000 acres by the year 2000.

The total production of all species for the year 1967/68 amounted to 206,000,000 super feet, of which 5-8 per cent was exported overseas and 11-6 per cent interstate.

The recent signing of an agreement for the development of a wood chip industry based on forest produce not currently marketable, will result in an increase of the annual cut by some 30 per cent in the near future.

TASMANIA

In Tasmania two main types of indigenous forest may be distinguished; eucalypt and myrtle. The eucalypt type has the wider distribution and is the more useful. The best stands are found in the watersheds of the Huon and Derwent Rivers in the south, and on the foothills and the lower slopes of the mountain ranges in the north-west and north-east. They rank with the world's best hardwood forests.

"Myrtle" or "rain" forest is the predominant type in the wetter parts of the island where annual rainfall exceeds 60 inches, such as the West Coast. It also occurs as an understorey to eucalypt in the 45- to 60-inches rainfall belt.

A supplementary source of future timber lies in the plantations of softwoods being established by the Commission. These now total 31,554 acres.

The Tasmanian timber industry has always been an important contributor to Victorian and South Australian markets. The main timbers in plentiful supply are messmate stringybark, alpine ash and mountain ash (collectively known as Tasmanian oak, and used for general building purposes including flooring, weatherboards and joinery, and for furniture). These species also provide woodpulp for newsprint, writing and printing papers, and for fibre board. Particle board is being produced from plantation-grown radiata pine.

Other timbers produced are myrtle beech (joinery, furniture and rotary cut veneers), blackwood (furniture and cabinet work, parquetry, cooperage, handles, sliced veneers), sassafras (turnery, veneers, clothes pegs) and small quantities of Huon pine (boat-building), celery-top pine (boat-building and joinery) and King William pine (joinery, pattern making, small boat-building, musical instruments). Large quantities of mixed species are also being used in the manufacture of wallboard.

About 51 per cent of current production of sawn timber is sold within the

State; 48 per cent is sold in other Australian States, and 1 per cent is shipped overseas, mainly to the United Kingdom.

The pulp and paper industry consumed 195·7 million super feet (Hoppus) of log timber in 1966-7, including timber used for the manufacture of fibre board and particle board.

A preliminary survey of Tasmanian forest resources indicates that the cutting of eucalypts at the present rate can be continued indefinitely, provided existing and future young growth is protected from fire. Organisation of forest fire protection is being steadily developed.

<center>*PAPUA-NEW GUINEA</center>

The Territories of Papua and New Guinea, with adjacent islands, including the Bismarck Archipelago, lie wholly within the tropics and comprise some 180,000 square miles. This is rather more than half the size of New South Wales. The Territories are administered conjointly by the Commonwealth.

Generally speaking, the configuration of the "mainland" and the main islands is extremely rugged with many peaks over 10,000 feet and one, Mount Wilhelm in the Bismarck Ranges, reaching 15,400 feet—twice the height of Mount Kosciusko.

As may be expected, a wide variation of climate is found, ranging from humid tropical on the coast to alpine, with occasional snowfalls, on the highest mountains. From 3,000 to 6,000 feet a most delightful climate is experienced.

The forests of the Territories may be classified broadly as Lowland Forest-Littoral, Rainforest and Mid-Mountain Forest.

Lowland Forest-Littoral

Species represented are calophyllum, kwila *(Intsia bijuga), Terminalia spp.* and New Guinea rosewood *(Pterocarpus indicus).* Swamp forests, carrying almost pure stands of *Terminalia brassii,* are to be found in the coastal areas of Bougainville.

Rainforest

Rainforest occupies much of the well-drained soils from sea level up to the tree-line at about 13,000 feet. The principal species are determined by altitude. Coastal and foothill forest contains most of the potentially accessible millable timbers. Important dominants include taun *(Pometia pinnata),* erima *(Octomeles sumatrana),* New Guinea walnut *(Dracontomelum mangiferum),* kwila *(Intsia bijuga),* New Guinea teak *(Vitex coffasus), Calophyllum spp.,* satinash *(Syzygium spp.)* milkwood *(Alstonia spp.),* kamarere *(Eucalyptus deglupta), Anisoptera polyandra* and many others. All of these are valuable timbers when used for the purposes to which their properties are best suited.

The stocking per acre varies greatly from place to place. From 2,000 to 60,000 super feet of mature timber per acre would cover the range of this

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type, but the average over large areas is low. Fairly extensive areas of selected forest will, however, average from 10,000 to 15,000 super feet per acre.

Certain of these areas are being made available to private enterprise, offering opportunity for the supply of a variety of cabinet and plywood timbers to Australian and overseas markets. A description of the principal of these timbers may be found in Chapter XIII.

Mid-Mountain Forest

There is considerable variation in the limits occupied by this type, ranging from 1,500 to 7,000 feet. It comprises the *Araucaria* and the oak forests.

These forests offer the best development of commercial species in the Territories but, except for a limited area in the Bulolo Valley, they will not be economically important for many years, due to inaccessibility. Klinkii pine *{Araucaria klinkii)* reaches a height of 280 feet and in association with hoop pine *(Araucaria cunninghamii)* sometimes achieves a stocking of 150,000 super feet per acre. Red cedar *(Toona australis)* is found in mixture. Almost pure patches of *Castanopsis* occur with *Pasania* and *Lithocarpus,* all of the oak family, well represented. Some silkwood *(Flindersia pimenteliana)* is also present.

The stands of the Bulolo Valley are estimated to carry 500 million super feet of pine. They are being harvested by Commonwealth-New Guinea Timbers Ltd. on a sustained yield basis. The plywood factory at Bulolo was established by this company with an annual output of 30,000,000 square feet of plywood. Plantations of the two araucarias will replace the original stands a. they are milled out.

Other than the development of the Bulolo Valley pine, exploitation of the timber resources of the Territories has been and is still on a very limited scale. This situation may well change in the not distant future when the properties of the more abundant species are fully understood and appreciated, and when problems of harvesting, transport and marketing are attacked with courage and vision.

Australia, with a expanding population, and a diminishing supply of indigenous softwoods and cabinet timbers, may well look to the Territory for much of these specialised requirements. Financial, political, or military crises could drastically curtail the flow of essential timber hitherto derived from sources far afield. The proximity of Papua-New Guinea and the fact of its inclusion within the Australian economy warrant the closest attention of the industry to this aspect of our timber economy.

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TABLE 4

SAWNWOOD[a]—APPARENT CONSUMPTION BY STATES[0]

Year	N.S.W.[b]	Vic.	Qld.	S.A.	W.A.	Tas.	N.T.[c]	Aust.[d]
	Total Apparent Consumption (Thousands of Superficial Feet)							
1938–39	328,952	238,732	168,199	89,371	68,157	43,937	35	937,340
1946–47	361,136	320,758	207,141	93,694	73,374	68,039	...	1,124,142
1959–60	589,831	516,515	276,752	169,232	125,384	95,207	2,478	1,775,399
1962–63	528,622	445,576	239,581	178,024	116,096	98,905	3,108	1,609,992
1963–64	583,447	462,722	255,499	195,673	131,309	99,816	4,000	1,732,466
1964–65	610,358	480,566	269,073	209,291	133,787	95,156	3,996	1,802,227
1965–66	563,855	460,418	254,620	197,680	148,290	104,313	5,378	1,734,554
1966–67*	553,351	459,486	240,821	160,673	138,674	92,772	3,721	1,649,498

"Source: Forestry and Timber Bureau.   *Provisional.   ... Not available.

(a) Includes Sawn Equivalent of Ply and Veneers; Excludes Sawn Sleepers; Includes broadleaved plus coniferous.
(b) Includes the Australian Capital Territory.
(c) Excludes figures of Production and Interstate Imports in 1938-39 and 1946-47.
(d) Excludes Northern Territory in 1938-39 and 1946-47.

TABLE 5

PLYWOOD—APPARENT CONSUMPTION, AUSTRALIA[1]

(Thousands of Square Feet ^{3}/ie" Basis)

	1938–39	1946–47	1959–60	1962–63	1963–64	1964–65	1965–66	1966–67*
Production	104,805	123,273	242,100	195,262	216,282	217,059	187,258	203,403
Imports	2,890	14	29,522	26,040	30,398	47,298	53,756	59,559
Exports	3,016	31	757	789	735	619	1,556	3,611
Apparent Consumption	104,697	123,256	270,865	245,945	245,945	263,738	239,458	259,351
Apparent Consumption per capita (square feet)	15·1	16·4	26·7	20·3	22·2	23·4	20·8	22·1

°Source: Forestry and Timber Bureau.   *Provisional.

TABLE 6

SAWNWOOD[a]—APPARENT PER CAPITA CONSUMPTION[0]
(Superficial Feet per Annum)

Year	N.S.W.[b]	Vic.	Qld.	S.A.	W.A.	Tas.	N.T.[c]	Aust.[d]
1938–39	119·7	127·6	167·4	150·0	145·9	181·6	...	135·3
1946–47	121·2	157·2	188·8	146·2	147·6	266·8	...	149·7
1959–60	153·4	183·7	187·4	181·2	174·4	271·2	103·3	174·7
1962–63	129·2	148·0	153·3	178·4	149·4	276·3	67·8	148·4
1963–64	140·4	150·9	160·2	191·5	164·3	275·0	80·0	156·7
1964–65	144·4	153·1	165·4	198·9	163·6	260·0	75·4	159·8
1965–66	131·0	144·1	153·5	182·5	177·0	281·9	97·8	150·8
1966–67*	127·7	141·4	142·7	145·5	160·7	248·1	64·2	140·9

"*Source:* Forestry and Timber Bureau.

•Provisional.

... Not available.

(a) Includes Sawn Equivalent of Ply and Veneers; Excludes Sawn Sleepers; Includes broad-leaved plus coniferous.

(b) Includes the Australian Capital Territory.

(c) Excludes figures of Production and Interstate Imports in 1938-39 and 1946-47.

(d) Excludes Northern Territory in 1938-39 and 1946-47.

TABLE 7

SAWNWOOD EXPORTS TO OVERSEAS*
(Thousands of Superficial Feet)

Year	N.S.W.	Vic.	Qld.	S.A.	W.A.	Tas.	Total
1938-39	8,101	569	*All*	—	26,178	1,311	36,631
1946-47	4,566	639	506	—	8,381	644	14,736
1959-60	5,135	646	533	337	8,086	1,219	15,956
1961-62	5,510	699	459	—	10,953	930	18,551
1962-63 .	4,349	564	504	10	9,224	1,114	15,765
1963-64	4,974	850	458	—	8,652	1,387	16,321
1964-65	5,776	578	600	3	10,913	1,075	18,945
1965-66	6,260	584	977	1	5,672	641	14,135
1966-67	5,215	562	494	—	6,781	792	13,844

Source: Forestry and Timber Bureau.

TABLE 8
TIMBER IMPORTS FROM OVERSEAS*
(Thousands of Superficial Feet)

Year	N.S. W.	Vic.	Qld.	S.A.	W.A.	Tas.	N.T.	C'wlth
			Logs (Sawn Equivalent)[a]					
1938–39	69,372	6,880	1,829	11,072		2	1	89,156
1946–47	1,712	703	—	—	19	206	—	2,640
1962–63	18,318	2,204	7,419	492	5,258	—	—	33,691
1963–64	13,399	1,526	8,202	370	5,465	—	1	28,963
1964–65	20,584	1,424	8,312	700	5,443	—	—	36,463
1965–66	11,067	1,628	4,493	248	5,345	133	—	22,914
1966–67	14,689	2,089	7,664	225	5,175	—	—	29,842
			Total (Logs and Sawn)[b]					
1938–39	139,563	83,663	4,489	50,726	5,138	5,620	36	289,237
1946–47	66,470	33,735	397	22,893	1,271	920	—	125,686
1962–63	178,298	47,364	17,840	58,024	10,222	130	981	312,859
1963–64	201,086	56,566	19,842	72,312	11,744	560	1,576	363,686
1964–65	209,017	62,026	21,337	77,439	16,643	114	2,208	388,784
1965–66	185,041	56,541	17,646	68,646	13,012	256	3,391	344,533
1966–67	196,224	60,496	19,051	56,769	15,074	294	2,093	350,001

*Source: Forestry and Timber Bureau.
—Nil or less than half the appropriate unit.
(a) Estimated recovery factor is 2/3 Hoppus Log Measure.
(b) Sawn timber excludes dunnage.

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TABLE 9
RAILWAY SLEEPER PRODUCTION"
(Thousands of Superficial Feet)

Year	(Type)	N.S. W.	Vic.	Qld.	S.A.	W.A.	Tas.	Aust.
1938-39	Sawn	421	1,759	8,560	2,000	20,598		33,347
	Hewn	29,816	7,296	9,060	4,556	18,816	3,004	72,548
	Total	30,237	9,055	17,620	6,556	39,414	3,004	105,895
1946-47	Sawn	964	344	9,685	502	23,807		35,302
	Hewn	29,695	7,554	5,707		92	1,558	44,606
	Total	30,659	7,898	15,392	502	23,899	1,558	79,908
1959-60	Sawn	17,399	3,538	39,543	941	42,534		103,955
	Hewn	24,597	32,306	768			3,500	61,171
	Total	41,996	35.844	40,311	941	42,534	3,500	165,126
1962-63	Sawn	24,245	5,280	26,516	1,873	45,149	566	103,629
	Hewn	24,317	16,560	893			2,863	44,633
	Total	48,562	21,840	27,409	1,873	45,149	3,429	148,262
1963-64	Sawn	19,109	6,827	37,192	1,830	43,603	922	109,491
	Hewn	22,496	18,883	977			3,083	45,439
	Total	41,605	25,710	38,169	1,830	43,603	4,005	154,930
1964-65	Sawn	19,047	6,947	27,627	2,045	49,172	850	105,688
	Hewn	20,631	20,152	880			2,487	44,150
	Total	39,678	27,099	28,507	2,045	49,172	3,337	149,838
1965-66	Sawn	26,794	7,774	25,566	2,171	57,870	864	121,039
	Hewn	27,044	21,535	880			3,969	53,428
	Total	53,838	29,309	26,446	2,171	57,870	4,833	174,467
1966-67*	Sawn	24,801	5,500	27,693	1,227	52,928	864	113,013
	Hewn	26,372	16,242	880			5,740	49,234
	Total	51,173	21,742	28,573	1,227	52,928	6,604	162,247

*Pro visional.

... Not available.

—Nil or less than half the appropriate unit.

"*Source:* Forestry and Timber Bureau.

TABLE 10

RAILWAY SLEEPERS[0]—OVERSEAS EXPORTS (Sawn and Hewn)

(Thousands of Superficial Feet)

Year	States of Shipment			Total	Destination					
	N.S.W.	fV.A.	Other States		Europe[a]	Africa[b]	Asia[c]	New Zealand	South East Asia[d]	Pacific Area
1938-39	11,571	22,463	2	34,036	1,438	9,702	5,799	16,896		201
1946-47	4,188	3,818	333	8,339	194	1,259	315	4,231		398
1959-60	4,743	26,955	391	32,089	7,019	824	20,397	3,810	1,942	39
1962-63	90	22,908		22,998	8,670	5,659	5,684	2,965		20
1963-64	401	21,099	78	21,578	543	12,019	5,119	3,894		3
1964-65	321	9,196	218	9,735	456	5,332	1,213	2,701		33
1965-66	428	4,344	20	4,792	1,472	723	337	2,240		20
1966-67	633	24,875	515	26,023	1,932	2,836	18,417	2,838		

— Nil or less than half the appropriate unit.

(a) Includes the United Kingdom; *(b)* Includes the Island of Mauritius; *(c)* The Asian Continent including Ceylon and Japan; *(d)* Includes Malaysia.

TABLE 11

°RAILWAY SLEEPERS—APPARENT CONSUMPTION
AUSTRALIA

(Thousands of Superficial Feet)

Ypm-	Production			Imports	Exports	
	Sawn	Hewn	Total			
1938-39	33,347	72,548	105,895		34,036	71,859
1946^17	35,302	44,606	79,908	—	8,339	71,569
1959-60	103,955	61,171	165,126	—	32,089	133,037
1962-63	103,629	44,633	148,262	—	22,998	125,264
1963-64	109,491	45,439	154,930	—	21,578	133,352
1964-65	105,688	44,150	149,838	—	9,735	140,103
1965-66	121,039	53,428	174,467	—	4,792	169,675
1966-67*	113,013	49,234	162,247	—	26,023	136,224

*Provisional Figures.

—Nil or less than half the appropriate unit.

°Source: Forestry and Timber Bureau.

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II

SYSTEMS OF MEASUREMENT

Many different systems are in use throughout the world for calculating the contents of log and sawn or otherwise converted timber. For example, in North America alone there are at least seven systems of measuring logs—the Doyle, Scribner, International, Spaulding, British Columbia, New Brunswick and Roy log rules. In addition there is the Brereton Scale, which gives the approximate true volume, and which is used largely in connection with export specifications. Again, some countries use methods and formulae similar to our own, but the mensuration is in terms of the metric system. In the case of sawn timber (termed "lumber" in North America) the unit of measurement is variously expressed in different countries in terms of superficial feet, board feet, cubic feet, cubic metres etc. Here we shall examine in detail only those systems generally applicable to Australia.

LOGS

Many of the overseas systems of measuring logs are based on the estimated average production therefrom of marketable sawn timber. Since average returns will vary considerably with different species and grades, such systems can only effectively apply to specific classes of timber. Two systems, the so-called Brereton Scale and the Hoppus Method, each having a direct relation to the actual solid contents of round logs are in use in Australia. The Brereton Scale which is also referred to as "true measurement", is used in South Australia, Western Australia, the Australian Capital Territory and the Territory of Papua-New Guinea, as well as in the case of logs imported from North America. The Hoppus Method applies to logs produced in the other states or imported from Borneo and Pacific Islands.

Brereton System

This aims at expressing in terms of superficial or board feet (q.v.) the contents of a round log. It is based on the formula for the volume of a cylinder, using as the variable factors the *average* of the end diameters of the log as

diameter, and the length of the log. The average diameter is arrived at by measuring (under the bark and at right angles to each other) two diameters at each end of the log, adding these four separate measurements, and dividing by four. Or, as is sometimes more convenient, adding the average of the two end diameters and dividing by two. Two measurements are necessary to obtain an average for each end diameter since few logs are perfectly round.

The formula: $(d^2 \times L \times \cdot 7854) \div 12$

(where d = average diameter in inches; L = length in feet)
will give very approximately the actual solid contents of the log in terms of superficial feet.

The above formula is not strictly correct in that it is based on the volume of a true cylinder, using the average of the end diameters of the log as a correction for taper, and also for oval ends which frequently occur. Were a log truly round and in true taper it would represent a frustum of a cone, and the formula therefore would yield a slightly different result. In the case of a reasonable taper, however, the difference is negligible.*

Variations in the physical "roundness" of logs (e.g., oval shapes) involve differences in the solid content and some illustration of this is given in Tables 4 and 5 on page 17. It would be impossible to incorporate these and other physical variations in any tabulated figures, and marked variations due to distortions from the round or the straight have to become the subject of allowances as between seller and buyer.

Hoppus Method •'

The Hoppus String Measure, as it was originally termed, is also sometimes known as the Quarter Girth Method, the latter designation arising from its formula. It is a very old system. A *Hoppus Calculator,* 2nd edition, dated 1738, is in the possession of the Timber Research and Development Association Ltd., United Kingdom.

Hoppus measurement is based on the formula:

$$G^2 \times 3/4L, \text{ or } \left(\frac{g}{4}\right)^2 \times \frac{L}{12} = \text{contents in super feet}$$

(where G = mean girth in feet, g = mean girth in inches, L = length in feet).

It is from the latter identity that the designation Quarter Girth System is derived.

Under the Hoppus Method the girth (under bark, at the centre of the log) is measured by a tape. When logs are not debarked it is necessary to cut away a ring of bark in order to measure the log. Occasionally, to avoid this an allowance is made for bark.

* The volume of a frustum of a cone is given by the formula: $.2618 \times L (D^2 + d^2 + D.d)$ where D and d = diameters at each end, and L = length. Where D and d are applied in inches, and L in feet, and the result divided by 12, the volume or content would be in terms of superficial feet. The contents of a perfect log with end diameters of 48 in. and 36 in., and 40 ft. in length, using the above formula = 4649·568 sup. ft. Using Brereton Scale $(d^2 \times L \times \cdot 7854) \div 12 = 4618 \cdot 152$ sup. ft.

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An advantage of the Hoppus Method is that it avoids the averaging of the four measurements involved in the Brereton System. Again, separate measurements made under the latter system can differ slightly since the measurements can be taken at various diameters which may not coincide owing to the shape of the log ends.

The relation of Hoppus measurement to the actual contents of a log measured under the Brereton System is constant and may be expressed as $\frac{\pi}{4}$, or as -7854:1.

The following are useful relationships in converting one measurement to the other:

To convert Brereton measure to Hoppus: multiply by -7854
To convert Hoppus measure to Brereton: multiply by 1-2732
To convert circumference to diameter: multiply by -31831
To convert diameter to circumference: multiply by 3 • 1416
To compute Brereton measurement using the mean girth:

$$\frac{g^2 \ x\, 2L}{300} \ (Approx.)*$$

Brereton measure is greater than Hoppus measure by 27.32%
Hoppus measure is less than Brereton measure by 21 .46%
To convert price per 100 super feet Brereton to equivalent price per 100 super feet Hoppus: multiply by 1 -2732
To convert price per 100 super feet Hoppus to equivalent price per 100 super feet Brereton: multiply by -7854.

"Oval" Logs

It is not generally appreciated to what extent the solid content of a log will vary in proportion to its distortion in shape. A common distortion is from the round to the oval.

TABLE 12

VARIATIONS IN CONTENTS OF LOGS "OUT OF ROUND"

Based on comparative values of ellipses and a circle.
Average of the diameters constant = 24 in.
Variations in the axis (i.e., "diameters") of ellipses: 2 in. Length: 20 ft.

Diameters	Girth	Sup. ft.	Brereton	Hoppus
			Sup. Ft.	Sup. Ft.
Average == 24 in.	in.	(Actual)	(Constant)	(vary acc. to g.)
a b				
24 24 (circle)	75-40	754	754	592
26 22	75-53	749	754	594
28 20	75-92	733	754	600
30 18	76-56	707	754	611
32 16	77-44	670	754	625

* Actually g2 x 2L   ÷301.6.

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TABLE 13

Based on comparative values of ellipses and a circle.
Girth constant = 24π = 75·40 in.

Diameters		Girth	Sup. ft.	Brereton	Hoppus
		in.	(Actual)	Sup. ft.	Sup. ft. (Constant)
24	24	75-40	754	754	592
26	21-9(22)	75-40	746	751	592
28	19-6 119V.)	75-40	720	743	592
30	17-1 (17)	75-40	673	727	592
42	14-3 (14)	75-40	602	704	592

Area of a circle: πr^2 or $D^2 \times \cdot 7854$.
Area of an ellipse: $\pi T.C.$
Perimeter (girth) of an ellipse: $\frac{1}{2}\pi(\sqrt{2(T^2+C^2)}+T+C)$
Where r = radius; D = diameter; T = semi-transverse axis; C = semi-conjugate axis.

For the purpose of illustration the relationship may be expressed as the proportion in area of ellipses to a circle, the former maintaining the same *average* diameter as the circle. To simplify the illustration, taper will be ignored and comparison made of a cylinder pushed out of shape with its cross section as an ellipse.

Waste in Conversion and Cost of Product

In the conversion of logs to sawn timber, waste inevitably occurs. The actual amount of waste can only be ascertained by the measurement of the marketable timber recovered from the log, or parcel of logs, after they have been sawn.

In Australian practice, the waste in conversion is usually accepted for costing purposes as a fixed percentage of the Hoppus measurement, such percentage varying according to the species and class of log concerned. The percentage of waste in conversion is determined in the first place by experience, based on the measured output recovered from an average parcel or parcels of a specific species and class of log.

To the cost of the log at mill must be added the cost of converting to sawn timber, based on the Hoppus measurement.

The fractional loss, such as one-third, one-quarter, and one-fifth, etc., or percentage loss, such as 20 per cent or 25 per cent, of the log, can be applied to the sawn output as follows:

Cost of Hoppus measurement, at mill say	$8.00 per 100 sup. ft.
Cost of conversion, say	$1.00 per 100 sup. ft.
(A) Cost of sawn log, Hoppus measure	$9.00 per 100 sup. ft.
Waste estimated at ⅕th of Hoppus measure: add ¼	$2.25 per 100 sup. ft.
	= $11.25 per 100 sup. ft

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(B) Cost of output

For fractional losses in conversion, as above:

For 1/5*th* loss in conversion	(a) + **1/4 (a)** — (b)
For 1/4th loss in conversion	(a) + **1/3(a)** = (b)
For 1/3rd loss in conversion	(a) + **1/2(a)** = (b)
For $^1/_2$ loss in conversion	(a) + (a) = .(b)

In other words, if the loss in conversion is $\frac{1}{x}$ of (A) then the cost of output will be increased by $(A) \times \frac{1}{x-1}$

For loss in conversion expressed as a percentage of the Hoppus measurement, the calculation is as follows:—

Cost, Hoppus measurement, at mill, say	$8 per 100 sup. ft.
Cost of conversion, say	$1 per 100 sup. ft.
(A) Cost of sawn log, Hoppus measure	$9 per 100 sup. ft.

Waste estimated at 20% of Hoppus measure,

i.e. *Recovery* estimated at 80% of Hoppus measure.

$$\text{Then, (B)} = \frac{900 \times 100}{80} \text{ cents} \qquad = \$11.25 \text{ per 100 sup. ft.}$$

In other words, multiply the cost of the sawn log, Hoppus measure, by 100, and divide by the estimated percentage of recovery.

The latter method must be used where the estimated percentage loss in conversion cannot be expressed as a simple fraction such as one-fifth, or one-quarter and so on.

The above examples do not take into account the value (if any) of "waste", i.e., slabs, sawdust, etc., nor of overhead or similar costs. It is intended here only to indicate the trade method of arriving at the estimated cost of the sawn timber converted from logs, based on an arbitrary estimate of the waste in conversion.

Measurement of Cordwood

Cordwood is the name given to round timber, measured under the bark in hardwoods and softwoods and used for fuel or pulping purposes as required. The unit, one cord, equals 128 cubic feet of stacked timber. Individual pieces are usually of a standard length of 8 feet with a minimum diameter of 4 inches at the small end.

In the Australian Capital Territory softwood is hauled in loads consisting of three cords which are found to average 2,700 super feet true round volume per load. One cord of hardwood is reckoned to weigh two tons (4,480 lb.).

METHOD OF ESTIMATING THE YIELD OF VENEER
FROM ROUND LOGS

Several methods of estimating the theoretical yield of veneer peeled from logs have been developed. One such method has been published by the Division of Wood Technology, New South Wales, in *Technical Notes,* vol. 5, no. 2. This involves the use of a nomogram or system of scales from which

may be read off the theoretical yield of veneers of various thickness. Corrections can be applied to cover some of the irregularities in shape common to most logs.

A formula sometimes used in plywood factories for estimating the theoretical veneer content of a log is as follows: *

$$\frac{B}{2} + \left(A - \frac{B}{2}\right) \; 3 \cdot 14 \times \frac{(A - B)}{2} \times \text{L.N.} \div 12 = \text{Yield in sq. ft.}$$

Where A = outside average diameter of log in in.
           B = diameter of core in in.
           L = length of log in ft.
           N = number of veneers per inch thickness.

It must be emphasised that such methods and formulae aim to indicate merely the theoretical yield and do not take into account the inherent defects to be found to a greater or lesser degree in logs of all species.

In practice, in the estimation of the expected yield of useful veneer, it is usual to rely upon experience based on the actual average yield from a particular timber species.

Thus for a species "A" there might be an expected yield of 9•3 square feet of 1/16 inch veneer per super feet of log based on Hoppus measurement, for species "B", an expected yield of 10-6 square feet, and so on. These yields are then expressed as percentages of the theoretical possible yield as follows:

Conversion percentage A: $\dfrac{9 \cdot 3 \times 100}{16}$ = 58 per cent (approximately)

Conversion percentage B: $\dfrac{10 \cdot 6 \times 100}{16}$ = 66 per cent (approximately)

WEIGHT OF A FLOATING LOG

Occasionally, in order to avoid overstrain of lifting gear, it is advisable to know the weight of a floating log. This can be determined by calculating displacement. The latter will vary slightly according to the degree of salinity of the water in which the logs are floating. Values for fresh water may be adjusted for salt water by multiplying by 1-027 (an accepted value for the specific gravity of salt water).

From the table below, the weight of a floating log can be determined with reasonable accuracy. The following data are required. (Fig. 1).

1. Mean vertical diameter in inches of the two ends (A).
2. Mean vertical distance in inches above water level (H).
3. Value of H as a percentage of A.
4. Actual contents in feet *(vide* Brereton Scale).

The percentage of H to A is found simply by multiplying H by 100 **and** dividing by A.

Using this percentage, the weight of the timber per 100 super feet can be read from the table. It should be noted that the values vary slightly according to whether the log is floating in fresh or salt water.

may be read off the theoretical yield of veneers of various thickness. Corrections can be applied to cover some of the irregularities in shape common to most logs.

A formula sometimes used in plywood factories for estimating the theoretical veneer content of a log is as follows: *

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Where A = outside average diameter of log in in.
　　　　B = diameter of core in in.
　　　　L = length of log in ft.
　　　　N = number of veneers per inch thickness.

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WEIGHT OF A FLOATING LOG

Occasionally, in order to avoid overstrain of lifting gear, it is advisable to know the weight of a floating log. This can be determined by calculating displacement. The latter will vary slightly according to the degree of salinity of the water in which the logs are floating. Values for fresh water may be adjusted for salt water by multiplying by 1-027 (an accepted value for the specific gravity of salt water).

From the table below, the weight of a floating log can be determined with reasonable accuracy. The following data are required. (Fig. 1).

1. Mean vertical diameter in inches of the two ends (A).
2. Mean vertical distance in inches above water level (H).
3. Value of H as a percentage of A.
4. Actual contents in feet *(vide* Brereton Scale).

The percentage of H to A is found simply by multiplying H by 100 and dividing by A.

Using this percentage, the weight of the timber per 100 super feet can be read from the table. It should be noted that the values vary slightly according to whether the log is floating in fresh or salt water.

* Acknowledgement: Associated Plywoods Pty. Ltd., Sydney.

The weight of the timber per 100 super feet being known, the weight of the log can be ascertained by applying this to the actual contents of the log according to the Brereton Scale.
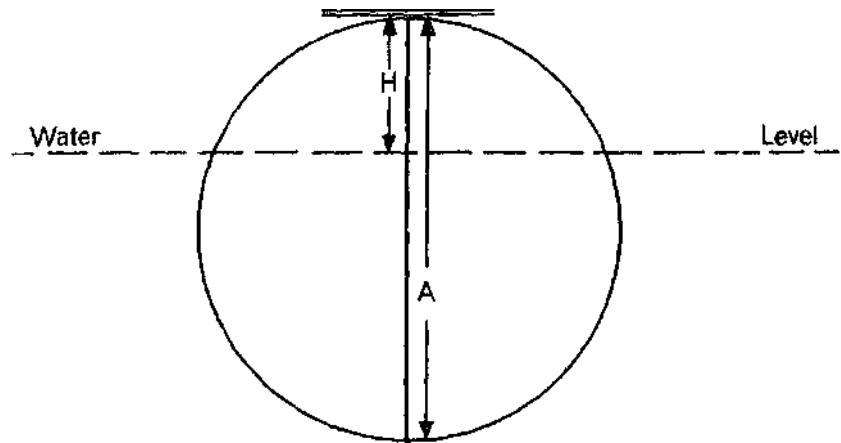
Figure 1.

TABLE 14

WEIGHT OF A FLOATING LOG

Percentage of diameter above W.L.	*lbs. per 100 sup. ft.* (fresh)	*lbs. per 100 sup. ft.* (salt)
50	260.1	267-1
48	273-3	280-7
46	286-6	294-3
44	299-7	307-8
42	312-9	321-3
40	325-9	334-7
38	338-8	348-0
36	351-6	361-2
34	364-2	374-1
32	376-7	386-9
30	388-9	399-4
28	401-0	411-8
26	412-7	423-9
24	424-2	435-6
22	435-3	447-1
20	446-1	458-2
18	456-5	468-9
16	466-5	479-1
14	475-9	488-8
12	484-8	497-9
10	493-1	506-4
8	500-7	514-2
6	507-5	521-2
4	513-2	527-1
2	517-7	531-7
0 (Awash)	520-2	534-2

Classification of Sizes

It may be advisable, under this heading, to mention the classification under which, according to their sizes, various pieces of sawn or converted timber fall. The terms are generally used very loosely.

Strip: Under 3/4 in. thick and up to 3 in. wide. A strip also refers to the pieces used in the seasoning of timber for separating the boards to facilitate drying. These are usually 3/4 in. or 1 in. thick and from 3/4 in. to 1 1/2 in- wide. Sometimes called stickers.

Batten: 3/4 in. and under 1 1/2 in. thick and from 1 in. to 3 in. wide.

Boards: 3/8 in. to 1 1/2 in. thick and 3 in. and over wide.

Planks and

Sheeting: Over 1 1/2 in. and up to 4 in. thick and over 6 in. wide.

Scantlings: Sawn to dimensions of up to 6 X 4 in.

Heavy scantling: \

Flitch: \ Over 4 in. thick and/or over 6 in. wide.

Baulk:)

Deal: Applied generally to European softwoods between 2 in. and 4 in. thick and 9 in. and wider.

Hewn timber: Timber shaped by axe or adze roughly to a given size.

(In North America the word "lumber" corresponds to the word "timber" as used in Australia. In the former countries, "timber" is defined as sawn material whose least dimension is 5 in.).

Superficial Feet

The unit of measurement of timber as used in Australia is the superficial foot. It is the equivalent of one square foot in area, 1 inch in thickness. A superficial foot is usually spoken of as a "super foot" and written in the abbreviated form, sup. ft. or s. ft.

Measurements of sawn timber (with certain modifications and exceptions mentioned later) and of the contents of logs are expressed in terms of super-ficial feet. Computations involving costs, statistics, etc., are usually based "per 100 super feet". In North America the corresponding term for "superficial foot" is "board foot" and computations in that continent are usually based "per 1,000 board feet", often abbreviated to per mb.m. (1,000 feet board measurement). In most British countries the superficial foot is the standard unit of timber measurement, though bases of computations vary (e.g. stand-ards, cubic foot, ton, load, etc.).

The method of finding the measurement of a sawn board in superficial feet is to multiply together width and thickness in inches and the length in feet, and to divide the result by 12. Thus the measurement in superficial feet of

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a board 10 inches wide, 1½ inches thick, and 16 feet in length is (10 inches X 1½ inches X 16) / 12 = 20 super feet. The Australian custom is to write the width and thickness thus: 10 x 1½, and the length thus 1/16. The North American custom is to write the thickness first, thus 1½ X 10. A number of boards of the same width and thickness but of various lengths, in Australia would be represented thus: 10 x 1½, 1/16, 2/17, 3/18, 1/20. In this example the sum of the lengths in feet (i.e., the lineal measurement) is 124 and the total measurement in superficial feet would be calculated thus:

$$(10 \text{ X } 1½ \text{ X } 124) / 12 = 155 \text{ sup. ft.}$$

Following is an example of a specification of a variety of sawn sizes together with the lineal and superficial footage of each size:

					Lineal ft.	Super
5 X 1	3/10	2/12	1/16	1/18	88	36^8
7 x 1	1/13				13	7^7
9 X 1	1/14				14	10^6
14 X 1	3/9	2/10	2/12	2/14	99	115^6
9 x 1½	2/10	2/12	2/14	3/16	120	135
16 x 1½	2/13	2/15	2/17		90	180
6 x 2	2/10	3/11	4/12	2/15	131	131
9 x 2	1/6	2/10	2/12	2/16	82	123
12 X 6	2/16	2/20	2/24	1/30	150	900
				Total		1,639/3

It will be noted that where, in calculating the above quantities, something more than an exact number of superficial feet results, this remainder is expressed in twelfths or inches, and is so denoted in small figures placed against the top of the right hand digit as shown.

As previously stated, the basis for costing, etc., is usually per 100 super feet. Assuming the price of the above parcel to be $5.00 per 100 super feet, the extension of the total would result as follows:

1639/3 @ $5.00 per 100 sup. ft. = $81.96 (to nearest cent)

Occasionally, as in the case of some expensive cabinet timbers, the custom is to cost on the unitary basis of one super foot.

Example:

*111** sup. ft. @ 10c. per sup. ft. = $17.73

Superficial Face Measurement

So far, in the foregoing remarks, only thickness of one inch or greater have been considered. A modified procedure is adopted for thicknesses of less than one inch. In such cases the measurement is based solely on the area in square feet of the board faces, the particular stock being identified, and its price determined, by reference to the thickness. The measurement of such stock is referred to as superficial face measurement, abbreviated to "sup. face", and to repeat, is simply the square footage of the stock concerned.

Example:

6 x 3/4, 10/20, 20/12, 20/14 (= 720 lineal) = 360 3/4 in. sup. face ft.

Lineal Measurement

This form of measurement refers to the sum of the lengths of boards or mouldings having the same dimension. It is also known as *running measurement.* Abbreviations for lineal feet and for running feet are written "lin. ft." and "ft. run." respectively. Round timber, such as piles and poles, and also hewn girders, are usually sold on a basis of lineal measurement. Lineal measurement applies also to mouldings and dressed timber of small dimension. In such cases the basis for costing, etc., is per 100 lineal feet.

Measurement of Dressed Timber

Methods of computing the measurements of dressed timber differ among some of the Australian states. For example, in Victoria and South Australia, the practice is to refer to quantitative measurements of *all* moulded timber including floorings, linings and weatherboards, in terms of *lineal* feet. In New South Wales and some other states the practice is to compute tongued and grooved items (and heavier moulded sections) in terms of the superficial measurement of the *nominal size* of the section. *Nominal size* refers to the original intended dimensions of the section before machining (e.g. 4 x 1) . *Finished size* refers to the dimensions (i.e. width and thickness) after machining (e.g. 3¾ X ¾). In the case of tongued and grooved (abbreviated T & G) items, the finished width refers to the face of the board, excluding the tongue. Further references to the terms "dressed" and "mould" and relative abbreviations DD, DAR, etc., are given in the Glossary.

Plywood Measurement

Plywood is manufactured in sheets of standard sizes and thicknesses, the commonest of which is 6 X 3 x 3/16ths. Plywood measurement is based on surface area in square feet (super face measurement).

OTHER MEASUREMENTS

The Petrograd Standard

The Petrograd Standard (abbreviated "std.") is used in Scandinavian countries and largely in the United Kingdom as a basis of costs, loadings, statistics, etc. Without examining the origin of this awkward and inconvenient figure, it is sufficient to state that it represents the equivalent of 1,980 superficial feet, or 165 cubic feet.

The Cubic Foot

In some British countries (e.g. British North Borneo) timber measurement as applied to both logs and sawn timber is calculated on the basis of the cubic foot (abbreviated "cu. ft."). The 7th British Forestry Conference (1957) passed a resolution that all British Commonwealth countries should use the cubic foot in referring to volumes of logs. To convert cubic feet into superficial feet or vice versa it is merely necessary to multiply or divide respectively by 12.

Example:

        1 cu. ft. = 12 sup. ft. 100 sup. ft. = 8 1/3 cu. ft.

Tonnage Measurement

This measurement is used in Malaya, Sarawak and several other countries and applies to both logs and sawn timber. The ton is assumed to consist of 50 cubic feet, or 600 super feet. It is important not to confuse this measurement, as used by the timber industries in the countries concerned, with the *shipping ton* as applied to timber. This latter is usually calculated at 40 cubic feet per ton.

The Load

The unit of 600 super feet is also known as a load and is in common use in the United Kingdom when applied to timbers of other than European origin. The load unit is also used extensively in Western Australia. It is important to know that the load unit, when applied to round timber, i.e., logs etc., refers to the actual contents (Brereton measurement) and must not be confused with the Hoppus system of measurement as is customary in the eastern states of Australia.

The Metric System

The unit of timber measurement under the metric system is the "cubic metre" (abbreviated "M^3"). It is the equivalent of 35.314 cubic feet or 423.77 superficial feet (100 super feet = 0.236 cubic metres; 100 square feet = 9.29 square metres; 100 lineal feet = 30.48 metres).

In some continental countries, the "metric foot", or 1/3 metre, is used in timber measurement. The metric foot equals 13 1/8 inches in English measure. For practical purposes, in converting metres to feet, it is often convenient to regard 4 metres as the equivalent of 13 feet, and vice versa. (4 metres = 13.1233 feet; 13 feet = 3.9624 metres.)

The "cord" is a unit of measurement equalling 128 cubic feet true measure.

The "cunit" is a unit of measurement (usually applied to round-wood for pulp manufacture) equalling 100 cubic feet true measure.

LOG MEASUREMENT TABLES

Tables for reckoning the contents of logs are not included in this handbook owing to the amount of space that would be required for effective tabulation. Such tables (Brereton, Hoppus, etc.) are available, however, and relative information may be obtained from the Timber Development Association and similar timber authorities.

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III

METHODS OF SAWING LOGS*

The proportion of marketable timber recoverable from a given quantity of logs is ever variable and depends upon a number of factors. Principal among these are the class and quality of logs to be sawn, the specification to which the output is required to conform, and the judgement of the sawyers.

The rate of production is also influenced by the above factors, but will also depend upon the design of the mill, the saws used, sufficiency of power, and various considerations of a mechanical nature. Not the least important factor, however, in the conversion of logs to sawn timber is the full use of experienced judgement and of care in sawing and selection.

Although these latter considerations may, and usually do, slow down production, it invariably happens that careful attention in the initial stages of timber manufacture is noticeably reflected in a higher quality product, and in lower costs in the subsequent processes of seasoning, re-manufacturing, machining, and general yard handling. Sawmill efficiency is not, therefore, to be measured only in terms of volume of production per man hour, but rather in timber value per man hour.

Mill design and methods of sawing in Australia are largely governed by the class of timber to be sawn, i.e., softwood or hardwood. These latter terms are used here in their broad meaning as applying on the one hand to the more soft textured timbers such as pine, coachwood, maple and similar cabinet timbers, and on the other to the great family of eucalypts and similar timbers of marked density.† The former are sawn to sizes suitable for finished work, whilst the majority of the latter are converted to dimension sizes for structural purposes. There are exceptions in both cases but, generally speaking, mill design and methods of conversion depend upon the class of logs to be sawn and are further modified by the average size of logs available.

* Information contained in this Chapter is drawn largely from *Trade Circular* no. 34 issued by the Division of Forest Products, C.S.I.R.O.

t The botanical difference between softwood and hardwood is explained in Chapter XIV.

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In sawing logs into boards at the mill, there are several distinct and fairly standardised methods of handling the log.

The simplest method is that of ripping the log into boards by means of a series of parallel saw cuts without any turning of the logs. This method is known as "live sawing" or "sawing through and through".

Other methods involve a turning of the log as sawing proceeds so that the cuts are made in different planes. These methods are known collectively as "sawing around".
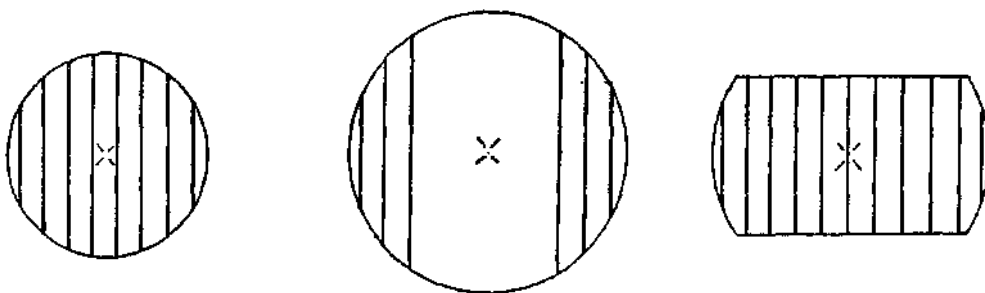
Live Sawing

Live sawing is illustrated in Fig. 2. This system is practised in the larger Australian radiata pine mills, in most of which gangsaws are used in converting plantation grown logs. Live sawing is also used for cutting cypress pine logs in New South Wales and Queensland, where the logs are passed over the usual breast-bench after a preliminary "spotting" or facing of one side on a breaking down bench.

Apart from these two instances, live sawing is not regularly used in Australia, though it is the usual method of sawing in Europe, particularly in the Baltic countries, and is also used to some extent in America for small logs.

The live sawing method is well suited to mass production, and gives the highest recovery from the log, at lowest milling cost. The logs are simply fed into the saws, and the boards emerge from them in a constant stream without any turning of the logs or returning of any material for re-cutting. Production is rapid and the procedure is standardised, requiring no high degree of skill. Operating costs are therefore held at a minimum.

The method lacks elasticity however, and is not suited to the production of timber of varied sizes and qualities. It is not possible, with live sawing, to segregate clear from knotty timber, nor can defective logs be handled without heavy loss. Furthermore, due to the mixed grain occurring in most of the boards, live sawing can be practised successfully only with light and easily seasoned timbers. Otherwise, heavy seasoning degrade is encountered in the form of cupping, warping and unequal shrinkage.

Single Cutting, 9"Log   Double Cutting, 12"Log

Figure 2. Live sawing with log gang saw, (a) (left) one log gang frame, *(b)* two gang frames arranged in tandem, central portion turned 90° between the two saws.

Live sawing is therefore restricted in its practice to the handling of the lighter species where logs of uniform size, of good form, and free from internal defects, are to be milled to produce standardised lines of no great range in quality. Where refractory timbers are to be treated, where virgin forests have produced trees of a large range of size and quality, perhaps over-mature and containing various internal defects, and where a sharp price differentiation exists between various grades, making it necessary to separate material of different quality in the cutting, live sawing gives way to methods based on sawing around.

Sawing Around

The various methods of sawing around all aim to separate material of different quality such as sapwood and truewood, clear portions and knotty portions, or sound timber and faulty stock, by means of breaking down, turning, or altering the position of the log during the sawing, so that the boards are cut in different planes. There are two main methods, each with a large number of minor modifications to suit different species, different sizes of logs and different market demands.

These two methods are "back-sawing" and "quarter-sawing". Back-sawing aims at the production principally of back-sawn boards, i.e., boards whose faces are, in general, tangential to the growth rings; while quarter-sawing is planned to produce mainly quarter-sawn boards, i.e., boards whose faces are generally parallel to the medullary rays, and at right angles to the growth rings.

Fig. 3 illustrates the difference between back-sawn and quarter-sawn boards. It will be obvious from the diagram that while back-sawing and quarter-sawing both involve the cutting of the log in different planes, the plane used for quarter-sawing in any portion of the log lies at right angles to that used for back-sawing the same portion of the log. Each method has its special advantages which will be discussed in turn.

Back-sawing*

Back-sawing is the most widely used method of sawing throughout North America, New Zealand and Australia, being the usual method of cutting practically all non-pored timbers, as well as many pored species. The method is illustrated in Fig. 4 for mills of the type equipped with a log carriage and bandsaw, or twin circular saw, and in Fig. 5 for the mill equipped with a breaking-down bench and breast bench.

As a general sawing method, back-sawing has a number of points in its favour. The method is highly flexible and is well suited to securing high-grade timber from faulty and varied logs. Compared with quarter-sawing, back-sawing has the following advantages:

1. Back-sawing will in general give a higher recovery from the log, and a greater output per hour from the same run of logs, while the method is somewhat simpler and more easily grasped by the average sawyer.

* Back-sawing is also known as backing off, plain sawing, flat sawing, or slash sawing, while back-sawn timber may also be referred to as backed off, plain sawn, flat sawn, or slash sawn, or alternatively as flat grained or slash grained.

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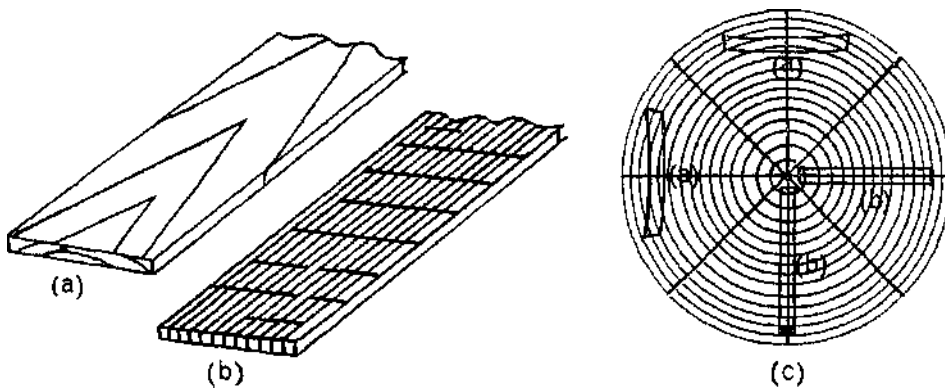
Figure 3. (a) A back-sawn board showing the growth rings at a tangent to the face of the board, *(b)* A quarter-sawn board with growth rings at right angles to the face, (c) Shows their position in relation to sawing.

2. For large over-mature or defective logs, a dozy, shaky, or knotty interior may be separated from an outer area of clear truewood, and that again from a layer of sapwood, more effectively and with less loss by back-sawing. Knots, if present, show in cross section in simple form, rather than as spike knots across the face, while defects such as ring shakes and gum or resin pockets may be completely cut out in one back-sawn board instead of affecting a number of adjacent quarter-sawn boards.

In many hardwoods, particularly in butt logs, there is considerable taper in the diameter of the defective "heart" surrounding the pith and it is profitable to saw *parallel to the log surface* leaving just enough sound wood to contain the faulty "boxed" heart for its removal in one piece from the saw bench to the dump.

3. A greater proportion of wide boards may be obtained by back-sawing than is possible by quarter-sawing logs of given sizes.

4. Back-sawn boards will ordinarily season more rapidly than quarter-sawn boards, and with less shrinkage in thickness.

5. With timbers such as Douglas fir and several of the pines, whose figure is formed by differences in texture of the two parts of the growth ring, a back-sawn face will reveal the figure, while a quarter-sawn face will be relatively characterless. A similar case can be made for back-sawing timbers with soft tissue *(wood parenchyma)* in concentric bands in the log, such as the tulip

Figure 4. In a sawmill equipped with a log carriage type breaking-down unit, back-sawn boards are produced as illustrated.
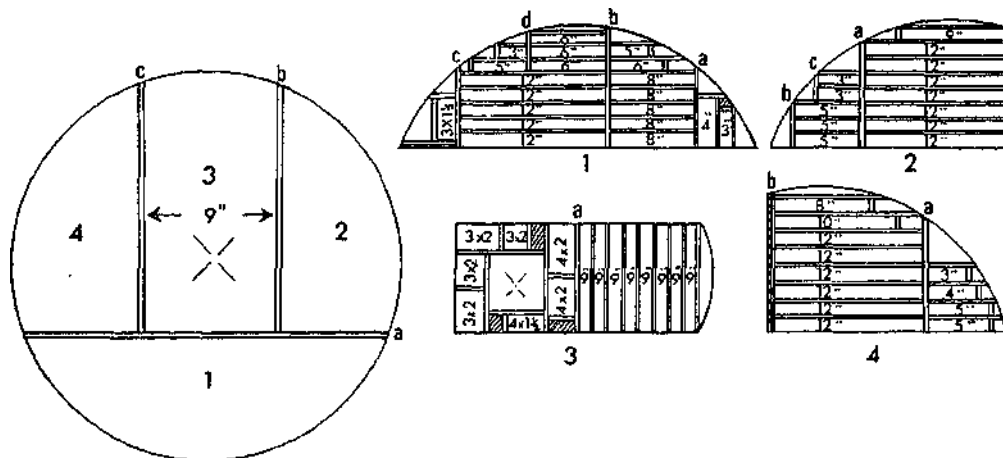
Figure 5. Back-sawing as practised in Australian sawmills with a breaking-down bench and breast-bench.
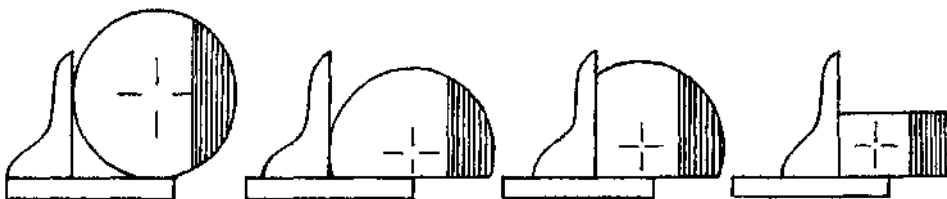
oaks and satinashes *(Eugenia spp.)* in which the natural figure can be much improved by staining the surface.

6. In many timbers, nails or spikes may be successfully driven into the back-sawn face, whereas driving into a quarter-sawn face would result in splitting. This applies particularly to eucalypt timbers used for case making, and also is of the greatest importance for sleepers and bridge decking.

On the other hand, there are cases where quarter-sawing possesses special advantages outweighing these features and justifying its use as a regular sawing procedure. These advantages are discussed in the following section.

Quarter-sawing*

Quarter-sawing may be practised for the following reasons:

1. For many decorative timbers, the figure is caused either by the effect of large conspicuous rays on a contrasting background, as in oak and in the sheoaks and silky oaks, or by the stripe or ribbon effect caused by an inter-locked grain, as in Queensland walnut and maple. In all such timbers, the figure is revealed only on the face of quarter-sawn boards, the back-sawn faces being plain and devoid of any distinctive features. Quarter-sawing is, therefore, regularly practised with such timbers.

2. In the case of coarse-textured timbers, flooring boards and joinery stock are frequently quarter-sawn to produce "edge grain" material of higher value than "flat grain" (back-sawn) material of similar quality because it shrinks less and wears much better. Edge grain flooring, for instance, will wear evenly and smoothly where back-sawn boards would sliver up and shell off. This applies particularly to Douglas fir, but is also important with many eucalypt species where used for factory flooring, decking, etc.

3. In many of the eucalypt species, gum veins are consistently present

* Quarter-sawing is also known as rift sawing or edge-sawing, while quarter-sawn timber is also referred to as rift-sawn, edge-grained, silver-grained, vertical-grained, comb-grained.

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throughout practically all logs. These gum veins show on a back-sawn face as broad splashes, which are a serious detriment to finished boards. On a quarter-sawn face, however, the gum veins show as narrow lines of far less serious character.

4. Quarter-sawn timber, though it dries more slowly, is markedly less likely to develop defects in seasoning than is back-sawn timber, being less prone to cupping, warping, and checking. It also shrinks less in width, and so may give less trouble due to hygroscopic "working" in use. With refractory timbers, such as the Australian eucalypts, this becomes a matter of great importance, because the saving in avoidance of seasoning losses is frequently more than sufficient to offset the disadvantages of slightly lower recovery, and somewhat slower production obtained when quarter-sawing, as compared to back-sawing. Another point of considerable importance is that quarter-sawn eucalypt timber, even though badly collapsed, can be successfully reconditioned with little chance of developing injury, but back-sawn timber is so prone to open checks in redrying that, for many species, the reconditioning of back-sawn timber is definitely not economical.

It is principally from the seasoning aspect, as well as the matter of the gum veins mentioned above, that quarter-sawing has been adopted in the Victorian and Tasmanian mills. So successful has it proved that the Division of Forest Products recommends its adoption in other states wherever finish timber is being cut from the native eucalypt species. In New South Wales and Queensland, in mills where the principal sizes in finished hardwoods are in flooring and weatherboard dimension, a high degree of satisfaction must result where these methods are employed.

This practice of quarter-sawing, together with the development about the same time of the processes of kiln seasoning and reconditioning, has been of the greatest assistance in the development of the finished hardwood trade of Victoria and Tasmania. Where in previous times the "ash" timbers were considered suitable only for scantling and rough timber, and were considered most refractory to season and unsatisfactory in service, they are now in keen demand for all forms of finish timber, as flooring, lining, weatherboards, joinery, and practically every other building line, besides forming the bulk of all timber used in motor body building, furniture making, and other wood-using industries.

In the mills, study of the peculiarities of the hardwood timbers has evolved a method of breaking-down and benching which results in a high recovery of quarter-sawn finishing material by a simple and straight-forward procedure, so that earlier criticism in Australia that quarter-sawing gave an unduly low recovery and low output per hour, is now refuted. Under the technique in use, both the recovery and the output are only slightly inferior to those obtained when back-sawing similar logs, while the saving of material from seasoning degrade greatly overbalances these two factors.

Method of Quarter-sawing

1. *Accuracy of Quartering Required.* Where quarter-sawing is practised with a view to developing the figure of decorative timbers, it is important to have

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the faces of the boards as nearly parallel to the rays as possible. For such timbers, specifications for quarter-sawn material usually demand that the growth rings shall show an angle of not less than 80 degrees to the face of the boards. In other words, the boards may not vary more than 10 degrees either way from the exact angle of the rays if they are to fulfil the specification. Such timber is referred to as fully quarter-sawn.

In cases where quarter-sawing is practised, as it is with the "ash" eucalypts, principally to avoid seasoning losses, there is no need for such a close adherence to the exact plane of the rays, and the quarter-sawing is done, as with back-sawing, in four planes only.

The specification to be fulfilled in Tasmania and Victoria defines quarter-sawn timber as timber in which the angle of the growth rings to the face is not less than 45 degrees. In such circumstances, a straight-forward technique can be used which will allow comparatively rapid cutting and high volume recovery. As will be seen from the diagrams illustrating the method, the material produced ranges from fully quarter-sawn material from the central portions of all the main flitches down to boards falling just within the specified limit and cut from the outer portions of the wings. On an average, roughly two-thirds of the output will show an angle of 70 degrees or more between the plane of the growth rings and the face, the remainder showing an angle of 45 to 70 degrees.

2. Processes Involved. In sawing logs for board production under Australian conditions, there are three steps or processes which must be distinguished to facilitate a clear understanding of the explanations and diagrams to follow. The first step consists of breaking-down the log into a number of flitches which can be handled by the bench crew. Cuts made in this initial breaking-down are termed primary preparation cuts. The second step is that of "sizing-up" and consists of re-cutting the flitches into pieces squared and cut to size ready for the final stage. These cuts made in sizing-up are termed secondary preparation cuts. The final stage is the "ripping-off" in which the sized pieces are passed through the saw again and again, a board being ripped off from the gauge side of the saw with every cut, until the piece is completely sawn up.

The first two steps are both preparatory steps, producing no boards from any cuts of the saw. It is only when the third stage is reached that the desired final products are obtained. It is necessary, however, to make the distinction drawn above, between the primary and the secondary preparation cuts, as in usual practice they are made on different benches.

3. *Mill Equipment.* In most hardwood mills, the equipment consists of two units, the breaking-down unit and the breast-bench. The breaking-down units used are the twin circular saw (with either the simple table top platform, or with a carriage equipped with hand-operated knees or dogs) and the reciprocating sash frame with vertical saws.

In most mills, only the primary preparation cuts are made on the breaking-down unit, leaving the secondary cuts, together with the ripping-off, to be done on the breast-bench. This procedure is always followed where the breast-bench is fully manned and equipped with power-driven rollers. There are some

A
Logs up to 24"diam.

B
Logs 25" to 28" diam.

C
Logs 29" to 35" diam.

D
Logs 36" to 40" diam.

E
Logs 41" to 45" diam.

F
Logs 46" to 50" diam.

G
Logs 50" to 56" diam.

Diagrams
H J & K show
Methods for Boxing Out
Defective Heart
for Logs about 48" to 56" Diam.

H
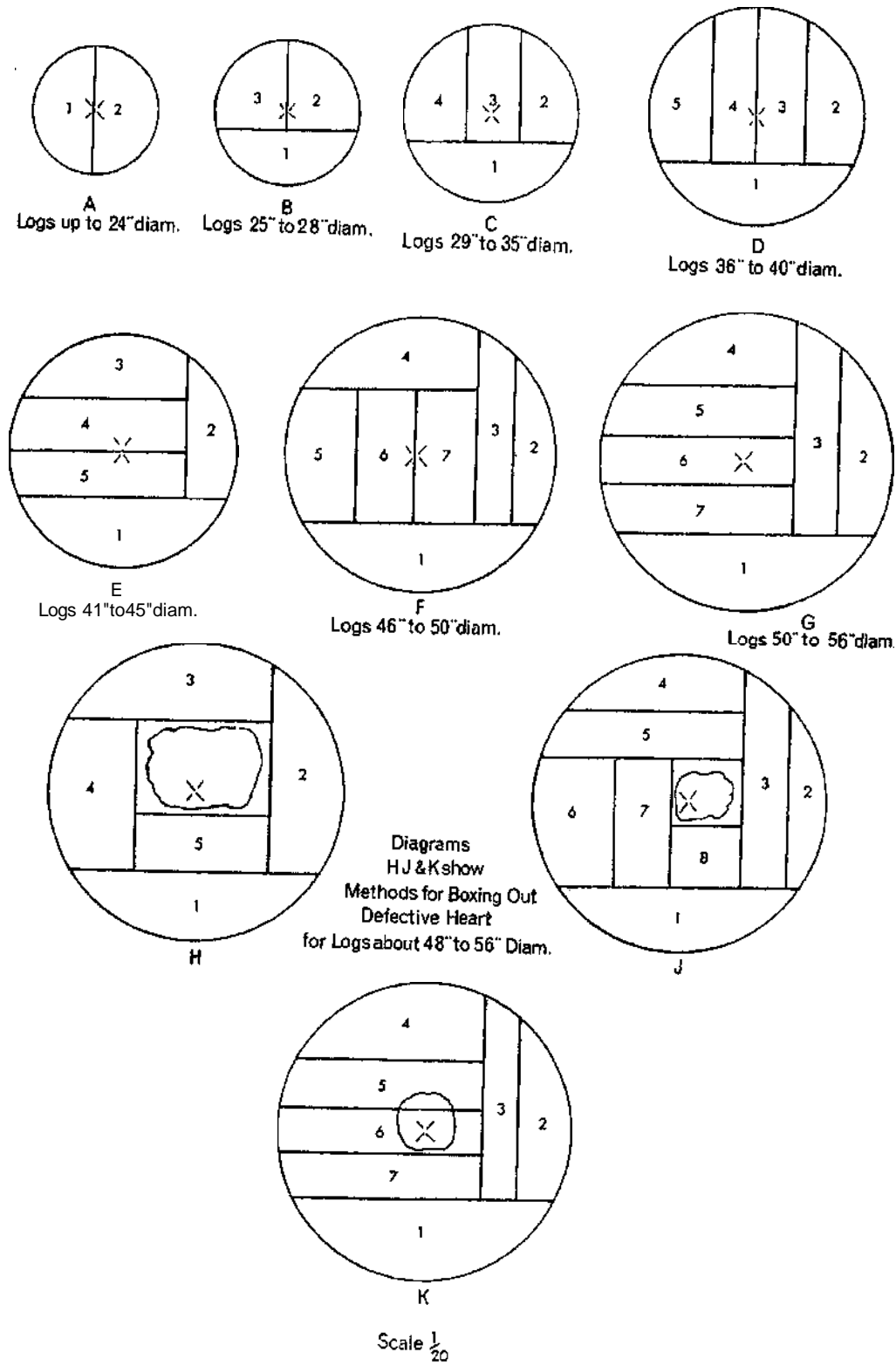
J

K

Scale $\frac{1}{20}$

Figure 6. Methods of breaking-down logs of various sizes with twin circular breaking-down saws.

mills, however, operating a slow bench with a two-man crew, where the breaking-down operator has time to make not only the primary cuts but the secondary cuts as well, thus serving the breast-bench with pieces already largely sized up. This entails a scale and setworks on the carriage to enable the sizing-up to be done accurately. In either case, the technique of breaking-down and sizing-up is the same.

4. *Primary Cuts.* In making the primary cuts on the breaking-down unit, the aim is mainly to reduce the log to flitches of a size and weight manageable by the breast-bench crew, at the same time segregating high quality stock from low quality stock as well as can be judged by what is seen of the log. The flitches so made are not cut to any definite size, as the sizing for width can only be done after the flitch is turned down. This is the chief point of difference from breaking-down for back-sawing, where the flitches are cut to a measured size to yield boards of a definite width. The fact that the flitches are not cut to any definite size makes it necessary to guard against avoidable waste due to inaccurate alignment on the table top or carriage.

Though the flitches are not cut to any definite size, there is a very marked tendency to follow along a standardised plan in the breaking-down, so that logs of certain diameters are almost always broken down in the same manner. The two factors influencing this procedure are the size and weight of the flitches which must be handled by the bench crew, and the clearances available in the saw frame. The usual twin circular saw has a vertical clearance between platform deck and upper saw collar of about 4 feet 6 inches, and a horizontal clearance between the saw and the frame of about 1 foot 6 inches. This will handle logs up to about 5 feet diameter. Any logs larger than this would require blasting or trimming with the axe.

The usual sash frame vertical unit has a clearance of 6 feet 6 inches to 7 feet, and will take logs up to this diameter at the large end. The general method of breaking-down with the twin circular saw unit is shown for logs of a range of sizes, including cases of defective heart, in Fig. 6.

The same procedure for large logs at mills equipped with a vertical sash frame breaking-down unit is illustrated in Fig. 7.

5. *Secondary Cuts.* The secondary preparation cuts, made usually on the breast-bench, constitute the most important stage in the sawing process, since the whole essence of quarter-sawing lies in the way in which these cuts are made. The procedure followed is illustrated in detail below for flitches produced from the logs shown in Figs. 6 and 7. In all cases, it is assumed that a right hand bench is used.

The first case is that of the small log up to 24-inch diameter, which has been halved on the breaking-down saw. (Log A in Fig. 6.)

The first two cuts are put through by eye, so as to give a balance between the central portion and the two rings, with due regard to the position of large unsound knots, dry sides, or other defects apparent on the flitch. These are cuts (a) and (b) in Fig. 8. The central portion is then turned slab side to the saw, and cut (c) is made removing the slab, which will be cut later to give a batten, paling, or small scantling. The gauge is then used for the first time, to
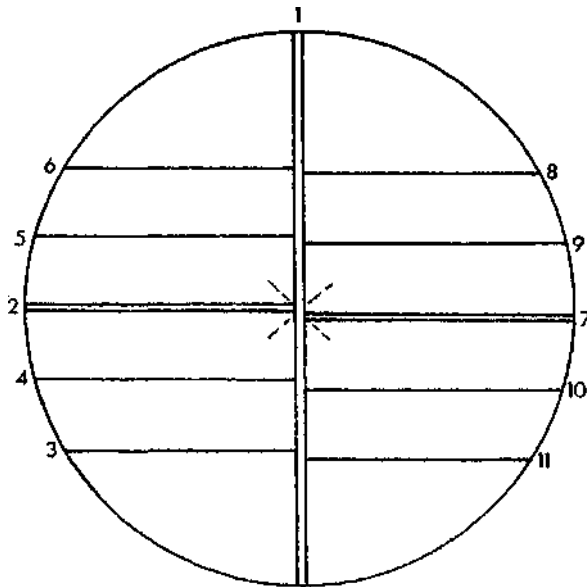
Figure 7. Method of breaking-down large logs with a vertical sash frame breaking-down saw. For a log approximately 60-inch diameter.

give a definite width which can be obtained in good quality material, free of heart, in this case, six inches. Cut (d) is then made with the outer or slab face of the flitch against the fence or face of the gauge. This completes the sizing-up of the first piece.

The remainder, or off cut from cut (d), is usually hearty or otherwise defective. It may be completely discarded or may be ripped to give a batten or small scantling piece, depending on size and quality. The sized piece (marked x) is then turned up, so that it rests on the face of cut (d), the gauge is set for the desired thickness of board—e.g., one inch—and ripping-off is commenced. As cuts (a) and (b) are not put through to measure, the last cut in ripping-off will always leave a face cut. Skilful benchers are able to hold the loss in face cuts to a low volume simply by eye.

The central piece disposed of, the two wing portions remain to be treated. These will be cut in a plane at right angles to that used for the central portion. Taking the right hand wing first, it is turned 90 degrees so that it rests on the face of cut (a). Cuts are then made one inch apart, giving four wide boards until point (e) is reached. Continued cutting in this plane would give boards
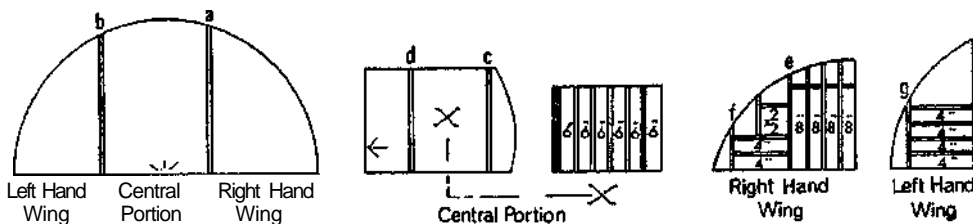
Figure 8. Cutting a 24-inch log on the breast-bench.

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showing too flat an angle of rings to the face. A 4-inch width is therefore obtained with cut (f), and the piece turned again to give the two 4-inch boards shown, with further cutting to obtain a 2-inch x 2-inch square from the last piece of the wing.

With the left-hand wing, cut (g) is put through by gauging from the face of cut (b), giving the 4-inch width in one cut. The piece is then turned down on to the face of cut (g) and the boards ripped-off until the cutting runs out.

In dealing with larger logs, the benches will have flitches of somewhat different character to handle. The next example log C in Fig. 6, is a log 30 to 36 inches in diameter, which has been broken down into four flitches. The cutting for this log is shown in Fig. 9.

The first flitch differs from the half log in the previous illustration (Fig. 8) in that it is cut off centre and is heart free. After making the first two cuts, therefore, the sawyer may take his width from the face of the flitch towards the slab, and put in cut (c) to measure, rather than putting in cut (c) at random and then gauging back to a fourth cut. Fig. 9 shows the first alternative, though many sawyers always work back from the outer cut (c) on the assumption that the breaking-down saw does not give a true face.

Flitches 2 and 4 are essentially similar to flitch 1, except that one wing is missing, and are treated along similar lines. The diagram for these two flitches is self-explanatory.

Flitch 3 requires special treatment as it contains the heart. Cut (a) is put through first by eye, dividing the flitch into two parts. Cut (b) then gives the width for the first or inner sized piece, leaving the "hearty" portion to be treated later. The outer portion may then be sized for width immediately by using a pin in a slotted plate on the left-hand side of the saw, a very common practice, or the piece is turned over 270 degrees, and the width taken from the gauge. It is not practicable in a flitch of this size to put in the outer cut first and then work inward, due to the cumbrous nature of the flitch and the lack of clearance on the off-side of the bench, so that the procedure shown in
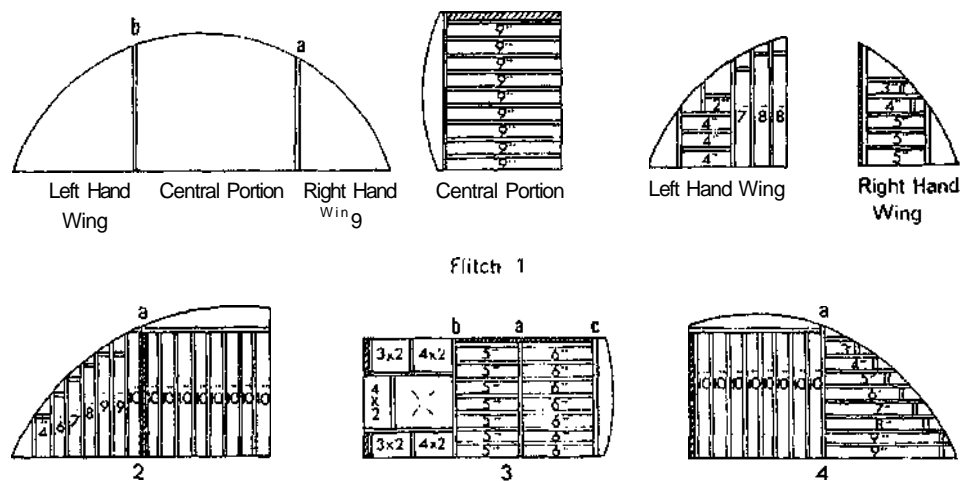
Figure 9. Details of cutting a 32-inch log on the breast-bench.

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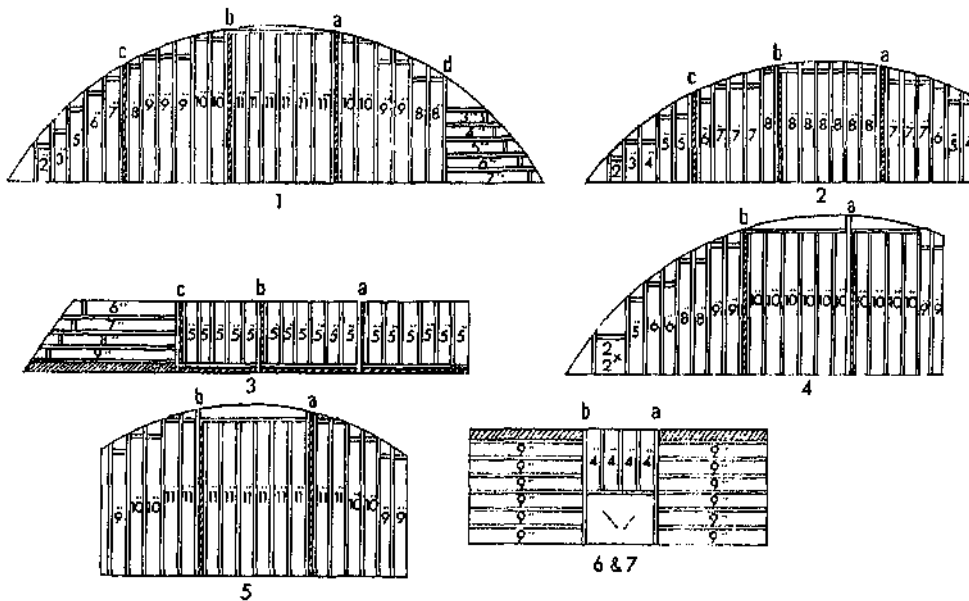
Figure 10. Details of cutting a 48-inch log on the breast-bench.

the diagram is generally followed. With these three cuts made, two pieces are sized ready for ripping-off. The slab offcut will then be cut for batten or paling residuals, while the central, or "hearty" portion to the left of cut (b) may yield battens, squares or scantlings.

The secondary cuts required for logs D and E (Fig. 6) are made along similar lines to those set out in Fig. 9 for log C. Slightly different treatment is met with in larger logs where the primary cutting involves turning the log more than once on the breaking-down platform. The treatment of log F, 46 to 50 inches in diameter, is therefore detailed in Fig. 10. This may be taken to typify the treatment of all large logs.

It is believed that the data given in Figs. 6 to 10 are sufficient to indicate clearly the general methods of procedure, and to give a clear grasp of the essential basis of quarter-sawing as it is practised in Victoria and Tasmania.

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IV

SAWMILL EQUIPMENT

Information relating to sawmill machinery is readily available from the various makers. In addition, several excellent books treat this subject very fully.* Therefore it is not proposed here to describe in detail all the various machines used in sawmilling but to discuss briefly the relative merits of some different types of equipment with regard to the purposes for which they may be used.

HEADSAWS

Circular Saws

In Australia the circular saw is often used as the headsaw for breaking-down logs. It is used singly, or, for deeper cutting, in the form of twin saws, i.e., one saw mounted above the other and cutting in the same plane (see Photo 1). Either a simple table top platform or a carriage with setworks can be used for passing the log through the saw. The single saw is limited to cutting relatively small logs and the twin saw, and, though capable of deeper cuts, is limited by the distance between the arbors of the two saws. A vertical frame saw, with one or two blades, is often used in conjunction with these other saws to make those primary cuts with which, by reason of their limitation, circular saws are unable to cope.

In hardwood mills the circular headsaw is usually confined to the breaking-down process, the flitches resulting therefrom passing on to the breast-bench. In most softwood mills the log is more or less converted at the headsaw and only the edging and docking carried out by the subsidiary saws.

Advantages of the circular headsaw are:

1. Relatively low cost of equipment.

2. Relatively low cost of saws and of their maintenance (compared with handsaws).

3. Simplicity in adjustment and operation (compared with bandsaws).

4. Less skill is required to maintain saws in order (compared with band-saws).

* See Bibliography at the end of this chapter.

5. Circular saws will stand more rugged usage than bandsaws and are not liable to the same extent of damage when fouled by stones, metal spikes, etc.

6. The log carriage, if installed, does not require an offset.

Disadvantages:

1. Relatively wide saw kerf resulting in greater waste in cutting.

2. Power requirements greater than other types of saw owing to the wider saw kerf and to the angle at which the teeth strike the timber. Blade friction is also greater.

3. Circular saws are unsuitable as a rule for deep cutting or the sawing of wide boards.

Vertical Frame Saw

This machine is equipped with a reciprocating vertical frame in which are mounted one or two saws. The logs are broken down into two or more sections which are then transferred to the breast-bench. The object of this type of frame saw (distinct from the sash gang) is to reduce logs to sections which can be handled satisfactorily by the other saws in the mill. Sometimes it is installed as the only headsaw in the mill; in other cases it is used as an adjunct to a circular breaking-down saw as mentioned under the previous heading.

Advantages of the sash frame saw are:

1. Low initial cost.

2. Simplicity of operation.

3. Will stand very rugged usage.

4. Capacity for sawing very large logs.

Disadvantages:

1. Very slow in operation.

2. Suitable for breaking-down only.

3. Sawing parallel to sapwood to exclude "heart" not possible with two parallel saw cuts.

Bandsaw

The bandsaw, used as a headsaw, consists of a continuous band of steel, toothed on one edge, passing over two wheels mounted one above the other. In general the diameter of the wheels determines the gauge of the saw which can be used, and, to a large extent, the size of the log which can be sawn satisfactorily. A log carriage with setworks and offset is necessary for use with the log bandsaw. Modern log carriages with power-driven, precision-setworks and automatic dogs are now manufactured in Australia.

The highest standards in construction and performance in breaking-down units are attained with the bandmill. The bandsaw (see Photo 2) is the fastest cutting, most economical in power and least wasteful in saw kerf among the sawmilling machines. Types for sawing logs are built generally with wheels between 6 and 10-feet diameter, their capabilities varying to some extent with different makers, but approximately as shown in Table 15.

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TABLE 15

CUTTING LIMITS AND POWER REQUIREMENTS OF LOG BANDSAWS
LARGEST LOG THAT MILL CAN CUT

Band wheel diameter, etc.		Through centre in diameter	Wheel width inches	Power h.p.
6	. . . . . .	36	9	75
7		45	11	100
8		60	12	175
9		70	13	200
10		84	15	250

In Australia band headsaws are confined mostly to the cutting of softwoods and are therefore located in regions where indigenous softwoods are available, such as in north Queensland, or in those cities through which softwood logs are imported from overseas. Although experience has shown that handsaws can be used quite satisfactorily in cutting Australian hardwoods, they have, in the main, proved unpopular for this class of work. Band headsaws are designed for a relatively high output and in Australia most installations of this type are employed in more or less fully converting the log and are not confined solely to breaking-down. Australian forests for the most part carry a relatively low footage per acre, necessitating a large number of comparatively small mills; the volume of logs available does not, in most cases, warrant installation of handsaws.

Log carriages of conventional pattern, equipped with either hand or power sctworks, are used in conjunction with both band and twin circular head-saws.

Multisaw edgers or power-fed breast-benches are used behind the bandsaw for edging purposes and for separating heart defects, whilst another smaller saw is usually employed in dealing with the offcuts so made.

Advantages of the band headsaw are:

1. Saw kerf can be reduced to almost half that of a circular saw used for the same purpose.

2. Higher output than other headsaws is possible owing to faster sawing speeds.

3. Deeper cutting is possible with the larger type of bandsaw than with other saws.

4. Less power is required owing to the finer gauges of saw used, and to the lesser friction of the blade.

Disadvantages:

1. High initial cost of equipment.

2. Relatively high cost of saws.

3. Greater skill is required in adjusting and operating the equipment, and in the maintenance of saws.

4. Will not stand up to rough work to the same extent as circular saws.

Gangsaw

The machine generally known as the Scandinavian gangsaw consists of a sash, fitted with a number of saw blades, operating with a reciprocal motion in a vertical frame (see Photos 4 and 5). The saws are spaced to cut a pre-determined thickness. Logs are fed into the machine, one behind the other, and are sawn "alive" to this required thickness. Once in operation, this thickness cannot be altered and to this extent the machine lacks flexibility. An edger or breast-bench located behind the gangsaw edges the boards thus sawn.

Gangsaws are suitable only for small, reasonably straight logs where sawing for grade is not an important consideration. In sawing this type of log, however, they are highly efficient since saw kerf can be reduced to a minimum, the sawing process is automatic and continuous, and relatively small labour costs are involved.

Gangsaws are often set up "in tandem", that is, one is placed behind (and to one side of) the other. The gangsaw which first receives the log is usually set up to make several cuts from the outside of the log only. The few boards thus derived go direct to the edger or flat bench for edging. The centre section, with a flat on opposite sides, is then turned over onto a flat side and passed through the second gangsaw. This cuts the boards to the thickness for which it has been set up. The width of these boards will already have been determined by the distance between the innermost saws of the first gangsaw.

Output from the tandem system is largely confined to fixed widths and thicknesses, but edging is reduced to a minimum.

For efficient conversion, logs require to be carefully sorted beforehand and restricted to pre-determined diameter limits.

Advantages of the gangsaw are:

1. High volume of production per man hour.

2. Simplicity of operation: minimum of skill required for operation and maintenance.

3. Relatively low cost of saws and of their maintenance.

4. Minimum of waste in sawing.

5. Accuracy in sawing.

Disadvantages:

1. Relatively high initial cost.

2. Inflexibility of operation.

3. "Blind" sawing methods.

4. Suitable only for limited class of logs.

Circular Rack-bench

The circular rack-bench consists of a table in two sections each of which travels simultaneously on rollers on either side of a circular saw. A machine cut rack is bolted to the underside of the tables and is driven by a pinion powered from the feed unit.

The circular rack-bench probably has a lower capital and installation cost than any other form of breaking-down unit of similar capacity. Because of

the simplicity of its construction it is adaptable as a portable or semi-portable sawing unit. It can be operated by workers with limited technical knowledge.

*Log Edger**

The essential features of the log edger (see Photo 3) are two saws mounted on one spindle or on two spindles in line, devices for setting these saws at pre-determined lateral spacings, and feeding mechanism to convey the logs up to and past the saws while they make two parallel cuts simultaneously. The simplest machine of this type is one in which the saws are set with collars at fixed distances apart on one spindle. In such a machine, the logs are usually fed through by a power-driven chain fitted with lugs or spikes at suitable intervals.

For sawmills where the logs vary in diameter and products are cut in a range of sizes, the log edger is fitted with a mechanism by means of which the distance between the saws may be altered. For this purpose the saws may be so fitted on the spindle that they and their collars can slide into various positions, or alternatively the spindle may be divided into two parts, one for each saw.

The log edger is principally used to prepare material for other production machines. Usually it is used to produce flitches of some definite thickness which can be resawn into finished timber by a gangsaw, radial arm bench, re-saw or main production unit.

The advantage of the log edger is that by making two cuts at the same time it increases its rate of sawing correspondingly.

Edger or Flat Bench?

In earlier remarks reference has been made to the edger as a means of treating the material which comes from the headsaw. Where the headsaw is used solely for breaking-down, thus producing mainly large pieces requiring further sawing, the edger is of little use. In most cases of this kind the breast-benches complete the work of reducing to size and at the same time cutting away wane and heart defects. Headsaws which almost completely saw around the log (as most Australian log bandsaws do) are often equipped with an edger. This machine is designed to reduce boards and flitches, which come from the headsaw, to required widths (if necessary) and at the same time to remove wane and/or heart or other defects.

Edgers are fitted with a number of ripsaws (two or more as may be re-quired) mounted on the same arbor and capable of being moved along the arbor to make whatever width of cut is desired. Because several cuts can be made simultaneously, the edger is much faster in production than the breast-bench. At the same time it is for the most part confined to sawing boards or flitches of limited thickness, seldom greater than 6 inches. Because it is called upon to make several cuts simultaneously, the edger requires considerable

* See C.S.I.R.O. Forest Products *Newsletter* No. 169. Also a report by Messrs. G. W. Wright and H. D. Roberts, D.F.P.: "The Christensen & Crozier Portable Log Edger Sawmill" published in *The Australian Timber Journal,* August, 1950.

power. To ensure reasonable accuracy, the saws, feed rolls, and arbor have to be maintained in first-class order.

A ripsaw is usually installed behind the edger to finish off the narrow edgings resulting from this process.

The principal advantage of the edger as compared with the flat bench is simply its higher rate of production. In this respect it undoubtedly excels. It is generally inferior to the flat bench in accuracy of sawing, requires a higher degree of adjustment and maintenance, needs considerable power, and the initial cost is high. In Australia, edgers are generally confined to operating in softwood mills in conjunction with log bandsaws or gangsaws.

The Breast-bench

As mentioned previously, the breast-bench deals with sections of the log, or flitches, which already have been broken down on a headsaw, usually of the vertical frame type. The breast-bench is of rugged construction, designed to handle large and heavy flitches, and fitted with saws up to 48 inches in diameter. Power-driven, reversible rollers, or a chain dogged to the end of the log, control the feed of the log into the saw. The weight of heavy flitches is carried on trolleys mounted on rails, in front of and behind the saw bench. Most hardwood sawmills, particularly those cutting to dimension, are equipped with two such saws, the second completing many of the pieces and the edgings which come from the first. Breast-benches used in this way are usually termed no. 1 and no. 2 in the order in which the flitches from the headsaw pass to them.

RESAWS

In Australia, the term "resaw" is usually applied to the bandsaws used in retail sawmills and occasionally as subsidiary equipment in log sawmills. As the name implies, these machines are employed in resawing larger flitches into smaller sizes. A breast-bench is also, in fact, a resaw, and so is a sash gangsaw which recuts flitches from a breaking-down saw into boards. The term is used here in its wider meaning.

In the process of resawing some boards are produced of higher grade than that of the flitch from which they are sawn. This is an important feature in sawmill economy, particularly in regard to the resawing of softwoods.

Circular Saw Bench

The circular saw bench, of lighter construction than those used in log mills and fitted with a quickly adjustable fence, is the most generally used for miscellaneous resawing. It can be more rapidly adjusted than the band resaw and small sections can be ripped to sizes at great speed by hand feeding. For recutting large flitches, however, a heavier gauge saw is necessary and in this respect the circular saw has the disadvantage of wide kerf—a highly important matter when resawn stock has to stand up to a specified size, and at the same time yield the equivalent in nominal measurement of the flitch from which it is derived. For this reason, and also because of its capacity for high production

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when large quantities of stock sizes are in regular demand, many mills install band resaws for this class of work.

Band Resaw

The band resaw differs from the log bandsaw in that the log carriage is replaced by vertical feed rollers and, in most installations, a system of live rollers and transfer chains return the flitches, after each cut, back to the feed rolls for further resawing. Band resaws generally have wheels of from 4 to 6 feet diameter, and use saws from 6 to 10 inches in width, or 16 to 18 gauge.* When resaws of this type are used in conjunction with a log band mill sawing softwoods, output may be increased very considerably.

Gang Resaw

The gang resaw, designed for resawing flitches, is scarcely known in Australia. Under certain circumstances, however, it is an admirable machine for the manufacture of boards and, in particular, for the quarter-sawing of joinery stock and flooring boards where accurately sawn, edge-grain timber is essential. The gang resaw requires only one flat side in the piece to be sawn; round-backs can be cut into quartered stock as conveniently as squared flitches. (A gang resaw would most effectively complete the sawing of the primary cuts shown in Fig. 10).

All the advantages claimed for the log gangsaw apply to the gang resaw, but normally it must be used in conjunction with a breaking-down saw and only clear pieces, with heart defects substantially removed, dealt with. It is therefore only suitable for use in mills handling logs of fairly large girth and containing a reasonably high proportion of clear timber, or in mills where comparatively narrow boards such as floorings and weatherboards, are sought.

Live Rolls and Transfers†

The output of the average mill is increased by judicious use of mechanised devices for transferring partly converted timber from one stage in its manufacture to another. The extent to which such devices (live rolls, belt conveyors, transfer chains etc.) are really advantageous depends largely upon the size of the mill and its layout. Over-elaborate systems can become more of a hindrance than a help, requiring too much attention in operation and expense in maintenance. On the other hand, in most sawmills the linking up here and there of a few power rolls, a conveyor belt, or a transfer chain with existing countershafts can work wonders in saving time and reducing fatigue. In large mills the installation of soundly designed conveying equipment is absolutely necessary if crowding of machines and accumulation of refuse is to be avoided. And in view of the shortage of skilled labour existing at the present time modern sawmill design more than ever demands the closest attention to these labour-saving devices.

* Saw gauge is measured according to Birmingham Wire Standard. (See Chapter V, Table 16).
† See D.F.P. *Newsletter,* no. 179, "Timber Conveying in the Sawmill".

Sorting Tables

The sorting table consists of a long table or framework over which pass a series of two or more endless chains or flexible wire ropes. The table is sited at the output end of the mill so that when the sawn output is placed on one end the boards and scantlings will move slowly in a transverse direction towards the other end of the table. The length of the table will depend upon the rate of production of the mill and number of grades and sizes it is desired to segregate. Men are stationed at intervals along and in front of the table; they pull off and stack the various grades and sizes as they pass. The stacks of graded timber are removed from time to time as necessary, the most effective machine for handling this class of work being the "timber carrier" or "straddle-truck" which eliminates the necessity for loading the timber on to wagons or trucks by hand.

Sorting tables, which are simple to install and maintain, are perhaps not used to the extent to which their usefulness in Australian sawmills would warrant. The facility with which timber may be segregated for subsequent treatment such as kiln- or air-drying, resawing, planing, or for various orders, makes such installations, in any sizeable mill, well worth consideration.

Power

It might be in order here to stress the importance of adequate power and power transmission in the sawmill. Fuel is rarely a problem in a mill which generates its own power, and scarcely ever in a log mill, where the demand for power per machine is usually the highest. The steady note of a saw in a well-powered mill is music to the ears of a timberman, but when at every cut, it runs tunelessly down the tonic scale, it becomes a depressing song. Saws which slow down in a cut—and in many mills they often do, even to the point where sawing has to stop until they recover revolutions—become highly inefficient and production suffers to a far greater degree than is generally realised. Equally, or more important is the psychological effect on operatives. Under-powered machinery causes constant frustrations of effort, induces exasperation, frayed nerves and ill-temper, and is not infrequently the cause of accidents. If a man is prepared to pull his weight he has a right to expect co-operation from his machine.

CHAIN SAWS*

Portable power-driven chain saws, while designed primarily for felling and cross-cutting in the forest, can be of great use in the sawmill.

These handy machines are designed for use by one or two men, and for cutting various size logs. They are powered either by electricity or petrol motor, and the power range varies from 3½ h.p. in the case of small "one-man" machines with an 18-inch blade, to 12 h.p. machines with a 7 foot blade for cross-cutting or "bucking" large boles.

* The use of chain saws under Australian conditions is discussed in D.F.P. *Newsletters,* nos. 168, 174 and 184.

The principle involved is that of a toothed chain running around a hardened and tempered elongated steel plate known as the guide rail. The driving motor, handle, and controls are at one end of the guide rail and the tensioning device and the handle for the assistant (in two-man machines) at the other end. The cutting chain is controlled by a clutch and throttle.

For bush work, a petrol-driven motor is of course, necessary, but for the sawmill, electricity, where available, is preferable.

Chain saws greatly reduce the time and labour necessary for the feeding and cross-cutting of logs. In the sawmill they can be of further use in cross-cutting large flitches or stacks of flitches.

The secret of success in the working of chain saws lies in proper attention to the care and maintenance of the cutting teeth. Full instructions and necessary sharpening equipment are usually supplied by the makers; nevertheless instances occur where operators have difficulty in maintaining good cutting performances. One important point is to ensure that at all times when in use, the teeth are *cutting* and not "rubbing" the timber.

Sharpening the Chain. The saw chain must be kept sharp. Cutting with a blunt chain throws extra load onto the sprocket and motor, and the operator. It is important to file each tooth the same amount to maintain even tooth height.

After sharpening, the chain should be washed in kerosene or solvent to remove steel filings from between the links, and then soaked in a dish of oil.

Hard, chromium plated cutters are available for gouge-type or "chipper" chains. These retain their keenness considerably longer than the ordinary type.

The Utilisation Section of the Division of Forest Products has developed a method by which the cutting chains used on power chain saws can be accurately sharpened by grinding on stock pattern gulleting machines. This method is described in Forest Products *Newsletter* no. 184, and further information is available on application to the Division.

Chain Versus Drag Saws

Chain saws have been made much lighter and more compact than drag saws and are therefore more portable. They will cut more rapidly because the chain of teeth, not requiring a reversal of direction, can be made to travel many more lineal feet per minute. These two points have tended to make the chain saw more successful than the drag saw. However, the latter has certain attributes which should not be overlooked.

Drag saws are more rugged and more simple in operation than chain saws, most of which have been drastically reduced in weight. This necessitates increased complexity of the engine.

Drag saws require a smaller initial investment, and hence a lower charge against total production during machine life. Should a large log be encountered when cutting small timber with a drag saw, it can readily be handled by replacing a short blade with a longer one. However, with a chain saw it is usually necessary to use an outfit which will cut the largest log likely to be encountered-

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Once a drag saw is started in the cut, it can be operated by one man, thus leaving the second man free for other duties. In the use of a chain saw, two men are needed at all times.

Engine vibration does not affect operators of a drag saw but with a chain saw it tires them rapidly.

Chain saws were originally designed for cross-cutting logs and baulks and this is still their principal function. However, there have been some developments in the use of these machines for breaking-down large logs in the bush and where facilities for handling them, as complete logs, do not exist. In such cases a gouge-type tooth, designed for cutting the fibres lengthwise, is used and of course the saw must have a wide enough blade. Equipment of various kinds has been designed for mounting the saws and guiding the blades horizontally through the log. However they have not so far gained any degree of popularity.

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V

SAWS AND SAW FITTING

Machine saws fall into three classes: circular, band and reciprocating. Within each class differences occur in gauge, shape and spacing of teeth, speed of running and so on, according to the work the saw is required to perform. Such work covers the sawing of woods of different thickness, density and texture. Each particular function of a saw therefore demands some special attention in its selection. The uses of circular saws are many and varied and include breaking-down, resawing, edging, cross cutting, routing etc., while bandsaws and reciprocating saws, as mentioned in the previous chapter, are principally confined to breaking-down and resawing, i.e. ripsawing. (The small or scroll bandsaw as used in woodworking shops is not included in this discussion).

The art of conditioning saws for their various uses is termed "saw fitting" or "saw doctoring". It calls for a high degree of patience and skill, particularly in the conditioning of bandsaws. The artisan engaged in saw fitting is called a saw filer, or saw doctor.

In order to understand the nature of saws and their treatment it is necessary to define some of their principal characteristics.

Gauge   The thickness of a saw blade expressed in terms of the Stubbs, or Birmingham Standard Wire Gauge. (See Table 16.)

Pitch   The distance between the points of two consecutive teeth.

Gullet   The space between two consecutive teeth.

Depth   The distance between the deepest part of the gullet and a line joining the two adjacent tooth points.

Hook   The angle made by the face, or inside line of the tooth nearest its point, and a line drawn from the tooth point to the centre of a circular saw, or perpendicular to the back of a band or reciprocating saw.

Back   The angle made by the back, or outside line of a tooth nearest its point, with a line joining that and the following tooth point.

Set (Spring)   The projection of the teeth on alternate sides of a saw to provide clearance for the blade. A saw is said to be "spring set" when so fitted. (See Fig. 11).

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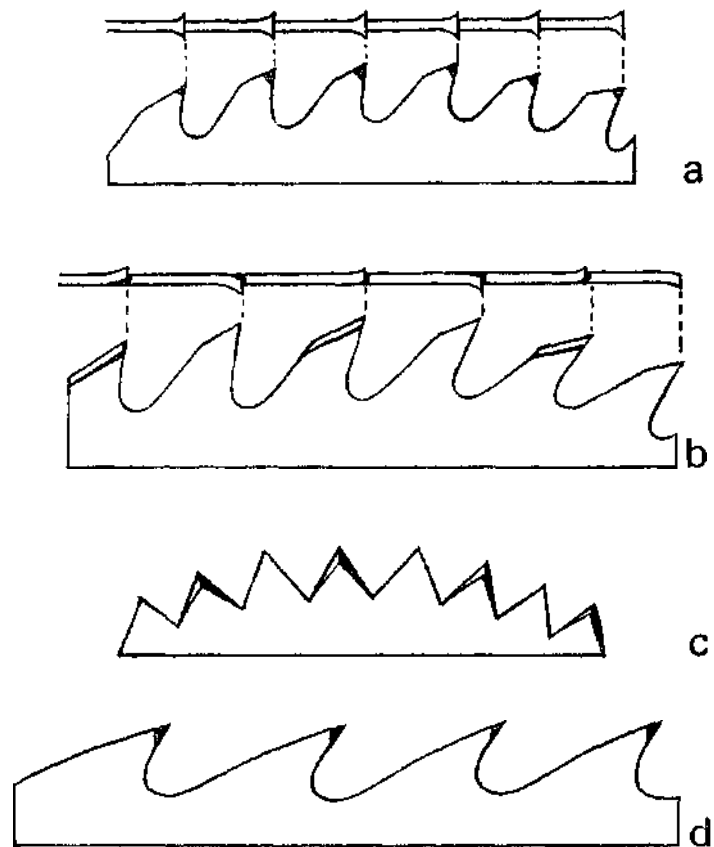
Figure 11. (a) Ripsaw teeth swage set. (b) Ripsaw teeth spring set. (c) Cross-cut saw teeth spring set. *(d)* Bandsaw teeth swage set (log and resaws).

Set (Swage)   The spread of a tooth on each side of the saw to provide clearance for the blade. A saw is said to be "swage set" when so fitted. (See Fig. 11).

Tension   The centre of a saw blade is expanded so that the cutting edge will remain taut, or in tension, when stresses are developed from the heating of the saw and the sawing loads.

CIRCULAR SAWS

Diameter and Gauge

The minimum diameter which can be used in a circular saw machine will depend upon the depth of cut required, but as a rule it is advisable to use a saw of the minimum size consistent with the work. Circular saws used for breaking down hardwood in Australian sawmills range up to 78 inches in diameter. Larger saws are used but generally require to be so thick that excessive saw kerf and power demand result.

The gauge required for a particular diameter depends upon the timber to be sawn, depth of cut, rate of feed, power available and the type of machine. The lighter the gauge the greater the difficulty in fitting saws to stand up to

TABLE 16

CIRCULAR SAWS

Recommendations for Fully Powered Saws (Tooth Speed = 10,000 ft. per min.)

Diameter	R.P.M.	Saw Gauge
30'	1275	11 to 10
36"	1060	11 to 9
42"	910	11 to 9
48"	800	10 to 7
54"	710	9 to 7
60"	640	9 to 5

Standard number of teeth: 54 to *66*.
Heavier gauge saws for hardwood, lighter gauge for softwood.
In spring set saws the set should be from 10/1000" to 15/1000" for hardwood,
and from 15/1000" to 20/1000" for softwood, each side of the blade.
For swaged saws, i.e. inserted teeth, and band saws, the usual practice is for a
swage 4 to 5 gauges more than the blade, and for softwood 5 to 6 gauges more.

continuous work, and the greater the care which must be exercised by the sawyer. Gauges recommended for saws cutting hardwoods and softwoods are listed in Table 16. It will be noted that whereas saws for cutting hardwood require heavier gauge blades, less tooth set or swage in proportion to gauge is necessary than is the case in most softwoods. The reason for this is that the fibres of hardwood cut more cleanly than do those of softwood, the latter tending to close in upon and pinch the blade.

Influence of Pitch on Cutting Efficiency

The distance from tip to tip between the teeth of saws has much more influence on power requirements than is realised. It is generally agreed that, where other considerations allow, a power economy is effected by decreasing the number of teeth.

A clean cutting action is much more efficient than a scraping and rubbing action. There are so many teeth on the conventional circular saw that often each tooth rubs and scrapes the wood. In such cases a reduction in the number of teeth will allow each tooth to make a positive cut and this fact alone must account for some of the improvement in efficiency. It has also been established that saw teeth lose their keenness much more rapidly if they do not make a clean cut, and therefore too many teeth on a saw will cause premature blunting.

Choice of Number of Teeth

The number of teeth advisable on a circular saw of given diameter, i.e., the tooth spacing, will depend upon the rim speed, timber sawn and rate of feed. In sawmills, about 54 teeth on saws of all diameters is a satisfactory number. More teeth are only desirable when cross-grained and knotty timber is to be sawn, or when cross-cutting. The greater the number of teeth the

smoother the cut, but a heavier gauge is necessary and more power is required. An excess of teeth will result in the sawdust being cut into fine powder, occasioning loss of power, overheating and a reduction of output. At the same time it is important to use sufficient teeth to secure the full benefit of the power employed. Generally it is more preferable to reduce speed than to reduce the number of teeth.

A reduction in the number of teeth on a saw necessitates careful preparation of the teeth. There are fewer teeth to do the work and therefore each tooth must do its share accurately and efficiently.

Tooth Pattern

Saw doctors are not always in agreement as to the best tooth patterns for the various types of work, experience eventually being the guiding factor. But several important considerations must always be taken into account in determining the tooth pattern to be used. Principal among these are: the timber to be sawn, the average depth of cut, the feed speed and the saw speed. These considerations determine respectively the strength of tooth necessary for cutting hardwood and knotty timbers, and those with twisted or uneven grain. It has been shown that reinforcement applied to the front of a tooth without affecting the hook at the tip of the tooth, is the most effective method of stiffening a saw tooth.

Hook

The greater the hook the finer the tooth and the sharper the angle at which it bites the wood. For this reason a saw with greater hook (and a chiselling action) will cut more easily and draw less power. At the same time, because there is less metal in the tooth, it will not stand up to as great a strain or wear as one with less hook. On the other hand, less hook, while giving a stronger tooth, effects more of a "plough" than a "cut", hence a greater load is thrown back on the tooth and more power is required. As suggested above, tooth strength can be obtained independently of hook by reimpressing the tooth just below the tip, giving a shape somewhat similar to that in Figure 12. The amount of hook recommended for circular saws is 30 degrees for all timbers. However, with tipped saws, hook angles as low as 15 to 20 degrees are desirable to add strength to the brittle tip.

Gullet Space

The "bite", that is, the amount of sawdust which each tooth is able to make and carry away from its cut, is determined by the gullet space. Other things being equal, therefore, the greater the gullet space, the more work each tooth can perform and the faster the feed that can be maintained. Owing to the stringy and coarse nature of softwoods, a saw cutting softwood will require more gullet space than one cutting hardwood. It is evident, too, that if an effective feed is to be maintained, a saw engaged in deep cuts requires more gullet space than, for instance, an edging saw. Care should be exercised when increasing gullet depth to avoid weakening of the teeth. Clogged gullets can

usually be identified by overheating of the saw and by contacted sawdust deposits in the gullet.

Gullets should always be ground smoothly and with full curvature. They should be free of nicks, sharp corners and ridges, which can cause cracks in the blade and obstruct the free flow of sawdust.

Set or Swage

Set, or swage, by increasing the width of kerf beyond the thickness of the saw blade, affords the blade a free run in the cut. Insufficient set, or swage, will cause friction and an increase in power. Too much set, or swage, involves waste of timber, puts added strain on tooth and blade, and absorbs power. Swaged saws will accept a faster feed than spring-set saws because the teeth are loaded symmetrically. However, they draw more power. Most of the circular saws used in Australian mills are spring-set, but handsaws are swage set.

For level saws of diameter up to about 42 inches, tooth set should be from 0.015 inch to 0.020 inch for hardwoods and from 0.026 inch to 0.025 inch for softwoods. Larger saws require larger sets. For swaged saws the usual practice for hardwood is to swage 4-5 gauges more than the blade for hardwood and 5-6 gauges for softwood.

From remarks under the foregoing headings it will be realised how interdependent the various factors governing the process of saw fitting are. A marked alteration of any one characteristic of a saw often requires compensating adjustments in all or most of the others; indeed, its effect can go beyond the saw into the realms of power supply and transmission. The importance of a proper balance of the relative factors can thus be understood, and the necessity for skill and patience on the part of the saw doctor becomes apparent.

Tension

Tension is produced in a circular saw by hammering the blade on a steel anvil with a specially crowned and shaped hammer. Hammering a blade in the middle third of its radius expands that zone, stressing the rim in tension. This stiffens the running saw against sawing forces and compensates for expansion of the rim when it heats during sawing.

Hence the following conditions will affect the degree of tension necessary in a circular saw: diameter, rim speed, gauge, rate of feed, species and moisture content of timber, number of teeth, etc. The amount of tension a saw should actually carry is therefore governed by practically all the conditions relating to its use and can only be determined by experience.

Tension must be applied uniformly. It is gauged by the amount the body of the saw falls away from a straight-edge when one edge of the saw is lifted from the bench. The concavity thus occurring is required to conform to a specific curvature, which is determined by experience. The saw is termed "tight" or "fast" where it fails to fall to the edge of the gauge, and "loose" where it falls away from it.

"Lumps" or slight bulges occurring in the saw blade through overheating or other causes must be hammered flat before tension is applied.

Speed

Choice of saw speed is tied to the choice of feed speed. The feed per tooth is determined as the greatest that will give a sawn surface of the required quality and not overload the teeth. For head saws and No. 1 saws the feed per tooth should be in the range of 0.05 to 0.125 inches per tooth. Pitch is largely determined by the gullet space required, and hence the predominant depth of cut. Minimum tooth speed is then found by dividing feed speed by feed per tooth and number of teeth per foot:—•

$$\text{Minimum tooth speed (ft./min.)} = \frac{\text{feed speed (ft./min.)}}{\text{feed/tooth (ft.)} \times \text{teeth}}$$

However, there is a possibility that a particular saw, moderately tensioned, may be unstable when run at this speed, and tend to vibrate or run off. Each combination of saw and machine has critical speeds at which this occurs. The operating speed should be steady and at least 10 per cent different from the main critical speed. A rough test is to run the saw idle, rubbing the rim with a stick until it is about operating temperature, and watching the blur of the teeth to see if it is wider than at lower speeds when slowing down. The ultimate test is in routine sawing, and if vibration or running-off is frequent, a change in operating speed of at least 10 per cent, preferably downwards, is likely to help. A change in tension may also help to a limited extent.

Stress, however, is laid on the importance of maintaining the speed of the saw in the cut at a uniform rate, because of the danger of encountering a critical speed as the saw slows down. If the available power is insufficient to maintain the saw at a uniform speed, it is better, by varying the transmission ratios, to use a slower speed and to fit the saw accordingly. A rim speed of 9,000 to 11,000 feet per minute is generally considered to be the most effective for cutting softwoods, and of 7,000 to 9,000 feet per minute for cutting Australian hardwoods. However as low a rim speed as 4,000 feet per minute can be used if conditions do not allow a higher uniform rate and if the saw is fitted accordingly as regards teeth and tension.

Sharpening

It is bad practice to run a dull saw, or cut any avoidable dirt. De-barking or washing of logs is of great benefit in reducing saw maintenance costs. If dirty logs or gritty timber must be sawn it pays to change the saw frequently. Dull saws "pound" the timber, throw added strain on tooth and blade, cause heating and tend to induce cracks. The saw should be maintained in perfect round so that each tooth will perform an equal share of the work. If the saw is at all out of round it should be "jointed" by bringing an abrasive stone gently up to the teeth while the saw is running. This should be done with the utmost care. However, an automatic saw sharpener, if used, will keep the saw in perfect round.

In filing, care must be taken to ensure that the original shape of the tooth is maintained, and in particular, that no sharp corners or file nicks are left in the gullets. These will induce cracks.

If cracks do occur they can often be stopped from running further into the

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blade by punching the metal on both sides at the end of the crack, or by drilling a hole of about one-eighth-inch diameter. The hole must be very smoothly drilled.

Cleaning the Teeth

Sometimes a resinous deposit collects in the gullets and on the sides of the teeth. This has to be removed before gulleting, otherwise the grinding wheel becomes clogged and will burn the teeth. When this "gum" results from soft-woods, a common remedy is to clean it away with kerosene or similar solvent. Kerosene, however, is ineffective in the case of the deposit from most of the eucalypt hardwoods since this is an accumulation of kinos which is insoluble in kerosene and spirits. The Division of Forest Products, C.S.I.R.O. recommends the use of a weak solution of caustic soda (1 oz. solid caustic soda to 1 gal. of water). The affected parts are soaked with the solution and the deposit can then be scraped off.

Care must be taken to keep the solution away from the eyes. If irritation of the hands should occur, this can be arrested by application of a weak acid such as vinegar or boracic.

A light jet of water played on the teeth while the saw is running will assist in keeping the teeth free of deposits and the cutting edge from overheating.

Some "Don'ts" For Circular Saws*

1. Don't run a saw that is out of round—keep teeth uniform in height.

2. Don't run a dull saw—keep it sharp and properly set. This applies to all saws.

3. Don't expect sharpness, however, to make amends for badly shaped teeth. Always maintain their original shape, set and bevel.

4. Don't forget that if your saw runs under strain it may lose tension. If you haven't the experience to correct this, then send your saw at once to an expert repairman or back to the factory for re-tensioning. Unless this is done it may result in cracking of your saw.

5. Don't feed the material to the saw unevenly. Feed uniformly and steadily so that each tooth will do an equal share of the cutting, because a light and unsteady feed causes a scraping and unsatisfactory cut.

6. Don't fail to follow the manufacturer's instructions for setting saws. Remember, softwoods require more set than hardwoods.

7. Don't forget the importance of seeing that your saw spindle, or mandrel, is level, runs freely, and has smooth even collars, and that it is kept well oiled at all times. Keep driving pulley and mandrel pulley in perfect alignment.

BANDSAWS

Bandsaws used in Australia vary in dimensions from about 6 inches in width and 20 gauge to 14 inches in width and 13 gauge. Lengths vary according to wheel diameters and design of mill. Much the same conditions as determine the design of teeth in circular saws apply to bandsaws, although some

* By courtesy: Henry Disston & Sons Inc.

Figure 12. Pattern of saw teeth used with a 14-inch 13-gauge band headsaw.

important differences exist. Because of the broader angle at which the teeth strike the wood, more hook is carried in a circular saw than in a bandsaw. The former tends to push the wood away from it but the latter has the opposite tendency. Hence handsaws, when in a cut, frequently creep slightly forward on the wheels.

As in the case of circular saws, higher running speeds require a longer tooth space. Saws cutting softwoods should be fitted with ample gullet space, and must carry more hook than when fitted for cutting hardwoods. These features enable high rates of feed to be maintained in softwoods, but it is important that attention be paid also to the *back* of the tooth and that it clears in the cut, otherwise the timber will crowd upon it and tend to push the saw back on the wheels. A low back, however, tends to produce a weak tooth. Effective balance between hook and back is one of the problems confronting saw doctors engaged in fitting handsaws.

Saws fitted for cutting Australian hardwoods require a very strong tooth and hence carry less hook and less gullet space than those fitted for fast feeds in softwoods. A general purpose tooth if carefully designed will give reasonably good results in both hardwoods and softwoods, but not the best results in either. Some mills fit saws separately for cutting each class of timber. The pattern of a saw tooth used with a 14 inch 13 gauge band headsaw is shown in Fig. 12. This saw has proved successful in sawing both Australian hardwoods and softwoods. Speed used is 8,500 feet per minute, and swage is 6 to 8 gauge, or even less for hardwoods.

Tooth Set

Bandsaw teeth are practically always swage-set, only the very fine saws used for woodworking being spring-set. Swage is effected by an instrument termed a "swage". This squeezes the tooth points out on either side. A similar instrument termed a "shaper" adjusts the swaged tooth point to its required gauge. Final shaping is achieved by sharpening.

The saw sharpener is entirely automatic. With each sharpening, the emery wheel, by means of a system of cams, passes over the whole contour of each tooth and so not only sharpens but also maintains the teeth of the saw to the required shape. It is essential that a full curvative be maintained in the gullet for sharp corners or ragged edges here will induce cracks. Grinding should be applied lightly and the emery wheel kept clear of "gum". Too heavy a grind will reduce tension along the tooth edge and produce burns which will cause cracks in the saw.

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Tension

    Tension is put into the saw by expanding the centre of the blade so that the strain, when the saw is stretched on the wheels, will come on the edges. The back of the saw however, is expanded to a greater extent than the toothed edge so that when the edge sustains the extra strain and heat engendered by the act of cutting, it will remain taut, or in tension, at this very important section of the saw. Since the strain and heat mentioned may run some small distance back from the teeth, some filers carry a "tire" or section of equal tension of from one to two inches in width at the toothed edge.

Tensioning

    Tensioning is effected by passing the blade longitudinally through powered rollers which can be set in a position to roll whatever section of the saw it is desired to expand. The amount of pressure required is judged, and applied, by the filer. It is of paramount importance to effect uniform tensioning of the blade throughout its length. "Tight" or "fast" spots must be treated individually. This is usually done with a special hammer.

    To test the tension, one end of that section of the saw being tested is raised from the bench. If the saw is in proper tension the central portion of the blade will fall away from the edges and conform to the shape of a metal gauge placed upon it. This gauge is ground to an arc of a circle. The measure of tension is expressed in terms of the diameter of this circle. It is usually from 25 to 50 feet in diameter according to the amount of tension required. If tight (i.e., insufficiently opened up) the blade will not fall away enough to match the contour of the gauge: if loose (i.e., opened up excessively) the blade will fall away from it and show daylight under the gauge.

    As in the case of circular saws, lumps or bulges in the blade, as discovered by a straight edge passed over the saw while it is lying flat on the bench, must be hammered out before tension is restored.

    The correct tension for a bandsaw will depend upon its width and gauge, and also upon the severity of the work it will be called upon to perform. It is not advisable to put so much tension in a saw that it will not lie flat from its own weight on the levelling bench.

    Table 17* gives recommended circles of tension for bandsaws of different widths and gauges.

Crown

    As already described, the back of the saw is expanded, or "stretched" as it is usually termed, to a greater degree than the toothed edge. This additional stretching of the back is called "crown" and is effected by special rolling of the back of the blade. Uniformity in fitting crown is essential (as in all other features in saw fitting) and is achieved by ensuring that the back edge, at all points round the saw, conforms to a gauge set against it. This gauge usually consists of a metal bar 5 feet in length with a slightly concave edge. The degree of concavity is the measure of the crown, and is usually in the vicinity of 1/64

  * By courtesy: Henry Disston & Sons Inc.

TABLE 17

Inch	Gauge	Circle (ft.)
1	17	30
7	18	30
7	19	35
8	16	30
8	17	35
8	18	35
9	15	30
9	16	30
10	14	30
10	15	35
10	16	40
11	14	40
11	15	45
12	13	40
12	14	40
13	13	50
13	14	50
14	13	50
14	14	50

Note: The above figures are approximate. The conditions in the
mill will govern whether the saw should be open a little more
or made stiffer than the figures show.

inch for each 5 feet. From this it will be seen that the back edge of the saw has
a greater perimeter than the toothed edge. To ensure a uniform tension on the
blade when the saw is fitted on the wheels and subjected to the strain mentioned in the next paragraph, the upper wheel is often tilted slightly forward.

Strain

The lower wheel of a band mill is fixed, but the upper wheel is so fitted that
it may be moved vertically in order to stretch the blade taut. The tension thus
exerted by straining the wheels apart is finally adjusted by means of a
weighted lever working through a system of knife-edges. The strain so placed
on the saw is very great and it is generally considered that it should be reduced as the saw wears down in width, though saw doctors are not always
agreed on this point. Too much strain will pull the tension out of the saw,
too little will induce vibration and allow the saw to snake when cutting cross-grained and knotty timber.

Cross-line

In addition to its vertical movement, the top wheel can be moved also in
"cross-line", that is, out of perpendicular to the line of cut. This should only
be used as an emergency measure to prevent the saw running forward or backward on the wheels if it should overheat in a cut. Working a saw in a cross-line should be avoided as far as possible since this will have the effect of twisting the blade.

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TABLE 18

BIRMINGHAM (OR STUBBS) WIRE GAUGE
SAW GAUGE EQUIVALENTS

Gauge No.	Approx. Fractional Part of inch	Decimal part of inch	Gauge No.	Approx. Fractional Part of inch	Decimal part of inch
0	$^{22}/_{64}$ scant	0.340	11	$^1/_8$ scant	0.120
1	$^{19}/_{64}$ full	•300	12	$^7/_{64}$ full	•109
2	$^9/_{32}$ full	•284	13	$^3/_{32}$ full	•095
3	$^{17}/_{64}$ scant	•259	14	$^5/_{64}$ full	•083
4	$^{15}/_{64}$ ful	•238	15	$^5/_{64}$ scant	-072
5	$^7/_{32}$ full	•220	16	$^1/_{16}$ full	-065
6	$^{13}/_{64}$ scant	•203	17	$^1/_{16}$ scant	-058
7	$^3/_{16}$ scant	•180	18	$^3/_{64}$ full	•049
8	$^{11}/_{64}$ scant	•165	19	$^3/_{64}$ scant	•042
9	$^9/_{64}$ full	•148	20	$^1/_{32}$ full	•035
10	$^1/_8$ full	-134			

Guides

Guides are set in a fixture just below the saw table and on an adjustable arm above the timber being sawn. It is important that guides be maintained close up to the saw blade in order to reduce vibration and to resist any tendency of the saw to deviate as a result of knots or cross grain in the timber. However, they should not rub the saw blade.

Cleaning the Teeth

Use the same advice as given for circular saws on page 65.

Speed

Bandsaws are best run at a tooth speed of from 9,500 to 10,500 feet per minute in softwoods and from 7,500 to 8,500 feet per minute in Australian hardwoods. Density of the timber to be sawn and the feed speed are the governing factors in determining the most effective saw speed. This applies to all saws since it is important that each tooth shall "bite" and not "scrape" the wood. Scraping heats the saw and causes the teeth to lose edge. Hence, hesitant action should be avoided and a steady feed maintained to the saw. (See also under "Circular Saws"). Sound is an important guide in determining whether a saw is functioning correctly and is often relied upon by experienced saw doctors and sawyers as a test of a saw's behaviour.

Welding and Brazing

Every handsaw has to be joined, of course, at one point at least, in the blade. This is effected by brazing or butt welding. The latter process is more difficult, but when well carried out gives a stronger joint and is being used to an increasing extent. The technique is fully described in an article by Hensler

and Jones listed in the Bibliography. Effective brazing is of such importance in the fitting of bandsaws that the following instructions, supplied by courtesy of Messrs. Henry Disston & Sons Inc., are reproduced here:

1. When cutting off the ends be sure to allow for the proper spacing of the teeth.

2. Square the ends of the saw carefully, then bevel the upper side of one end and the lower side of the other, by filing, grinding or milling. The laps must be uniform, smooth, flat and must taper to a knife edge. The closer the laps fit the better will be the joint and the stronger it will hold.

3. Saws up to 7 inches wide should have at least ½-inch laps; 8-, 9- and 10-inch saws, 5/8-inch laps; 11- to 14-inch saws,¾ -inch laps, and saws over 14 inches, 7/8-inch laps. Wider laps may be used at the discretion of the filer.

4. After the ends have been properly bevelled, place one end at the centre of the brazing clamp, directly over the irons, with the back of the saw against the ledge of the clamp. Then tighten the end clamp to hold the blade in place and place the other end in corresponding position. The back edge of both ends of the saw must be straight and in line. The point of the top lap must cover and fit the lower lap perfectly, and the points of the teeth must be spaced properly to correspond with the other teeth in the blade.

5. When the ends are securely in position, raise the top end and clean the laps with dilute muriatic acid, and wipe dry with clean white waste, or a rag. Cut a strip of braze metal a trifle longer than the width of the saw, and y_{ui} of an inch wider than the laps. Clean the solder in the same manner as the laps and place it carefully between the laps. Fit the irons, which must be straight and level in the clamp, to raise the saw slightly at the brazed point.

6. Place the irons in the furnace and bring them to a bright cherry-red heat. Just before the irons are applied, cover the inside of the laps with zinc chloride flux or borax paste. As the irons come from the furnace, scrape off the scale, apply them quickly, the bottom iron first as originally adjusted, and secure the clamp firmly and evenly. As soon as the clamp is tightened loosen the other clamps which hold the saw in position. This is to allow for expansion and ensures a better finish when the braze is dressed. Remove the irons as soon as they are black and cool the brazed part of the saw with oil.

At the hammering bench, file off the excess braze metal. The brazed area has lost tension and is distorted. This area must be flattened and re-tensioned. Cover the brazed part with a heavy oil and heat carefully with a blow torch until the bright part turns a straw colour. This will stiffen the braze and prevent bending while it is being handled.

7. When satisfied that the braze is properly flattened and tensioned, place a curved block under the brazed portion. Clamp the saw to the bench on each side of the block and file the surface carefully. It is very important to maintain an even gauge throughout the braze. Polish it with emery cloth. Use a wire gauge to measure the thickness of the braze, which should not be thinner than the saw. When this operation has been completed, test again with a straightedge and tension gauge.

8. The brazed part of a bandsaw, and about an inch on each side of the braze, is a little softer than any other part of the blade. For that reason this part of the saw is more subject to bending when being changed or when handled in the filing room. Also the brazed part is more liable to lose tension than any other part of the blade.

9. Irregularity of tension, or bends, in a bandsaw are two common causes of cracks. It is, therefore, of great importance that the brazes in every bandsaw should be examined at the end of each run. If any bends are found in the brazes, or if the tension has pulled to any extent, the bends should be straightened and the tension restored.

10. It must be remembered that the brazed part is the weakest part of the saw. The brazes must be kept in proper condition by constant attention to reduce the chances of cracks and possible serious accident.

11. Many filers slightly reduce the height and swage of the tooth affected by the braze in order to reduce the strain upon it.

Welding Teeth on Bandsaws

The art of welding has so advanced in recent years that it can be applied successfully to the thin steel blades of bandsaws. Whereas butt welding, i.e., the joining of the blade, can be, and is, effectively accomplished, the generally satisfactory method of brazing—part of the stock-in-trade of the efficient saw filer—would appear to make the practice unnecessary. However, the welding of new teeth, where required, is highly recommended. Acetylene welding is regarded as superior to the electric method and can be handled easily in the filing room.

The efficiency of a bandsaw is in proportion to its width—the saw progressively becomes weaker as the blade is worn away in the process of re-grinding. If, as the result of an accident, such as the striking of a spike, a number of teeth are badly damaged, it is common practice to grind the saw down until a new set of good teeth are obtained all round the blade. In this way valuable saw material is wasted (in large saws this can amount to an inch or more of blade) and a large part of the effective life of the saw is lost. However, welding new teeth in place of the broken ones this loss is avoided. The procedure, which is much less difficult than butt welding, is set out briefly as follows:

1. Cut a piece of plate from an old saw and shear it into a rough shape big enough to form a tooth or that part of the tooth required. File a bevel of about 45 degrees on the stump of the old tooth and on this new piece. Be certain that the grain of the metal in the new piece runs parallel to that of the saw. Ordinarily, when teeth are torn off the saw, the base of the tooth remains above the gullet line and by making the weld above this line there is less danger of weakening the tension in the body of the blade.

2. Place the saw on the bench over an anvil and butt the new piece to it so as to form a V. Clamp the two firmly in place. It is advisable to insert under each a very thin packing so as to raise the weld just clear of the anvil. The reason for this is that actual contact with the anvil will cause the latter to

absorb heat from the edges of the plate and cause failure in the weld. A special clamp and anvil designed for this welding process has been produced by some saw makers and takes care of all these points.

This is a very broad outline of the method employed and some experimenting must be engaged in before success can be expected, as with all saw fitting procedures.

Welding Cracks

Cracks, both in handsaws and circular saws, may be permanently eliminated by means of welding. The process is as follows:

1. Punch the end of the crack.

2. Run a line of light punch marks along the course of the crack so that it may be followed when hot.

3. Forge right in from one side and then heat treat as for welding.

4. Hold a piece of saw blade close up to the edge of the saw to carry off the heat and avoid burning the edge of the saw.

Some Don'ts For Bandsaws*

1. Don't run an unevenly tensioned saw.
2. Don't run a saw with case-hardened gullets.
3. Don't run the back edge of the saw against the guide frame.
4. Don't run a saw with too much or too little set.
5. Don't run a dull saw.
6. Don't allow wheels to become out of line.
7. Don't run a saw with a short back.
8. Don't run wheels with worn faces.

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VI

PLANING

In practically all cases, the mechanical planing of timber is accomplished by passing the surface or surfaces of the timber to be planed across the cutting edges of fast revolving knives, or cutters. These are fitted into a "cutter block" or "head" which is rotated at high speed. According to the design of individual machines, timber can be planed (or "dressed" as it is often termed) on a face, or on any or all of four sides in one operation, and may be finished to a flat surface, or shaped (moulded) to a required pattern. Planing machines vary in design according to the class of work they are required to perform and are power or hand fed as the function of the machine demands.

A machine which simply planes, or dresses, a smooth surface on one or both faces of a board is usually termed a surfacer (double surfacer or "thicknesser" if both faces are planed in one operation). A machine which is designed to plane four sides in one operation, including the cutting, or moulding, of required shapes, is variously termed a moulding machine, a planer-and-matcher, or a four-header. Modern high speed machines of the latter kind are often equipped with a fifth head, designed to give the top surface of the material (such as the face of flooring) an especially smooth and even finish, and at the same time to increase the potential rate of production.

Most Australian sawmills catering for the retail trade, or specialising in flooring or similar lines, are equipped with one or more planing machines of the types mentioned above. These produce dressed material in the form of shelving, panelling, decking; matched boards such as flooring, lining, weatherboards, etc., and mouldings such as architraves, skirtings, beading, etc. A great many other types of machine, each using the principle of the revolving cutter head, have been designed for the specific requirements of joinery and furniture manufacture. They include jointers (buzzers), spindle moulders, routers and so on. These latter types of machine are hand fed in the sense that power-driven rolls for automatically feeding the timber to the cutters are dispensed with; the timber is passed across and held up to the cutters by hand.

No attempt will be made here to describe in detail the various types of planing machines mentioned in the foregoing remarks. Full description and details of technical performances are to be found in manufacturers' catalogues

which are readily available. It is important, however, for those controlling the use of, or operating planing machines, to understand some fundamental principles involved in the technique of machining timber with rotary cutters.

The following remarks attempt to indicate the more important of these principles. Close adherence to all of them is generally impracticable where, as often occurs, machines are called upon to plane a variety of timbers to a variety of shapes. A satisfactory set-up for this type of all-round work is generally achieved by a compromise of the factors involved. But where large quantities of the same or similar material are required to be planed, as occurs in the wholesale production of flooring, etc., or where the highest possible finish in repetition work is demanded, as in furniture and joinery factories, close attention to fundamental principles will ensure a higher rate of production and a better standard of manufacture.

Balance

Cutter blocks, with cutters fitted, irrespective as to whether they are running vertically or horizontally, must remain in perfect dynamic or running balance. Cutter blocks should be, and invariably are, supplied by the makers in perfect running balance. In fitting cutters to the blocks it is important to ensure that they are not only equal in weight, but that their centres of gravity are as nearly as possible equidistant from the spindle. Only by so doing will the effect of centrifugal force exerted by unbalanced cutters be avoided. When, in order to cut a particular moulded profile, two different shaped cutters are used on opposite sides of the same cutter block, dynamic balance becomes a problem but, nevertheless, one which must be overcome if excessive vibration is to be avoided. Normally, however, identical cutters are fitted on opposite sides of the cutter block. In this case the commonest fault in balancing arises from differences in the grinding of the cutters. This can be avoided by the use of the automatic grinder which will grind all cutters in a set of the same type (other than moulding cutters) exactly the same. Many modern machines are fitted with circular cutter blocks designed to carry six or more cutters, the efficient treatment of which practically demands the use of an automatic grinder.

As an illustration of the effect of centrifugal force,* let us consider the case of a cutter head running at 3,500 r.p.m. and out of balance by half an ounce at a mean distance of three inches from the centre of the spindle. The centrifugal force exerted in this case is equal to nearly 33 pounds! From this example it can be understood how improper balance in the cutter head will cause excessive vibration, resulting in uneven finish, and, if prolonged, ultimate damage to the machine.

Cutting Angle

The cutting, or approach angle is that formed by the cutting face of the knife and a line drawn perpendicular from the centre of the spindle, Fig. 13. This cutting angle is important because, to ensure the best finish, some

* Centrifugal Force = $\cdot000341 \times WRN^2$ where W = weight in lbs, R = radius in ft, N = r.p.m.

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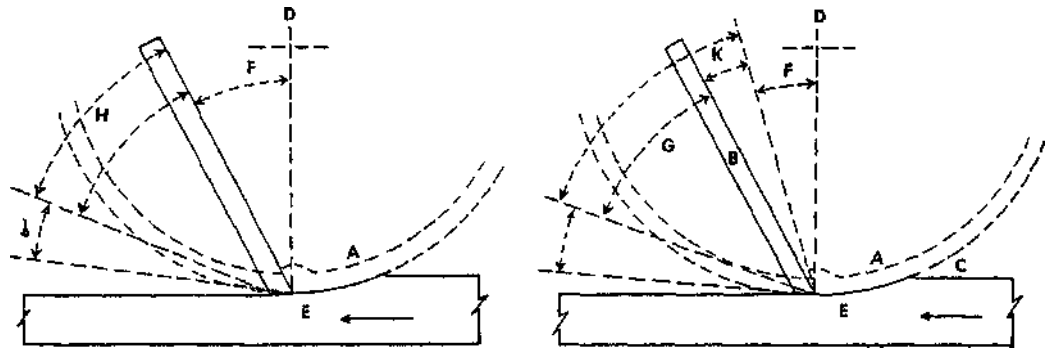
Figure 13. The cutting angle may be reduced by face-bevelling the cutter, the sharpness angle being increased by the face-bevelling. *A.* Cutterblock. *B.* Cutter. *C.* Cutting circle. *D.* Radial line. *E.* Timber. *F.* Cutting angle. *G.* Grinding angle. *H.* Sharpness angle. *J.* Clearance angle. *K.* Bevel angle.

variation of it is necessary in planing timbers of widely different texture (such as pine and Queensland maple). Timbers characterised by interlocked grain, particularly when quarter-sawn and showing figure, demand special attention in this respect.* Such timbers require a lesser cutting angle than do firm, straight grained timbers. The same may be said of the general run of Australian hardwoods as compared with the softer timbers.

Another element affecting the cutting angle is the moisture content of the timber to be planed. It is desirable to use a greater cutting angle for green timber than for seasoned timber. In general terms it may be said that, other conditions remaining the same, increasing the cutting angle will tend to prevent roughing, or raising the grain, in green or partly seasoned timber, while decreasing the cutting angle will tend to prevent the tearing out of the grain in dry timber.

Variation in the cutting angle, however, is not the only factor in avoiding roughing or tearing of the grain. The number of cuts per inch (q.v.) is also important in obtaining the desired conditions.

Cutting angle is more or less determined in the first place by the design of the cutter block and the diameter of the cutting circle (Fig. 13). In other words, the lie of the knife in the cutter block and the distance of the cutting edge from the centre of the spindle determines the angle at which the face of the knife approaches the timber. This angle, as determined by the above conditions, cannot be increased, but it can be decreased by the honing of a face bevel on the leading edge of the knife, see B Fig. 13.

It should always be remembered that the finishing cut is made at that point where the edge of the knife passes through the line drawn perpendicular to the centre of the spindle. The actual cut commences, of course, before this point is reached and continues upwards against the advancing timber. Lifting of the grain is checked by the chip breaker. The deeper the cut the greater the amount

* It will generally be found that the best finish will be obtained on the side of the board nearest the sap, or outside, of the log. The board should be fed to the machine so that, on the finish side, the knives will cut with and not against the grain.

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of wood which will have to be removed against the grain and to ensure the smoothest finish it is therefore necessary that the size of the rough stock be uniformly kept to the minimum.

Clearance Angle

Clearance to the back of the cutter is provided by the grinding of a bevel (Fig. 13). The greater the cutting circle the less is required for clearance, but the amount of clearance bevel actually carried is usually governed by the toughness of the timber to be planed. A sharper bevel (up to 60 degrees) and hence a keener—but weaker—cutting edge may be used in soft timber, but in planing hardwoods it is advisable to reduce the clearance bevel to 45 degrees or less.

Number of Cuts Per Inch

The speed at which the cutter blocks in any particular make of machine are designed to revolve is generally constant and is usually in the region of 3,500 r.p.m. Where motorised heads are fitted this speed is usually standard. * To run

TABLE 19

NUMBER OF CUTS PER INCH BASED ON RATE OF FEED
FOR SPINDLE SPEED OF 3,500 RPM

Feet per Min.	*Number of knives in cutter block*				
	2	4	6	8	10
20	29				
25	23		Number of cuts per inch tabulated to nearest		
30	19		whole number.		
35	17				
40	15	29			
45	13	26			
50	12	23			
55	11	21			
60	10	19	29		
70	8	17	25		
80	7	15	22	29	
90	7	13	19	26	
100	6	12	17	23	29
120		10	15	19	24
140		8	13	17	21
160		7	11	15	18
180		6	10	13	16
200		6	9	12	15
250			7	10	12
300			6	8	10
350				7	8
400				6	7
450					6
500					6

* The speed of cutter heads in some modern machines is rated as high as 7,200 r.p.m.

cutter heads at a speed greater than that for which they are designed is inadvisable and can be dangerous. It will be seen then, that variation in the number of cuts per inch is usually achieved by varying the rate of feed, though, if the design of the cutter head allows, the same effect will be achieved by fitting a greater or less number of knives in the block, see Table 19.

It is obvious that mechanical planing by means of rotary cutters produces a series of very small waves on the planed surface. Since the timber is advancing during the cutting process these waves do not correspond to an arc of a circle but are shallower. The greater the number of cuts to the inch the smoother will be the planed surface, but the rate of feed will be correspondingly slower. It is clear however, that if we add more knives to the cutter head, more cuts per inch will be achieved for the same rate of feed, or, similarly, a greater feed can be maintained for the same number of cuts per inch. To secure this improved performance cylindrical cutter heads with multiple cutters are fitted to many modern machines.

In determining the number of cuts per inch required for satisfactory work, the class of timber, whether it is seasoned or unseasoned, and the quality of

TABLE 20

A GUIDE FOR DETERMINING CUTTING ANGLES AND KNIFE CUTS PER INCH. NORMAL TRADE FINISH

Class of Timber	Seasoned		Unseasoned	
	Cutting Angle	Cuts per inch	Cutting Angle	Cuts per inch
		(approximate)		
Western red cedar	25	10	30	8
Borneo cedar	20	10	30	8
Kauri	20	12	30	10
Douglas fir	15	12	25	10
Red cedar	25	12	25	10
Baltic pine	20	12	25	10
Radiata pine	15	12	20	10
Coachwood	15	12	20	10
Hoop pine	15	14	20	12
Japanese oak	15	14	20	12
Silver ash	15	14	20	12
Cypress pine	15	14	15	12
Stringybark	12	14	15	12
Alpine ash	12	14	15	12
Tallowwood	12	14	15	12
Blackbutt	10	14	15	12
Queensland maple	10	15	15	12
Spotted gum	10	15	15	12

If grain lifts in seasoned timber decrease the cutting angle and/or increase the number of cuts per inch.

If surface roughs in unseasoned timber increase the cutting angle and/or decrease the number of cuts per inch. For higher quality finish in seasoned timber increase the number of cuts per inch.

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finish required, must be taken into account. In planing Australian hardwoods and timber with figured grain a greater number of cuts per inch is necessary (to prevent tearing out of the grain) than with soft and straight-grained timbers. To prevent roughing or raising of the grain in unseasoned timber, fewer cuts per inch should be used. For smoother and finer finish, such as is required in joinery and furniture, the number of cuts per inch must be increased, see Table 20.

From the foregoing remarks it will be understood that different kinds and conditions of timber often need different methods of working and that a machine adjusted to do good work in one class of timber may, in another class, without change in adjustment, produce quite different results.

The Chipbreaker

As mentioned earlier, the chipbreaker to some extent prevents, or checks, the tearing of the grain when the cutter has passed the point of deepest cut and is moving in its circular action up and against the grain of the timber. The chipbreaker is designed to press firmly down on the timber close to the point where the cutter emerges. In so doing it also serves to hold the timber rigidly against the table and thus acts as a pressure bar. It is important that the chipbreaker should be kept as close up to the cutters as possible, and at all times be free to follow any irregularities on the upper surface of the timber. Pressure is applied by either dead weight or springs. Dead weight, owing to the inertia involved, is excellent for this purpose of holding down but does not hold its pressure over ridges as evenly as a spring. A combination of both weight and spring would appear to be ideal in this respect.

The Pressure Bar

In moulding machines, pressure is necessary not only to keep the timber firmly down against the table, but also against the side fence. Only by so doing can evenness and accuracy in profile be obtained. The amount of pressure necessary usually varies according to the size of the stock being planed; it should be sufficient to adequately hold the timber firmly against table and fence, but excessive pressure will act as a brake on the free run of the timber through the machine and may cause frequent stoppages.

Cutters and Cutter Blocks

Cutters, made in various kinds of steel alloy, differ in type according to the design of the cutter block in which they are to be used. Most cutters are faced with a laminated cutting edge of high speed steel. Circular (cylindrical) cutter blocks have the advantage of being capable of setting more than four cutters —in very high speed machines such cutter blocks are fitted with as many as sixteen cutters, enabling rates of feed up to 700 feet per minute to be maintained. The circular cutter block affords the maximum amount of metal for a given diameter of cutting circle. The tendency of shavings to pack under the lip is avoided and the danger of breakage of cutters is very greatly reduced.

A feature of the circular cutter block is the use of corrugations on the back of the cutter and in the slot of the block. Thus the proper lie and projection

of the cutter is fixed exactly when re-setting. This feature also eliminates the possibility of the cutter driving back in the block.

Solid cutters, designed for moulding standard profiles, are cast and machined in such a way that the cutters form an integral part of the block and constitute a single unit. Such units, being readily interchangeable, eliminate the necessity for the longer and somewhat painstaking process of setting up individual cutters. Modern planer design incorporates as much as possible the use of interchangeable, or "loose", cutter blocks, whether as a solid unit just described, or in the more conventional slotted form. Loose cutter blocks reduce enormously the time spent in setting up standard profiles as well as ensuring accuracy in manufacture.

Cutter setting and jointing devices which ensure that each cutter performs the proper amount of work are often built into the machine as integral parts of the modern planer.

Cutters should always be kept sharp and frequently, but lightly, jointed. "Heel" should never be allowed to become more than y_{32} inch wide. (Heel is the slight bevel at the cutting edge produced by jointing).

Exhaust Systems

No remarks on planing mill efficiency would be complete without reference to the importance of the proper disposal of chips and shavings arising from the planing processes. For if this refuse is not efficiently removed as it occurs it will clog the machinery, cause costly stoppages, and produce pitting and bruising in the planed surfaces. In addition it will constitute a dangerous fire hazard.

The best method of shavings disposal is by an exhaust system comprising fan, cyclone and flues. To function efficiently such a system must be designed to take care of each individual installation in the mill and the order in which these are coupled to the system, as well as the method, is important. Design of exhaust systems is a function of ventilation engineers who should always be consulted when consideration is being given to the installation of planing mill equipment.

Some "Don'ts"

1. Don't attempt to start up a machine without checking over all cutter bolts.

2. Don't overstrain cutter bolts; it is dangerous.

3. Don't run a machine with cutter blocks out of balance.

4. Don't let chipbreakers or pressure bars become stiff or congested with shavings. They must always have free movement. Keep chipbreakers close up to the cutters.

5. Don't be satisfied with poor finish—check over cutting angles and rate of feed.

6. Don't allow cutters to become dull.

7. Don't carry more pressure on the feed rolls or pressure bars than is necessary.

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8. Don't allow the grooves in feed rolls to choke with shavings.

9. Don't "joint" cutters to the extent that they develop excessive heel.

10. Don't overheat high speed steel by heavy or careless grinding. This will cause cracks in the cutters.

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VII

VENEER, PLYWOOD, BLOCKBOARD, PARTICLE BOARD, AND FIBREBOARD

VENEER

A modern definition of veneer is: "timber in the form of a thin layer of uniform thickness".* It is produced by sawing, slicing or rotary cutting (peeling).

The art of veneering is one of the oldest known. Almost every historical era is represented by examples of beautiful veneers and skilled craftsmanship in their use. The outer coffin of Nepthys, veneered with cedar (now in the Metropolitan Museum, New York), is some 4,000 years old. The Roman author Pliny declared that the proudest possession of Julius Caesar was a beautifully veneered table, and in his *Natural History* he describes at some length the various timbers suitable for veneers, placing emphasis (as is done today) on the value of roots and butts of certain trees as a source of beautiful figure.

Belonging to a later period, many examples of veneered work are to be found in the creations of great craftsmen such as Chippendale, Sheraton, Jean Riesener and others.

Economical Use of Rare Timbers

The foregoing should serve to prove that the efficient use of veneers, besides being economical in the consumption of rare timbers, can produce artistic effects and a high degree of permanence, qualities which have been recognised from the days of the Pharaohs to the present time. This should dispel any impression that veneered work is inferior; the question of inferiority only arises when the veneer itself is of poor quality or the standards of workmanship is low.

* British Standards Institution.

Effective Use of Figured Timbers

Veneered construction has not only produced the exquisite pieces of furniture and rare panellings which are the legacy of craftsmen of the past, it has also made possible in modern times factory production of repetition furniture of equal merit. Full justice could not be done to the beauty of figured timber by using it in the form of solid boards. From one inch of figured timber it is possible, however, to slice thirty or more sheets of veneer.* When these are glued to a core of suitable material, a high-grade panel is obtained. This panel has all the beauty of the figured timber, combined with high stability, strength and uniformity. The economy in use of the valuable figured timber is obvious.

Moreover the use of figured veneer makes possible the utilisation of dense timbers which, because of their weight, would be unsuited for use as solid timber.

Many of the choicest figured timbers owe their attractiveness and ever-changing variations in lustre to the presence of marked differences in grain direction over adjacent areas. Such timbers would be difficult to season satisfactorily as solid boards, but present no difficulty in the form of veneer. Burls, crotches and stumps are thus most effectively utilised as veneer.

The use of veneer facilitates the preparation of designs which enhance the natural beauty of the figured timber for incorporation in furniture panels, etc. Of particular value and effect is the extensive use of matched design in furniture suites and in wall and door panelling. Similar matching* of design in solid timber would not be possible.

Nature has not been prodigal in providing Australia with beautifully figured and grained timbers. Those we do possess, however, are the equal of the world's best and, if their supply is to be maintained, every process which will eliminate or lessen waste of our valuable timbers must be employed. This country's supply of furniture timbers, for example, Queensland maple, Queensland walnut, red cedar, blackwood, silver ash and so on would not now be so precarious had the practice of veneering been applied to their use in earlier days.

MANUFACTURE OF VENEER

Several methods are used in the manufacture of veneers, namely, slicing, semi-rotary slicing, sawing, or rotary cutting (peeling). The slicing methods yield the best finish and are usually employed when the veneer is to be used as a facing for furniture, doors and high-class panelling. Rotary cutting is employed in the manufacture of all types of plywood and for all purposes, including decorative finished products.

("Cross-banding" is the term applied to those sheets of veneer which are laid with the grain running at right angles to the core and face of the finished panel). The highest quality three-ply, when required for fine panelling, is usually faced with slice-cut veneer.

* For special purposes veneer may be cut as thick as ¼ inch or as thin as 1/80 inch and with great accuracy. High grade slice-cut veneer for the aircraft industry can be produced to tolerances as low as four thousandths of an inch.

Slicing

The slicing of veneers is usually confined to decorative timbers, the beauty,- of which is enhanced, as a rule, by quarter cutting. (With some species, rotary peeling will produce the most effective figure).

The logs are first sawn into flitches in such a way as to develop the best figure. The flitches, after steaming or heating in water are held in a horizontal position and cut into thin veneers by moving a knife over the flitch or moving the flitch past a stationary knife.

Care is taken to keep the sheets of veneer together in consecutive order to facilitate matching, that is, the preparation of designs. Sliced veneer is usually 1/32 inch thick, but considerably thinner veneers are cut for special purposes.

Semi-rotary Cutting

Semi-rotary cutting is carried out on a veneer lathe. Figured logs are sawn into quarters, which are then set up eccentrically in the lathe at a corner nearest the sapwood. As the lathe revolves, slices of veneer are removed from the flitch. It is thus possible (if the flitch is properly positioned in the lathe) to obtain practically a true quarter cut, i.e., radial figure. Ordinary rotary cutting gives a back cut, i.e., tangential figure. For many figured timbers the semi-rotary cutting is definitely advantageous.

In the cutting process, the veneer is forced abruptly away from the flitch by the knife, and this often causes fine breaks or checks to appear on the side of the veneer next to the knife. The checked side of the veneer is called the "loose" and the other the "tight" side. This difference is important in gluing veneer as face stock, since the loose side should be glued down where possible, the tight side being less liable to show defects in finishing.* However, such defects are less pronounced in thinner than in thicker veneers.

Before a flitch is sliced to veneer, it is either heated in water or steamed in
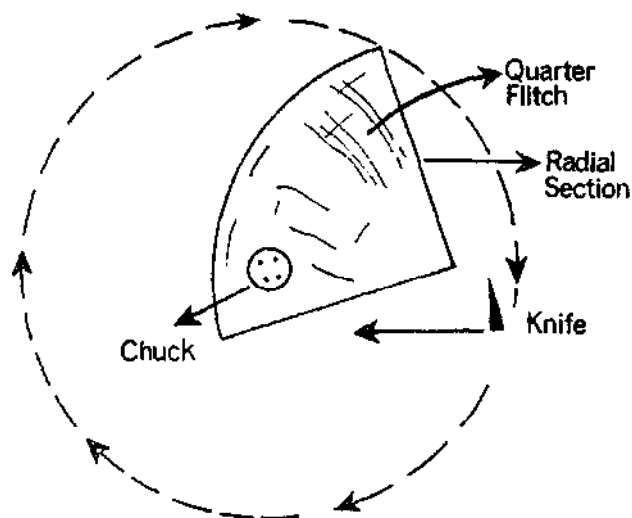
Figure 14. Semi-rotary cutting.

* T. R. Truax.

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order to soften the timber. Various times and degrees of heating are necessary according to the species treated, and experience with individual timbers is necessary to achieve best results.

Sawing

When, because of hardness, brittleness, or too "wild" a grain, timber does not lend itself to slicing or peeling, a veneer saw may be used. Usually such saws are of very large diameter with small, finely set teeth, and designed specially for the purpose of cutting thin veneers with a minimum of sawdust. This method is rarely used in Australia.

Drying Veneers

A common method of drying veneers in Australia is by the use of a suitable type of seasoning kiln equipped with steam coils and blower. The veneers are fitted into special racks or frames before being moved into the kiln. In some cases the veneer, especially thicker stock, is stripped, as is timber, before being introduced into the kiln.

The progressive type of seasoning kiln (mentioned in Chapter XV) is sometimes used in the drying of veneer, particularly of rotary-cut veneers preparatory to their manufacture into plywood. In some plants, veneer is dried at room temperature by suspending it from special holders or arranging it in racks. This requires more time than the high temperature methods, and the veneer is usually not held flat during the drying period.

An efficient but expensive type of veneer drier consists of a long heating chamber equipped with roller or belt devices upon which the veneer is laid and maintained flat and carried steadily through the chamber. Heating coils and fans are located along the chamber and the degree of humidity, heat and air circulation used in the drying process may be controlled.

It is important to dry veneers with as little delay as possible in order to prevent the growth of mould which may occur when veneers are closely stacked in damp conditions.

Timbers with highly decorative figure are usually more difficult to dry than plainer types, and great care has to be taken in the drying process. Sometimes, best results are achieved with the more difficult types by air-drying in normal temperature.

High Speed Mechanical Driers

Because the bulk of plywood is produced from synthetic adhesives and hot-pressed at temperatures well above 212°F, making low veneer moisture content essential, drying time and moisture content control have become increasingly important. This has resulted in the use of high speed mechanical driers which produce excellent veneer of any desired moisture content. (See Photo 7).

These units give short drying times, improved veneer quality and favourable economy.

The screen drier developed by the CS.I.R.O,* is still used widely in

* See D.F.P. *Newsletter,* No. 215.

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industry. Advantages of this screen drier, as compared with a mechanical roller or mesh belt drier, are the low capital cost, ease of construction, use by untrained personnel, and the small number of moving parts with consequent ease of maintenance.

Scarf Jointing of Veneers*

The shortage of peeler logs for production of plywood necessitates the utmost economy in the utilisation of available timber. The increasing use of splicing equipment in Australian plywood mills shows that manufacturers are well aware of the fact that they must make maximum use of available resources.

The end scarfing of veneers is one method of effecting savings. With suitable machinery and organisation, labour costs of this process appear to be similar to the cost of splicing. Scarf jointing of veneers makes possible the use of materials coming from short billets, round up off-cuts, and from peeled veneers found faulty in part of their length. Further particulars can be obtained on application to the Division of Forest Products, C.S.I.R.O., South Melbourne.

BLOCKBOARD AND VENEERED PANELS

The term "core", used in connection with veneered panels or plywood, refers to the inner layer about which the panel or plywood is built. In three-ply the core is laid at right angles to the grain of the two outer layers of veneer. In multi-ply, or plywood built up with more than three layers of veneer (viz., five-ply, seven-ply, etc.), the core is laid parallel to the surface layers and the alternate layers are cross-banded, that is, laid at right angles to them. This form of construction gives balance to the panel and prevents warping since any stresses which might occur through shrinkage are equalised on either side of the core. Veneered panels are therefore nearly always made up of an odd number of laminations.

In the manufacture of furniture, it is common practice to use a core of wood built up laterally by gluing a number of narrow strips together to form the desired width. Common practice is to use strips narrower than 3 inches. Short strips can be butted (provided the butts are staggered), resulting in great economy of timber. This class of work is usually known as blockboard, and is now made with modern automatic equipment.

Blockboard is now used by the furniture industry for the manufacture of almost every class of cabinet-work. To derive the full advantage of core construction it is important that the same care be given the preparation of panels as is exercised in their fabrication into furniture. Experience obtained in industry and laboratory research has resulted in a highly developed technique of manufacture.

Blockboard differs from commercial all-veneer plywood in that the core is made of edge-glued strips of sawn timber of desired thickness. This does not possess the equalised strength characteristics of an all-veneer plywood, because the strength of the core predominates. A thick timber core permits

* See D.F.P. *Newsletter,* no. 217.

dowelling, dove-tailing and other cabinet-making operations which are not satisfactorily made with the thinner all-veneer plywood. A further advantage of blockboard for the manufacture of furniture is that the core can be banded along the edges with strips of timber or veneer of the same species as the face veneer.

A five-ply construction is favoured for the better grades of blockboard since it is better balanced, is more dimensionally stable, possesses more equalised strength distribution, and is of better appearance. The use of three-ply construction is generally cheaper, but unless special precautions are observed, the panel may not be strong, the appearance may suffer due to the core defects showing through the face veneer, and the panel will have a greater tendency to warp.

It is very important that the timber used in the core plates be uniformly dried to a low moisture content. The actual moisture content value should be that which the furniture, or other product for which the veneered core stock is to be used, will reach during the service or exposure for which it is intended, otherwise joint trouble may occur.

The glue is spread on the edges of the strips by a small glue roller, by lifting a metal grid work from a trough of glue and momentarily touching a stack of strips on this grid or some other method. Many cases of unsatisfactory gluing can be traced to lack of cleanliness in the glue trough or to improper temperature of the glue.

Room-temperature-setting urea resin glues can be used for edge-gluing. These glues produce bonds which are more water-resistant than those made with animal glues and their curing can be accelerated through the application of heat. The moisture content of the timber at the time of gluing is, however, more critical for room-temperature-setting urea resin glues. They usually require a wood moisture content of at least 6 per cent to produce satisfactory joints. The glue manufacturers' instructions concerning the preparation and use of these adhesives should be carefully followed. A small glue spreader fitted with a grooved rubber-covered roller is the most convenient method of spreading the urea resin on the strips.

In using room-temperature-setting urea resin glue, care must be taken that the glue does not remain in the pot at room temperature for a period longer than that recommended by the glue manufacturer. One method of overcoming this difficulty is to enclose the glue storage at the spreader with a cold water jacket.

After the strips have been spread with glue, they are placed in a clamp and pressure is applied. Large automated machines hold the strips in a clamped position while heat is applied to set the adhesive.

Edge-gluing presses which utilise steam heated platens or radio-frequency* heating are now used for rapidly curing glue joints. Reduced labour costs and shorter gluing cycles are the main advantages of this equipment.

Panels glued with a urea resin glue, which has been cured by radio-frequency heating, can be safely faced almost immediately after removal from the press. Contrary to some opinion and practice, a high-grade veneer should always be

* Radio-frequency drying is discussed in D.F.P. *Newsletters* nos. 163, 164 and 167.

used for cross-band material. Care should be taken to use only straight-grained tight-cut veneer for this purpose. Many warping problems in veneered core stock can be attributed to cross-grain wood in the cross-band veneers.

Veneer Care and Recovery

When room-temperature-setting urea resin glues are used, the moisture content of the cross-band veneer should not be below 6 per cent and preferably 8 per cent to ensure high-quality bonds. If the veneer is not produced and dried in the plywood or furniture plant but is purchased, it will often be wrinkled when received, and its moisture content may be unsuitable for fabrication into plywood. In this case, the veneer must be flattened and re-dried to a moisture content appropriate to the type of adhesive that will be used. Such operations may be carried out in a platen re-drier which consists of a vertical series of smooth steam-heated plates, or platens. The platens alternatively close to flatten the veneer and open to allow moisture to escape. Veneers are inserted and removed during the open part of the cycle.

Figured face veneers are usually 1/32 inch thick. Care must be taken in the flattening and drying of some special veneers which may be too fragile to be dried in a platen drier. It is customary to lightly sprinkle two or three sheets of veneer with water and place them between heated timber or plywood cauls. This process is repeated many times until a bundle of cauls and veneers is built up. Pressure is gently applied and the bundle is clamped overnight. The cauls can be conveniently heated in a platen drier.

The veneer for cross-bands and backs is cut to dimensions slightly greater than those of the finished panel. If the sheets are too narrow to cover the complete panel, they must be spliced to make up the required width. Usually it is not considered necessary to joint the edges of cross-band veneer prior to taping providing they are clipped straight and true. These veneers are then fastened together along the edge with a perforated paper tape in a taping machine. The tape should be applied to the loose side of the veneer, that is the inner side of the veneer as it comes from the log. Perforations in the tape permit the adhesive between the cross-band and core to reach a maximum surface of veneers along the joint. Alternatively, if a tapeless splicer is used, the edges of the veneer should be jointed prior to splicing.

The figured face veneers are prepared in much the same manner as plain veneer, except, of course, that these veneers are usually arranged and matched in artistic geometric patterns. The first step is to cut the flitch veneer to approximate size. Then, according to the grain, figure, and the desired type of matching, the veneers are trimmed to shape with true edges on a guillotine cutter which both clips and joints in one operation. Tapeless splicing is widely used for splicing plain face veneers, but tape is generally used for splicing fragile and highly figured face veneers. In the case of face veneers the tape should always be placed on the face side where it can be removed from the finished panel.

In the manufacture of five-ply panels, the cross-bands are fed through the spreader and glue is simultaneously spread on both sides so that one side will be bonded to the core stock, and the other side to the face or back veneer.

Veneers can be bonded by either the cold-press method or by the hot-press method. Hot pressing with Tego glue film is occasionally used when bonding very thin and porous face veneers. One reason is that liquid glue may "bleed through" very thin veneers and thus mar the finish. The moisture content of the veneers and cores must be more carefully controlled when hot-pressing to avoid checking of the fragile face veneers and the formation of blisters caused by steam pockets in the core.

The usual procedure in laying up cross-banded veneered panels for cold-pressing may be summarised as follows. A retainer board, three or four inches thick and slightly larger in area than the stock to be pressed, is placed on an empty truck near the out-feed side of the glue spreader. This retainer board is then covered with a smooth flat sheet of thin plywood or sheet metal known as a caul. A face veneer, with its taped side down, is placed in position on the caul. As the first cross-band comes from the spreader it is carefully laid with its taped side up, on the face veneer. A core is laid up next, then another cross-band from the spreader, taped side down, and finally a back veneer.

A second caul is placed on the pile and the laying-up operations are repeated. The process is continued until a stack or bundle three or four feet high containing forty or fifty assemblies is built up. A retainer board is placed on the top of the stack, and the entire bundle is moved away on the truck to the press.

In the manufacture of three-ply panels a similar process is used but the core is passed through the glue spreader instead of the cross-bands.

The purpose of the cauls is to keep the veneered panels flat and to prevent defects in any one panel being transmitted to adjacent assemblies. Opinion varies between different manufacturers as to the relative merits of metal and wood cauls. Metal cauls, usually sheet aluminium, are favoured for their thinness, lightness, high conductivity of heat, and the fact that squeezed out glue does not readily stick to their smooth surfaces. On the other hand, more care is required in handling metal cauls, because they are easily dented and dents mar the face veneers of the plywood. Plywood cauls with waxed surfaces give good service providing they are kept clean and smooth. The cauls are waxed to prevent the panels being glued together by the glue squeezed out during pressing.

Although hand-operated or power-driven screw presses are still used for cold-pressing, the hydraulic press is more widely used in modern plants. In the hydraulic press the upper platen is fixed and pressure is applied by the lower platen which is mounted on a hydraulic ram.

After pressing, the panels are moved into a drying room* where the temperature is maintained at 110°F. to 120°F., with a relative humidity of 40 to 50 per cent. This room should be equipped with powerful fans as in a timber kiln to ensure good air circulation throughout the pile.

Veneered panels, bonded with a room-temperature urea resin and cured in

* See C.S.I.R.O. Division of Forest Products *Trade Circular* no. 21, "Drying Rooms for Furniture Stock."

a "hot room", usually do not require drying since this type of glue introduces considerably less moisture into the panels than vegetable and casein glues.

It is to be noted that throughout this section stress has been placed on the control of moisture content at all stages of manufacture. The importance of moisture content cannot be over-emphasised, for it is the most important single factor in the manufacture of veneered panels.

In addition to those of timber, cores of materials derived from wood waste, such as particle board are manufactured in Australia for use in panel work.

Particle board is the newest of a widening range of wood-based furniture and building-board sheet materials. It is also known as chipboard, chipcore, chipcraft, shavings board, flake board and wood-waste board.

As the name implies, wood-particle board is essentially a mechanical aggregation of small pieces of wood such as chips, splinters, slivers, shavings or a combination of these mixed with an adhesive, usually a urea-formaldehyde resin, and then heated and compressed in a suitable form to the board dimensions and density required.

Its characteristics are quite distinct from those of hard fibre boards and insulating boards which are made by reducing wood to its fibre elements and then reforming these into board shape, using the felting characteristics of the individual fibres and fixing them under high temperature and pressure.

Particle board has so far given greatest competition to timber core stock and blockboards as used in the furniture industries, and to the thicker plywoods.

It is increasingly being used for purposes where utility or decorative panels are required. It can be used both with and without facings.

Synthetic and Other Facings on Plywood

Plywood may also be faced with materials other than timber veneers. Aluminium, stainless steel, and synthetic materials are used as facings on plywood for special purposes. Increasing quantities of plastic overlayed plywood are being produced for interior decorative purposes.

PRINCIPAL TIMBERS USED IN AUSTRALIA FOR THE
MANUFACTURE OF VENEER AND PLYWOOD*

The plywood industry in the following areas produces veneer and plywood mainly from the species listed: t

  * = Peeled only
** = Peeled and/or sliced

NORTH QUEENSLAND

**	Black Bean	*Castanospermum australe*
**	Queensland Walnut	*Endiandra palmerstoni*
*	Bally Silkwood (Tarzali Silkwood)	*Cryptocarya oblata*

* For description of these timbers for veneer and plywood purposes see *The Commercial Timbers of Australia* by I. H. Boas (C.S.I.R.O.).

t Detailed information relating to plywood and its uses is available from the Plywood Association of Australia Limited, 3 Dunlop Street, Newstead, Brisbane, Queensland.

*	Red Silkwood (Cairns Pencil Cedar)	*Palaquiwn galactoxylum*
*	Kauri Pine	*Agathis microstachya* & *A. palmerstoni*
**	Maple, Queensland	*Flindersia brayleyana* & *F. pimenteliana*
*	White Cheesewood (Milky Pine)	*Alstonia scholaris*
*	Magnolia (Pigeonberry Ash)	*Galbulimima belgraveana*
*	Northern Brush Mahogany (Red Carabeen)	*Geissois biagiana*
*	Rose Alder	*Ackama australiensis*
*	Rose Butternut	*Blepharocarya involucrigera*
*	Sassafras, Northern	*Doryphora aromatica*
*	Satin Sycamore	*Ceratopetalum succirubrum*
**	Silky Oak, Northern	*Cardwellia sublimis*
**	Silver Ash	*Flindersia pubescens* & *F. bourjotiana*
*	Silver Quandong	*Elaeocarpus grandis*
**	Tulip Oak	*Heritiera spp.*
*	Carabeen	*Sloanea spp.*
**	Yellow Walnut	*Beilschmiedia bancroftii*

Other Rainforest Timbers

SOUTH QUEENSLAND

(a) Veneers purchased from north Queensland and country areas of South Wales, both peeled and sliced.
(b) Hoop Pine *(Araucaria cunninghamii)*
(c) Imported Island Species for peeling——Seraya, Anisoptera
(d) Imported Sliced Veneers—Gaboon, Sapelle, Pearwood.

COUNTRY AREAS OF NEW SOUTH WALES

Negrohead Beech	*Nothofagus moorei*
Coachwood	*Ceratopetalum apetalum*
White Birch	*Schizomeria ovata*
Yellow Carabeen	*Sloanea woolsii*
Silver Sycamore	*Cryptocarya glaucescens*
Sassafras	*Doryphora sassafras*
Southern Silky Oak (Prickly Ash)	*Orites excelsa*
Brown Alder (Corkwood)	*Ackama paniculata*
Brush Mahogany (Red Carabeen)	*Geissois benthami*
Spotted Gum	*Eucalyptus maculata*

SYDNEY

(a) Imported Island Species
(b) Imported Sliced Veneers
(c) Australian Veneers

MELBOURNE

Radiata Pine	*Pinus radiata*
Victorian Ash	*Eucalyptus regnans*

Imported Island Species
Imported Sliced Veneers
Australian Veneers

SOUTH AUSTRALIA

Radiata Pine	*Pinus radiata*

WESTERN AUSTRALIA

Radiata Pine	*Pinus radiata*
Karri	*Eucalyptus diversicolor*
Jarrah	*Eucalyptus marginata*

Ramin (Imported)
Imported Sliced Veneers

TASMANIA

Tasmanian Ash	*Eucalyptus regnans*
Blackwood	*Acacia melanoxylon*
Myrtle Beech	*Nothofagus cunninghamii*

Imported Island Species

SLICED: Pronounced figure or beauty of appearance is usual requirement.

Ash, silver	Oak, silky
Bean, black	Oak, tulip
Blackwood	Satinay
Candlenut	Silkwood, bolly
Cedar, red	Walnut, New Guinea
Jarrah	Walnut, Queensland
Maple, Queensland	Walnut, yellow

Knotty radiata pine has also been very effectively used when stained.

ROTARY: Shape of log and freedom from shakes, etc. are important. They must peel smoothly and not check freely. The following are the most widely used:

Alder, blush	Birch, white
Alder, brown	Carabeen, yellow
Alder, rose	Coachwood
Ash, mountain	Karri
Beech, myrtle	Kauri, Queensland
Oak, silky	Pine, radiata
Oak, tulip	Quandong, silver
Pine, hoop	Sassafras
	Walnut, yellow

Bindang)
Cedar, Borneo) Borneo
Jongkong)
Ramin)

Kauri (Solomon Is., New Hebrides)
Pine, klinkii (New Guinea)
Taun (New Guinea; Solomon Is.)
Walnut, island (Solomon Is.)

PLYWOOD*

Plywood is the name applied to the product obtained when thin layers of timber, i.e. veneers, are glued together, with the grain of one ply generally running at right angles to the grain of the ply above and below it. The plies or layers are usually arranged in an odd number, so as to preserve a balanced structure about a central ply or core. So we have three-ply, five-ply or any greater multi-ply.

Plywood is made from a variety of timbers, all of different colour, grain and texture. No two pieces, even from the same tree, are absolutely identical. In this, nature has provided the pleasure and interest of variation; has avoided the monotony of appearance which is so characteristic of most man-made materials.

Timbers from the tropical rain forests of northern Queensland and the towering mountain ash of the temperate forests of Victoria and Tasmania are converted into plywood with equal ease.

Under modern methods, plywood is a scientifically manufactured material utilising to the full the sterling qualities of timber which have made it pre-eminent amongst structural materials and eliminating timber's defects to a considerable degree.

The distinguishing features of plywood are the thin veneer plies and the crossings of the grain in alternate plies.

Though plywood is a laminated material, i.e., it is built up of lamina or plies, it is not to be confused with the generally accepted meaning of the term "laminated" as applied to timber. (See Chapter IX).

In Australia, plywood may be obtained in a variety of sizes, thicknesses and grades. (Plywood bulkheads up to two and a half inches thick are used in ship-building). Its uses are unlimited: ordinary grades are available for general constructional purposes, special grades for use where high resistance to water is required and fancy grades for displaying the beauty of our finest decorative timbers for furniture manufacture, panelling and so on.

Conversion into plywood not only preserves all the valuable properties of solid timber, but at the same time eliminates to a large extent many of its disadvantages.

PLYWOOD PRODUCTION IN AUSTRALIA

In the period since 1946 plywood production in Australia has doubled. Current production is in the vicinity of 210 million square feet.

In recent years, the Australian plywood industry has reorganised itself to produce a wide range of veneers and plywood products including those of the

* Detailed information relating to plywood and its uses is available from the Plywood Association of Australia Limited, 3 Dunlop Street, Newstead, Brisbane, Queensland.

very highest quality. This has been made possible by the use of modern equipment (some of it highly specialised), by the use of new adhesives and by the introduction of improved techniques.

Types of Plywood

Plywoods bonded with several different types of glue are available. There are grades for interior work which usually require moisture-resistant or highly moisture-resistant types, and there are glue grades available for exterior applications which are fully water-proof bonded. In exterior applications, only the waterproof and boilproof bonds can ensure satisfactory results.

Plywood and glue-line standards are covered in several Australian Standard Specifications. These include AS085 Australian standard specification for pinus structural plywood, AS086 Australian standard specification for plywood for marine craft, AS087 Australian standard specification for exterior use, AS088 Australian standard specification for interior use. These reference numbers should be used when specifying so that no misunderstanding can occur. Only phenolic type "A-Bond" glue-lines described in AS090 "methods of testing plywood" are recommended for exterior applications.

Plywood is fully protected against Lyctus borer attack in both New South Wales and Queensland by timber marketing Acts. All susceptible veneers are immunised.

For protection in situations where decay hazard is unavoidable, effective preservatives have now been developed and treated material is becoming more and more readily available. Fire resistance can be improved by impregnation with appropriate phosphates and other proprietary chemicals.

ADVANTAGES OF PLYWOOD CONSTRUCTION

Economies in the Use of Timber

By converting a log into plywood instead of sawn timber, distinct economies are effected. This is an important feature at times when demand is at a maximum and supplies of basic raw materials are difficult to obtain.

High Uniform Strength

Timber is approximately 25 to 45 times stronger along the grain than across the grain. This is bound up in the fact that the structural elements (cells) of the timber are arranged with their longitudinal axis parallel to the length of the tree.

Thus it can be seen that by manufacturing plywood with the grain of alternate laminations at right angles, the strength tends to be equalised in all directions.

The versatility of plywood in this regard and its adaptability as an engineering material is exemplified by the fact that it can be obtained without difficulty in a variety of constructions to conform to any desired strength requirements.

Reduced Shrinking, Swelling and Warping

A disadvantage of solid timber is its propensity to "move", that is shrink and swell with moisture content changes.

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TABLE 21

PERCENTAGE VARIATION IN DIMENSION PER 1 % MOISTURE CONTENT CHANGE

Species of Timber	Plywood {three-ply 3/16 in.)		Solid Timber	
	Parallel to grain of face plies	Perpendicular to grain of face plies	Tangential	Radial
Hoop pine ...	-010	-014	-22	-17
Coachwood ...	-015	-021	-29	-19
Silver ash ...	-014	-023	-27	-20

From a consideration of the construction of plywood it will become apparent why movement is reduced. As dimensional changes occur mainly across the grain, and the grain of adjacent layers is at right angles, the whole sheet tends to remain stable, providing it is of balanced construction around the central ply. The longitudinal stability of each ply prevents any tendency for the cross-grain movement of the plies above and below.

A comparison between the shrinkage of solid timber and plywood of the same species is given in Table 21.

In the case of hoop pine, the tangentially cut solid timber has a 0-22 per cent variation in dimension for each 1 per cent moisture content change, while for the plywood (with the veneer peeled in the same direction) the figure is 0-014 per cent. In simpler terms, the shrinkage of the plywood is approximately one-sixteenth that of the solid timber!

Construction of the sheet in accordance with sound practice ensures plywood which is highly resistant to warping. Extreme care must be taken in the selection of the veneers and in the control of their moisture content to guard against undue stresses being set up during the final conditioning of the plywood following the introduction of moisture from the adhesives used, while at the same time it is essential that the individual plies on either side of the central ply or core shall have similar characteristics. Without such care, the sheet would be unbalanced and variations in the amount and direction of shrinkage or swelling with moisture content changes would tend to cause warping.

Non-splitting Qualities

Plywood, by virtue of its approximately equalised strength in all directions, can be nailed or screwed close to the edge without danger of splitting. This is a very valuable characteristic of plywood when used in furniture and house construction.

Availability in Relatively Large Sizes

There is practically no limitation to the size of plywood that can be produced. Panels up to 6 X 50 ft. are prepared for special uses by single-sheet production and by scarf-jointing standard panels. The standard sizes however,

are 6 X 3 feet, 6 x 4 feet, 7 X 3 feet and 8 X 4 feet (the first dimension is along the grain of the outer plies), and it is found that panels of these sizes are adaptable for the majority of uses.

Ease of Drying Without Degrade

Solid timber, particularly much of the Australian hardwood, is difficult to dry without degrade. The thicker the timber the greater the stresses which develop in drying and the greater the tendency to check or split.

The drying of very thin veneer without degrade is a relatively simple matter, since the stresses which are set up are not to be compared with those which occur in solid timber. The subsequent re-drying of plywood after the introduction of moisture during the gluing operation presents no difficulties with normal thicknesses. Drying times are measured in minutes instead of days or weeks.

Ease of Fabrication of Curved Surfaces

Flat plywood can frequently be bent to meet the demand for curved surfaces when the proper thicknesses and construction are used.

When compound curvatures are required, the sheet is often formed by pressing the assembled veneers between male and female dies of the required shape, or by laying the veneers over a form of the desired shape and pressing by the so-called "vacuum process" or the more modern "bagmoulding" process. In the last-named process, both heat and pressure may be used to cure the adhesive. The shape thus formed possesses all the strength characteristics and general properties of normal plywood.

MANUFACTURE OF PLYWOOD

The manufacture of plywood is a highly technical process, and to give full details of the separate steps would be far beyond the scope of this work. A brief description, however, will give an idea of the procedure and the types of machines which are used.

Selection of Logs

Logs for peeling must be carefully selected. They should be as nearly cylindrical as possible, otherwise there will be excessive waste in truing up to a cylinder before the peeling of a continuous sheet of veneer can begin.

The heart should be as nearly central and the log as free as possible from defects, such as knots, splits, gum veins, etc.

In other words, the most perfect logs are used and a specially high royalty must be paid to obtain them.

Preparation of Logs

The selected logs are cross-cut into required lengths. If billets are placed in pits or chambers and heated with hot water or steam to soften the fibres, peeling is facilitated. Most species and thicknesses peel well without preliminary heating.

*Peeling**

The lathe for rotary peeling of veneer is a very heavily constructed machine, built to withstand the shocks and stresses encountered during the peeling operation (see Photo 8). Even slight movement of the knife will cause irregular cutting, and prevent the manufacture of high-quality veneer. The log is held rigidly in "dogged chucks" and revolved against the firmly held and carefully sharpened knife. The veneer comes away in a continuous ribbon as the log revolves, and the knife is automatically advanced towards the centre of the log. The sheet of veneer is run out on to a conveyor table and cut into suitable widths without stopping the flow from the lathe.

The thickness of the veneer is adjustable. The commonest thickness is y_{10} inch, but $1/_8$ inch, $1/_{10}$ inch and $1/20$ inch are also standard thicknesses. For some decorative purposes veneer is rotary cut to $\%_2$ inch and veneers as thin as $1/80$ inch are peeled to manufacture aircraft plywood.

Clipping

The veneer is next passed to a clipper which cuts it into lengths suitable for the manufacture of the finished panel (see Photo 9).

Drying

Drying of the veneer to the desired moisture content is accomplished either by air-drying, drying in kilns or tunnels but usually in mechanical driers (see Photo 7). The required moisture content may vary between 5 per cent and 12 per cent according to the type of adhesive in use.

Jointing, Taping, Edge-gluing

The production of plywood to rigid specifications necessitates the elimination of certain types of defects, for example knots, splits, and so on. These defects are clipped from the sheet to give, in many cases, narrow widths of clear veneer. These pieces are later joined together edgewise to form full-sized sheets for outer or centre veneers.

This operation is carried out with the aid of a taping machine or an edge-gluer or splicer (see Photo 10). The taping machine applies a layer of ordinary paper tape to hold the pieces together edge to edge until the sheet is finally made into plywood, when it is removed by steaming or sanding.

The edge-gluer or splicer does not require the use of paper tape, but, as the name implies, actually glues the pieces together, edge to edge.

The middle layer of a sheet of three ply is known as a "centre" or "core". Il consists of one or more pieces of veneer with the grain at right angles to the outer veneers. It is prepared by clipping the standard lengths of veneer to the correct size.

Glue Mixing

The various ingredients of the glue mix are placed in mechanical mixers fitted with paddles revolving in opposite directions and agitated until a glu< of a smooth, creamy consistency is obtained.

* For "semi-rotary" slicing, and sawing of veneers, see this chapter, page 84, "Veneer"

Glue Spreading and Assembly

The core pieces of a three ply construction are passed between the rollers of a double roll glue spreader which applies a carefully regulated amount of liquid glue to each surface (see Photo 11). These pieces are carefully laid between the outer veneers. The sheets are then ready for pressing.

The "stack" method of gluing is being generally superseded by the use of hot-plate presses, especially in the curing of synthetic resin adhesives. After gluing and assembly the plywood sheets are loaded directly between the heated platens of the press.

Pressing

Hydraulic presses capable of exerting pressures over the whole of the sheet of up to 300 lb. per square inch are employed to bring the various veneers in the assembly into intimate contact (see Photo 12). This ensures that the adhesive can play its part in cementing the sheet firmly together.

Re-drying

Cold-pressed plywood absorbs moisture from the glue. It is necessary to remove this moisture and bring the moisture content of the sheet into equilibrium with atmospheric conditions. This is accomplished by air-drying in kilns or tunnels as used for the drying of veneer.

This is unnecessary in the case of hot-pressed plywood where the amount of moisture absorbed from the glue is carefully controlled in such a manner as to restore to the veneers the amount of moisture necessary to bring the plywood sheet into moisture equilibrium with the atmosphere. An exception is plywood hot-pressed with a dry film glue. In this case it is necessary to add moisture after pressing either by spraying or dipping.

Trimming

The plywood sheets are cleanly cut on all edges, using double trim saws, that is, two saws mounted on the same spindle.

Sanding

The sheets are sanded to a smooth finish on multiple drum or wide belt sanders. Thin and finely figured veneers are usually finished by hand-controlled belt sanders.

Bundling For Transport

Plywood is bundled in different ways, depending on its quality and the distance which it has to be transported. High-grade material is usually completely covered with heavy kraft paper. Material for interstate distribution is customarily assembled twelve sheets to a bundle (3/16 inch plywood).

Adhesives

It is generally recognised that the adhesive or bonding agent used in the manufacture of plywood is of the utmost importance. Its characteristics determine the nature of the final product.

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Different adhesives are employed to give plywood various properties. Plywood for the manufacture of furniture and for interior work in house construction needs to be well bonded, but not necessarily of high water resistance. Urea resin glue is used, therefore, for the bulk of plywood manufacture for these purposes.

Plywood, for uses where it is exposed to the weather, must be bonded with an adhesive which is immune to deterioration by water, fungi and bacteria and must withstand the severe stresses which are developed due to the absorption and desorption of moisture. "Synthetic resin glues" have been developed for this purpose. First and foremost are the phenol formaldehyde resins, of which the well-known adhesive, Tego film, is a good example. In this type of adhesive, the resin is impregnated into a paper carrier. To make the bond, the resin-impregnated paper is placed between the sheets of veneer and "set" in a hot press under regulated conditions of heat and pressure. Other phenol-formaldehyde resins of the liquid type are spread in the usual way with a double roll glue spreader. Resins of this type are similar in character requiring a temperature ranging between 280 and 320°F. to effect a "cure" and thus set the resin. The bond obtained will withstand prolonged immersion in boiling water and is immune to damage by micro-organisms.

The urea-formaldehyde resin glues are another form of synthetic adhesive which are finding extensive use for the production of durable interior grades of plywood. They are applied as liquids and can be set either hot or cold. When set hot, temperatures as low as 210°F. are adequate to effect a cure. Unless specially fortified, resins of this type are not resistant to boiling water, but will withstand cold soaking. They are immune to attack by micro-organisms. These adhesives do not provide waterproof bonds as do the phenol-formaldehyde type. Urea resin glues should not be used in plywood exposed to weather or wet conditions. (See Chapter VIII).

PROPERTIES OF PLYWOOD

The remarkable strength and light weight of plywood, its availability in large flat sheets, resistant to warping and splitting, its ease of working, its ease of bending and being formed in simple or compound curvature, and its ready availability in a range of types and grades all combine to indicate a bewildering variety of uses.

Plywood is a familiar enough material to the builder or engineer, but it is not always appreciated to what extent its range of utilisation has been extended by modern research. Its traditional advantages—availability in large areas, high strength/weight ratio, distributed strength, dimensional stability, stiffness, and so on—are well known, but the presence of glue has been looked on with suspicion as a source of weakness, to yield under severe conditions of use such as extremes of temperature, humidity and stress.

So it was with some of the older types of "natural" glue, but the advent of phenolic resins and their application to the utilisation of timber have brought about striking changes which have raised plywood to the forefront of structural materials. Glued joints can now readily be made which will be as satisfactory and as durable as the timber itself under any service conditions.

Nail-holding Ability

The ability to hold nails firmly is an important property in all structural work and in boxmaking. Plywood has been shown to have high nail-holding power even when nailed close to the edges.

Acoustic Properties

Plywood panels compare favourably in acoustic properties with other building materials. It has been shown to have excellent sound absorption when used in theatres and large offices. A developing process is that of perforating plywood for acoustical purposes.

Insulation

Like any timber product, plywood has excellent insulating properties if properly installed with suitable joint strips to prevent air leakage.

USES OF PLYWOOD

Structural Uses

The resurgence of timber as a structural material often involves the use of plywood as gussets or in another form of construction as flanges or webs of composite beams. Economical and efficient design is possible only if the highest safe stress is used and also maintained during the life of the structure. For some usages the hazard of decay can be minimised by design, the use of naturally durable species of timber and good and adequate maintenance. Similarly, possible insect attack can usually be countered by the elimination of sapwood. For both these hazards, preservative treatment of plywood is often the easiest and most economical method of ensuring maintenance of its strength.

Furniture

In the past about 75 per cent of the veneer and plywood manufactured in Australia was used in the furniture trade. Developments in housing will necessitate increased furniture production, but, with increased demands from other sources, significant changes are taking place in this proportion. Some substitutes have arisen to challenge the supremacy of plywood in the furniture field. Some other materials possess some of its attributes, but no material possesses all of them.

Both plain and fancy plywood are manufactured—utility grade for use in unseen positions, fancy grades where appearance is the prime consideration.

House Construction and Fitting

Representative uses in this field are as follows: Prefabricated house construction, interior linings and ceilings, exterior sheathing, floorings, partitions, flush doors, modernizing of panel doors to give a flush door appearance, built-in breakfast nooks, roofs of huts, garages and so on.

Care must be taken to use the correct grade of plywood for many of these applications. For all exterior uses, where exposed to the weather, waterproof glued grades, that is phenol-formaldehyde bonded material must be specified.

For walls and ceilings, plywood has the advantages of ease and speed in

erection and the avoidance of the cracks which often develop in plaster. Plywood does not crack when it is subjected to a knock. The panels are nailed directly to studs or joists. Nails may be driven close to the edges. The panels expand and contract so little with changing humidity that they may be closely butted.

Quarter-inch or $3/16$ inch plywood is customarily specified for interior linings, and so on, while $3/8$ inch material is used for exteriors. Since plywood is very resistant to puncturing or fracturing, it has a definite advantage over certain types of building materials. A further advantage is that plywood walls and ceilings may be finished as soon as erected, while plaster, in wet weather, may remain damp for weeks.

Random Matched and Grooved Plywood

This is designed for interior panelling where real timber planked walls are desired. The faces of the full sized panels are random grooved and pre-finished at the factory so that the wall can be installed without further finishing. It offers a permanent finish and adds to the appearance of otherwise plain walls and doors. Figure in the timber and the richness of real timber cannot be duplicated by synthetic imitations.

Flooring

Though not, as yet, used extensively in Australia for flooring, plywood is becoming accepted for this purpose; as a sub-floor it saves labour, eliminates air leakage, has fewer joints, and prevents squeaking floors. Three-quarter-inch five-ply is generally used for this purpose. It may be used as a surface flooring or covered with carpet or linoleum.

Flush Doors

The plywood flush door lends itself to simplicity in design. From the housewife's point of view, the absence of dust-collecting ledges makes a strong appeal.

Concrete Formwork*

The special advantages of plywood in the fabrication of concrete formwork have been demonstrated over the years by its ever-increasing use in the construction of bridges, dams, buildings and other structures.

The advantages are mainly in the available dimensions of plywood coupled with its smooth surface finish, and high strength. Full value can be obtained when the plywood is used as repetition formwork for the production of large numbers of units in the same mould and also, in permanent shuttering where the pleasing appearance of the plywood is used as the final surface covering concealing the cold, hard concrete.

Plywood for formwork is used in thicknesses varying from $3/16$ inch to $3/4$ inch and may serve as a sheathing and lining combined. Thin panels, for example $3/16$ inch and 1/4 inch, are easily bent for use in curved forms. Reverse

* See *Plywood For Concrete Form Work* issued by the Plywood Association of Australia, 3 Dunlop Street, Newstead, Brisbane, Queensland.

moulds can be nailed or screwed to the plywood panels close to the edges without fear of splitting.

The Division of Forest Products, in collaboration with the Plywood Association of Australia, has in recent years carried out considerable research into the techniques involved in the use of plywood for concrete formwork and structural processes generally.* The result of this work is available to architects, engineers and the building industry upon application to the Association.

Boat Building

Marine grade plywood is made in conformity with AS086. This grade is largely used in boat building. Acceptable species are listed in the specification and are specially selected, of medium strength and weight, but of high strength/weight ratio, high impact strength and uniform fine texture. The species generally have good finishing and weathering properties and the glue bond is completely waterproof.

Ship Fitting

Plywood is used extensively in interior work in ship construction. With the advent of waterproof bonds, its use rapidly extended to various exterior applications where qualities of durability and weather resistance are essential. Some examples are, the sheathing of small craft, construction of wheelhouses, decking and fabrication of ribs and numerous other uses.

Strength, light weight, availability in large sizes, ease of handling and fabrication, and non-splitting properties all combine to make plywood an excellent material for such uses.

Other Uses

Plywood is used in the making of boxes and crates, caravans and trailers, partitions, garages, farm building including troughs, silos, sheds and stalls, gusset plates in trusses for use in roof and bridge construction, motor car parts, truck bodies, radio cabinets, restaurant booths, table tennis tables, toys, theatrical scenery and props, card tables, display panels, railway carriage fittings, barrels and canoes.

In all the above and a thousand other uses, the ability to order in large panels and exact sizes saves much waste of material and enables the user to calculate the quantities required almost exactly. (For "Finishing of Plywood" see Chapter XVII).

PRESERVATIVE TREATMENT OF PLYWOOD

Owing to its form of construction, that is, from thin sheets or veneers, plywood is far more easily penetrated by preservatives than is solid timber. Under normal circumstances, Australian plywood is singularly immune to damage by external agencies. The sapwood of most hardwoods is, however, liable to attack by the powder-post borer (lyctus), and a small proportion of sapwood veneer may be so attacked unless it is treated before use. (See Chapter XVI

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* See *Timber Engineering Design Handbook* (Chapter 9) published by C.S.I.R.O. in association with Melbourne University Press.

"Timber Preservation".) A simple treatment, however, developed by the Forest Products Division of the Commonwealth Scientific and Industrial Research Organisation (C.S.I.R.O.) is in constant use at plywood mills handling susceptible veneers. This enables even the sapwood to be used with complete safety from borer attack. The green veneers are fed by means of rollers through a bath containing certain chemicals such as boron, sodium fluoride or chlorinated hydrocarbons, after which they are close stacked for about four hours.*

The veneers are then dried and processed in the normal way. They are not discoloured or altered in appearance by the treatment.

Another treatment for lyctus-susceptible veneer involves the addition of toxic chemicals to cold setting glues used in plywood manufacture. This method avoids the necessity for dipping equipment and the additional handling involved in the dipping process.

Plywood made from veneers treated as above is not susceptible to attack by lyctus borer. It is, however, essential to remember that even treated plywood should not be nailed to studs which contain sapwood liable to borer attack. If the studs are attacked, the borer may eat its way out through the plywood and leave the characteristic small hole but it will not destroy the plywood.

Serious damage to boats has demonstrated that unprotected and untreated marine grade plywood is not proof against marine borers, neither has such any more decay resistance than normal timber of the same species. Preservative impregnation to an approved loading is the best protection against marine borers, and decay in plywood is prevented by keeping it continuously saturated by water or at a moisture content below twenty per cent when it is untreated.

Fireproofing of Plywood

Plywood may be made relatively protected against spread of flame by the methods described in Chapter XVIII.

The treatment of plywood against flame spread is of importance where it is used as wall linings not only in offices and dwellings but more particularly in ships. Cabins and even holds are often lined with plywood, not only for the sake of appearance but also to give a hard-wearing surface capable of withstanding rough usage and hard knocks.

PLYWOOD AS A STRUCTURAL MATERIAL

Information regarding the strength properties of Australian plywoods is rather restricted. Work in this field is being carried out.

It is not possible within a small space to give even a summary of the data available on general design in plywood; the design of plywood gusset plates, box and "I" beams with plywood webs, and so on.† The data available is concerned with Australian plywoods used for structural work.

* For details of boric acid treatment and plant required, see C.S.I.R. *Journal,* vol. 12, no. 1 February 1939. Also D.F.P. *Newsletter* no. 171.

† Engineers and architects are advised to consult *Technical Data on Douglas Fir Plywood for Engineers and Architects,* published by the Douglas Fir Plywood Association, which is available in the libraries of the Timber Development Association, 525 Elizabeth Street, Sydney and of the Division of Forest Prods., CSIRO, Yarra Bank Rd., Sth. Melbourne.

One widely developed use for plywood in Australia is in the provision of gusset plates for wooden beams and girders.

These have several advantages: (a) cheapness, (b) ease of fitting, (c) they can be used as spacers as well as gussets and (e) they permit the use of timber connectors, thus permitting better design of difficult joints.

The construction of roofs and floors, beams (box and I beams), portal frames and curtain walls is developing as a use for structural plywood.

The Myer Music Bowl* in Melbourne, accorded world acclaim for its unique design, is roofed essentially with plywood. The specification called for ½ inch thickness of ply with a thin skin of aluminium. The huge canopy covers an acre without a single internal column or stanchion. The special properties of plywood made this particular design possible.

Some "Do's" and "Don'ts"

1. Plywood is supplied in flat panels. Keep it flat. Do not stand it up on edge, but lay it flat and keep it covered.

2. In erecting plywood, do not save on nails. It is better to overdo nailing than the reverse. Nail at 6 inch centres along edges and 12 inch centres on intermediate supports.

3. Nailing should commence at the centre and proceed outwards towards the edges. Nail as close to the edge as possible. Plywood will not split when so nailed.

4. For exterior use:

(a) Order waterproof (phenolic bonded) plywood, to the appropriate Type A Bond standard specification.

(b) Do not allow plywood to lie exposed to the weather while awaiting erection.

(c) Have the grain of the exposed face vertical.

(d) Give a priming coat before or immediately after erection. If available, use aluminium paint as primer.

(e) Fill all exposed edges with putty before priming.

(f) Use only high-grade paints and follow the manufacturer's instructions.

(g) Thin oil paint primer with high-grade raw linseed oil to promote its absorption.

(h) Let each coat dry thoroughly.

STANDARD SIZES, GRADES AND SPECIFICATION FOR PLYWOOD

Standard sizes for plywood are 6 X 3 feet, 6 x 4 feet, 7 X 3 feet, 7 X 4 feet, and 8 X 4 feet. Larger sizes up to 6 X 50 feet, scarf jointed or not scarf jointed, are also available.

The standard thicknesses and number of plies are shown in the following table:

* Architects: Yuncken, Freeman Bros., Griffiths & Simpson. Awarded Memorial Architectural Award.

TABLE 22

Thickness in inches	Number of plies permitted
$1/8$	3
$5/32$	3
$3/16$	3
$1/4$	3 or 5
$5/16$	3 or 5
$3/8$	3, 5, 6 or 7
$7/16$	3, 5, 6 or 7
$1/2$	3, 5, 6, 7 or 9
$5/8$	5, 6, 7, 9 or 11
$3/4$	5,6, 7, 9 or 11
$13/16$	5, 6, 7, 9 or 11
$7/8$	5,6,7,9 11 or 13

Structural plywood and marine plywood are available in a different range of thicknesses and constructions.

Copies of specifications for plywoods and protein adhesives can be obtained by writing to: Standards Association of Australia, 80/86 Arthur Street, North Sydney, N.S.W. 2060, or the Plywood Association of Australia Pty. Ltd., 3 Dunlop Street, Newstead, Queensland 4006.

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VIII

GLUES AND THEIR USES

The practice of using glues for joining one piece of timber to another is of extreme antiquity and a classical and oft-quoted example of its early employment is in the elaborate mummy-cases of the Pharaohs. For many centuries, however, the glues themselves and the method of using them were closely guarded craft secrets, and only recently have they become part of the general technique of industry.

Today there are many kinds of adhesive freely available, and the potential user may well find difficulty in selecting the one most suited to his purpose. The aim of this chapter is to assist him in this matter.

The Principle of Gluing

Scientific investigation has established that adhesion between two solid bodies may be of two kinds:

1. Natural or specific adhesion produced by molecular forces of the same kind as those holding together the molecules of any solid body, and

2. Mechanical adhesion by the setting of an adhesive, or glue, that has obtained a key by filling crevices in two adjacent glued faces.

Certain glues function in both ways, and with most modern glues, used correctly, the adhesive has a shearing strength greater than that of the timber (H.E.Desch).

USES OF GLUES IN THE WOODWORKING INDUSTRY†

Glues are used for two main purposes: for the manufacture of plywood and in assembly work. In the former, large sheets of thin veneer are spread with the adhesive and bonded together in a hydraulic press, the platens of which are heated by steam or hot water. The process is under exact control at every

* Condensed from *Constructional Research Bulletin* No. 2 by R. A. G. Knight, B.Sc. (Eng.) A.M.J.Mech.E. issued by the Timber Research and Development Association, U.K. (sections indicated by footnotes inserted by the compiler).

t D.F.P. *Trade Circular,* no. 49, provides a summary of the properties and uses of timber adhesives.

stage, and the machinery involved is of the precision type. In assembly work—a term applied to the gluing together of pieces of timber to make such articles as furniture, houses, aircraft and boats—the areas to be spread are comparatively small, the methods of applying pressure can seldom compare with those of the hydraulic press in uniformity or intensity, and the operations are usually carried out at ordinary workshop temperatures.

The function of pressure in the making of a glued joint is often misconstrued. Its sole use is to bring the two surfaces close enough together to give a uniform glue line of the correct thickness. The amount of pressure required depends on the stiffness of the timber and whether or not it is flat, as well as on the nature of the glue. If the surfaces are uneven, as with rough sawing or because of excessive twisting, the resultant glue-line, instead of being uniformly thin, will vary from place to place, with serious reduction in the bond strength. Under certain conditions, chiefly in assembly work, where it is difficult, for practical reasons, to assure close contact between the surfaces to be joined, special adhesives with "gap-filling" characteristics have been developed, giving bond almost as strong as can be obtained from close-fitting joints.

Bond Quality Types

To keep abreast with modern manufacturing methods and plywood quality required by industry the Standards Association of Australia in conjunction with plywood manufacturers has produced a "Bond Quality Scale" in which the bonding efficiency is divided into four types. The scale and types are defined in Australian Standard AS 01-1964:

"Bond Quality Scale— The scale used when assessing by comparison with standard plates the results of knife tests in accordance with AS 090.2, method of test for bond quality of plywood, to establish the quality of the bond between adjacent veneers or between a veneer and a core."

Type A Bond— A satisfactory bond after soaking in water at 100°C. (212°F.) for 72 hours, or after steaming at 30 lbs/in^2 for 6 hours. Such bond is intended to withstand prolonged exposure to severe exterior conditions without failure of the glue-line.

Type B Bond— A satisfactory bond after soaking in water at 100°C. (212° F.) for 6 hours. Such bond is intended to withstand exposure to exterior conditions for a considerable period without delamination occurring.

Type C Bond— A satisfactory bond after soaking in water at 70°C. (158°F.) for 3 hours. Such bond is intended to withstand wetting and drying without delamination occurring.

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Type D Bond—	A satisfactory bond after soaking in water at 21°-24°C. (70°-75°F.) for 16-24 hours. Such bond is intended to withstand occasional wetting and drying without delamination occurring.

Recommended Uses*

Australian Standards require plywood for marine craft (AS086) to conform to Type A bond. Plywood manufactured with a Type B bond is suitable for such uses as concrete formwork, and as permanent sheeting when protected from extreme exposure or subjected to only occasional surface wetting.

Plywood with Type C bond is intended for use in positions protected from the weather and will withstand occasional wetting and drying without adverse effects. Type D is a bond intended only for interior usage where it will withstand the effects of changes of climatic conditions such as temperature and humidity without deterioration. It is usually used in plywood for decorative panelling, furniture and other purposes.

Type A bonds are obtained only from phenolic and epoxy type resins. Melamine and urea resins will produce plywood with Type C or D bonding depending on concentration of the melamine and the degree of extension. Plywoods of various kinds were being produced in Australia in June 1968 in the following proportions: marine (AS 086) 6 per cent, exterior use (AS 087) 20 per cent, and interior use (AS 088) 74 per cent.

Glues in Common Use

The more common timber glues may be clarified into a number of groups according to their origin and constitution. These are briefly described in the following pages. All are *organic* in origin with the exception of sodium silicate. The remainder are grouped into *natural* and *synthetic*. The latter are further sub-divided into *thermosetting* and *thermoplastic*. In Australian plywood manufacture only three of the thermosetting group are used at present, viz: urea formaldehyde, phenol formaldehyde and tannin formaldehyde.

Mixtures of the various kinds of glues can be made for particular purposes but their uses and properties vary so much that they cannot be described in general terms and are omitted from this chapter. In all cases the manufacturers instructions should be carefully followed.

There is no one glue or class of glues that is superior in all respects to all the others. Each class, because of its superiority in one or more particulars, may be expected to find preferences for certain purposes. (T. R. Truax).

Inorganic Glue

Sodium Silicate: The adhesive is a mixture of sodium silicate and water. It sets by loss of water and has a very sharp point of change from liquid to solid. It is very strong when dry but has a low wet strength and low water resistance.

The glue is highly alkaline and stains timber. It is used in paper lamination in conjunction with casein and in fabrication of corrugated cardboard.

* As recommended by the Plywood Association of Australia Limited.

Organic Natural Glues

Starch and Dextrines: These are mixed with water and a resin may be used to improve "tack". Urea formaldehyde glues are often added to assist water resistance. Setting is rapid with loss of water and the glues are colourless to pale brown. They are more water resistant than sodium silicate and are more commonly used in Australia than all others. One example is as a label glue.

Animal Glue:* This is a protein produced from animal tissue, hides, hoofs, horns, etc. The adhesive is sold as a solid varying in form from powder to the so-called cake, as a jelly, and in liquid form. It is colourless and strong smelling, e.g. gelatine, and the adhesive is prepared by mixing the protein with water and heating to 120°-130°F. until the glue melts. The common practice of boiling the mix is entirely wrong and one that causes rapid deterioration. Jelly glues are prepared by warming alone and require no addition of water. The liquid form is sold ready for use.

Setting takes place by loss of water. It has high dry and low wet strength and is subject to bacteriological and fungal attack. The assembly time is short and it sets quickly. A joint prepared with this glue may be released by the application of heat. Animal glue has been in use for centuries and has a high reputation for strength and durability under dry conditions, for its non-staining characteristics and for the ease with which the joints can be machined or finished with hand tools. It has no irritant effects on the skin. The main disadvantage is its lack of resistance to dampness.

Many factors which affect the strength of the joint enter into the use of animal glue: pressure, length of assembly period, kind of assembly, temperature of timber, glue and assembly room, amount of spread, grade of glue, and water content, all play an important part in gluing practice.

Animal glue was once used in large quantities in the timber industry but is now replaced by poly vinyl acetate (P.V.A.) glues. It finds use on paper tapes, envelopes, etc.

Casein Glue: This is a product of skim milk by addition of hydrochloric or lactic acid. The curds produced are spray dried and the adhesive then prepared by mixing the casein with water and an alkaline material such as caustic soda or sodium silicate and lime. The glue sets by a chemical reaction and loss of water.

As casein stains timber badly research was carried out and urea formaldehyde was produced as a substitute. Casein glue is susceptible to bacteriological and fungal attack, has moderate water resistance and is used as a hot or cold setting adhesive. It was used in quantity for plywood manufacture prior to World War II and is now used to a small extent in paper sizing.

Soya Bean: The raw material for soya bean adhesive is produced from soya bean cake after the oil has been extracted. The adhesive is prepared in a similar manner to casein, water and an alkaline material being added. It sets by chemical reaction and loss of water, and has lower dry and wet strengths than casein. No soya bean adhesives are used in Australia although large quantities are used in the United States in the plywood industry.

* See D.F.P. *Trade Circular,* no. 14, "The Preparation and Use of Animal Glues."

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*Blood Albumin:** This adhesive is derived from blood obtained from slaughter houses, and is purchased as a dry flake and mixed with water and such chemicals as lime or ammonia added by the user. It is not available as a ready-to-use glue in Australia and is not used.

The glue has a relatively high water resistance and is hot setting, requiring a temperature in excess of 90°C. Blood glues are only moderately strong and are very liable to attack by moulds and bacteria, which can destroy them completely. Special care is necessary to avoid health hazard. It is used in the plywood industry in U.S.A. in conjunction with phenol formaldehyde.

Organic Synthetic Glues—Thermosetting

Synthetic resin glues have two great advantages over all those so far described: they are extremely resistant to moisture and immune from attack by moulds and bacteria. Their introduction has provided adhesives that can be more durable than the timber itself. The limiting factor in the utilisation of laminated products is no longer the glue but the timber itself.

The price to be paid for this is the accurate control necessary in mixing, application and pressing operations, for the synthetic resins are precise chemical compounds that tolerate no haphazard handling. That they have become essentially practical materials is shown by their adoption by all classes of industry.

Urea Formaldehyde: This is a synthetic resin produced by the reaction of urea and formaldehyde. It is normally supplied in two parts, the resin itself and the hardener or catalyst, the former being available both in syrup and powder forms and the latter as a liquid or powder. In a few cases, resin and hardener are sold together as a ready-mixed powder, and the user adds water to prepare the adhesive for use. When the components are separate, they are mixed before use in such proportions as 6 or 10 parts of hardener to 100 parts of resin by weight. Often an extender and filler are added.

The adhesive, which is colourless, sets by "condensation"—a form of "polymerisation". It is not affected by bacteria or fungus and has a relatively high water resistance if unextended. The water resistance is improved by the addition of melamine formaldehyde or resorcinol formaldehyde adhesives.

Urea formaldehyde is used as a cold or hot setting adhesive and glues of a wide variety of uses are available, ranging from hot-press plywood adhesives setting at 140°C. (284°F.) to assembly glues that set at temperatures down to 10°C. (50°F.), and between these extremes are the so-called warm-setting glues in the region of 60°C. (140°F.), which are really very slow cold-setting mixes.

This matter of temperatures is vastly important with all synthetic resins, for they set by a delicate chemical action which is accelerated or retarded by rise or fall of the temperature. Users have often overlooked the variations of summer heat and winter cold and the glue has been blamed for the ensuing variations in setting rates. Manufacturers can supply hardeners to compensate for changes in temperature conditions, and the user is strongly recommended to accept their advice.

* See D.F.P., C.S.I.R.O. *Trade Circular,* no. 29, Part C.

There is also a method of using urea glues known as "separate application", which avoids the necessity of mixing the components. The resin is applied to one side of the joint and the hardener to the other, the setting taking place when the two are put together. The method permits of very rapid gluing operations, but is applicable also to the slower-setting varieties. Obviously, only the liquid forms of resin and hardener can be employed in this process.

Urea glues are not difficult to use provided manufacturers' instructions are strictly followed. There is some risk of dermatitis to the operatives, but this can be minimised by cleanliness and a suitable barrier cream. The set resin action has a dulling action on edged tools, although it gives no trouble with high-speed steels. Urea glues are strong in the dry state and will stand indefinite soaking in cold water. The normal types fail if the water temperature exceeds 70°C, but the fortified kinds withstand boiling. Micro-organisms are without effect on these adhesives.

These glues have poor gap filling properties but this can be improved by addition of a filler. Large quantities of these adhesives are used throughout the world in the production of plywood intended for interior use.

Melamine Formaldehyde: This resin is produced by the reaction of melamine and formaldehyde and the adhesive is prepared by the addition of water and a hardener or catalyst. It sets by condensation, is colourless and not affected by bacteria or fungus. It can be used only as a hot setting adhesive and has better gap filling properties than urea formaldehyde glues.

It is usually used in conjunction with urea formaldehyde adhesives to obtain improved water resistance. Large quantities of the resin are used in the production of such panels as "Formica", "Laminex" and "Panelyte". The resin is used in the form of a partially cured impregnated tissue paper film. This film was once popular as an overlay for plywood for concrete formwork. It is also used in the furniture industry to avoid the defect known as "bleed through".

Phenol Formaldehyde: The first phenolic resin glues were made in film liquid and powder forms for plywood manufacture, and their setting necessitates a temperature as high as 150°C. (300°F.). Later developments gave to industry a liquid resin which, in conjunction with appropriate hardeners, would set at temperatures ranging from 10° to 120°C. (50° to 250°F.).

All that has been said for the ureas regarding cleanliness, careful mixing and the need for precise temperature-control applies even more strongly to the phenolics. As most of them are soluble in the mixed state only in alcohol or caustic soda, cleansing of equipment is troublesome, and the dermatitis risk is perhaps, even greater. On the credit side, however, they have most desirable properties in the set glue line and are practically indestructible.

Phenol formaldehyde resin is produced by the reaction of cresol or phenol and formaldehyde. The adhesive produced is a red-brown liquid containing 40-60 per cent solids and used in conjunction with a filler. It sets by condensation and is a truly waterproof adhesive. It has high durability in exterior exposure and is not affected by bacteria or fungus. It has fair gap filling properties and can be used only as a hot setting adhesive.

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Large quantities are used in the plywood industry throughout the world in the production of plywood for exterior use. It is sometimes used in conjunction with resorcinal formaldehyde adhesives and is also used in the plywood industry in the solid form as a partly cured impregnated tissue film commonly known as "Tego Film", for plywood production or as an overlay.

Resorcinol Formaldehyde: The resin is prepared by the reaction of resorcinol and formaldehyde and the adhesive by the addition of a filler to the resin. It has properties similar to phenol formaldehyde but is more expensive. This cold setting, waterproof adhesive sets by condensation.

Large quantities are used in Australia in scarf jointing operations and in boat building. It is not affected by bacteria or fungus.

Tannin Formaldehyde: The raw material for this resin is obtained by extracting tannins from the bark of wattle, mangrove and other trees. The adhesive is prepared by the addition of formaldehyde to the extract. It is usually used in conjunction with a fortifier of phenol resorcinol formaldehyde.

As a glue it has similar properties to phenol formaldehyde but is less expensive. It sets by condensation. Adhesives of this type are at present being used in plywood manufacture in Australia.

Epoxy Glues: The base resin is prepared by the reaction of epichlor hydrin with bispenol alpha and the adhesive is prepared by the addition of a hardener or catalyst (usually an amide) to the base. It sets by polymerisation, is colourless, and is either cold or hot setting. It has excellent gap filling, wetting and flow properties and the water resistance is good, but inferior to resorcinol formaldehyde.

The glue has negligible shrinkage during setting and is not affected by bacteria or fungus. However it is relatively expensive and the hardeners are very-toxic. It is not used in the plywood industry. It is excellent for adhering metal to metal, metal to glass and such application where conventional glues are inadequate.

Organic Synthetic Glues—Thermoplastic

Poly Vinyl Acetate (P.V.A.): The resin is produced by the reaction of acetic acid and polystyrene and the adhesive is prepared by the addition of water to form an emulsion. Commercial P.V.A. adhesives have in most cases a large proportion of inert filler (e.g. chalk) added. The liquid is white and becomes colourless on setting, which takes place at room temperature by loss of water.

The glue has infinite "pot life", good gap filling properties, is not attacked by bacteria or fungi but its water resistance is very low. It is not used in plywood manufacture at present but is finding increasing use in the wood working industry in assembly work. The greatest proportion of joinery is now manufactured with P.V.A. Research is being carried out on water resistant P.V.A. adhesives and their application to plywood manufacture.

Elastomeric Glues: This term covers adhesives of the "contact" rubber based type. They usually consist of neoprene "tackifier" fillers, antioxidants and a solvent. They set at room temperature by loss of the solvent, but both surfaces must be coated with adhesive.

These glues are not waterproof, are low in heat resistance and in strength in long term loading. They are commonly used in metal to metal and metal to wood joints.

Extenders to Synthetic Adhesives

A substance added to a synthetic adhesive to provide body and reduce cost, or to impart some other desirable characteristic, is known as an "extender" to the user. When added by the manufacturer of the resin it is called a "filler". Low protein wheat flour and wood flour are the most common substances used. Dried blood is used in overseas countries.

Limited amounts of these substances do not appreciably affect the durability of the adhesive but excessive quantities cause progressive weakening.

Selecting the Correct Adhesive*

Group I—Waterproof and Weatherproof Adhesives: To qualify for the waterproof and weatherproof group an adhesive must have shown itself to be virtually indestructible and have exhibited no weakening or signs of failure under prolonged soaking under water or long exposure to the most severe weathering conditions.

Such durability is supplied only by phenolic type adhesives with Type A bonds manufactured under Australian Standard specifications for marine craft.

Group II—Weather-resistant Adhesives: These are glues which are suitable for exposed use when protected from extreme conditions of weathering and are subjected to only occasional surface wetting.

These conditions can be satisfied in plywood manufactured to Type B bonds in both phenolic and epoxy type adhesives. It should be stressed that the criterion is full exposure to the weather and under these less exacting conditions their performance is good, but this limitation excludes them from the weatherproof group. Type B bond is considered suitable for such uses as concrete formwork.

Group III—Semi-durable Adhesives: If a glued joint is exposed to weather, it will be in the wetted state for some part of the time, and an obvious requirement is that the bond should not fail completely, although it may be permissible for the adhesive to lose a large proportion of its dry strength. Unfortunately, damp conditions are favourable to the growth of moulds and bacteria, and if the glue is of a type attacked by these micro-organisms, complete destruction may occur.

It might seem that glues with these characteristics should not be used at all in damp environments, and indeed to specify one of the resins would save any doubts on this score. On the other hand, these semi-durable adhesives have performed well under such circumstances, particularly in large joints, and the user need not necessarily reject them out of hand.

Melamine and urea resin adhesives made to Type C bonds normally are

* See Chapter XXV for specifications recommended by the Australian Standards Association.

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suitable for this group. These are designed to withstand occasional wetting and drying without adverse effects.

Group IV—Interior Adhesives: Adhesives used completely and continuously in indoor situations with good ventilation are subject only to changes in air temperature and humidity. For such positions any glue which gives a satisfactory dry strength is all that is necessary although failure could take place if accidental saturation with water occurred.

Type D bonds are suitable for dry indoor situations using glues made from blood albumin, casein and soya bean derivatives.

METHODS OF USING GLUES

In plywood manufacture gluing operations are entirely mechanised. The mix is prepared in power-driven machines of the paddle type, spread on the veneers at a rate of so many pounds per hundred square feet, and the plywood is bonded in heated presses working under a definite temperature pressure and time schedule. The user of plywood is unlikely to be concerned with details of these processes.

Assembly work, however, is much more an individual matter in respect of both the operative and the joint. Manufacturers usually send out with their adhesives excellent and complete instruction sheets but all too often these are ignored, either through laziness or because the operative thinks he knows all that is necessary. Examination of defective joints has shown that careless or wrongful application is a far more common cause of failure than bad glue— although the adhesive itself is usually blamed.

The usual glued joint has five zones from face to face: (1) Adherend, (2) Interface, (3) Adhesive, (4) Interface, (5) Adherend.

The *adherend* can be any material required to be joined, viz; wood, plastic, metal. In general the surfaces of these should not be too rough.

The *interfaces* are the most important zones for this is where the adhesion takes place. It was thought initially that adhesion was purely a mechanical key, i.e. the glue filled the crevices, penetrated the adherend and became entangled with it. This theory is discredited by the observation that an increase in the roughness of the adherend does not necessarily increase the adhesion.

It is now thought that the strength of the joint is the result of many minute forces reacting between the molecules of the adherend and those of the adhesive.

There are three basic rules which cover many aspects of gluing theory and cover the conditions of use of the various adhesives:

1. The adhesive must "wet" the adherend but must not react with it.

2. No large residual stresses should develop in the adhesive. This covers such features as:—

 (i) Shrinkage of the glueline
 (ii) Thickness of the glueline
(iii) Presence of fillers, extenders, plasticisers, etc.

3. The adhesive must not be more rigid than the adherend.

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Age of the Adhesive's Constituents

Glues are seldom purchased ready for immediate use: animal glue needs a preliminary swelling, the prepared casein powder must have water added, while a hardener must be mixed with the resin to form the adhesive. Prepared casein powder has a storage life of about twelve months if kept dry, and resin will remain usable for three to six months after manufacture under normal temperature conditions. Makers usually put an expiry date on their packages, and the user should see that material is not used beyond its recommended life period.

Mixing

Before attempting to mix a glue, make sure that the buckets, jars or other receptacles are spotlessly clean. This applies with equal force to the paddle of the mixing machine and to hand whisks, spoons or sticks. With the synthetic resins in particular, traces of acid or alkali will completely alter the setting characteristics of the selected resin-hardener combination.

Always adhere strictly to the quantities prescribed for the mix. If these are given by weight, then weigh the constituents on scales or a balance that is accurate and sufficiently sensitive for the quantities involved. If proportions are by volume, use proper measuring vessels, not an old botde or a can that is heavily dented. Take note of how one material should be added to another.

Pot Life

With casein and synthetic resin glues, the makers state that the pot life of the mix is so many hours, and in the case of resins, it will be quoted at various temperatures. If the time were two hours, glue mixed at, say, noon would become unusable at 2.00 p.m. As a rule the end of the pot life is made self-evident by the glue's changing from a liquid to a rubbery solid.

With all types of glues the manufacturers give detailed directions in regard to methods of mixing and the pot life of the mix. These should be followed within close limits if good results are to be expected.

Spreading the Glue

Most adhesives are viscous but not necessarily sticky liquids, and can be applied to the timber by brush, spatula or roller. A more reliable joint results if the glue is well rubbed on to the timber than if poured or smeared. There is a general tendency in assembly work to apply too heavy a spread, and although this is better than too light an application, it is conducive to weak joints, particularly with the close-contact type of adhesives. There is no advantage in double-spreading—spreading both of the faces to be joined—but it is advisable when the surfaces are rough to ensure that no voids occur in the glue-line, and for such work a gap-filling adhesive should be used.

Open and Close Assembly

Some makers advise a period of open assembly for their glues, to expose the spread areas to the air for so many minutes before placing them together.

This is traditional with animal glues to prevent the hot thin glue being forced out of the joint too much by pressure, and, with casein, it leads to stronger joints. Tests have usually failed to indicate any significant advantage of the practice where synthetic resins are concerned. Closed assembly is the time elapsing between putting the spread surfaces together and the application of pressure, and with the resins there is a connection between this period and the pot life.

Pressing or Clamping

The function of pressure has been described earlier in the chapter, and, within limits, the intensity required is dictated by the flatness of the timber surfaces and the close-contact or gap-filling characteristics of the adhesive employed. However much or little is used, pressure must be sustained until the glue has set. It is not uncommon to find jigs so designed that the tightening in one place leads to a relaxation elsewhere, which causes the joint to open and break the continuity of the glue-line.

Conditioning of the Joints

In the paragraph on pot life the glue was spoken of as solidifying, the term "setting" being deliberately avoided. The change of the liquid to the solid state is only the beginning of the setting operation, and the starting point for the development of strength by the joint. Animal and casein glues contain much water, and will not become very strong until this is removed by diffusion into the timber, from which it is subsequently lost by drying. Resin adhesives do not contain as much water as the other two, but the completion of the chemical setting action takes time and such water as they introduce must be eliminated. For these reasons joints should be conditioned or stored* so that they can dry off before full loading is applied. There is, of course, no need to retain them in the clamps for the whole period, but while makers' instructions usually specify minimum clamping times, they do not always mention the necessary conditioning period that must follow.

High Frequency Curing

High frequency dielectric heating equipment is being used increasingly for many specialised gluing operations in woodworking and plywood factories. In particular this process lends itself to the rapid curing of glues in repetition work such as the edge and scarf jointing of veneers, the assembly of T.V. and radio sets and similar products, door manufacture, laminating and so on.

Materials to Overlay Plywood

Overlay materials are added to plywood to impart some desirable property, e.g. abrasive resistance. They must not be confused with surface finishes described in the next section. Usually in sheet form these are placed on the plywood by hot pressing, either during the manufacture of the plywood or in a subsequent operation. Overlay materials used in the industry are:—

* See D.F.P. *Trade Circular,* no. 21, "Drying Rooms for Furniture Stock."

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(i)   Melamme urea formaldehyde impregnated film

(ii)   Phenol formaldehyde impregnated film

(iii)   Thick impregnated paper

(iv)   Poly-vinyl-chloride (P.V.C.) films.

Prime-finishes

Prime-finishing applies to the operation in which the surface of the sheet of plywood or other board material is sealed or otherwise prepared for the finishing operation.

A well known prime-finish is that produced by the "micro-sealing" operation. Heat is applied to the surface of the plywood by means of friction rollers, and the lignin component of the wood melts and flows, and a permanently "densified" and partly sealed wood surface is produced. Usually a melamine resin in liquid form is applied to the surface of the plywood during the operation to improve the gloss and generally assist the process.

Occurrence and Removal of Glue Stains*

Casein and vegetable glues containing caustic soda produce stains on certain kinds of timber. Some glues stain the timber more than others, and those containing the most alkali are likely to be most injurious. The staining is due to the action of the alkali in the glue on the tannins and other constituents of the timber, whereby a substance related to ink is formed.

Casein and vegetable glue stains can be almost entirely removed by sponging the stained surface with an oxalic-acid solution prepared by dissolving one ounce of oxalic-acid crystals in about 12 ounces of water. Still better results may sometimes be obtained by moistening the timber first with a sodium-sulphite solution made up in the same concentration as the oxalic acid. In this way very stubborn stains can be almost obliterated. The acid must be thoroughly removed from the timber afterwards or it may affect subsequent finishing treatments.

Successful gluing depends on both the adhesive and the technique of application. Makers are usually well-informed about their products but if they are merely regarded as suppliers much of this knowledge is of little avail. User and maker should collaborate, the former by putting the whole of his problem to the latter who in turn should place his accumulated experience at the user's disposal.

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* United States Forest Service: *For. Prod. Lab: Technical Note 146.*

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IX

GLUED LAMINATED CONSTRUCTION

INTRODUCTION

Our conceptions of steel as the standard structural material have undergone a radical change. In glued laminated construction we may well find the answer to a number of problems troubling us today, both from constructional and calculatory points of view. Lamination leaves a free hand to the designer in adapting dimensions and shapes to his purpose, at the same time producing clean, efficient, and aesthetically acceptable structures.

Lamination is the process of building up comparatively thin pieces of timber into' larger members which may be either straight or curved. The pieces are bonded together with glue, or sometimes with mechanical fastenings. The grain of the laminates is parallel, in contrast to plywood in which the grain alternates with each lamination.*

Most laminated construction involves the use of members in which the laminates are laid horizontally. This enables the members to be curved and allows the design of segmental or parabolic arches which are in themselves economical structural forms and in addition have aesthetic appeal. This fact is stressed because it implies a radical departure from the more common type of framed construction in timber.

Laminated construction also simplifies the design of fixed joints in such members as portal frames, thereby gaining economy through continuity in the structure. This method also allows the fabrication of beams of greater length and cross-section than would be possible in solid timber. Spans of 150 feet are not uncommon in laminated construction, while in America one span of 232 feet has been achieved with a bowstring truss, the top chord of which is laminated. In Australia, during the last war, laminated construction was used in order to relieve the demand for steel. Long spans of built-up members were substituted for steel in structures such as aircraft hangars.

With laminated construction the effect of defects on the strength of a beam decreases as the number of laminates increases. The consistency in strength

* *Glued Laminated Timber Structures* by R. T. Walters: Timber Research & Development Association Ltd., U.K.
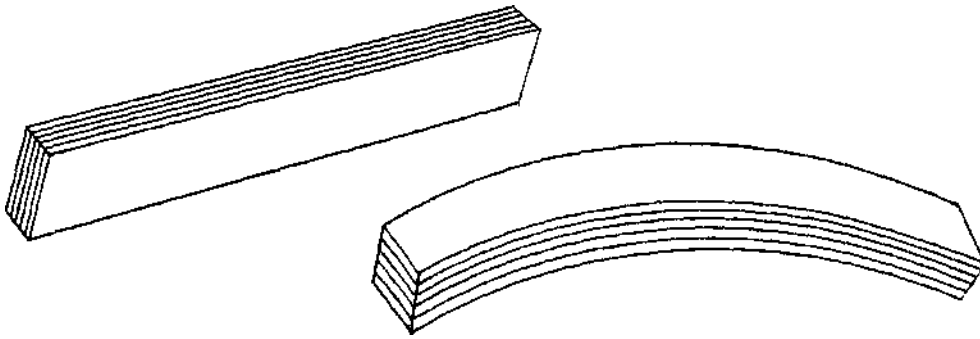
Figure 15. (Left) A beam laminated vertically. (Right) Beam laminated horizontally.

which thus may be obtained enables higher working stresses to be assumed for a given grade of timber than would be permissible if the member were solid.

Components may be built up to any desired length or cross-section and members may be tapered or moulded to give the greatest strength where it is most needed. The greater strength in beams permits the safe use of longer spans which are specially useful in decreasing the number of supports on factory floors and garage space under houses and other building's. In Queensland deep hardwood beams are used as cantilevers over external walls to provide more shade and weather protection to the base walls.

Structural simplicity is perhaps the characteristic of laminated construction which makes the most immediate appeal to the designer. In solid timber he has a material which already combines lightness with great strength. Lamination allows the designer to mould timber to the dimensions and shape best suited to his purpose. The resulting structural forms are clean, efficient, and often beautiful. If required, as is often the case in church interiors, a fine finish can be given to the structural members, (see photos 13 and 14).

Laminated construction also has a special appeal to builders because the laminations are made in seasoned timber and there is no fear of later shrinkage to spoil plaster and other materials nailed to them. No unsightly face checks develop in internal step treads in contrast to the case when hardwood (usually insufficiently seasoned) is used.

Laminated timber has a special advantage in its high resistance to fire. A single sheet of paper will catch fire quickly and burn rapidly but a number of sheets, in the form of a book, are hard to set alight and will smoulder slowly. The same applies to a single lath of timber as opposed to a beam made up of a large number of laminae held together by a fireproof adhesive. The great heat of a destructive fire can cause steel to distort or collapse while, under the same conditions, timber beams may merely char and still retain a major part of their original strength with little or no distortion (see Chapter XVIII).

The fact that timber (including laminated members) has, in comparison to steel, a very high resistance to heat absorption and a low co-efficient of expansion can prove of great assistance to the designer. A laminated bow-string arch, 90 feet in length, is said to have less than one-twentieth of the

movement under expansion of a steel arch of the same dimensions, and would not require pivoted joints or sliding base plates to take up expansion.

The resistance of timber to corrosion by such agents as steam or acid fumes offers another great advantage in the use of laminated members in factory construction. In illustration, the laminated arches in a dye factory at Mascot, New South Wales, were found to be unaffected by steam and sulphuric acid fumes which, in four years, seriously damaged the steel fittings in the roof structure.

A further advantage in laminated construction is that, in the fabrication of large members, the individual pieces of timber used can be of comparatively short length and small cross-section. This greatly facilitates seasoning. Also, high-grade timber is not necessary in the fabrication of large members, though some qualitative selection is advisable in certain of the component laminates to ensure maximum efficiency.

Laminating of timber is not a new process; its use in construction in Europe has extended over the past fifty years and it has proved both durable and efficient. With the development of water-resistant glues and modern processing methods, laminated construction has become far more widely accepted and has found many new uses. It was introduced into Australia for structural purposes in 1939 by a company* which erected a number of buildings of 105 feet span for the Department of the Interior. The Australian company claims that its methods are unique in that, in the assembling of a typical laminated arch of 105 feet span, the gluing process is carried out in a single operation of short duration.

Laminated timber is familiar in many articles of everyday use such as tennis racquets, axe-handles, skis, and so on. Furniture lends itself particularly to design in this form of material since a light, strong and graceful article can be made with efficient joints and economies can be effected in material.

In such work and particularly in curved sections, it is common practice to use veneer in the laminates. The veneer used may be from 1/6 to 1/4 inch in thickness according to the nature of the work and the severity of the curves required.

In the aircraft industry outstanding results have been achieved by glued laminated construction. In this specialised field, however, great care has to be exercised in the selection of the timber, as regards both species and quality.

Laminating can be used for work formerly produced by steam-bending and it has the great advantage that the timber is not crushed or partly fractured, as is often the case in bent timber.

METHOD OF GLUE LAMINATING†

Any timber which can be glued satisfactorily can be laminated, and the thickness of the laminations can vary from 1/64 to 1 inch or more. For

* Ralph Symonds Limited.

† F. A. Dale: Structures and Materials Section, Div. of Aeronautics, C.S.I.R.O. See also Forest Products *Technical Note,* no. 1: "Gluing Techniques for Timber Engineering Structures." Available on application from Division of Forest Products C.S.I.R.O.

general building construction purposes, the usual thickness used in Australia is 1 3/16 inch and the width of the laminations 4 inch. The timber used must be free of doze and not susceptible to attack by borers. Moisture content should not exceed 12 per cent. In the case of curved members the thickness of the laminations depends on the radius to which they will bend, fifty times the thickness being a reasonable minimum, but this may vary with the timber and the glue used. The gluing surfaces of the laminations should be dressed uniformly flat and parallel. Mis-cut and tapered pieces must be discarded. Well-cut, peeled or sliced veneer should need no further surfacing.

Casein or cold setting synthetic resin glues are generally used; animal glues are not recommended. For furniture and other work not likely to be exposed to the weather, commercial casein glues are cheap and convenient, staining being their only drawback. Where the work may be exposed at times to the weather, aircraft quality casein glue will give very good service, especially if the work is kept well painted. In very humid conditions, or where continuous wetting may occur, as in boats, hot-setting phenolic resin glue is the only reliable glue at present available in Australia. Hot- and warm-setting (above 70°F.) urea resin glues have durabilities between those of aircraft casein and the phenolic resins.

Moulds or forms on which the laminations are laid up and pressed are usually of timber rigid enough to withstand the gluing pressure without distortion. Large structural members such as arches can be made up on blocks or posts set at intervals along the curve, but smaller members are best made on continuous moulds. Sufficient pressure should be applied to the laminations to ensure uniform, close contact with the gluing surfaces, and this should be checked with dry laminations before gluing up. Pressure may be applied by bolts, clamps, screw or hydraulic presses, or band cramps (see photos 15 and 16).

With clamps or bolts, care should be taken to distribute the gluing pressure and so prevent local distortion or crushing.

Heat is applied to the laminations to set the hot-setting resins or to speed up the setting of other glues. Ovens, steam and hot water hoses, or electrical resistance heaters can be used, the latter being cheap and flexible. High-frequency heating is not yet developed sufficiently except for mass production of simple items, but it can be used to reduce the time in the press very considerably. Recent developments include a conducting glue, and resistance wires embedded in the glue-line.

Gluing should not be carried out in the open air, though sometimes this cannot be avoided when large members have to be fabricated on the site. Most water-resisting glues have a short working life, and are subject to a sudden setting reaction when exposed to draught and/or heat. The best practice is for all gluing to be carried out in the factory where draught and humidity can be kept under control (see also Chapter VIII).

Selection of Material for Structural Members*

While it is true that laminated construction provides a means of utilising low-grade material for high-strength structural members, for best results it is

* D. E. Kennedy, Canadian Forest Service.

nevertheless necessary to exercise some care in the selection and sorting of the timber that goes into the finished product.

Some of the material should be of a good grade. These better-grade boards should be reserved for those positions in the member which will carry the highest stress. In the case of flexural members such as beams and stringers, at least one-third of the total volume of timber should be of high quality. This material should be divided more or less equally between the extreme tension and compression faces. The remainder of the flexural member may contain timber of lower grades.

It is not considered the best practice to mix back-cut and quarter-cut timber in the same laminated member because the expansion and contraction of timber due to changes in moisture content differ considerably in the radial and tangential directions and mixed material is conducive to the occurrence of secondary stresses within the laminated timber. As far as is practicable, merefore, the timber should fall into one category or the other, with the angle of 45 degrees taken as the dividing line between back-cut and quarter-cut timber.

Edge-jointing of Laminations

It is not practicable to construct very large laminated members without employing two or more boards to make up the required width of lamination. For instance, a laminated member 13 inches in width can be fabricated by using boards of nominal 6- and 8-inch widths, dressed on the edges to a net width of, say, 5 1/2 and, say, 7 1/2 inches respectively. In order to avoid the occurrence of a cleavage plane running completely through the member, it is customary to stagger these edge joints in each successive lamination.

End-jointing Laminations

Except in the case of very short laminated timbers, it will always be necessary to end-joint timbers to make up laminations of the required length. For this purpose, a number of end joints of various types have been devised.

Tests have shown, however, that the plain scarf joint gives results that are quite satisfactory and it is not usually necessary to employ more complicated forms of joint. The steeper the slope of the plain scarf, the less efficient will be the glued joint. If the laminations are considered as acting in tension, a plain join of a slope of 1:12 will give 90 per cent efficiency. However, if the joint is fairly close to the neutral axis of the beam a steeper slope may be used.

PRESERVATION

Wherever laminated members come into contact with the ground, or are subject to constant humidity, they should be treated with a satisfactory preservative. (See Chapter XVI.)

FURTHER INFORMATION

A comprehensive handbook of timber laminating and moulding has been prepared jointly by the C.S.I.R.O. Divisions of Aeronautics and Forest Pro-

ducts; see also *Notes on Design Stresses and Procedures for Glued Laminated Timber* and *Timber Engineering Design Handbook* published by the C.S.I.R.O.

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X

FINGER JOINTING

Short lengths are a problem in both the producing and remanufacturing sections of the wood-using industry and generally are either discarded or sold at depressed prices.* Because of the limited demand for shorts, portions of logs that would produce them are often destroyed in quantity by the saw-millers. Further losses occur in docking sawn lengths to the nearest foot, and again, during remanufacture, shorts of high-grade timber are produced in docking specific lengths out of trade lengths.

With increasing costs of timber, the loss of material and reduction in returns by the discounting of short and unpopular lengths has become a serious matter and has stimulated the search for an economical means of end jointing. Gains in many sections of the timber and dependent industries will result if practical and efficient means of joining timber lengthwise are developed at costs that would allow: (a) recovery of short lengths, (b) production of timber in the exact length required by the user, and (c) docking to raise grade.

Finger jointing holds some promise of at least partly solving this problem. Research and experimental work on finger joints is proceeding in Australia and commercial application has commenced.

Finger joints are produced by cutting several interlocking scarfs or wedges in the end section of pieces of the same width (see photo 17). Compared with a full scarf joint these smaller scarfs are easily machined and assembled, and by reducing the length of the piece over which the scarf extends, material saving is effected. Moreover, recent developments in glues and jointing equipment provide means of assembling random lengths into a continuous length that can be docked to the customer's exact requirements. The speed of jointing, and mechanisation of conveying the pieces to be jointed, have achieved economies in jointing costs so that many new fields of application seem possible.

The details of joints of this type have been subjected to intensive study overseas. Due to practical difficulties in preserving sharpness of cutters ending

* Condensed from a paper presented to the 1959 Australian T.I.S. Conference by M. W. Page, Div. of Forest Products, C.S.I.R.O.

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in points, a compromise has been made between theoretical excellence and practical optimum, the toothed tenons, wedge dovetails (or fingers), being generally made with blunt ends.

Because of an increasing local interest in finger jointing, the Division of Forest Products decided to investigate the characteristics of this type of joint in a range of our commercially-important timbers. The results of these studies are available on application to the Division.

To date, finger joints have been produced and tested in radiata pine, mountain ash and alpine ash, jarrah and brush box, representing the density range of our commercial timbers. As a result of this work it is expected that in all these species finger joints could be made on a production basis that would have 60 per cent of the bending strength of matched, unjointed controls. As an indication, the following average efficiencies were attained in the laboratory:

Radiata pine	..	..	..	..	74 per cent.
Mountain ash	..	..	..	..	78 per cent.
Jarrah ..	..	..	..	..	78 per cent.
Brush box ..	..	..	..	..	73 per cent.

Finger jointing has made rapid progress in the United States, and for some time jointed joinery stock, vat staves, wood-pipe stock, flooring, mouldings and railway wagon components have been an accepted part of their timber economy.

Finger Jointing

Parallel development can take place in this country and so increase the yield of high-grade timber and help alleviate the problem of disposing of short lengths. A number of plants are operating in Australia, one jointing radiata pine in South Australia, some in Queensland on hoop pine and other timbers, and at least one other working ash-type eucalypts in Victoria.

Finger Jointing Equipment

Production type finger jointing equipment is at present being manufactured in both North America and Germany. Machinery is available ranging in capacity from small units capable of joining six to eight pieces per minute up to large set-ups with a potential output of 80 to 100 linear feet per minute.

The items of equipment required for finger jointing are the following:

1. A docking saw or saws for removing defects.

2. A planing machine capable of handling lengths as short as eight inches.

3. Machinery for fashioning the finger profile on the ends of the individual pieces. These machines somewhat resemble a single end tenoner. Essentially they consist of a means of holding the timber rigidly while traversing it first past a trim saw to square the end, and then past a rotating vertical spindle carrying the profiled cutters. One interesting machine of German origin employs saws instead of cutters, the saws being mounted on two spindles

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which are canted from the vertical by an amount equal to the slope angle of the fingers. The profiling machine also incorporates an automatic glue applicator mounted directly behind the cutter spindle.

4. An assembly machine for rapidly assembling the finger-jointed shorts into a continuous ribbon of timber, and for cutting this ribbon into predetermined lengths. The most modern machine of this type is produced in the United States.

XI

MOSAIC PARQUETRY,
WOOD BLOCKS

This volume does not aim to cover in detail the finished products of timber in all their wide variety. It is therefore not intended to describe the more conventional types of flooring but to give some brief details of the comparatively recent development of "mosaic parquetry" flooring. Mention also will be made of the advantages of wood blocks for factory floors.

The more conventional types of domestic flooring are known as straight run, end-matched, secret-nailed and parquetry. Widths vary from 3 to 6 inches (parquetry usually from 2 to 2 1/2 inches). The range of species available in Australian woods is wide and many of these are very handsome and highly serviceable. The principal species used for conventional flooring are listed at the end of this chapter.

MOSAIC PARQUETRY

In recent years there has been developed in Australia a type of flooring which has come to be known as mosaic parquetry (see photo 18). It originated in Europe where it is becoming increasingly popular.

Mosaic parquetry is a form of parquetry overlay which is manufactured to precise dimensions and pre-assembled in the form of a small square of "tiles". Each tile is made up of (usually) five accurately machined blocks or "fingers", assembled and glued together to form units each (usually) 4 1/2 inches square. The tiles, when laid, are so arranged that the direction of the grain in each lies at right angles to that of its neighbours.

To facilitate the laying of the tiles, the units are arranged in geometrical squares to designed patterns with a facing of paper (which is later removed) or a backing of aluminium foil. The facings or backings bind the tiles together preparatory to their setting in a mastic adhesive.

Sub-floors

Mosaic parquetry may be laid on concrete or timber sub-floors, or on old floors which have been in existence for a long time. In each case a mastic

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adhesive is employed. But in order to ensure a satisfactory application and an attractive finish, the following precautions and/or preparatory work must be effected.

Concrete Sub-floors

Surfaces must be level and smooth. Irregularities should be ground off. Dampness must be avoided and the area well ventilated. When risk of dampness exists, damp courses should be incorporated where possible. Surfaces must be well cured and free from dirt, grease, paint and so on.

Timber Sub-floors (New Buildings)

The sub-floor should consist of seasoned, tongued and grooved, straight-run flooring not wider than four inches. Where possible, the joints of the sub-floor and those of the mosaic overlay should be arranged to run at an angle of 45 degrees. While not essential, this arrangement will tend to spread the effect of any movement of the sub-floor and reduce any subsequent risk of dishing.

The sub-floor, as with all floors, should be of thoroughly seasoned timber. However, before laying either the sub-floor or the mosaic overlay, both should be allowed to reach the equilibrium moisture content of the building, under exactly the same conditions to which the flooring will be exposed, including direct sunlight through windows or other factors which will raise the temperature of the floor. (See Ch. XV.) Central heating or air-conditioning plant, if installed, should be in operation well before the flooring work is commenced.

The sub-floor should be firmly nailed to the joists, the nails punched, and the surface level-sanded prior to the laying of the mosaic overlay.

Use of Existing Timber Floors

The mosaic overlay should be stored in the area on which it is to be laid for a period sufficiently long to ensure adjustment of its moisture content to that of the existing floor upon which it is to be laid.

The nail-holding of old floors should be carefully checked and the nail heads punched below the floor surface. Re-nailing may be necessary to ensure a firm, even surface. Should there be holes or deep scorings in the floor, they must be cleaned out and filled with a suitable mastic wood-filler. The floor must then be level-sanded and all dirt, wax, paint and so on removed from the surface.

Advantages of Mosaic Parquetry

Because such small sections of timber (for example 3/4 inch wide, 4 1/2 inches long and 3/8 to 5/8 inch thick) can be used to build up each tile, mosaic parquetry flooring offers a use for short ends, offcuts and odd pieces which normally would be regarded as waste. Hence producers of mosaic parquetry frequently are able to offer timber floors in what are normally regarded as higher grade cabinet timbers. These decorative species would prove far too expensive if supplied in straight run conventional flooring, even if such were available in the required lengths and sizes.

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Standard flooring timbers such as tallowwood, brush box, blackbutt, Tasmanian oak, karri, and others assume a much enhanced finish when laid as mosaic parquetry.

Other advantages claimed for mosaic parquetry are: speed and simplicity in laying; use of a great variety of timber species including those too expensive or unsuitable for conventional flooring; greater scope for individual pattern design; convenience in handling and storage; greater exactness in estimating costs of laying.

"Industrial Quality" Mosaic Parquetry

In the process of the selection and inspection of the "fingers" which comprise the tiles, some of the former, while being perfectly sound and functionally satisfactory, may be rejected as unsuitable for a high quality finish. These are graded as "industrial quality", a grade suitable for applications in factories where an overlay on concrete is desired, or where a floor will be covered by carpets and so on.

Other Uses for Mosaic Parquetry

Mosaic parquetry may be used for counter tops, window displays, and in similar fittings where its characteristic geometrical pattern is applicable.

WOOD BLOCKS

Wood blocks, such as formerly were used extensively for paving city streets but requiring much lesser depth, have many advantages when used in the floors of factories, particularly of those engaged in the heavy industries. Wood blocks of timbers such as brush box and jarrah, the end-grain of which is the wearing surface, offer a non-skid, abrasive resistant surface combined with high insulating, sound absorbent, shock resistant and long wearing properties. In few other materials are all these characteristics to be found in combination. For this reason wood blocks, laid on a concrete base, have proved highly successful as a flooring material for the heavy industries.

PRINCIPAL AUSTRALIAN TIMBERS SUITABLE FOR FLOORING

Alpine ash, Tasmanian oak *(Eucalyptus delegatensis)*
Blackbutt *(E. pilularis)*
Brush box *(Tristania conjerta)*
Cypress pine *(Callitris columellaris)*
Forest red gum (*E. tereticornis*)
Grey satinash *(Cleistocaly gustavioides)*
Hoop pine *(Araucaria cunninghamii)*
Jarrah *(E. marginata)*
Johnstone River hardwood *(Backhousia bancroftii)*
Karri *(E. diversicolor)*
Lemon scented gum *(E. citriodora)*
Loblolly pine *(Pinus taeda)*
Mountain ash *(E. regnans)*

Radiata pine (Monterey pine) *(Pinus radiata)*
Red mahogany (*E. resinijera*)
Rose gum (*E. grandis*)
Rose maple *(Cryptocarya erythroxylon)*
Satinay *(Syncarpia hillii)*
Slash pine (*Pinus elliottii*)
Spotted gum *(E. maculata)*
Sydney blue gum *(E. saligna)*
Tallowwood *(E. mycrocorys)*
Tulip oak *(Heritiera spp.)*
Turpentine (*Syncarpia glomulifera*)
White mahogany (*Eucalyptus acmenioides*)

Many other Australian timbers are suitable for flooring but are not in such common supply as the abovementioned species. As mentioned in the foregoing text, a wide variety of timbers, in addition to the above, may be used for mosaic parquetry flooring.

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IMPROVED TIMBER

* The terms "improved" or "densified" timber mean "timber changed mech-anically by impregnation or compression or both". It may be described as an assembly of timber veneers usually first treated with synthetic resins and improved or densified by a further application of heat and high pressure.

Many processes have been devised for treating timber in this manner to improve its mechanical and electrical properties and its dimensional stability under varying conditions. Apart from normal conversion to plywood, these processes however, always involve one or more of the three basic treatments—synthetic resin impregnation, heating and application of pressure. Improved timber is sometimes known as compregnated timber or compreg, but in Australia it is known generally as densified timber.

Densification is usually affected by pressures up to about a ton per square inch, applied at temperatures of about 300°F. The specific gravity of *timber substance* is practically the same for all species, being about 1 -5, whereas the specific gravities of the various species themselves, as they occur in nature, range from less than 0-2 to more than 1-0 due to the presence of interstices or voids in their structure. There is thus plenty of room for increasing the density by reducing the void space, and it has been found that as the density is increased the strength also is increased. Prior impregnation of the veneers with a synthetic resin further contributes additional strength.

Not all strength properties are improved (that of izod may be reduced) and of those that are, compressive strength is the only important property which consistently increases very much more rapidly than the density. Spectacular increases in shear strength, for example, are related more to the resin used and its distribution than to increase in density.

Temperature of pressing has a critical effect on the degree of compression. While it has long been known in a general way that the plasticity of timber

may be increased by raising its temperature, it has recently been shown that for dry timber, of some species at least, this effect is greatly accentuated at temperatures in the vicinity of 350°F., which appear to correspond with the softening point of dry lignin. This material which is one of timber's main constituents is thought to bind together the cellulose fibres and to be largely responsible for the compressive strength of timber.

Material built up from laminations of timber and bonded with synthetic resin glues comes under the heading of "densified timber" since high pressure is always used in bonding, causing a compression of the surface cells of the veneers, and possibly assisting the penetration of the resin into the timber. The bonding pressure is held very high in order to increase the compression of the timber.

The usual method of bonding laminated stock is by soaking the plies in synthetic resin solutions (with or without special impregnating pressures) and subsequent hot pressing. So high a proportion of synthetic resin may be contained by this material that with thin plies it may perhaps more fittingly be regarded as resin reinforced with timber.

The advantages of densified laminated timber are many. Local weaknesses of the solid timber are practically eliminated; rapid seasoning can be carried out without deterioration, owing to the thinness of the plies; moisture changes are reduced to a minimum; the resin acts to restrain recovery from compression; mechanical strength, especially in compression and shearing, is greatly increased. Used as a bearing surface it has much greater resistance to surface wear.

Disadvantages could be the presence of unsuspected weaknesses in gluing and the difficulty encountered in subsequent gluing and working the finished material by orthodox methods. The weight of timber is materially increased but is still substantially below that of metal members which it may be called upon to replace (See Table 23).

It is sometimes desired to give laminated timber a more uniform strength in the plane of the laminations. For this purpose the grain of adjacent plies is oriented at different angles, the most usual angle of course being 90 degrees. As in plywood, this can be done in any kind of laminated stock, including compressed and impregnated stock, though in many cases, especially in aircraft construction, the strength desired in compressed and impregnated laminated stock is in one predominant direction.

In building up the laminations for densified wood the thickness of the veneers is decided by the nature of the material required. The thinner the veneers the greater the uniformity, degree of impregnation, compression and density. The degree of impregnation also depends in some measure on the characteristics of the resin and the manufacturing process.

It is thus necessary that (a) the timber chosen will yield well cut veneers economically, and (b) that these can be impregnated with resin to the degree required for the product under manufacture.

Although improved timber has been made with timbers having an air dry (12 per cent moisture content) density as high as about specific gravity 0·8, timbers between about 0·5 to 0·6 are preferable, with an air dry weight per

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TABLE   23

Material	Specific Gravity	Tensile Strength (tons/sq. in.)	Compressive Strength (tons/sq. in.)	Young's Modulus 10^6 lb./sq. in.
Duralumin	2.85	25	25	10.5
Improved Wood (parallel to grain)	1.35-1.40	14-20	12-18	3.5-6.0

cubic foot between 30 and 40 pounds. Hoop pine has been found to be ideal for this purpose.

A most important field for the use of laminated timber of moderate thickness is in aircraft construction, where the good mechanical properties of natural timber are highly desirable, especially if the most serious defect of non-conformity can be removed.

Strengths in shear and compression of densified laminated timber are from 60 to 120 per cent higher than solid timber parallel to the grain and from 100 to 150 per cent higher perpendicular to the grain. The stiffening of the cells and vessels has its chief result in a considerable increase in compressive strength. The great differences between compressive and tensile strength met with in solid timber are nearly eliminated in densified timber. Strength in impact is somewhat reduced by the addition of the rigid synthetic resin.

Improved timber of high density and high resin content is extremely moisture resistant and prolonged immersion in water causes only negligible absorption or change in volume. With its excellent mechanical properties, it occupies an important place between natural timber and non-ferrous metallic materials. In illustration, some mechanical properties of improved timber may be compared with those of duralumin.

From these figures, it is evident that on a strength/weight basis, densified timber is comparable to duralumin in certain mechanical properties. Also these mechanical properties can be manipulated by varying the veneer timber, the type of resin, the resin content and the density of the materials.

The extent to which individual properties may be improved is shown in Table 24. The figures represent the *average* of the maximum values ascer-

TABLE   24

MAXIMUM PROPERTIES (PARALLEL TO GRAIN)

Ultimate Tensile Strength—lb./sq. in. 55,000
Modulus of Elasticity—lb./sq. in. 5,500,000
Ultimate Compressive Strength—lb./sq. in. 40,000
Modulus of Rupture parallel to laminations—lb./sq. in. 45,000
Ultimate shear strength—lb./sq. in.—
    Parallel to laminations 6,100
    Perpendicular to laminations 9,000
Izod Parallel Laminations—ft. lb. 20

turned for the respective properties as determined by tests of various types of densified timber. The materials were made and tested by the Division of Forest Products. It should be stressed that these properties do not refer to any one single product.

Densified timber has been made commercially in England, the Continent of Europe, the United States and Australia for several years and has found many uses. An interesting application during the last war was in the manufacture of the variable pitch wooden airscrews which were made in Australia as well as in England, America and Germany. For this type of airscrew, natural timber is not sufficiently strong to withstand the stresses at the blade root but airscrews with a root section of densified timber were developed successfully for use in certain types of aircraft.

Improved timber has many other uses where good mechanical or electrical properties arc required. The following examples illustrate the diversity of uses for which this material is suitable.

General Uses: Bearings (including windmill bearings), ball and roller bearing cages, gear wheels, brake linings, pulleys, rollers, trolley wheels, press tools and substitutes for certain metallic parts in the munitions industry, carriage, lift and escalator floors, and band-saw guides.

Aircraft Industry: Variable pitch wooden propellers, joysticks, instrument panels, fuselage stringers, spar webs, seaplane float struts, wireless masts, spar booms for main and tail planes and packing blocks.

Ship and Boat Building Industry: Bearings for stern tubes, rowlock blocks, pulley blocks and sheaves.

Textile Industry: Shuttles, bobbins and picking sticks and a substitute for laminated canvas rollers.

Electrical Uses: Instrument mounting panels, terminal boards, mounting blocks for switches, fuses, cut-outs, relays, and so on; switch operating rods and handles, insulating stools, radio and telephone insulators, barriers, core spacers, slot wedges, busbar supports, bushes, brush gear bases, channelling and clips for cables, fish plates for electric railways and generally in high tension electrical insulation.

The Australian made product should find many other uses for which it is ideally suited and also should provide a useful substitute for some materials often unobtainable or which must be conserved for urgent requirements. It must not, however, be regarded generally as a substitute material since it has definite and highly valuable applications, and is proving superior to many materials previously used for the same purpose.

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XIII

PRINCIPAL COMMERCIAL TIMBERS USED IN AUSTRALIA

Owing to so many different species of timber occurring in Australia, it would be impracticable to describe in this chapter all those which have some practical use.

Therefore a number of species has been selected as representing those in more common use or as serving a particular purpose.

In addition a description is given to those timbers commonly imported into Australia.

The timbers have been placed into three groups based on a botanical classification, namely: Group I, Non-pored Timbers—*Conifers;* Group II, Pored Timbers—*Hardwoods (Non-Eucalypts)*, and Group III, Pored Timbers —*Hardwoods (Eucalypts).*

Each timber has been described in a concise manner in an endeavour to outline its characteristic properties. In each case the standard trade common name is given, also its standard trade reference name and any other common names, together with country or states of origin. The general characteristics of the timber such as colour, texture, grain and other properties are given as well as principal uses and other important facts. Also given (where available) are density figures, durability, class and strength group classifications and shrinkage data.

In explanation, the numbers given under Density refer to lbs. per cubic foot, A.D. meaning Air Dry at 12 per cent moisture content. Strength group and Durability classifications are as outlined in Chapter XXII, Tables 40 and 42. Shrinkage figures represent shrinkage to 12 per cent moisture content, based on green dimension. Where other figures are shown in brackets they refer to the relative percentages of shrinkage after reconditioning.

For timber trade purposes the Australian Standards Association has published timber grading specifications in which timbers produced in Australia are included under three large groups:—

(I) *Pines* (All conifers, native and exotic).

(II) *Hardwoods* (Mostly Eucalypts, with a few botanically related hard timbers, by individual species and regional occurrence).

(III) *Rainforest Timbers* (Including all species, soft and hard, not included in (I) and (II) above).

In Chapter XXV (Technical Standards in the Timber Industry) these specifications are numbered in relation to these groups and each has been indicated in the lists of timbers below for easy reference by means of a footnote.

TIMBERS DESCRIBED*

Group I: Non-pored Timbers—Conifers

STANDARD TRADE NAME	BOTANICAL NAME
Cedar, western red	*Thuja plicata*
Fir, Douglas	*Pseudotsuga taxifolia*
Hemlock, western	*Tsuga heterophylla*
Kauri, aneityum	*Agathis obtusa*
Kauri, Indonesian	*Agathis alba*
Kauri, Queensland	*Agathis palmerstoni,*
	A. robusta, A. microstachya
Kauri, Queensland north	*Agathis microstacliya*
Kauri, vanikoro	*Agathis macrophylla*
Matai	*Podocarpus spicatus*
Pine, Baltic, red	*Pinus sylvestris*
Pine, Baltic, white	*Picea abies*
Pine, black	*Podocarpus amarus*
Pine, brown	*Podocarpus elatus*
Pine, bunya	*Araucaria bidwillii*
Pine, Caribbean	*Pinus caribaea*
Pine, cypress, black	*Callitris calcarata*
Pine, cypress, white	*Callitris columellaris*
Pine, celery-top	*Phyllocladus rhomboidalis*
Pine, hoop	*Araucaria cunninghamii*
Pine, huon	*Dacrydium franklinii*
Pine, King William	*Athrotaxis selaginoides*
Pine, klinkii	*Araucaria klinkii*
Pine, loblolly	*Pinus taeda*
Pine, parana	*Araucaria angustifolia*
Pine, patula	*Pinus patula*
Pine, radiata monterey	*Pinus radiata*
Pine, slash	*Pinus elliottii*
Pine, western yellow	*Pinus ponderosa*
Redwood, California	*Sequoia sempervirens*
Rimu	*Dacrydium cupressinum*
Sempilor	*Dacrydium elatum*
Spruce, sitka	*Picea sitchensis*

Group II: Pored Timbers- -Hardwoods (Non-eucalypts)

Alder, blush	*Sloanea australia*
Alder, brown	*Ackama paniculata*
Alder, rose	*Ackama australiana*

* For the full list of standard names refer to SAA.0.2—1965 Nomenclature of Australian Timbers, and SAA. Int. 363 1954 Standard Nomenclature for Commercial Timbers Imported into Australia.

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STANDARD TRADE NAME	BOTANICAL NAME
Amberoi	*Pterocymbium beccarii*
Anisoptera	*Anisoptera polyandra*
Ash, crow's	*Flindersia australis*
Ash, hickory	*Flindersia ifflaiana*
Ash, silver	*Flindersia bourjotiana*
Ash, silver	*Flindersia pubescens and F. schottiana*
Bean, black	*Castanospermum australe*
Beech, Myrtle	*Nothofagus cunninghamii*
Beech, N.Z. silver	*Nothofagus menziesii*
Birch, white	*Schizomeria ovata*
Blackwood	*Acacia melanoxylon*
Bollywood	*Litsea reticulata*
Box, brush	*Tristania conferta*
Calophyllum	*Calophyllum inophyllum*
Carabeen, white	*Sloanea macbrydei*
Carabeen, yellow	*Sloanea woollsii*
Cedar, Borneo	*Shorea spp.*
Cedar, red	*Toona australis*
Cheesewood, white	*Alstonia scholaris*
Coachwood	*Ceratopetalum apetalum*
Damson	*Terminalia sericocarpa*
Erima	*Octomeles sumatrana*
Geronggang	*Cratoxylon arborescens*
Hardwood, Johnstone River	*Backhousia Bancroftii*
Hickory	*Carya ovata, C. laciniosa and C. glabra*
Kapur	*Dryobalanops spp.*
Katon	*Sandoricum indicum*
Keruing	*Dipterocarpus spp.*
Kwila	*Intsia bijuga*
Lauan	*Shorea spp.*
Magnolia	*Galbulimima baccata*
Mahogany, brush	*Geissois benthami*
Mahogany, miva	*Dysoxylum muelleri*
Mahogany, rose	*Dysoxylum fraseranum*
Malas	*Homalium foetidura*
Maple, Queensland	*Flindersia bray ley ana*
Maple, rose	*Cryptocarya erythroxylon*
Maple, scented	*Flindersia laevicarpa*
Mararie	*Pseudoweinmannia lachnocarpa*
Meranti	*Shorea spp.*
Mulga	*Acacia anew a*
Nyatoh	*Sapotaceae spp.*
Oak, blush tulip	*Heritiera actinophylla*
Oak, brown tulip	*Heritiera trifoliolata*
Oak, Mackay tulip	*Heritiera spp.*
Oak, Japanese	*Quercus mongolica, Q. glandulifera Q. dentata*
Oak, red tulip	*Heritiera peralata*
Oak, silky	*Orites excelsa, Grevillea robusta and Cardwellia sublimis*
Penda, brown	*Xanthostemon chrysanthus*
Penda, red	*X. whitei*
Penda, southern	*X. oppositifolius pachysperma*
Penda, yellow	*Tristania pachysperma*
Pepperwood	*Cinnamomum laubatii*
Poplar, pink	*Euroschinus falcatus*

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STANDARD TRADE NAME	BOTANICAL NAME
Quandong, silver	*Elaeocarpus grandis*
Quandong, tropical	*Elaeocarpus largiflorens*
Ramin	*Gonystylus warburgianus*
Rosewood, N.G.	*Pterocarpus indicus*
Saffron-heart	*Halfordia kendack*
Sandalwood	*Santalum spicatum*
Sandalwood	*Santalum lanceolatum*
Sapele	*Entandrophragma cylindricum*
Sassafras	*Doryphora sassafras*
Sassafras, northern	*Dorophora aromatica*
Sassafras, southern	*Anthero&perma moschatum*
Satinash, grey	*Cleistocalyx gustavioides*
Satinash, white	*Eungella sp. aff. smithii*
Serayah, red	*Shorea spp.*
Serayah, white	*Parashorea spp.*
Serayah, yellow	*Shorea spp.*
Sheoak, W.A.	*Casuarina fraseriana*
Silkwood, bolly	*Cryptocarya oblata*
Silkwood, silver	*Flindersia acuminata*
Siris, red	*Albizia toona*
Siris, yellow	*Albizia xanthoxylon*
Sycamore, silver	*Cryptocarya glaucesccns*
Taun	*Pometia pinnata*
Teak, Burma	*Tectona grandis*
Teak, N.G.	*Vitex cofassus*
Tea-tree, broadleaved	*Melaleuca leucadendron*
Turpentine	*Syncarpia glomulifcra*
Walnut, brown	*Beilschmiedia sp.*
Walnut, Pacific	*Mangifera sa/om on ensis*
Walnut, N.G.	*Dracontomelum mangiferum*
Walnut, Queensland	*Endiandra palmerstoni*
Walnut, yellow	*Beilschmiedia bancroftii*
Willow	*Salix spp.*
Yellow-wood	*Flindersia xanthoxyla*

Group HI: Pored Timbers—Hardwoods (Eucalypts)

Ash, alpine	*Eucalyptus delegatensis*
Ash, mountain	*E. regnans*
Ash, silvertop	*E. sieberi*
Barrel, brown	*E. fastigata*
Blackbutt	*E. pilularis*
Blackbutt, W.A.	*E. patens*
Bloodwood, red	*E. gummifera*
Bloodwood, red	*E. intermedia*
Box, coast grey	*E. bosistoana*
Box, grey	*E. hemiphloia*
Box, red	*E. polyanthemos*
Box, yellow	*E. melliodora*
Cadaga	*E. torelliana*
Gum, blue, southern	*E. globulus*
Gum, blue, Sydney	*E. saligna*
Gum, forest red	*E. tereticornis*
Gum, lemon scented	*E. citriodora*
Gum, manna	*E. viminalis*
Gum, mountain (grey)	*E. cypellocarpa*
Gum, river red	*E. camaldulensis*

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STANDARD TRADE NAME	BOTANICAL NAME
Gum, rose	*E. grandis*
Gum, spotted	*E. maculata*
Ironbark, broadleaved red	*E. fibrosa ssp. fibrosa*
Ironbark, grey	*E. drepanophylla*
Ironbark, grey	*E. paniculata*
Ironbark, narrowleaved red	*E. crebra*
Ironbark, broadleaved red	*E. fibrosa ssp. fibrosa*
Ironbark, red	*E. sideroxylon*
Jarrah	*E. marginata*
Kamarere	*E. deglupta*
Karri	*E. diversicolor*
Mahogany, red	*E. resin if era*
Mahogany, southern	*E. botryoides*
Mahogany, white	*E. acmenioides and E. umbra ssp. umbra and E. umbra ssp. carnea*
Mallet, brown	*E. astringens*
Marri	*E. calopliylla*
Messmate, Gympie	*E. cloeziana*
Stringybark, messmate	*E. obliqua*
Stringybark, red	*E. macrorrhyncha*
Stringybark, white	*E. eugenioides, E. globoidea and E. phaeotricha*
Tallowwood	*E. microcorys*
Tuart	*E. gomphocephala*
Wandoo	*E. redunca*
Yertchuk	*E. consideniana*

Group I: Non-pored Timbers—Conifers
Bindang (see Kauri, Indonesian)

CEDAR, WESTERN RED

An important tree in the humid regions of the north Pacific coast of north America, Western red cedar *(Thuja plicata)* is used extensively for manufacturing shingles, weatherboards and other exterior fittings where durability and ease of working are important factors. It is reddish-brown in colour having a sapwood of pale appearance. Other uses include interior decoration, boat building, corestock and greenhouses.

Density: A.D. 23   Shrinkage: Radial 1.2
                                     Tangential 2.5
                                       Durability Class *2*

FIR, DOUGLAS

Douglas fir (*Pseudotsuga taxifolia*) is mainly found growing on the Pacific coast of North America, primarily British Columbia, Vancouver Island, Washington and Oregon. The timber is pale in colour and is most desirable for structural purposes being strong and moderately hard for a softwood. It is also used extensively for plywood and veneer manufacture, joinery, mouldings and when preservatised for heavy constructional work, also weatherboards and flooring. One of its great advantages is in the large sizes obtainable which are free from knots. Other common names are British Columbia pine and Oregon pine.

Density: A.D. 32   Shrinkage: Radial 2-0
Strength Group: D.   Tangential 3-8
                                       Durability Class 4

HEMLOCK, WESTERN

Western hemlock *(Tsuga heterophylla)* is to be found most extensively in the Pacific north west of North America. The timber is yellowish in colour moderately soft and easy to work. In proportion to its weight it is one of the stiffest and strongest softwoods

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and is used considerably in light and medium constructional work. The timber is also utilised for joinery, interior decorations, furniture, flooring, cooperage and box shooks. It is free of resin.

Density: Green 41, A.D. 29   Shrinkage: Radial 2-2
                                                Tangential 4-0
                                    Durability Class 4

KAURI, ANEITYUM

Referred to botanically as *Agathis obtusa,* Aneityum kauri is not very well known in Australia and extensive information on the timber is not available. The Division of Forest Products points out that it would be similar in most respects to Vanikoro kauri, as well as those kauris growing in north Queensland and Borneo.

For this reason reference should be made to the descriptive detail dealing with Indonesian, Queensland and Vanikoro kauris.

KAURI, INDONESIAN

Indonesian kauri (*Agathis alba)* is found in the East Indies, Borneo, Malaya and the Philippines. Other common names include mangilan, bindang, damar, minyak and almaciga. The timber is white to pale yellow-brown in colour with little difference between sapwood and truewood. It is of straight grain, very fine texture and has no pronounced taste or odour. The timber seasons well, is very easy to work, although it is not durable when exposed to the weather.

Main uses include general construction, draining boards, pattern making, tank and vat staves, pencils, sounding boards and paper pulp.

Density: A.D. 31   Shrinkage: Radial 1-1
                                     Tangential 1-7

KAURI, QUEENSLAND

Queensland kauri is found in both north and south Queensland. In north Queensland there are two species *Agathis microstachya* and *Agathis palmerstoni* and in the south of the State *Agathis robusta.* The timber is pale to light brown, of very uniform texture, being easy to work, machines well and takes stain and polish. It is used for cabinet work, plywood, joinery, shelving, pattern making, linings, turnery, sounding boards for musical instruments, flooring, staves and butter boxes. Also makes good battery separators.

Density: Green 45, A.D. 30 (N.Q.)   Shrinkage: Radial 2.2
           A.D. 25 (S.Q.)   Tangential 3.5
Strength Group: Lower than D.   Durability Class 4

KAURI, VANIKORO

Botanically known as *Agathis macrophylla,* this species is confined to the Santa Cruz group of islands in the south-west Pacific. The tree is found mostly on mountain slopes up to 1700 feet altitude, in very high rainfall areas. The straw-coloured heartwood is almost indistinguishable from the slightly paler sapwood. As with most kauris, the timber has a characteristic speckled appearance on quarter-sawn surfaces. The soft wood, averaging about 34 lb. per cubic foot, is easily worked by hand or power tools, it glues well, and is readily peeled or sliced to veneer. Its main uses include veneer for plywood and matches, boat planking, and internal joinery.

MATAI

The major forests of matai or black pine *(Podocarpus spicatus)* occur in central portions of the north island of New Zealand. The timber is of a pale colour being used for flooring, tallow casks and similar cooperage work. It is said to be one of the best timbers in the world for both industrial and domestic flooring as well as for decking and sills. It is also used for weatherboarding and plywood manufacture.

Density: Green 68, A.D. 38   Shrinkage: Radial .. .. 1 - 5
                                                Tangential 3-1
                                    Durability Class 2-3

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PINE, RED BALTIC

This timber is referred to in the Australian trade as red baltic *(pinus sylvestris)* as well as fir, red and yellow deal, Scots pine, northern pine and Baltic. It grows in Norway, Sweden, Finland, Estonia, Latvia, Denmark, Germany, Poland, Czechoslovakia, France, Switzerland, Spain, Russia, Scotland and England. The timber is creamy-while in the sapwood, the heartwood being reddish brown. The red Baltic works well and is used for all types of building work, namely framing, flooring, joinery, corestock, carriage work, sleepers and power poles. It is stronger and more durable than Baltic white wood *(Picea abies).*

Density: Green 50, A.D. 33   Shrinkage: Radial 2-1
Strength Group: D.   Tangential 4-4
                                         Durability Class 4

PINE, WHITE BALTIC

While Baltic pine or European white wood *(Picea abics)* grows in central Europe and Scandinavia with a similar habitat as *Pinus sylvestris.* Other common names are while ileal, while fir, spruce, Norway spruce and white pine. The timber is white in colour and is not durable, it works well, takes paint and glue and is used for interior joinery, box shooks, flooring, weatherboards, general building construction and paper pulp.

Density: Green 42, A.D. 27   Shrinkage: Radial 1-6
Strength Group: D.   Tangential 3-1
                                         Durability Class 4

PINE, BLACK

Black pine *(Podocarpus atnarus)* so named from its darker coloured bark, is confined to the rain forests of North Queensland. It is similar to northern kauri in hardness and texture although a shade darker in colour. It has similar uses to kauri for plywood, cabinetwork and joinery.

Density: A.D. 28   Shrinkage: Radial 1-7
Strength Group: Lower than D.   Tangential 3-7
                                         Durability Class 4

I'INI',, BROWN

Brown pine *(Podocarpus elatus)* is a native of the rain forests of New South Wales anil Queensland ranging from the Illawarra District to Cairns. In timber type it is very similar to its close botanical relative Matai *(Podocarpus spicatus)* in New Zealand. A little browner in colour and slightly heavier than hoop pine, brown pine is used for many of the same purposes in building, joinery and furniture. It is, however, more liable to split when nailed near ends of boards but is much more durable when exposed. As with all coniferous timbers, the sapwood is immune to lyctus borer attack.

Density: A.D. 38   Shrinkage: Radial 1-7
                                       Tangential 3-7
                                         Durability Class 2-3

PINE, CARIBBEAN

Bunya pine *(Araucaria bidwillii)* is often sold with hoop pine under the name "Queensland pine" and has practically the same wide range of uses in plywood, joinery, furniture, boxes and general building. There is little difference in structure and properties except that bunya pine often has more pink shades in colour, is a little lower in average weight and often saws with a rougher surface in wet timber.
The knots are more uniform in size than in hoop pine but have a greater tendency to shrink and fall out as the timber seasons. On the other hand its greater toughness and lighter weight have made it popular for hollow masts of boats. The tree is confined to Queensland between Gympie on the coast and the Bunya Mountains on the main Divide north of Dalby. Hoop pine is preferred for plantations because of better seed yield but bunya pine can be grown in frosty hollows where hoop pine would not survive.

Density: A.D. 33
Strength Group: D.   Durability Class 4

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PINE, BUNYA

Caribbean pine *(Pinus caribaea)* has been introduced into Australian plantations for general softwood production. In tropical parts of Queensland it has proved superior in quality to the slash and loblolly pines being more uniform in texture with softer latewood rings closer in type to radiata pine. It has the same uses as the other resinous pines and can also find place for many uses for which hoop pine is preferred.
Density: A.D. 32
Strength Group: D.   Durability Class.   4

PINE, WHITE CYPRESS

White Cypress pine *{Callitris columellaris)* is found in Queensland, New South Wales and Victoria. Of a yellow to dark brown colour, with many knots, the timber has a distinctive odour, and is resistant to decay and termite attack. It is widely used for house framing, weatherboards, flooring, linings and at times for furniture.
Black Cypress pine *{Callitris calcarata)* is very similar to white Cypress pine, though somewhat darker in colour and not so durable.
Density: Green 60, A.D. 43   Shrinkage: Radial.   .   .   .   ...   2 - 3
Strength Group: D.   Tangential   ..   ..   ..   2 - 8
                                            Durability Class   1

PINE, CELERY-TOP

Within the Commonwealth celery-top pine *(Phyllocladus rhomboidalis)* grows in Tasmania and New Guinea. The timber is exceptionally durable being used principally in chemical vats, boat building, carriage work, joinery, flooring and other joinery uses. It is pale coloured, straight grained with fairly distinct growth rings.
Density: Green 66, A.D. 40   Shrinkage: Radial   1-6
Strength Group: D.   Tangential   ..   ..   . .   3 - 3
                                            Durability Class.   2

PINE, HOOP

Hoop pine *{Araucaria cunninghamii)* is found on the coastal areas of eastern Australia from Coffs Harbour in the south to Cairns in the north, also in the New Guinea highlands. Other trade names are Richmond River pine, colonial pine, Queensland pine and Dorrigo pine. An excellent timber for all types of mouldings, flooring, shelving and joinery as well as for butter box cases and the manufacture of plywood and veneer. It is a little stronger than Douglas fir and has much superior nail and screw holding power making it ideal for internal house framing when protected from *A.nobiidae* attack. Hoop pine takes paint and preservatives very well and is popular for boats and caravans. The timber is a light brown to a pale cream colour, growth rings being very distinct. It works very easily and makes high quality particle boards.

Density: Green 55, A.D. 35   Shrinkage: Radial.   .   .   .   .. .   2 - 5
Strength Group: D.   Tangential   ..   ..   ..   3 - 8
                                            Durability Class   4

PINE, HUON

Huon pine *(Dacrydium franklinii)* occurs only in Tasmania. The timber is pale yellow, straight-grained and gives off a characteristic odour. It is in demand for boat building because of its durability, ease of bending and low shrinkage. Other uses include joinery, turning, pattern making and tourist ornaments.
Density: Green 60, A.D. 32-5   Shrinkage: Radial.   .   .   .   .. .   2 - 5
Strength Group: D.   Tangential   ..   ..   ..   3 - 0
                                            Durability Class   2

PINE, KING WILLIAM

King William pine *(Athrotaxis selaginoides)* is frequently referred to as King Billy pine and grows in Tasmania. The timber is yellowish-pink in colour with straight grain and fine texture, being easy to work, soft and durable. Main uses are boat building,

pattern making, weatherboarding, staves and Venetian blind slats. Suitable for sounding boards of violins and pianos.

Density: Green 39, A.D. 25   Shrinkage: Radial 1-5

Strength Group: D.   Tangential 3-8

     Durability Class 3

PINE, KLINKII

A considerable quantity of klinkii pine *(Araucaria klinkii)* grows in New Guinea and, together with hoop pine which it very closely resembles, is being utilised to make excellent plywood. The timber is suitable for interior work, joinery, flooring, and battery separators. Wide boards are available which season well and finish with a satiny pale yellow to pale brown lustre.

Density: A.D. 28   Shrinkage: Radial 2-2

Strength Group: D.   Tangential 4-0

     Durability Class 4

PINE, LOBLOLLY

Loblolly pine *(Pinus taeda)* is also known as southern pine, pitch pine and Queensland field pine. The tree is indigenous to the United States and has been planted to some extent in plantations throughout Australia. The timber is yellowish to reddish-brown in colour with very distinct growth rings. It takes screws and nails well and is used for general building purposes, flooring, as well as for boxes and cases.

Density: A.D. 32

Strength Group: D.   Durability Class 4

PINE, PARANA

Growing in extensive forest regions in southern Brazil, Paraguay and Argentina, Parana pine or Brazilian pine *(Araucaria angustifolia)* is the most important softwood grown in South America. In seasoning the timber is very variable and needs careful handling. The sapwood is reddish-pink with truewood of pale cream. It glues well, is easy to work and is prone to split when nailed or screwed. The timber has a wide range of uses including all building constructional work, interior joinery, furniture and mouldings. It will not taint foodstuffs. Quite large quantities have been imported into Australia as veneer and plywood.

Density: A.D. 35   Durability Class 4

PINE, PATULA

Patula pine *(Pinus patula)* is another of the softer pines introduced into Australia which finds application for general building purposes, flooring, mouldings, internal light fixtures, turnery and boxes.

Timber grown on higher lands in South Queensland has proved lighter and softer than hoop pine with much lower nail holding power. This is a disadvantage when this timber is used for ceiling battens unless special care is taken. It is excellent for small mouldings.

Density: A.D. 30   Durability Class 4

Strength Group: Below D.

PINE, RADIATA MONTEREY

This very important tree may be found in many parts of Australia principally in plantations. The standard trade reference name is *Pinus radiata,* other common names are insignis pine and Monterey pine. The timber is white to a creamy yellow with distinct growth rings. Its main uses are for mouldings, floorings, linings, weatherboards, shelving, joinery, turnery, corestock, match splints, box shooks and plywood manufacture. The timber takes preservatives very well. With proper silvicultural methods now being employed the quality of this plantation-grown exotic pine timber will further improve.

Density: Green 53, A.D. 32   Shrinkage: Radial 2-5

Strength Group: D.   Tangential 3-9

     Durability Class 4

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PINE, SLASH

Pinus elliotti is the standard trade reference name for slash pine. Indigenous to the United States, it has been grown very successfully in plantations throughout various parts of Australia. The timber is yellow to red brown, being used for joinery, general construction, flooring, plywood, pulp and case shooks.

Density: A.D. 43

Strength Group: D.   Durability Class   4

PINE, WESTERN YELLOW

Western yellow pine *(Pinus ponderosa)* is also marketed under these common names: yellow pine, British Columbian soft pine, Californian white pine and ponderosa pine. It is found throughout the Pacific coast of North America from British Columbia to New Mexico. It has a pale yellow sapwood and reddish-brown heartwood, growth rings being clearly defined. The timber is used for joinery, turnery, pattern making, furniture, general construction work and boxes.

Density: Green 60, A.D. 27

REDWOOD, CALIFORNIA

The most important stands of California redwood *(Sequoia seinpervirens)* are confined to a narrow coastal strip ten to thirty miles wide on the western coast of the United States from southern Oregon to within a few miles of San Francisco.

The sapwood of the timber is white, the heartwood being a mahogany colour. It is extremely resistant to decay and is known throughout the world for its durability. Redwood is used for joinery, weatherboards, shingles, posts, pipes, staves and for heavy constructional work such as bridges and industrial building. It is worked easily and paints well. The tree is the tallest growing tree in the world, one at present being 364 feet in height.

Density: Green 46, A.D. 25   Shrinkage: Radial   ..   .. 1 - 3
                                               Tangential   2-2
                                   Durability Class   2

RIMU

The principal indigenous timber tree of New Zealand, rimu or red pine *(Dacrydium cupressinum)* possesses many excellent qualities but unfortunately the past high production of this timber cannot be sustained due to its very slow rate of growth. It has a light brown sapwood, the heartwood being moderately durable, stable and often highly figured. The bulk of supplies available are used in building construction, flooring, furniture and for the manufacture of plywood.

Density: Green 60, A.D. 36   Shrinkage: Radial   ..   ..   .. 2 . 2
                                               Tangential 4.9
                                   Durability Class   3

SPRUCE, SITKA

Sitka spruce *(Picea sitchensis)* grows on the Pacific coast of North America from Alaska to northern California. The timber ranks high in strength for its weight and being of uniform texture it is sought after for aircraft construction. It is pale yellowish-brown in colour. It is easily worked but is not resistant to decay. Sitka spruce is used for flooring, weatherboards, linings and joinery. Large quantities go into boxes, crates and ladders.

Density: Green 36, A.D. 28   Shrinkage: Radial   2-2
                                               Tangential   3-8
                                   Durability Class   4

Group II: Pored Timbers—Hardwoods (Non-eucalypts)

ALDER, BLUSH

Blush alder *(Sloanea australis)* is also known as maiden's blush and blush carrobean. It is a coastal rain forest tree ranging from New South Wales to North Queensland. The pink to reddish good working timber is often sold with rose alder but is sometimes

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harder and more liable to face checking. It is used mostly for veneers, plywood, furniture, panelling, flooring and general internal home framing. Unlike rose alder which is immune to lyctus attack, the sapwood of blush alder is readily attacked and must be immunised for permanent work.

Density: A.D. 43   * Shrinkage: Radial 2-7
                                                    Tangential 5-3
                                     Durability Class   4

ALDER, ROSE AND ALDER, BROWN

Rose alder (*Ackama australiensis*) and brown alder *{Ackama paniculata)* are the common names of timber from two closely related species. Rose alder is also known in Queensland as feathertop and pencil cedar. Brown alder is sometimes referred to as either corkwood, pencil cedar or rose alder. Their habitat is from central New South Wales rain forests to north Queensland. The timbers from these two species are almost indistinguishable being a light to a deep pinkish-brown in colour. Main uses are plywood, joinery and small turned articles such as shoe heels, brushware, etc.

Density: A.D. 42   Shrinkage: Radial 4-5 (2-5)
                                                Tangential 7-5 (5-0)

AMBEROI

Amberoi *{Pterocymbium beccarii)* occurs frequently in the rain forests of Papua and New Guinea. It is a light, porous non-durable wood susceptible to lyctus borer attack and sap stain. The timber is whitish in colour with an oak-like grain on the quarter face, and can be used for interior finishing and veneer backs. It works easily, seasons well, but does not finish well.

Density: A.D. 26
Strength Group: D.   Durability Class   4

ANISOPTERA

Anisoptera *(Anisoptcra polyandra)* grows principally as a timber tree in Malaya, Papua, New Guinea, Siam, Borneo, Indo-China, Burma, and the Philippine Islands. It has a number of common names and can be referred to as anisoptera, mersawa, mentasawa, garawa and karawa. The timber is pale yellow to light brown in colour, the sapwood being susceptible to the lyctus borer. It contains silica and offers some difficulty in sawing and planing, however, indications are that it is suitable for utility plywood. The timber is not durable in the weather but is excellent for indoor construction. Very wide clear timber is obtainable which makes it suitable for furniture and interior fittings.

Density: A.D. 39   Shrinkage: Radial 2-4
Strength Group: D.   Tangential 6-2
                                     Durability Class   3-4

ASH, CROW'S

Growing in northern New South Wales and south Queensland, Crow's ash *(Flindersia australis)* is also known as Australian teak. The timber is yellow in colour, greasy, hard and heavy. It makes excellent decking and flooring, being used extensively in shipbuilding, for sleepers and props in mining and carriage work. It is a favourite timber for moulded hand rails, window and door sills, but any sapwood must be pressure impregnated against lyctus and fungi attack.

Density: Green 68, A.D. 57   Shrinkage: Radial   ..   .. 3 - 0
Strength Group: B.   Tangential   4-0
                                     Durability Class   1

ASH, HICKORY

Hickory ash *{Flindersia ifflaiana)* is found in north Queensland where it is also known as Cairns hickory and hickory. The timber is slightly greasy, of medium texture and

* Bull. 3, D.W.T., N.S.W. Forestry Commission.

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yellowish-brown in colour. Hickory ash is a most important structural timber in north Queensland, particularly for heavy work. It turns well and may be used for flooring and tool handles.

Density: Green 75, A.D. 62	Shrinkage: Radial	.	.	.	.	.	3-0
Strength Group: B.	Tangential	.	.	.	4-5		
	Durability Class	..	..	..	..	1	

ASH, SILVER

Silver ash is the common trade name of a group of timbers of the genus *Flindersia*. The main species are Queensland silver ash *(F. bourjotiana),* northern silver ash *(F. pubescens)* and southern silver ash (F. *schottiana).* The last-named is known as bumpy ash in Queensland and cudgerie in New South Wales. They grow in the coastal areas of eastern Australia from the Hastings River in New South Wales to north Queensland. The timber is almost white to light brown, generally straight-grained but at times interlocked and wavy. It is used extensively for furniture work and fancy veneer manufacture, is easy to work with hand or machine tools, bends well and takes an excellent polish.

Density: Green 57, A.D. 43	Shrinkage: Radial	..	..	. . 3 - 5	
	Tangential	..	. .	.. 5-5	
	Durability Class	..	..	. .	.. 3

BASSWOOD

Basswood *(Endospermum medullosum* and *E. formicarium)* occurs as one of the species of heterogeneous rain forests of Papua and New Guinea. It is a whitish timber with regular bands of soft tissue and with crystals visible on the transverse surface. It can be used for furniture, interior finishing and cases. Works easily, seasons and finishes well.

| Density: A.D. 26 | | | | | |
| Strength Group: D. | Durability Class | .. | .. | .. | .. 4 |

BEAN, BLACK

Growing in regions of continuous rainfall in north eastern Australia, black bean *(Castanospermum australe)* can be highly recommended for decorative work, carved articles and panelling. It is a handsome cabinet timber and is used for plywood, veneered panels and flush door manufacture. The sapwood varies from white to a yellowish colour turning to a very deep brown in the truewood. It machines reasonably well but is difficult to glue owing to its greasy nature.

Density: A.D. 44	* Shrinkage: Radial	.	.	.	. 2.0(1.5)
	Tangential	..	. . 6 . 0 (3.5)		
	Durability Class	..	..	..	.. 1-2

BEECH, MYRTLE

Myrtle beech is the standard trade common name of *Nothofagus cunninghamii.* The tree is distributed throughout Tasmania and parts of Victoria and is also well known as Tasmanian myrtle, beech, myrtle or Tasmanian beech. The timber is of reddish-brown colour, of fine and uniform texture. As logs are frequently faulty it is not regarded as a good milling type. It is popular for cabinet and furniture manufacture, flooring, linings and decorative veneers.

Density: A.D. 44	Shrinkage: Radial	..	..	.. 3-0 (2-5)
	Tangential	. .	. . 6 5 (4-5)	
	Durability Class	..	..	..	.. 4

BEECH, NEW ZEALAND SILVER

New *Zealand* silver beech *(Nothofagus menziesii)* is widely distributed throughout both North and South islands of New Zealand. The timber is straight-grained, easy to work, strong but not durable in contact with the ground. It is principally used as flooring,

* Considerably greater shrinkages have been recorded.

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interior finish, furniture for bent work, agricultural implements, billiard tables, tool handles, rifle stocks, staves and crates and boxes. It is of pinkish to light brown in colour.

Density: Green 58, A.D. 39	Shrinkage: Radial	..	..	..	**3·4**
	Tangential	..	,.	..	**9·1**
	Durability Class	..	..	..	**4**

BIRCH, WHITE

Commonly known in New South Wales as crabapple or New South Wales white ash. White birch *(Schizomeria ovata)* occurs in the coastal districts of New South Wales, southern Queensland and on Fraser Island. The sapwood of the timber is very susceptible to the lyctus borer but with modern immunising treatment white birch has become important both as joinery and veneer timber. Of white to light brown in appearance, there is very little distinction between the sapwood and truewood. In addition to joinery, veneer and plywood manufacture it is also used in the manufacture of coffin boards, pegs, match splints and turned articles. White birch *(Schizomeria whitei)* in North Queensland has similar qualities and uses.

Density: A.D. 39	Shrinkage: Radial	..	..	..	**3·0**
	Tangential	..	..	..	**6·5**
	Durability Class	..	..	..	**4**

BLACKWOOD

One of Australia's most decorative timbers, blackwood *(Acacia melanoxylon)* is distributed throughout high rainfall areas in New South Wales, Victoria, South Australia and mountain areas of North Queensland, its best development being in western Tasmanian areas. There is now practically no blackwood of commercial size in New South Wales. The timber bends and turns well, works easily and takes a high polish. Blackwood is golden to dark brown in colour, usually straight-grained but occasionally yielding beautiful fiddle-back figure. The timber is extensively used for interior decorative work, mouldings and bank and shop fittings, panelling, for railway carriages, ships and public halls. Another important property is its unsurpassed qualities for stave manufacture, particularly in tight cooperage.

| Density: A.D. 33/40 | Shrinkage: Radial | . | . | . | . | . | .1-8 |
| | Tangential | .. | | .. | | .. | 4-5 |

BOLLYWOOD

Also known as bolly gum, brown bollywood and brown beech, the bollywood tree *(Litsea reticulata)* is found in rain forests of New South Wales and Queensland. The timber is of moderately fine and uniform texture, pale brown to yellowish-pink in colour. The timber is suitable for interior joinery, turning, furniture and plywood manufacture. The sapwood is very susceptible to the lyctus borer.

Density: A.D. 33	Shrinkage: Radial	.	.	.	.	.	.2-5
	Tangential	.		.		.	.5-0
	Durability Class	..		..		..	.. 4

BOX, BRUSH

Brush box *(Tristania conferta)* is distributed throughout the heavy rainfall areas of northern New South Wales and southern Queensland. The timber is pinkish-brown, fine and close textured with a somewhat curly grain, hard and tough with good wearing qualities, it dresses well and is regarded in New South Wales as one of the best timbers for bridge and wharf decking. It is probably the most popular flooring in eastern Australia.

Density: Green 75, A.D. 54	Shrinkage: Radial	.		.	.		.4-8(3-8)
Strength Group: B.	Tangential		..		..		9-7(7-0)
	Durability Class	..		..		..	2-3

CALOPHYLLUM

Growing in Malaya, Borneo, Celebes Islands, Papua-New Guinea and other islands of the East Indies and the Pacific, this timber is commonly referred to as beach calophyllum *(Calophyllum inophyllum)* and bush calophyllum (C. *kajewski).* Of deep red

colour, the beach calophyllum has an interlocked grain and due to the habit of growing in a twisted and gnarled form its uses are limited. It is highly figured, and is sought after for shipbuilding keels, pulley blocks, boat knees and ribs. Bush calophyllum is used for joinery, flooring and panelling. The timber is easily worked, but unfortunately its supply is limited. Red touriga *(Calophyllum costatum)* of similar quality grows in North Queensland rain forests.

Density: A.D. 44   Durability Class   3

CARABEEN, YELLOW

The natural habitat of yellow carabeen *(Sloanea woollsii)* is in the brush forests of northern New South Wales and South Queensland. Rather easy to work and finish, the timber is a pale brownish colour, moderately close textured, with the sapwood susceptible to the lyctus borer. The timber is mainly used for flooring, lining, turnery, joinery, cases, form work and veneer manufacture. White and grey Carabeen *(Sloanea langii and S. macbrydei)* with timbers of the same qualities are milled in North Queensland.

Density: A.D. 36   Shrinkage: Radial   .   .   . 2-5 (2-0)
                                  Tangential 6-0 (4-0)

CEDAR, BORNEO *

There are many species of *Shorea* (Borneo cedar, Pacific maple, lauan, meranti) growing throughout the Malay Peninsula, Borneo, East Indies, Siam, Indo-China, Papua and New Guinea. The timbers of these species vary from white to yellow to deep red in colour, some are heavy, hard and strong, and others very brittle and light. In many instances the sapwood is susceptible to lyctus attack and because of this the majority of this timber imported into Australia is immunised. The uses are many, principally for all types of interior work, such as joinery, mouldings, linings, trim, furniture and plywood for both commercial and decorative purposes.

                       Durability Class   4

CEDAR, RED

Responsible in many ways for the extension of colonisation along the coast of New South Wales and Queensland, red cedar *(Toona australis)* is now nearing extinction in many districts. It is a speciality timber of rich reddish-brown colour being light, very durable and easy to work with both hand and machine tools. It is highly prized for superior class furniture and cabinet work, pattern making and racing boats.

Density: A.D. 28   Shrinkage: Radial 2.0
                                    Tangential 4.0
                       Durability Class   1

CHEESEWOOD, **WHITE**

White cheesewood *(Alstonia scholaris)* grows principally in north Queensland and is known as milky pine or milkwood. Cream to yellowish-white, the timber saws and dresses well and is used for interior work and pattern making. The sapwood is susceptible to the lyctus borer.

Density: A.D. 25   Shrinkage: Radial 3.5
                                    Tangential 5.5
                       Durability Class   4

COACHWOOD

Coachwood *(Ceratopetalum apetalum)* is an important rain forest timber growing in the coastal areas of New South Wales. It has been found exceptionally adaptable to peeling and its plywood has been used considerably in aircraft production. It is pinkish-brown in colour, of fine and uniform texture and is used for furniture, joinery and interior work. It is also utilised for turnery, such as handles, dowels, shoe heels, bobbins and various tourist articles.

Density: A.D. 39   Shrinkage: Radial   3-8
                                    Tangential   .   .   . 7-5

   * For further details of principal colour groups see Serayah, Red, White and Yellow.

DAMSON

Damson *(Terminalia sericocarpa)* is confined to north Queensland rain forests from the vicinity of Mackay to Cairns where it is also known as sovereignwood from its pale golden colour and attractive sheen when polished. The coarse grained timber is firm, but good working, and glues well after seasoning. The wide sapwood is susceptible to lyctus attack and requires treatment. Best uses for magnolia are in quarter sliced veneers and panels, plywood, furniture, internal joinery and general house framing under cover.

Density: A.D. 40   Durability Class 4

ERIMA

Erima *(Octomeles sumatrana)* is also commonly called binuang, illimo and binoewang. It is found in New Guinea, Papua, Borneo, Sumatra and New Britain. Greyish-yellow to light brown in colour, the timber is of soft coarse nature and open-grained. It is chiefly manufactured into corestock for doors, veneers and interior fittings. The sapwood is lyctus susceptible, the heartwood producing attractive ribbon grain when cut on the quarter.

Density: A.D. 24   Shrinkage: Radial 1.9
                                 Tangential 4.3
                                 Durability Class 4

GERONGGANG

Geronggang *(Cratoxylon arborescens).* This timber which grows in Sarawak and Malaya is soft and light. Sapwood is pale yellow or pinkish, the heartwood bright salmon-pink when freshly cut, deepening to reddish-brown when dry. The grain is straight, the texture rather coarse but even. It seasons well and can be worked without difficulty. Suitable for interior joinery, offering a cedar-like finish.

Density: A.D. 34   Shrinkage: Radial 2.6
Strength Group: D.   Tangential 4.5
                                 Durability Class 4

HARDWOOD, JOHNSTONE RIVER

This timber, confined to the Johnstone River area of north Queensland, is known as *Backhousia bancroftii.* It is light grey coloured, hard, close-textured, with a generally interlocked grain. The timber is slightly difficult to work by hand, but machines well, and has been milled to flooring, for which purpose it has excellent wearing qualities. In the green condition it has been used in building construction as plates, studs and joists. The timber has an average density of 58 lb. per cubic foot, and is fairly durable exposed to the weather and in contact with the soil in well-drained locations.

Density: A.D. 58

HICKORY

The true hickorys are found throughout the eastern half of North America, the most important species being *Carya ovata, Carya laciniosa* and *Carya glabra.* This timber is world renowned for its toughness and resilience and is a speciality timber which is used for vehicle spokes, rims, shafts, axe, pick, sledge and hatchet handles, and for golf club shafts, ladder rungs, and aeroplane work. The sapwood is white and the heartwood is red in colour. Colour gives no indication of its strength because weight for weight, sound hickory has the same strength and toughness regardless of whether it is red, white or mixed red and white. The timber is rather hard to work in both sawing and planing.

Density: A.D. 48

KAPUR

Kapur *(Dryobalanops spp.)* is light to dark reddish-brown, darkening on exposure, with a creamy sapwood. The timber has a characteristic camphor-like odour but is much harder and heavier than true camphorwood. Grain usually straight, coarse

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texture, moderately hard and heavy, it is not durable in moist conditions. This timber can be used as a substitute for camphorwood m furniture, but is generally used as flooring, for boat building (small), general construction work and carriage framing Kapur occurs in Borneo and Malaya.

Density: A.D. 45

KERUING

Keruing is the name used in Malaya, North Borneo and Sarawak for timber of the genus *Dipterocarpus*. Other names are apitong (Philippines), gurjun (Burma) and vans (Thailand). The timber is moderately hard to hard, fairly heavy (50 to 57 lb per cubic foot A.D.). The grain is straight, texture rather coarse but even. Heartwood varies from light red to dark brown or dark purple-red. Large sizes clear of knots and maior defects are obtainable. Canal-resin is commonly present. The sapwood is rarelv attacked by lyctus. Keruing absorbs preservatives readily. A good general purpose constructional timber, it is used for beams, joists, flooring, bridges and wharves (treated) poles and sleepers (treated).

| Density: A.D. 46 | Shrinkage: Radial | . | . | . | . | 5·5/6·4 |
| | Tangential | . | . | . | . | 11·6/13 |

KWILA

Widely distributed throughout the East Indies and Papua and New Guinea, kwila *(Intsia bijuga)* is also commonly called melila or bendora. Being very durable in the ground the timber which is of a dark brown colour is excellent for bridge building piles girders, decking and shipbuilding. It makes excellent flooring and it is sometimes substituted for teak. It is not resistant to marine borers.

Density: Green 63, A.D. 55	Shrinkage: Radial	..	..	1-2
Strength Group: B.	Tangential	....	..	2·6
	Durability Class	..	..	2

LAUAN

(See Cedar, Borneo)

MAGNOLIA

Magnolia, sometimes known by the misleading name of pigeonberry ash in north Queensland, is botanically listed as *Galbulimima baccata* and quite unrelated to rose maple *(Cryptocarya erythroxylon)* frequently called pigeonberry ash in south Queensland and New South Wales. The timber is soft to firm to work, nearly white near the outside of the log, and sometimes with a dark brown somewhat greasy cylinder of heartwood. This is best dried and used separately for scantling and flooring.

The sapwood is susceptible to Iyctus attack and when immunised finds favourable use in veneers, plywood, mouldings, flooring and interior work generally.

| Density: A.D. 40 | Durability Class | . | . | . | . | . | . | 4 |

MAHOGANY, BRUSH

Brush mahogany *(Geissois benthami)* is found in brush forests on the north coast of New South Wales and is better known as red carabeen and red bean. The timber is pinkish-brown in colour with a yellowish sapwood, being fine and uniform in texture. It is easy to work although in some instances is very hard on wood-working tools. Principal uses are in cabinet work, joinery, handles, turned articles, veneer and plywood, case manufacture and rough construction.

| Density: A.D. 40 | Shrinkage: Radial | . | . | . | . | . | 3· | 5 |
| | Tangential | . | . | . | . | 7·5 |

MAHOGANY, MIVA

This timber grows in New South Wales and Queensland and in the latter State is Icnown as pencil cedar. Miva mahogany *(Dysoxylum muelleri)* is rich red in colour, straight-grained, easily worked and glues, stains and polishes well. Mainly used in

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furniture making, interior decoration and for general house construction where durability is necessary.

Density: A.D. 40   Shrinkage: Radial .   .   .   .   .   . 2·5

                                     Tangential   ..   .. 4·5

MAHOGANY, ROSE

Rose mahogany *(Dysoxylum fraseranum)* is found in northern New South Wales and south Queensland and is sometimes known as rosewood in the former State. The timber is a reddy brown colour of fine, fairly uniform texture, the sapwood being susceptible to lyctus borer. The truewood is exceptionally durable and can be used in exposed positions. It is an excellent cabinet timber, very easy to work and suitable for mouldings, turnery, interior joinery, carving, floorings, linings, shop and office fittings, and if available in sufficient quantities would make attractive veneer.

Density: A.D. 44   Shrinkage: Radial .   .   .   .   .   . 2·5

                                       Tangential   ..   .. 4·5

MALAS

Malas *(Komalium foetidum)* occurs as one of the species in the heterogeneous rain forests of Papua and New Guinea. It is a brown to reddish timber with an absence of soft tissue. It can be used for boat framing, heavy and light construction. Works easily and seasons well.

Density: A.D. 50

Strength Group: B.   Durability Class   .. 2

Found principally on the Atherton Tableland in north Queensland, Queensland maple *(Flindersia brayleyana* and *F. pimenteliana)* can be regarded as one of Australia's most popular veneer and cabinet timbers, and among the world's finest cabinet timbers. It is of light to pinkish brown in colour, is easily handled with machine tools although its grain which is sometimes interlocked, may pick up in dressing. It is distinctively ribbon-grained when quarter-sawn and often shows high figure. Sapwood is immune from lyctus attack. All types of finishes can be applied with excellent success—wax, french polish, bleaches and fuming. Mainly used in interior decorations, for panelling, furniture, stairways and shop fittings as well as mouldings, household joinery, partitions and in small craft construction. It is in very great demand for veneer and plywood manufacture and generally in short supply.

Density: A.D.   34·7   Shrinkage: Radial .   .   .   .   .   . 2·8

                                       Tangential   ..   .. 6·7

MAPLE, ROSE

Growing in the brush forests of eastern Australia from northern New South Wales to the ranges of southern Queensland, rose maple *{Cryptocarya erythroxylon)* as a timber is used principally for flooring, lining, furniture and plywood manufacture. It is a light pinkish-browny colour, the sapwood being susceptible to attack by the lyctus borer.

Density: A.D. 42   Shrinkage: Radial .   .   .   .3·0

                                       Tangential   .. 6·5

MAPLE, SCENTED

Scented maple *(Flindersia laevicarpa)* derives its name from the pleasant sweet odour which is always noticed when the firm, close textured, good working, pale pink timber is cut. With the two species of similar properties sold together as Queensland maple, it is the only other known Flindersia which is immune to lyctus attack in the sapwood. The timber is moderately strong with considerable durability. It is a popular timber with builders for dressed weatherboards, external joinery, flooring and general house framing. The tree is confined to the Cairns district, North Queensland, where it is also known as rose ash.

Density: A.D. 45   Durability Class 2-3

MARARIE

Mararie *(Pseudowienmannia lachnocarpa)* occurs principally in northern New South Wales and Queensland. It is very close-grained, the timber being of pink to mauve colour. One of our finest hardwoods, it is largely utilised for machine bearings, heavy frames, coach building, handles, mallets, etc.

Density: A.D. 55   * Shrinkage: Radial   .   .   .   .   .   .   5'4

MERANTI, RED

(See Cedar, Borneo and Serayah)

MULGA

Mulga *(Acacia aneura)* is widely spread throughout the dry interior of South Australia, Western Australia, New South Wales and Queensland. The timber is heavy, and hard, turns well and takes a high polish. Because of its fine, contrasting dark brown and yellow colour, it is used primarily for ornaments and larger furnishings such as lampstands and tables.

The tree is protected on Crown areas of arid N.S.W. because of its value in soil erosion control and in Queensland for the stock fodder value of its leaves in times of drought.

Density: A.D. 75

NYATOH

Nyatoh includes timbers of the species *Palaquium hispidum, P. maingayi* and *Ganua motleyana.* It is produced mainly in Malaya and is used principally in furniture manufacture. It requires slow and careful seasoning, as it is subject to surface checking. Nyatoh species are rarely susceptible to lyctus borer.

OAK, BROWN TULIP

Known also as crowsfoot elm, booyong and stave wood, *Heritiera trifolialata* grows in brushwood forests from northern New South Wales to north Queensland. The timber is dark brown in colour, of medium texture, grain being somewhat interlocked. The timber has been used for cabinet making, flooring, joinery, mouldings, panelling, railway panelling, railway carriage construction and for plywood manufacture.

The sapwood is very susceptible to the lyctus borer, but is now extensively used for internal house framing after preservative treatment by a pressure process. Blush tulip oak *(Heritiera actinophylla)* which has a slightly lighter and softer timber, usually paler in colour, is very similar in structure and properties to brown tulip oak and is used for the same purposes. It is common on the Macpherson Ranges between New South Wales and Queensland.

Density: A.D. 55   Shrinkage: Radial   .   .   .   .   .   3'0
                                    Tangential   ..   . .   ..   6'5

Durability Class 4

OAK, JAPANESE

There are a number of species of oak growing in Japan; the most common are *Quercus mongolica, Q. glandulifera* and *Q. dentata.* These are known by the respective trade names of ohnara, konara and kashiwa. The sapwood is distinct from the heartwood, being paler brown in colour. In addition to having an attractive figure when cut on the quarter due to the presence of medullary rays, it is also of pleasing colour, strong and durable. The timber is mainly employed for panelling, cabinet work, furniture, heavy structural construction wheelwright's work, flooring and high-class joinery. It is a most versatile timber.

Density: A.D. 43   Durability Class   2-3

OAK, RED TULIP

The principal range of red tulip oak *(Heritiera peralata)* is over the tropical coast

* Bull. 3, D.W.T., N.S.W. Forestry Commission.

forests of north Queensland. The timber is moderately heavy and strong from white in the sapwood to reddish-brown in the truewood, and susceptible in the sapwood to the lyctus borer. The timber's best uses are for internal decoration, cabinet work, bentwood furniture and because of its attractive appearance, veneer and plywood manufacture. It is extensively used for flooring and internal building framing when immunised. Mackay tulip oak (*Heritiera sp.*) which appears to grow only in the vicinity of Mackay, north Queensland, is reported to be easier to machine and peel for veneers than the other tulip oaks and is more highly favoured by plywood manufacturers.

Density: A.D. 49   Shrinkage: Radial   ..   .. 3·9
                                    Tangential   ..   ..   .. 6·8

OAK, SILKY

The common name silky oak refers to three timbers *Orites excelsa*, *Grevillea robusta* and *Cardwellia sublimis* which are distributed from north Queensland to as far south as the northern rivers of New South Wales. In latter years however, the *Cardwellia sublimis* has been more commonly used because supplies of the other two timbers which grow in southern Queensland and northern New South Wales are practically exhausted. Of light pink to brownish colour, the timber has the usual prominent oak figure due to the presence of medullary rays. It is regarded as an important cabinet timber being of attractive appearance when quarter-sawn. Large quantities of silky oak are used in the manufacture of plywood and veneers, which together with solid timber have considerable use in the furniture industry.

Density: A.D. 33   Shrinkage: Radial   ..   .. 1·5
                                    Tangential   ..   ..   .. 5·0

PENDA

Four trees are generally grouped under the name of penda—brown penda (*Xanthostemon chrysanthus*), red penda (*Xanthostemon pubescens*), southern penda (*Xanthostemon oppositifolius*) and yellow penda (*Tristania pachysperma*). In natural habitat in north Queensland red penda is also called Atherton penda; brown penda is also known as Johnstone River penda, while yellow penda is referred to as Johnstone River yellow-wood. The most important of these four trees is the red penda the timber of which is fine textured, tight-grained, compact and dense, being hard on saws and very difficult to plane and nail. It is of pale to brownish-pink in colour. The pendas are used in all ordinary hardwood construction for homes and, with the exception of yellow penda, for heavy constructional work such as bridges and decking.

Density: Brown penda: A.D. 63
         Red penda: A.D. 63
         Southern penda: A.D. 70
         Yellow penda: A.D. 51

PEPPERWOOD

Pepperwood (*Cinnamomum laubatii*) is a lighter and softer timber than its close botanical relative camphor laurel (*Cinnamomum camphora*) and lacks its strong and pleasant aroma. Pepperwood is a pale coloured, soft, very easy working timber ideally suited for veneers, plywood, light mouldings and internal house trim. It is native to north Queensland rain forests in the Cairns district.

Density: A.D. 25   Durability Class   4

POPLAR, PINK

Also known as maiden's blush and blush cudgerie, pink poplar (*Euroschinus falcatus*) occurs in scattered stands in jungle areas from northern New South Wales to north Queensland. The timber resembles Queensland maple in appearance but not in quality, being pale pink in colour, of soft open texture and straight grain. Due to limited availability it is utilised mainly for brake blocks, case timber, coffins, cheap furniture and shelving.

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Density: A.D. 30

* Shrinkage: Radial . . . . . . 1·3
Tangential . . . . 4·1
Durability Class 4

QUANDONG, SILVER

Silver quandong is the standard trade common name for the timber *Elaeocarpus grandis,* which grows in the coastal rain forests from central New South Wales to north Queensland. White to brown in colour, the timber is of soft and uniform texture, and easy to work with hand or machine tools. Its excellent working qualities make it suitable for all types of ornamental interior trim as well as for furniture, linings and flooring. Sometimes used as a substitute for spruce. Northern quandong *(Elaeocarpus foveolatus)* and tropical quandong *(Elaeocarpus largiflorens),* slightly softer and lighter in weight with very similar qualities, are also produced in north Queensland.

Density: A.D. 29

Shrinkage: Radial . . . . . . 1·5
Tangential .. .. .. 4·5
Durability Class 4

RAMIN

Ramin *(Gonystylus warburgianus)* is the common name for nine species of this genus which are distributed throughout the Philippines, Malaya and Borneo. Other trade names are melawis and ahmin. The timber from these different species all resemble one another, being pale to white in colour with interlocked grain and moderately fine texture. Sapwood is not readily distinguished from the heartwood. The timber is subject to blue stain. It works well, is suitable for interior work, particularly for mouldings and for furniture manufacture, plywood and cases. The sapwood is lyctus susceptible.

Density: A.D. 41

Shrinkage: Radial . . . . . . 2·4
Tangential .. .. .. 6·2
Durability Class 4

ROSEWOOD—NEW GUINEA

New Guinea rosewood *(Pterocarpus indicus)* occurs as one of the species in the heterogeneous rain forests in Papua and New Guinea. It is a reddish, ring-porous timber with a pleasant odour. It can be used for turnery, furniture and face veneers. Works easily, seasons and finishes well.

Density: A.D. 40

Durability Class 1

Strength Group: C-D.

SAFFRON-HEART

The saffron-heart *(Halfordia kendack)* grows in a restricted area confined to south east Queensland and Fraser Island. The timber is specifically suitable for fishing rods, and archers' bows, selected material being very strong and resilient. It is of pale saffron colour and is said to rival imported greenheart for the uses mentioned above. Saffron-heart *(Halfordia scleroxyla)* with similar properties is found on the Atherton Tableland where it is also known as jitta. During the 1939-45 war this timber was used for stern bearings in fast naval craft.

Density: A.D. 67

Shrinkage: Radial . . . . . . 4·0
Tangential . . . . 7·5

SANDALWOOD

Commercial areas of sandalwood are mainly confined to Western Australia and small sections of South Australia, the standard reference name being *Santalum spicatum.* The timber is light yellow to light brown in colour and from it is manufactured essential oils as well as joss sticks which are exported in large quantities to eastern countries. Smaller ornamentations, such as serviette rings, book ends, carved articles and trinket boxes can also be readily manufactured from this timber. Queensland sandalwood *(Santalum lanceolatum)* from dry inland areas is now almost cut out.

Density: A.D. 51

* Bull. 3, D.W.T. gives Radial—2·8; Tangential—4·2.

SAPELE

The tree of sapele (*Entandrophragma cylindricum)* is confined to the forests of West Africa in regions of comparatively heavy rainfall. The sapwood is pale in colour while the heartwood varies to a reddish-brown. The timber has interlocked grain and because of this feature highly prized veneers are produced. It is hard to work owing to its irregular grain and is therefore principally manufactured into veneer for high class cabinet work and panelling.

Density: A.D. 44

SASSAFRAS

Grown in bnishwood forests throughout the coastal areas of Victoria, New South Wales and Queensland, sassafras (*Doryphora sassafras)* is a hardwood, although it is mistakenly referred to by the trade as a softwood. The timber is of a yellowish-green appearance, comparatively light but not durable, the sapwood being immune to lyctus attack. During recent years it has found increasing usage and at the present time is being employed with success in the cabinet trade, and in the manufacture of handles, turnery, brushes and general joinery work.

Five other species of sassafras with similar structure and working properties except for density variations between 33 and 42 lb. per cubic foot occur in Queensland. These are sassafras *(Daphnandra micrantha),* grey sassafras *{Daphnandra repandula)* and northern sassafras *{Daphnandra dielsei, Doryphora aromatica* and *Dryadodaphne nove-guinensis).*

Density: A.D. 36	Shrinkage: Radial	2·5
	Tangential	6·0
	Durability Class	3·4

SASSAFRAS, SOUTHERN

Unlike *Doryphora sassafras,* southern sassafras *{Antherosperma moschatum)* extends as far south as Tasmania, prominent also in Victoria and south eastern New South Wales. It is similar in appearance to sassafras being almost white and of fine texture. Southern sassafras is particularly suitable for turnery work such as clothes pegs, handles, bobbins, shoe heels, toys and small ornaments.

| Density: A.D. 36 | Shrinkage: Radial | 2·5 |
| | Tangential | 6·5 |

SATINASH, GREY

Occurring in the north eastern highlands of Queensland grey satinash (*Cleistocalyx gustavioides)* is also locally called water gum. It may be classed as an ordinary timber working species being neither difficult nor easy to handle. The timber is of yellowish-grey colour, medium texture and interlocked grain. When stained it gives an attractive figure on the back sawn face. Principal uses are in general house construction, furniture manufacture, boat building, floorings, skirtings, linings and plywood.

Density: A.D. 47	Shrinkage: Radial	2·0
	Tangential	5·5
	Durability Class	2·3

SATINASH, WHITE EUNGELLA

White eungella satinash takes its name from the Eungella Range, west of Mackay, North Queensland, where it is found in large quantities. It is also logged in the mountain rain forests of the Atherton Tableland west of Cairns.

The timber closely resembles grey satinash in type but usually is a little paler in colour, lighter and softer to work, and a little less durable. It has at present very similar uses to grey satinash and with adequate seasoning could well perform the functions of the ash eucalypts of southern States.

| Density: A.D. 45 | Durability Class | 3 |

SATINAY

Satinay *(Syncarpia hillii)* is found in considerable quantity only on Fraser Island, Queensland, to the east of the city of Maryborough. Some small patches of timber also occur on the mainland opposite the southern tip of the island and a few miles to the south. Closely related botanically to turpentine, satinay is known locally as Fraser Island turpentine.

At its best, satinay is a magnificent tree reaching a height of about 130 feet with girths breast high of 15 feet and more. Smaller trees have very long, straight and clean boles which, with high strength and great resistance to damage from fire, decay, insects and marine borers of the shipworm group, makes them specially suitable for use as marine piling. The sapwood lends itself to impregnation with modern non-leachable all-purpose preservatives to give maximum protection to piles and transmission poles. The close textured, hard timber affords a good wearing surface for bridge and wharf decking.

When seasoned and dressed, satinay provides very durable milled weatherboards (chamferboards) for exterior sheeting. With very few blemishes, satinay is also very popular for its fresh pink colour and handsome figure, particularly in quarter sawn boards. Satinay is used in building framing, external joinery, parquetry and furniture required to withstand hard wear as in public schools.

Density: Green 75, A.D. 52	Shrinkage: Radial . . .	4·5 (3·0)
Strength Group: B-C.	Tangential	9·5 (6·0)
	Durability Class	2

SERAYAH, RED

Red meranti (Malaya), tangile, red lauan, red serayah, Borneo cedar *(Shorea spp.).* The timber varies in colour from pale pink to purple-brown and darkens on exposure. White lines often show on the longitudinal surfaces, due to intercellular canals. The sapwood is paler and sharply defined and is susceptible to attack by lyctus. Figure not prominent except on quarter-cut surfaces. Finishes well with occasional silky sheen. Is fairly durable in dry situations but not in contact with the ground. Used for house framing, doors and windows, shelving, small boat planking, lower grade furniture and plywood. Soft to moderately hard.

Density: A.D. 28-45	Shrinkage: Radial	3·6
	Tangential	7·7
	Durability Class	4

SERAYAH, WHITE

White meranti (Malaya), white lauan (Philippines) *(Parashorea spp.).* A light honey-coloured timber with a distinct pink tinge, darkens on exposure. Sapwood distinct, often darker than heartwood, due to stain, and is susceptible to lyctus attack. Grain interlocked, giving ribbon figure when quarter-cut, texture coarse. Seasons well, easy to work, and finishes fairly well. Only moderately durable. Used for lower grade cabinet work and furniture making, interior finish, boat building, shop fittings. Soft to moderately hard.

Density: A.D. 42-48.	Shrinkage: Radial	3·4
	Tangential	7·8
	Durability Class	4

SERAYAH, YELLOW

(Shorea spp.) Light yellow-brown, usually with a distinct pink-red tinge darkening on exposure. Narrow pale sapwood not readily distinguishable from heartwood. susceptible to attack by lyctus. Grain usually interlocked and sometimes wavy, texture moderately coarse and even. Works easily with hand or machine tools to give a slightly lustrous finish, not durable. Seasons well with only small shrinkage. Used for general construction work, interior finish, joinery, veneer and plywood. Soft to moderately hard.

Density: A.D. 36-46	Shrinkage: Radial	1·0
	Tangential	3·2
	Durability Class	4

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SHE0AK, WESTERN AUSTRALIA

Occurring sparsely through the whole of the jarrah belt. Western Australian sheoak *(Casuarina fraseriana)* is a medium weight, medium strength timber, brown in colour with the large rays characteristic of almost all of the Casuarinaceae. It makes excellent light cooperage and its main usage is for this purpose and for furniture and panelling. The sapwood is very susceptible to lyctus attack.

Density: Green 60, A.D. 46	Shrinkage: Radial	1·2
Strength Group: D.	Tangential	4·5
	Durability Class	2

SILKWOOD, BOLLY

Commonly known as tarzali or tarzali silkwood, bolly silkwood *(Cryptocarya oblata)* is confined to the coastal jungle areas of north Queensland. The truewood of this species is from reddish-brown to pink, the sapwood, which is susceptible to lyctus attack, being sometimes paler in appearance. The timber is straight-grained, uniform in texture and easy to work. It is primarily used for plywood, linings, doors, panelling, furniture and cabinet work.

Density: A.D. 34	Shrinkage: Radial	2·8
	Tangential	7·2
	Durability Class	4

SILKWOOD, SILVER

The standard trade common name for the timber of *Flindersia acuminata* is silver silkwood which is also known as Putt's pine, white silkwood and silver maple. Its natural habitat is confined to the Atherton and Evelyn tablelands of Queensland. Susceptible to attack by the lyctus borer, the timber is a pale yellowish-brown in appearance, of a regular grain and easy to work with hand or machine tools. It is used for decorative purposes, cabinet work, general house construction, churns, moulds and staves for tallow and meat casks.

Density: A.D. 30·5	Shrinkage: Radial	2·0
	Tangential	4·5

siris, RED

Red siris *{Albizia toona)* grows principally in north-eastern Queensland notably on the Atherton-Ravenshoe tableland. Also known as acacia cedar, the timber is dark red in appearance being very durable although not very strong. It is mainly used in general building, cabinet work, turnery, fittings and plywood panelling.

Density: A.D. 43	Shrinkage: Radial	2·0
	Tangential	4·5
	Durability Class	2·3

SIRIS, YELLOW

Yellow siris, also known as yellow bean, and sometimes "flindersia" from its greasy appearance resembling *Flindersia australis,* is botanically listed as *Albizia xanthoxylon.* It is pale yellow in colour, lustrous on the surface, durable when exposed and one of the easiest working cabinet timbers in north Queensland rain forests. For these reasons it is prized for building small boats, joinery and mouldings.

Density: A.D. 38	Durability Class 2·3

SYCAMORE, SILVER

This species is distributed from southern New South Wales to north Queensland and as well as its standard trade common name of silver sycamore *(Cryptocarya glaucescens)* it is also known as brown beech, native laurel, and jackwood. The truewood is pale to yellow-brown, the sapwood is lighter coloured and is not susceptible to the lyctus borer. It has good working properties and is suitable for use in interior joinery, mouldings, furniture, veneer and plywood manufacture and for case shooks.

Density: A.D. 39	Shrinkage: Radial	3·0
	Tangential	7·5

TAUN

Taun *(Pometia pinnata)* is found in Papua, New Guinea, Solomon Islands, Borneo, Malaya and the East Indies. It is also known as ohabu and is the main timber produced in coastal sawmills in New Guinea where it is largely used in house construction. As a medium hard cabinet timber, it is free of defects, cuts and dresses well, is of straight grain and light pink to medium red in colour. Its uses are furniture, joinery, and boat building. Supplies are plentiful.

Density: A.D. 41	Shrinkage: Radial	.	.	.	.	3·4
Strength Group: C.	Tangential	.	.	.	.	5·6

TEAK, BURMA

Occurring mainly in monsoonal forests of India, Burma, Siam, Sumatra and Java, teak *(Tectona grand is)* has been a timber sought after for many centuries for boat decking and general shipwright work. The timber is brown in colour, somewhat coarse and uneven textured, oily, moderately hard and strong. It finishes well, and is very resistant to decay. It is also used for heavy constructional work, sills, doors, panelling and other decorative work and flooring.

Density: Green 56, A.D. 43	Shrinkage: Radial	.	.	.	.	1·2
	Tangential	.	.	.	.	2·2
	Durability Class	. .	..	. .	..	1

TEAK, NEW GUINEA

New Guinea teak *(Vitex cofassus)* occurs as one of the species in the heterogeneous rain forests of Papua and New Guinea. This tree does not grow to a large size and has very poor form. It is a light brown timber with an absence of soft tissue and an absence of tyloses. Because this timber is very stable it can be used for boat building. It can also be used for furniture, interior finishing, piles, posts and light construction. Works easily, seasons well under a moderate schedule and finishes well.

Density: A.D. 44						
Strength Group: C.	Durability Class	..	..	. .	..	2

TEA-TREE

The broad-leaved tea-tree *(Melaleuca leucadendron* and *M. quinquineruia)* grows in New South Wales and Queensland. A pale pinkish coloured, close textured hard timber, it is readily polished and is used for general building purposes, also for flooring, lining, mouldings, carvings, boat knees and oyster stakes. The sapwood is susceptible to the lyctus borer.

Density: A.D. 47	* Shrinkage: Radial	.	.	.	.	3·7
	Tangential	..	..	..		6·9
	Durability Class	.	.	.	.	3

TURPENTINE

Known as lustre and turpentine *(Syncarpia glomulifera)* the habitat of this tree is along the eastern coast of Australia. It is a heavy timber being very durable and particularly resistant to fire, insects and marine borers. It is mainly used for heavy structural work especially wharf piles and wherever durability is required. It also makes excellent flooring. Turpentine is a reddish-brown in colour.

Density: A.D. 52, Green 75	* Shrinkage: Radial	.	.	.		7·0 (3·5)
Strength Group: B.	Tangential	..		..		14·5 (7·0)
	Durability Class	..	..	. .	..	1

WALNUT, PACIFIC

Pacific walnut also known as island walnut *(Mangifera salomonensis)* grows in the Solomon Islands and only in recent years has it been exported to Australia in any quantity. This timber varies from cream in colour, to dark streaky brown. It is suscept-

* Bull. 3, D.W.T., N.S.W. Forestry Commission.

ible to lyctus in the sapwood. Its main uses are for mouldings, furniture and cabinet work, joinery and veneer manufacture. Works well and gives a lustrous finish.

Density: A.D. 33   Shrinkage: Radial   ..   ..   .. 1 - 6
                                         Tangential   3-3
                                   Durability Class   4

WALNUT, NEW GUINEA

New Guinea walnut *(Dracontomelium mangiferum)* is one of the most widely sought timbers of the Territory but is in limited supply. It makes excellent veneer, particularly when sliced. It is also used for high class cabinet work. The sapwood is wide and pale and subject to lyctus attack, the heartwood varying from pale to almost black in colour. The timber works well and can be finished with an excellent lustre. It is also known as laup in New Britain and damoui in Papua.

Density: A.D. 35   Shrinkage: Radial 2-1
                                           Tangential   4-6
                                   Durability Class   3-4

WALNUT, BROWN

Brown walnut *(Beilschmiedia sp.)* is a good working, light brown cabinet timber of the laurel family *(Lauraceae)* which is very well represented in North Queensland rain forests. It has medium weight and strength and is well suited to use in interior flooring, joinery, mouldings, house framing, furniture and plywood. Immunisation of all sapwood is necessary to prevent lyctus attack.

Density: A.D. 46   Durability Class   .. 4

WALNUT, QUEENSLAND

This tree grows in a restricted region on the coastal tablelands of north Queensland, its standard trade reference name being *Endiandra palmerstoni.* Other common names are walnut bean and Australian walnut. In the United States it is referred to as orientalwood. The figure and generally attractive appearance of Queensland walnut has made it most popular throughout the veneer markets of the world. The timber (which is not a true walnut) is basically brown in colour, relieved by variations of black, grey, chocolate and even pink shades and streaks. Quarter sawn faces yield a regular striped figure. The timber takes high polish. It is essentially a decorative timber and is widely used in both veneer and solid form for all types of high class furniture, interior fixings and panelling. Walnut, due to a silica content, has an abrasive effect on woodworking tools.

Density: A.D. 42-5   Shrinkage: Radial 2-5
                                          Tangential   5-0
                                   Durability Class   3-4

WALNUT, YELLOW

Known as canary ash in Queensland, yellow walnut *{Beilschmiedia bancroftii)* is solely confined to areas surrounding the Atherton Tableland. The sapwood is very wide and susceptible to the lyctus borer, and is immunised with preservatives for sale. Due to its blunting effect on knives and cutters, yellow walnut has been mainly utilised by the plywood and veneer industries. It is popular for panels of sliced veneer, giving a similar finish to silver ash.

Density: A.D. 36   Shrinkage: Radial 2-0
                                           Tangential   4-0
                                   Durability Class   4

WILLOW

There are over 200 species of willow *(Salix)* distributed throughout the world some of which grow in Australia. The timber of the various species is similar in appearance and properties. It is usually white to pinkish in colour, being soft, straight-grained and of fine texture. Uses are cricket bats, artificial limbs, brake blocks, toys, clogs, charcoal and flooring.

Density: A.D. 28

YELLOW-WOOD

Yellow-wood *(Flindersia xanthoxyla)* is found between the Richmond River in northern New South Wales and Gympie in southern Queensland. In New South Wales it is also known as long jack. Yellow-wood is medium yellow-brown in colour, fine textured, straight or interlocked grain and moderately heavy, hard and strong. It is an excellent timber for carriage framing, shipbuilding, flooring, baseball bats, handles, spokes, felloes, shafts and for other industrially turned products.

Density: A.D. 46	Shrinkage: Radial	3-5
	Tangential	6-0
	Durability Class	2-3

Group 111: Pored Timbers—Hardwoods (Eucalypts)

ASH, ALPINE

Known as woolly butt or red mountain ash, as white-top stringybark and gum-top stringybark, alpine ash *(Eucalyptus delegatensis)* is found in the south eastern section of Australia and Tasmania—in south eastern New South Wales, the highlands of Victoria and Tasmania. In overseas markets, it is one of the species commonly referred to as Tasmanian oak, Victorian oak or Australian oak. Of pale brown colour, the timber is open in texture, fairly straight-grained and with prominent growth rings. The sapwood is lyctus susceptible. During drying the timber can warp and check badly and it is thus recommended that reconditioning should be carried out. It is an excellent timber suitable for many purposes including joinery, flooring, mouldings, weatherboards, furniture and general construction. It has also been satisfactorily veneered and pulped for manufacture into paper. A fairly good bending timber.

Density: Green 65, A.D. 39	Shrinkage: Radial	4-5 (3-5)
Strength Group: C.	Tangential	8-0 (6-5)
	Durability Class	4

ASH, MOUNTAIN

Mountain ash *(Eucalyptus regnans)* is also known as white ash, swamp gum, Tasmanian oak and Australian oak. This species occurs in eastern Victoria and Tasmania, and is recognised as the tallest hardwood tree in the world. The timber is light to pale brown in colour with prominent growth rings, of open texture, straight grain and easily worked. The sapwood is rarely attacked by the lyctus borer. The timber generally needs reconditioning during seasoning because of excessive collapse. Like alpine ash it is a timber suitable for many uses particularly flooring, linings, weatherboards, joinery, furniture, cabinet work, cooperage, veneers and for general construction. From it is also manufactured wood wool, mechanical pulp, match splints, and case shooks. It is a good bending timber.

Density: Green 65, A.D. 44	Shrinkage: Radial	7-0 (4-0)
Strength Group: C.	Tangential	14-0 (7-5)
	Durability Class	4

ASH, SILVERTOP

Silvertop ash *(Eucalyptus sieberi)* is also known in the trade as coast ash, black ash, mountain ash and, in Tasmania, as ironbark. The tree occurs in southern New South Wales, Victoria and Tasmania. Gum veins are common in the timber which is of a brown-pinkish colour, the grain is frequently interlocked and growth rings are discernible. It is not a durable timber in the ground and is generally used in building construction, vehicle construction and for flooring, furniture, handles and chemical pulp.

Density: Green 75, A.D. 53	Shrinkage: Radial	5-0
Strength Group: B.	Tangential	12-0
	Durability Class	4

BROWNBARREL

The standard trade common name for *Eucalyptus fastigata* is brownbarrel, other names are cut-tail, black mountain ash, silver or whitetop woollybutt. The timber is moderately

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hard, straight-grained, of open texture, and very pale brown in colour. Its main uses are in building construction, flooring and case manufacture.

Density   A.D.   48   * Shrinkage: Radial a-0
                                              Tangential_ifj-0

Blackbutt *(Eucalyptus pilularis)* grows extensively along the east coast of Australia from northern Victoria through New South Wales to Fraser Island, Queensland. The timber is brown in colour of open texture, straight grain and with gum veins a constant characteristic. It is hard, strong and readily worked with hand or machine tool. Blackbutt is used for all types of construction work, including bearers, joists, plates, studs, rafters and battens, as well as for flooring, weatherboards, bridge planking and sleepers.

Density: Green, 70. A.D. 55   Shrinkage: Radial 4-0
Strength Group: B.   Tangential 7-0
                                     Durability Class 2-3

BLACKBUTT, WESTERN AUSTRALIA

The Westerrn Australian blackbutt *(Eucalyptus patens)* is found throughout the jarrah and k,nri t'nirstN of that State. It is heavy, hard and durable finding particular use in constructional work, wagon building, sleepers, joinery, and interior fittings. The sapwood is very suscepptible to lyctus.

UniMtv. Green 70, A.I). 34   Shrinkage: Radial 3-5
Sirriitfth Oiotip: B.   Tangential 6-9
                                   Durability Class 3

BLOODWOOD, RED

Found in New South Wales and Queensland, red bloodwood *(Eucalyptus gummifera* and *E.intermedia)* or bloodwood is known as such because of the red kino deposits which are frequently found immediately under the bark of the tree. The timber is very coarse, dark red in colour, conspicuous because of the number of concentric gum veins present, and is most durable. It is used for house stumps, posts, sills, piles and sleepers.

Density: Green 70, A.D. 55   Shrinkage: Radial 3-0
Strength Group: B.   Tangential 6.0
                                   Durability Class 1

BOX, COAST GREY

Coast grey box *(Eucalyptus bosistoana)* is confined to eastern Victoria and New South Wales in its distribution. The timber is light brown in colour of uniform texture and interlocked grain. It is used primarily for heavy constructional work, for piles, poles and sleepers.

Density: Green 80, A.D. 69   Shrinkage: Radial 4-0
Strength Group: A.   Tangential 8-0
                                   Durability Class. 1

BOX, GREY

Grey box *(Eucalyptus microcarpa* and *moluccana)* is well known as gumtop box because of its typical "box" lower bole bark with smooth upper bole and limbs. It is distributed in coastal areas and for some hundreds of miles into the interior of Queensland, New South Wales and Victoria where it prefers the heavy clay soils of the so-called "box" flats. The pale coloured timber resembles white mahogany but is heavier and much harder to work. It has similar properties and uses to the ironbarks in building and engineering.

Density: Green 80, A.D. 70   Shrinkage: Radial 4-0
Strength Group: A.   Tangential 8.0
                         Durability   Class 1

BOX, RED

The red box *(Eucalyptus polyanthemos)* is generally a small tree and is widespread

* Bull. 3, D.W.T., N.S.W. gives Radial—5-8; Tangential—9-4.

over Victoria and New South Wales. Of red colour, the timber has an interlocked grain, is very tough, strong and durable in the ground. It is essentially a heavy constructional timber, being used in buildings, bridges, poles and sleepers.

Density: Green 75, A.D. 64   Shrinkage: Radial .. .. 3 - 5
Strength Group: B.   Tangential 6-0
     Durability Class 2

BOX, YELLOW

Yellow box *(Eucalyptus melliodora)* is found widely distributed throughout Victoria, western New South Wales and southern Queensland. It is a dense timber, yellowish-brown in colour, of uniform texture and hard and difficult to work. Yellow box, because of its durability and strength, is used for sleepers, poles, cross-arms and bridging.

Density: Green 80, A.D. 64   Shrinkage: Radial 3-0
Strength Group: B.   Tangential 60
     Durability Class 2

CADAGA

Growing in jungle areas in north Queensland, cadaga *(Eucalyptus torelliana)* is the only one of this genus in Queensland to survive in tropical jungle conditions. The timber is not durable in the ground, although it has strength and toughness. Its main uses are in the Cairns-Atherton districts where it has a high reputation as structural hardwood, principally for domestic buildings and bridge decking. Its colour is light to chocolate brown.

Density: A.D. 57   Durability Class 2-3

GUM, SOUTHERN BLUE

Chiefly found in Tasmania, southern blue gum *(Eucalyptus globulus)* is also known as blue gum or Tasmanian blue gum. The timber is open-textured, light-brown in colour with the sapwood susceptible to lyctus borer attack. It is difficult to season and sometimes suffers from collapse. Southern blue gum is used widely in heavy and light constructions, wagon building and, because of its strength and good bending properties, is sought after for spokes, felloes, shafts, etc.

Density: Green 75, A.D. 56   Shrinkage: Radial . . . . 5 0 (3 - 9)
Strength Group: B.   Tangential .. .. 11-0(6-5)
     Durability Class 3

GUM, SYDNEY BLUE

An important timber tree in New South Wales and southern Queensland, Sydney blue gum *(Eucalyptus saligna)* has also been successfully planted in South Africa where it is known as saligna gum. The timber is light red in colour although it can vary to a much darker or lighter hue. The grain is usually straight, of rather coarse texture. The timber is fairly resistant to decay. Sydney blue gum is a general construction timber being used for flooring, weatherboards, sleepers and case manufacture.

Density: Green 70, A.D. 52   Shrinkage: Radial 5-3 (3-7)
Strength Group: B.   Tangential .. .. 9-6(5-8)
     Durability Class 3

GUM, FOREST RED

Forest red gum *(Eucalyptus tereticornis)* occurs in New South Wales, Victoria and Queensland. In the latter State, it is sometimes referred to as blue gum. Hard and heavy, the timber is dark red in colour, of uniform texture, the sapwood being susceptible to lyctus. The timber is durable and has been used for poles, paving blocks, posts, for flooring and sills. Because of its even texture and density it has been used for many years with great success for bearings in windmills. Long lengths are not readily obtained.

Density: Green 75, A.D. 61   * Shrinkage: Radial . . . . 5-0(3-5)
Strength Group: B.   Tangential .. 8-0(5-5)
     Durability Class 2

* Bull. 3, D.W.T., N.S.W. gives Radial—2-8; Tangential—5 • 6.

GUM, LEMON SCENTED

Lemon scented gum *(Eucalyptus citriodora)* was included under the standard trade common name "spotted gum" in Technical Standard No. 0-2—1940 of the Standards Association of Australia because of the similarity of *Eucalyptus maculata* and *E. citriodora* both in the outward appearance of the tree and their timber qualities. However, in view of the completely different essential oil yielded by the leaves of *E. citriodora* which contain a high percentage of citronella, it is now named separately. In its natural state it is confined to Queensland, extending westward over the Dividing Range and northward from near the 25° south latitude, just north of Maryborough, to the Herberton Range west of Cairns. A little spotted gum *(E. maculata)* mixes with it on its southern border and then stretches through southern Queensland to the south coast of New South Wales.

For general constructional purposes the timber of lemon-scented gum can be accepted as at least equal to the best spotted gum in quality. It is in fact higher in average density, rarely falling below 63 lb/cu. ft. in mature air dry timber and is probably a little more decay resistant. The timber generally is darker in colour than the spotted gum from southern localities, the paler and lighter timber of which is better suited for use in flexible tool handles.

Density: Green 75, A.D. 63   Durability Class 2
Strength Group: Mostly A.

GUM, MANNA

Manna gum *(Eucalyptus viminalis)* is found growing throughout the eastern States of Australia. It is not very strong, nor durable, the timber being pale yellow to pinkish-white in colour. It is used for general house construction, flooring, joinery, carriage building, tool handles and case manufacture. Sapwood is susceptible to lyctus attack.

Density: Green 75, A.D. 48   Shrinkage: Radial . . . 5-2(3-2)
Strength Group: C.   Tangential .. 12-2(6-9)
     Durability Class 4

GUM, MOUNTAIN (GREY)

Mountain (grey) gum is the standard trade common name of the timber of *Eucalyptus cypellocarpa* which is also known as mountain gum. Its distribution is restricted to the eastern coast of New South Wales and Victoria. Of pale yellow to brown in colour, the timber is hard, heavy, strong and durable with a close straight grain. Its uses are for beams, girders, bridges, house frames and flooring.

Density: Green 72, A.D. 54   Shrinkage: Radial 5-0
Strength Group: C.   Tangential 11-0
     Durability Class 3

GUM, RIVER RED

Found principally along river banks, river red gum *(Eucalyptus camaldulensis)* has reached its best development along the Murray River in New South Wales and Victoria. It is also widely distributed throughout South Australia and Queensland. Other common names are red gum, river gum and Murray red gum. The grain of river red gum is interlocked and close-textured with frequent pockets of gum, which reduce its breaking strength below that expected for its density. It is a most durable timber in the ground and because of its hardness is in special demand for sawn house piers.

Density: Green 70, A.D. 56   Shrinkage: Radial . . . . 4-0(2-5)
Strength Group: D & B.   Tangential .. .. 8-5(4-5)
     Durability Class 2

GUM, ROSE

Also known as flooded gum, rose gum *(Eucalyptus grandis)* occurs as a large forest tree in the north coast districts of New South Wales and Queensland. The sapwood which is light coloured is susceptible to lyctus, the heartwood of dark red resembles

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Sydney blue gum. Rose gum is utilised for general building construction, weatherboards, flooring and case manufacture.

Density: A.D. 42	* Shrinkage: Radial	. . 4 - 1
	Tangential	. . 6. 7
	Durability Class	, . 3.4

GUM, SPOTTED

Spotted gum *{Eucalyptus maculata)* is an important hardwood growing principally on the south coast of New South Wales, as well as in smaller stands on the north coast and in Queensland. The sapwood of spotted gum is very susceptible to lyctus borer. The grain of the timber can vary from straight, interlocked or wavy, being of open texture and coarse. It is used for heavy constructional work where shock resistance is desirable, for domestic buildings, weatherboards, flooring, for axe handles, vehicle bodies, planking, frames for boat building, sleepers and cases. It is a good bending timber.

Density: Green 75, A.D. 61	Shrinkage: Radial	. . 4 - 5
Strength Group: A & B.	Tangential	. . 7 - 0
	Durability Class	. . 2 - 3

IRONBARK, GREY

One of our prime hardboards, grey ironbark *(Eucalyptus paniculata* and *E. drepanophylla)* grows from the east coast of New South Wales to the Atherton Tableland in north Queensland as well as on Fraser Island. The timber of grey ironbark varies from very pale chocolate to darker shades including reddish-brown in colour and is commonly interlocked in the grain. It is hard to work, strong, tough and very durable in the ground. It is used for all types of heavy constructional work, in particular for poles, piles, wharf and bridge girders and deckings.

Density: Green 80, A.D. 69	Shrinkage: Radial	. . 4 - 0
Strength Group: A.	Tangential	. . 7 - 0
	Durability Class	. . 1

IRONBARK, RED

Red ironbark has been used to describe generally three species, which have been given the standard trade names of broad-leaved red ironbark *(E. fibrosa spp. fibrosa.)* narrowleaved red ironbark *(E. crebra)* and red ironbark *(E. sideroxylon).* The timbers are all alike and the following description is applicable to all three. They occur in Victoria, Queensland and New South Wales and are all characterised by the thick, hard corrugated bark which gives them their name. The timber is dark red in colour with a pale sapwood. Due to their immense strength and durability they are keenly sought after for piles, poles, sleepers, cross-arms and girders for wharf and bridge construction.

Density: Green 80, A.D. 67	Shrinkage: Radial	. . 4 - 5
Strength Group: A.	Tangential	. . 7 - 0
	Durability Class	. . 1

JARRAH

For many years jarrah *(Eucalyptus marginata)* has been the most abundantly produced hardwood in Australia, the annual cut being over 100,000,000 super feet sawn. The tree occurs in the south-west corner of Western Australia, this being its only location in the Commonwealth. Jarrah is reddish-brown in colour, the sapwood being pale and narrow and rarely attacked by lyctus. It is hard and heavy and works reasonably well. In Western Australia it has been used as a utility timber, for piles, poles, decking, wharves, bridges, sleepers, as sawn scantling for domestic construction, flooring, weatherboards, road paving blocks, doors, windows, furniture, furniture veneer and shingles. Large quantities have been sent to the United Kingdom, the Union of South Africa, and India (sleepers).

Density: Green 73, A.D. 54	Shrinkage: Radial	. . 5 - 5
Strength Group: C.	Tangential	. . 8 - 0
	Durability Class	. . 2

* Bull. 3, D.W.T., N.S.W. Forestry Commission.

KAMARERE

Occurring in dense patches along the rivers of New Britain and the Philippine Islands, kamarere *(Eucalyptus deglupta)* reaches a very large size frequently topping 200 feet in height, with a diameter of six feet. The timber is red-brown with a marked ribbon figure, similar in appearance to karri. Uses include building frame, boat planking, weatherboards and interior finish.

Density: A.D. 40   Durability Class.   3-4

KARRI

Another tree solely indigenous to Western Australia, karri *(Eucalyptus diversicolor)* is also restricted in distribution to the south-west corner of that State. Karri is reddish-brown in colour, hard, heavy and tough and fairly difficult to work, although when polished it finishes with an excellent appearance. Wharf and bridge contractors have used much of this timber because of its great strength and availability in large sizes and long lengths. Other uses are for concrete formwork, wagons, carriage construction, ship building, cross-arms and general house construction, including flooring, interior trim, furniture and of recent years plywood panelling and structural plywood. It is not susceptible to lyctus.

Density: Green 73, A.D. 56   Shrinkage: Radial.   5-0
Strength Group: B.   Tangential.   .   .   .   10-0
                              Durability Class   3

MAHOGANY, RED

Occurring in the coastal forests of eastern Australia from Sydney, New South Wales, to Maryborough, Fraser Island and the Cairns district in north Queensland, red mahogany *(Eucalyptus resinifera* and *E. pellita)* is also known in Queensland as red stringybark and red messmate. Of dark red colour and interlocked grain, it is a heavy timber, resistant to decay and fungi. It is easily seasoned and it is fairly readily worked with hand or machine tools. Structurally, red mahogany is particularly valuable. It is used for flooring and weatherboards, as well as for house framing and heavier construction. It is also used in railway wagons, and shipbuilding and for railway sleepers.

Density: Green 72, A.D. 59   Shrinkage: Radial.   3-6
Strength Group: B.   Tangential   5-6
                              Durability Class.   2-3

MAHOGANY, SOUTHERN

Southern mahogany *(Eucalyptus botryoides)* is also known as bangalay, Gippsland mahogany and mahogany. It occurs in the south-eastern coastal areas of Australia reaching its best development in southern New South Wales and Gippsland, Victoria. Of excellent durability, the timber is very hard, reddish-brown in colour with an interlocked grain of coarse texture. Used primarily for sleepers, it also finds considerable use in general building constructions.

Density: Green 75, A.D. 57   Shrinkage: Radial.   4-5
Strength Group: B.   Tangential.   .   .   .   9-0
                              Durability Class   2

MAHOGANY, WHITE

Known in Queensland as yellow stringybark, white mahogany *(Eucalyptus acmenioides, E. umbra spp. umbra, E. umbra spp. carnea)* grows extensively on the east coast of Australia from Sydney in the south to Atherton in the north. A structural timber of the highest quality, white mahogany is yellowish to brown in colour, of interlocked grain and is heavy, hard and tough. It is not susceptible to lyctus attack. It is also used for sleepers, cross-arms, wagon and carriage work and telegraph poles, bridge work and exposed flooring.

Density: Green 80, A.D. 59   Shrinkage: Radial.   3-0
Strength Group: B.   Tangential.   .   .   .   5-5
                              Durability Class   1

MALLET, BROWN

Indigenous to the south west of Western Australia, brown mallet *(Eucalyptus astringens)* is of considerable importance as its bark is a rich source of tannin. The timber is light reddish-brown in colour and has been used with success for the manufacture of handles. It is a very tough timber being superior to American ash, karri or spotted gum, ranking slightly less in this respect to American hickory. It is not susceptible to lyctus.

Density: Green 70, A.D. 63   Shrinkage: Radial 4-5
Strength Group: B.   Tangential   7-0
                           Durability Class . . . . . . 2 & 3

MARRI

Known also as red gum in Western Australia, marri *(Eucalyptus calophylla)* is its standard trade common name. Occurring in the jarrah belt the tree yields a light coloured strong timber which is easily worked, although marked by the presence of many gum veins which exude quantities of gum or kino. It is used where strength and elasticity are required, particularly in shafts for carts, whims and axe and tool handles. The sapwood is very susceptible to lyctus.

Density: Green 72, A.D. 56   Shrinkage: Radial 3-7
                           Tangential   6-6
                           Durability Class   3

MESSMATE, GYMPIE

Gympie messmate *(Eucalyptus cloeziana)* is the standard trade common name for yellow messmate and the dead finish of the Cairns District tablelands. The tree grows in commercial quantities in the Gympie district of Queensland as well as in other areas of the central coastal belt of that State. Of pale yellowish appearance with a uniform grain, the timber works remarkably well under the saw and axe and is used primarily for general building purposes as well as for sleepers, transoms, walings, bridge construction and fencing.

Density: A.D. 62   Durability Class 1
Strength Group: A-B.

STRINGYBARK, MESSMATE

One of the most important structural timbers in south-eastern Australia, messmate stringybark *(Eucalyptus obliqua)* is one of those timbers which are referred to as Tasmanian oak and in itself is commonly called messmate, stringybark and brown-top stringybark. Its widest distribution is in Tasmania and Victoria, smaller quantities growing in New South Wales and South Australia. It is pale brown in colour of open texture with well-defined growth rings. The sapwood is susceptible to lyctus attack and during seasoning reconditioning is a necessity. Messmate stringybark is widely used in home building, framing, weatherboards, flooring, interior work, furniture, joinery and for posts, piles, wharf construction, railway sleepers, staves, case shooks and wood wool manufacture.

Density: Green 70, A.D. 48   * Shrinkage: Radial 5-5 (3-5)
Strength Group: C.   Tangential 11-5 (5-7)
                           Durability Class 3

STRINGYBARK, RED

Also known as mountain stringybark, red stringybark *(Eucalyptus macrorrhyncha)* is widely distributed throughout the eastern States, occurring chiefly in Victoria and New South Wales. The timber which is pale red and fairly close-textured is not highly valued although in coastal areas it is superior to that which grows further inland. Its main uses include poles, weatherboards, framing, wheelwright's work and fencing. The sapwood is susceptible to the lyctus borer.

Density: A.D. 56   t Shrinkage: Radial 5-3

    * Bull. 3, D.W.T., N.S.W. gives Radial—5-5; Tangential—6-8.
    t Bull. 3, D.W.T., N.S.W. Forestry Commission.

STRINGYBARK, WHITE

The standard trade reference names for white stringybark are *Eucalyptus eugenioides,* *E. phaeotricha* and *E. globoidea;* in Queensland it is also called pink blackbutt. Found principally in New South Wales and parts of Queensland and Victoria, white stringy-bark is brown to pale pink in colour, of straight grain, hard, strong and tough. It is mainly a heavy structural timber, its chief uses being for poles, sleepers, cross-arms and general construction. A good bending timber.

Density: Green 70, A.D. 52   Shrinkage: Radial   .   .   .   .   5-5(3-0)
Strength Group: B.   Tangential   ..   ..   10-0(5-0)
                                  Durability Class .   .   .   .   .   2 & 3

TALLOWWOOD

Tallowwood *{Eucalyptus microcorys)* does not grow in commercial quantities below the Hawkesbury River in New South Wales and extends through the coastal forests north as far as Maryborough in Queensland and Fraser Island. This timber, of a greasy nature, is one of the most popular flooring timbers and, because of this quality, is world renowned. Of light to yellowish-brown in colour, it is very hard, strong and tough, being of excellent durability and moderately easy to work and finish. The sapwood is susceptible to the lyctus borer. In addition to flooring it is also used in home building for sills, weatherboards, exterior flooring, framing, stumps, roller-skating rinks, and for poles, cross-arms, sleepers, bridges and carriage work.

Density: Green 75, A.D. 62   Shrinkage: Radial   4-5
Strength Group: A-B.   Tangential   6-5
                                    Durability Class   1

TUART

Available only in limited quantities tuart (*Eucalyptus gomphocephala)* is restricted in its habitat to a small coastal area near Perth in Western Australia. The timber is light yellow in colour, very tough, strong and has an interlocked grain. The railways are its main user, particularly for heavy carriage work. Also used for boat knees (natural bend) and steamed boat frames. Sapwood is susceptible to lyctus.

Density: Green 78, A.D. 64   Shrinkage: Radial   4-0
Strength Group: A.   Tangential   .   .   .   7-0
                                    Durability Class   1

WANDOO

Found solely in Western Australia in conjunction with the jarrah forests, wandoo *{Eucalyptus redunca)* is a timber of exceptional strength and durability. It is light to reddish-brown in colour, close-textured with an interlocked grain. Principally used for sleepers, poles, bridge, wharf and carriage work, it is also sought after by wheelwrights. The sapwood is not susceptible to lyctus. The whole tree is also the raw material for a substantial tannin industry, the bark sometimes containing as much as 20 per cent and the timber up to 11 per cent of tannin.

Density: Green 80, A.D. 68-5   Shrinkage: Radial   2-5
Strength Group: A.   Tangential   3-5
                                    Durability Class   1

YERTCHUK

Commonly referred to as New South Wales messmate or yellow messmate in Victoria, yertchuk *{Eucalyptus consideniana)* is one of the ash group of eucalypts and has similar properties to that of *Eucalyptus regnans.* Of light brown colour, open texture and interlocked grain, the timber has been found suitable for general construction, flooring, sleepers and firewood. It occurs in the central coastal ranges of New South Wales and in eastern Queensland.

Density: A.D. 58-5   Shrinkage: Radial   6-5
Strength Group: B.   Tangential   .   .   .   9-0
                                    Durability Class   2

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Part Two

WOOD TECHNOLOGY, TIMBER TREATMENTS AND OTHER SPECIAL CONSIDERATIONS

XIV

THE GROWTH AND
STRUCTURE OF TIMBER

To understand the properties of timber,* it is necessary to be familiar with its structure which is altogether different from that of any other material of construction. Under a magnifying glass a piece of iron, for example, appears to be practically homogeneous. On the other hand, a piece of timber appears as a network with openings of various shapes and sizes. Fig. 16 shows the general appearance of the end grain of a piece of timber. The various openings visible in this photograph are the cavities of the different types of cells which are formed during the growth of the tree. Each type of cell has its own particular function in the growing tree. Before trying to understand the details of this structure, it will be helpful to consider the various parts of a tree and the way in which it grows.

Fig. 17 illustrates a portion of a cross-cut end of a log. In the centre is the pith, and around it in order, lie the truewood, the sapwood and the bark. The sapwood and the truewood are divided into what are commonly known as growth rings,† Between the sapwood and the bark, there is a very thin layer—not visible in the illustration—called the cambium layer. What is the significance of these various layers and how do they come into existence?

THE GROWTH OF THE TREE

Growth in Height

The increase in the height of any seedling or tree, or in the length of a branch, is due to the division and growth of numerous special cells at the extreme tip. The subsequent elongation of the growing tip is the only length-

* See D.F.P. *Trade Circular,* no. 3.

† To overcome the confusion between the terms heartwood and "heart" which latter, in Australia, is commonly applied to the central and frequently more or less decayed portion of the tree, the term truewood has been adopted to describe that sound portion of the tree between the sapwood and the heart. This term is especially applicable since, while the heart of many Australian trees is useless, the truewood provides the bulk (and in many cases all) of the usable timber.

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wise growth that occurs in the tree, and the cells which give rise to this growth are thin-walled and do not, in themselves, produce woody tissue. When the tree is young vertical growth is rapid but as it matures the growth slows down appreciably. A short way back from the growing tip some of the cells formed
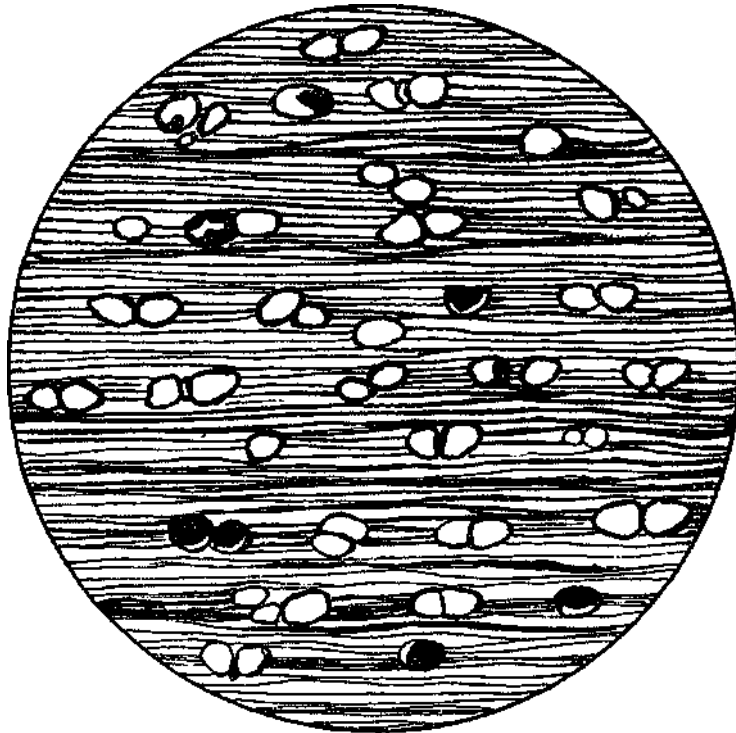
Figure 16. Appearance of end grain of hardwood.

Figure 17. End section of a log, showing pith, truewood, sapwood and bark.

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undergo definite changes. Some of them, those on the outside, go to form the important cambium layer which is discussed more fully below.

Growth in Girth

As the young tree grows in height, there is a corresponding growth in girth, which is the result of the division and growth of the cells of the cambium layer. This very fine layer is composed of soft thin-walled cells which lie just beneath the bark and which extend all around the stem from the roots to within a short distance of the growing tip. By division they give rise, on the outside, to cells forming the inner living portion of the bark, and on the inside, to much thicker-walled cells which form the woody cylinder of the tree—the first wood cells so produced surround the soft primary cells of the pith. As time goes on, the stem gradually increases in thickness by the addition of new wood cells on the outside of those already formed. This is well illustrated in Fig. 18, which shows the pith, the wood cells formed during four years' growth, the position of the cambium layer and the bark. The cambium layer thus functions in the laying down of both the wood and the bark on the stem and branches of the tree.

The main thing to note is that growth in height occurs only at the growing tip by the division and growth of the special cells located there, while growth in girth is the special function of the cambium layer; the wood of the tree is formed by division and growth of the cells of this layer. Neither the wood cells nor the bark cells of the cambium layer influence growth in height. Wood or bark produced at any particular height above ground remains always
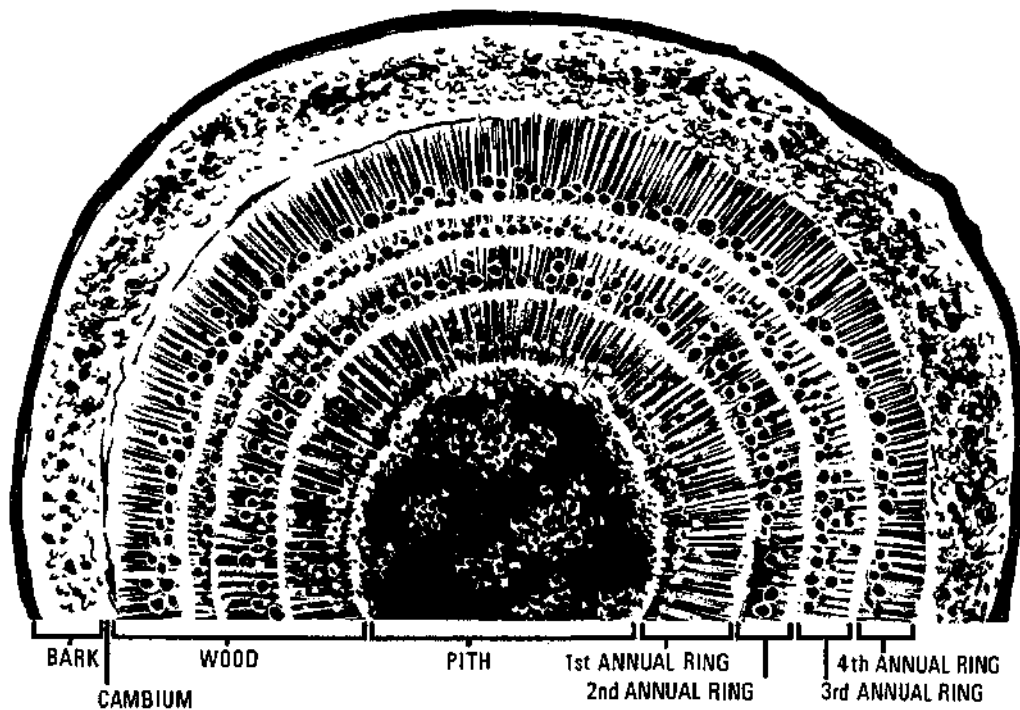
Figure 18. Portion of a section across four-year-old English ash.

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at that height. This can be readily demonstrated by driving a large nail or spike into the trunk of a young tree at a definite height above ground. As the tree grows both in height and girth it will be found that the nail or spike remains at a constant height above the ground, although it will become gradually embedded in the trunk as the new wood cells are laid down around it.

Sources of Food

The wood cells by the cambium layer are of different types. When first formed, they are living cells and certain of them serve for the conduction of water (containing some mineral salts) from the roots to the leaves. In the leaves, the green colouring matter, in the presence of sunlight, converts certain constituents of the air into sugars, starch and so on, which are suitable food for the growing cells of the tree.* The solutions which rise through the sap-wood to the leaves are enriched there by the food material and then pass down the inner layers of bark cells, thus providing the growing cambium cells with materials for the formation of new wood and bark. Some of the food material on its way down also reaches the living wood cells just inside the cambium layer by means of special cells called medullary ray or ray cells. These are produced for this purpose and for food storage. They will be considered later in detail.

Thus, there is a distinct upward movement of water in the living wood cells just beneath the cambium layer to the leaves; and a downward movement of food materials in solution, through the inner bark cells, to the roots—the food materials being used to supply the cells of the cambium layer. If the cambium layer is damaged, for example, by cutting through bark right around the stem at any height, the supply of materials from leaves to roots is interrupted and the tree will gradually die. This is what happens when a tree is "ringbarked".

Growth Rings

The growth in girth of a tree is not usually regular throughout the year, but varies with the seasons. In cold climates, there is a complete cessation of growth during the autumn and winter. At the beginning of spring, growth is at a maximum and the wood produced is light in weight. Towards the end of spring and throughout the summer, the rate of growth diminishes until it almost or quite ceases in the winter. This means that, following the light, quickly grown spring wood with large open cells, the tree produces denser wood, consisting of thicker-walled cells. Repetition of this process year after year leads to the formation of definite yearly rings of growth, known in countries with a cold climate as annual rings. Each annual ring starts with the less dense spring wood, and ends with the denser summer wood (see photos 19 and 20).

In the more temperate climate of Australia, although similar growth rings may be produced, they do not always mark years of growth but simply

* For the chemical constituents of wood, see D.F.P. *Trade Circular* no. 28,

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climatic changes. Such rings should not, then, be referred to as annual rings, but as growth rings; and, if they are not true annual rings, the terms "early wood" and "late wood" should be substituted for spring wood and summer wood respectively. Growth rings of the eucalypts, for example, are not as well defined as true annual rings produced by trees grown in colder countries, and are sometimes very difficult to distinguish. In many tropical and sub-tropical trees, growth is more or less regular throughout die year, and no distinct growth rings are produced.

Growth rings are not, properly speaking, rings. They are sheaths or cones of wood, one surrounding the other, with the pith as a central axis.

MICROSCOPIC STRUCTURE

Figs. 19 and 20 illustrate two small blocks of wood highly magnified. It is noticeable that these two pieces differ considerably in their cell structure; they have been chosen as representing two distinct classes into which practically all timbers can be divided. Fig. 19 represents a piece of what is commonly known as "hardwood" or "pored" timber, and Fig. 20 a piece of "softwood" or "non-pored" timber.

The terms hardwood and softwood are misleading. Many timbers falling into the Fig. 19 class are quite soft, and some timbers falling into the Fig. 20 class are comparatively hard.

Wood Containing "Vessels"—"Pored" Timbers

Into this group of timbers fall many of the woods common to timber users. The most important are the eucalypts, blackwood, oaks, maples, walnuts, ashes, beeches, willows, mahoganies, basswood and hickory. Fig. 19 shows a diagrammatic representation of the structure of these woods, the most outstanding feature being the presence of the large tubular wood vessels. Running up the stem of the tree, these wood cells, when newly formed, serve to conduct solutions from the roots to the leaves. Each vessel, in the first place, is made up of cells joined end to end. The cross walls are broken down either completely or partially, to form long tubes each of which may be many yards long. Each such tube is spliced at each end on to a similar one, providing a continuous means of conduction from the roots to the leaves. It will be noticed in Fig. 19 that the vessels frequently occur in groups and that there are openings or pits in their side walls, allowing passage of solutions from one vessel to another or to other types of neighbouring cells. The vessels themselves, although sometimes difficult to distinguish, as in coachwood *(Ceratopetalum apetalum),* are frequently large enough to be seen easily with the naked eye, for example, in the oaks or mountain ash *{Eucalyptus regnans).* They appear then on the cross section of the stem as small holes or pores.

The distribution of the vessels in each growth ring gives rise to a further very useful division of the timbers of this class. In timbers such as the imported oaks and hickory, Australian red cedar *(Toona australis)* and white cedar of Queensland *(Melia azedarach),* the vessels are larger and more concentrated in the early or spring growth. Such timbers are called "ring

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pored" (see photo 20). Practically all Australian pored timbers, however, fall into the second class known as "diffuse pored" because the pores are distributed or diffused more or less evenly throughout the early and the late wood.

Further examination of Fig. 19 shows numerous, small, thick-walled cells with small cavities (see also Fig. 16). These wood fibres, as they are termed,

Diagram of Hardwood
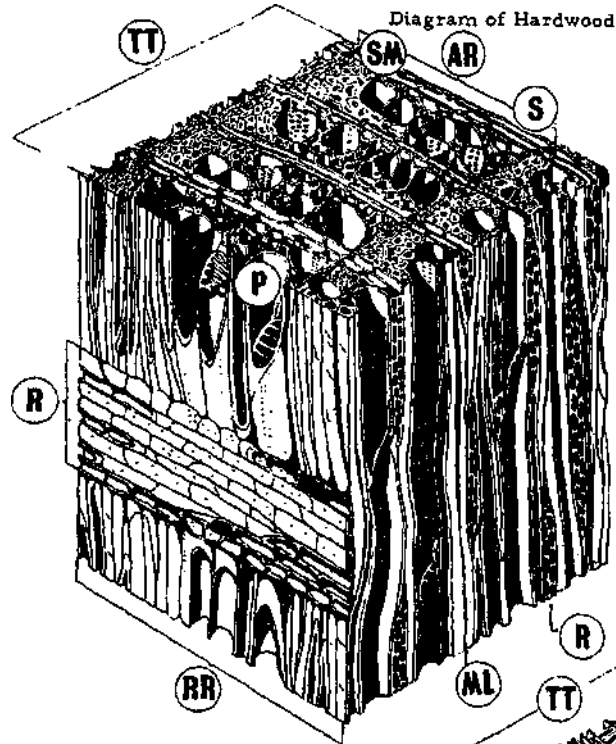
The Structure of Hardwood

This drawing represents the cell structure of 0 block of hardwood about 1-32 inch high. The portion TT corresponds to the top surface of o stump or end surface of a log, and RR corresponds to a surface roughly parallel to the radius of the log. The hardwoods have specialised vessels or pores (P) for conducting sap. The pores vary in size and are visible in some species. Most of the smaller cells are wood fibres which give hardwood its strength. They usually have small cavities and relatively thick walls, containing pits which allow a passage far sap to reach from one cavity to another. The rays (R) are strips of short horizontal cells that extend in a radial direction. They store and distribute food. The annual ring (AR) is usually sharply defined. As a rule the springwood (S) is more porous than the summerwood (SM) formed later in the year.

All the cells In wood. Including pores, fibres, ray cells, etc., ore firmly cemented together by a thin layer of lignin at the middle lamella (ML).

Diagram of Softwood
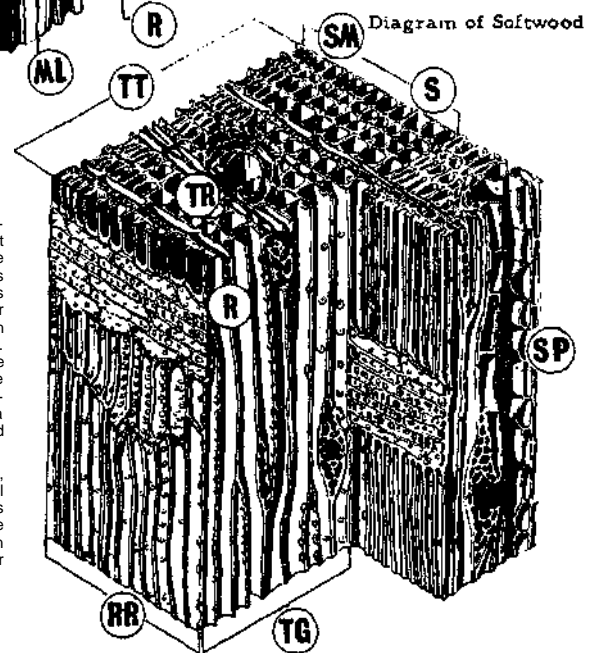
The Structure of Softwood

This drawing represents the cell structure of a minute block of softwood about 1-32 inch high, like the drawing of the hardwood structure. The rectangular units which make up this surface are sections through various cells, mostly tracheids or water carriers, (TR), the walls of which form the bulk of the wood substance. Springwood cells (S) ore distinguishable from the summerwood cells (SM). The springwood growth is more rapid, and Together with the summerwood, make up a year's growth. The rays (R) store and distribute horizontally the food material.

The symbol SP indicates a simple pit, an unthickened portion of the cell wall forming a valve through which the sap is circulated through the tree. The surface TG, at right angles to the quarter sawn surface, corresponds to the flat grain or plain sawn surface of timber.

Figure 19. Pored timber—Hardwood.

Figure 20. Non-pored timber—Softwood.

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are most important from the point of view of strength. Their length is great compared with their diameter, but they are smaller in every way than the vessels which are distributed between them. Like the vessels, the wood fibres have their length parallel to the height of the tree. Their sole function is the support of the tree. It will be noticed that the fibres in the late wood of the growth ring gradually become smaller in diameter and thicker-walled. In timbers such as many of the eucalypts, where the growth rings tend to be indistinct, this feature is not so apparent.

Another feature to notice in Figs. 16 and 19 is the presence of rows of cells whose length is at right angles to the length of the vessels and fibres, that is, they are horizontal in the trees. These are the medullary ray cells. They have comparatively thin walls, are used for the storage of food materials, and retain life somewhat longer than the other cells. Rays, as groups of these cells are termed, vary greatly in size and number, and also in the number and arrangement of the individual cells in the group. They are useful features for distinguishing between certain timbers, and are sometimes visible to the naked eye on a cross section, being more than   of an inch thick in some true oaks, sheoaks and in the silky oaks. The silver grain of these timbers seen on longitudinal radial surfaces is due to these large rays. In eucalypts, on the other hand, the rays are often difficult to see on the cross section even with a hand lens. On a split radial or quartered face, however, they appear as a fine mottling or cross hatching.

Surrounding the vessels, although not evident in Fig. 19, there are frequently patches of "soft tissue" composed of thin-walled cells. This soft tissue often appears as bands which at first glance can sometimes be mistaken for growth rings. In coach wood *(Ceratopetalum apetalum)* and rose mahogany *(Dysoxylon fraseranum),* the bands of soft tissue provide the "figure" (see photo 21); while in the Queensland black bean *(Castanospermum australe)* the large quantity of soft tissue surrounding the vessels makes them a prominent and contrasting feature of the figure in the timber (see photo 22).

Woods-Without "Vessels"—Non-pored Timbers

The common timbers falling into this class include the following: pines, firs, spruces, cypress pine, hemlock, Douglas fir, hoop pine, kauri pine, New Zealand white pine and so on. The outstanding feature of the timber of these species is the simplicity of their structure—see Fig. 20. There are no vessels and no wood fibres, but functioning for both and intermediate in size are cells of a single type, known as tracheids. Like the vessels, the tracheids have communication pits in their walls.

Some timbers in this class appear to have pores irregularly distributed on a cross section (see photo 19), but on microscopic examination these prove to be openings surrounded by a layer of very small cells and are quite distinct from vessels. These openings are known as resin canals and serve only as a means of disposal of resinous materials produced by the tree. Rays are present, but are never conspicuous; they function in the same way as in the woods containing vessels.

In the very young tree all the wood is sapwood. The first wood produced is made up of living cells, and these function largely in conducting water from the roots to the leaves. When the cells are first formed by the cambium layer they consist of thin-walled tubes of cellulose, a substance of which cotton is a pure form. The cells contain living matter, and grow rapidly, the walls becoming thicker and undergoing a change known as lignification, which adds considerably to their strength. Further changes go on over a long period. The living matter in the cells dies; tannins and other substances, some of which are coloured, escape from the dying cells and permeate the wood; and in some cases the cell cavities become blocked by outgrowths from the walls, or by gummy or resinous matter.

Thus, the inner layers of sapwood become converted into the less permeable and usually darker coloured truewood. Although this change is not accompanied by an increase in strength, the materials deposited in the cells help to give resistance to the attacks of fungi and insects. This is why truewood is, as a rule, so much more durable than sapwood.

All the cells in the truewood are dead, they contain water, but do not serve in conducting solutions or water to the leaves. That is to say, the cells towards the inside of the sapwood die, and cease to function in conducting solutions, but new cells produced on the outside of the sapwood take up their work. The old cells then function simply by giving support to the tree. This continues year after year until the woody portion of the tree may consist almost entirely of dead cells which are surrounded by a zone of living wood cells. In some timbers this zone is very narrow but in others it may be quite wide. In certain species it has been found that little, if any, truewood is formed.

Sapwood, owing to the fact that its cells are more permeable, is much more readily penetrated by preservative fluids. Hence, if properly treated it can be rendered as durable, or even more durable than truewood. In such a case, being quite as strong as the truewood, it is really a superior article.

FIGURE, TEXTURE AND GRAIN

When describing the appearance of a particular wood species, the four features commonly quoted are colour, figure, texture and grain.

These features are of considerable importance in the grading and selection of timber, especially for furniture, joinery and similar purposes.

Figure

Figure refers to the pattern produced on longitudinal surfaces of wood resulting from one or a combination of three characteristics: (a) the arrangement and relative dimensions of the tissues, (b) the nature of the grain, and (c) colour variations. The inter-relation of these results in almost infinite variation is figure. It may be enhanced by the plane of cutting. Back-cutting and quarter-cutting give different figuring in timbers showing marked differences in the early and late wood of their growth rings. Veneer manu-

facturers particularly, pay close attention to the direction in which a log or flitch of figured wood is cut, so that the most effective material can be produced. The art of matching for the production of fancy plywoods, decorative panels and flush doors is highly developed, especially in marquetry, and some specialists produce pictures out of wood, taking advantage only of natural figuring.

The manufacturers of some other materials pay wood a compliment by sometimes imitating the figuring of attractive wood specimens.

Texture

Texture refers to the relative size and amount of variation in size of the cells. We use the terms *coarse, fine, even* and *uneven* texture in relation to wood. The differentiation between coarse and fine texture applies to hardwoods and is made on the dimensions of the vessels and the width and abundance of the rays. Timbers in which the vessels are large or the rays broad are said to be coarse texture (for example silky oak), but when the vessels are small and the rays narrow, the timber is said to be of fine texture (for example coachwood). The even and uneven texture may be found in either softwoods or hardwoods. Softwoods such as Douglas fir, where the contrast between the early wood and late wood in the annual ring is very clearly marked, are usually termed *uneven* in texture, as are the ring porous hardwoods like red cedar. Softwoods with little or no contrast between early and late wood in the growth rings (for example hoop pine) or diffuse porous hardwoods (for example sassafras) are said to have even texture. Woods of fine or even texture are generally the easiest to stain and polish and are preferred for manufacturing purposes; coarse or uneven texture may be chosen for some decorative effect.

Grain

Grain and texture should be used to refer to two quite distinct characters of wood but more often than not they are confused in everyday use.

Grain should refer to the direction of the fibres and associated wood elements relative to the axis of the tree or the longitudinal edges of individual pieces of timber, whereas texture, as we have seen above, refers to the relative size and the amount of variation in size of the cells.

The term *grain* is incorrectly used in a number of ways, for example, *edge* or *vertical grain* is used to refer to timber that is cut so that its width is at right angles to the growth rings, that is, parallel with and abundanc of the medullary rays; the term *quarter-cut* is much better and is now widely used in Australia. Similarly, timber cut with its width parallel with the growth rings may be described as *flat-grained,* but should be known as *back-cut*—a term which is also widely used in Australia.

In hardwoods, the terms *coarse* and *fine* grain are frequently applied to characteristics that depend on the size of the elements and therefore, as previously mentioned, are more properly described as texture. In softwoods, the same terms are used to describe the width of the growth rings, the former to wood with broad annual rings, and the latter to wood with narrow annual

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rings. This feature is neither grain nor texture and is better described as fast- or slow-grown.

Timber that breaks with a short brittle fracture is often described as "short in the grain". The description is inept as the failure has nothing to do with the length of the fibres, nor is it connected with their direction in relation to the verticle axis of the tree, but with their brittleness, that is, the readiness with which the fibre walls fracture at right angles to their length. Brittleness may be an inherent property of the species or it may be caused by such factors as fungal decay, brittle heart, exceptionally low density (for the species), compression wood, or even maltreatment in seasoning. The brittle fracture should not be confused with the type of fracture that may occur in cross-grained timber.

Using the restricted meaning of the term the following types of grain may be distinguished:

Straight grain. The fibres or other main elements are practically parallel with the axis of the tree. This type is desirable for structural timbers, bending stock, handles and some other manufactured items.

Sloping grain. Elements are not parallel with the long axis of the piece. Its effect varies with the severity and manner in which the slope occurs. This distinguishes: (a) cross grain, (b) diagonal grain, (c) spiral grain, (d) interlocked grain, and (e) wavy grain.

Sloping grain in its various forms may: (a) reduce strength, (b) increase tendencies to distort in seasoning, (c) accentuate difficulties of machining, and (d) enhance figure.

The detection of sloping grain requires close examination of the direction of the pores and wood elements. The point of a nail scratched firmly along the length of a board will follow the general direction of the fibres. The presence of coarse pores, surface checks, and the effect of wetting with drops of a coloured liquid may be useful indications; the pattern of the growth rings may be misleading.*

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* Further information is given in *Trade Circular* 43, "Figure in Timber", and 48, "Sloping Grain in Timber", both of which may be obtained from the Division of Forest Products, CSIRO P.O. Box 310, South Melbourne.

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XV

THE SEASONING OF TIMBER

WHY TIMBER SHOULD BE SEASONED

Timber is seasoned principally in order to bring it to the condition best suited for its ultimate use. Because seasoning is always accompanied by shrinkage, which is also the cause of any checking or warping which may occur, timber can rarely be used satisfactorily in its green or even partly seasoned state. Because it is a natural organic material, it is a food for, and susceptible to attack by staining or decay fungi and a large variety of wood boring insects.

For use in structural grades, timber is rarely seasoned before use, and the shrinkage must be considered and allowed for in order to minimise its effects. In precise applications, such as flooring, joinery or furniture, timber should be seasoned to the point where only minimum movement can take place, to prevent unsightly cracks or gaps appearing, and certainly to obviate any possible warping or distortion in the finished article.

Although the elimination of shrinkage and its possible resultant effects of cracking and warping are considered to be the principal advantages of seasoning, there are many others. The most important improvements in timber resulting from seasoning are as follows:

1. A reduction to the minimum in shrinkage, checking and warping in the timber.

2. Timber dried and kept below a moisture content of 20 per cent is impervious to fungal attack whether by staining or rotting fungi, because there is insufficient moisture in the wood for them to exist.

3. The number of insects likely to attack the timber is markedly reduced.

4. A considerable reduction in weight, leading to savings in freight and handling costs.

5. An increase of 50 per cent or more in the strength and hardness of timber when dry.

6. Seasoned timber can be treated with paints or other finishes with dependable satisfaction.

7. Timber can be satisfactorily glued with all types of adhesives, giving maximum bond strengths.

8. Dry timber used as a fuel will give twice as much heat as green timber and will ignite more easily.

9. The drier the timber, the greater are its thermal insulation properties, a reason for the popularity of timber clad buildings in cold climates.

10. Seasoning changes timber from a moderately good conductor of electricity into a satisfactory insulator.

From the above it can be easily seen why seasoning is a most important factor in the efficient utilisation of timber.

The Structure of Timber

It is debatable whether a bountiful nature has provided trees to be man's delight in their natural form, or to be a most valuable material for man's use in their converted state. Regardless of this, nature has *designed* timber to be a means of transporting moisture from the ground to the leaves, and as a structural support for the large and heavy crown of leaves and branches that it carries. Because seasoning is concerned with the movement of moisture in timber, and shrinkage is dependent on the fine structure of wood itself, a knowledge of the structure of timber is necessary for a better understanding of seasoning.

In order to permit the passage of water up the tree, wood is composed of very small long and narrow tube-like cells having a hollow centre termed the "cell cavity". The walls, made mainly of cellulose, make up the actual woody material. The cells are tapered at each end in order to interlock together for strength, and the water conduction from one cell to another occurs through small openings in the cell walls called "pits". These cells vary enormously in size and cell wall thickness, thus giving the different timbers their different properties such as strength and figure.

The cellulose in the cell wall is in the form of long threads similar to cotton which is another form of cellulose. The threads are usually laid down with their length nearly parallel to the tree trunk, except around knots or where the wood is cross grained. The cells themselves, glued together with lignin, also have their length mainly parallel to the trunk of the tree to permit the water to travel up the leaves.

This water taken from the ground by the roots contains a mixture of minerals from the soil together with other complex compounds and is called the "sap". The sap travels up the outer woody section of the tree trunk called the "sapwood", which is often lighter in colour than the inner wood or heartwood.

In the leaves, carbon dioxide and water are converted by the action of sunlight into sugars, which in turn are joined together to form starch and are carried down the inside of the bark of the tree. They are finally converted to cellulose and laid down in new cells as the tree trunk increases in diameter.

The food from the leaves is carried from the inner bark into the sapwood through cells which run in a radial direction from the bark to the centre of

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the tree. Because of their direction they are called medullary rays , and these may have some effect on shrinkage as will be mentioned later, because they are at right angles to the majority of cells.

THE PROCESS OF SEASONING

The cell cavities and cell walls in a tree are saturated with water which continually travels up from the roots. Once the tree has been felled and trimmed into a log, this moisture begins to evaporate. Because of the structure of the cells, the water can travel relatively quickly through the ends of the log, but it is much slower to move cross ways through the timber. When the log is sawn into boards, a much greater surface area is exposed, and moisture can then dry from the faces and edges. This is the start of seasoning, and the process and some important definitions will be described below.

Moisture Content

The degree and definition of "seasoning" is related to the quantity of water in the timber. The moisture content is defined as the weight of water in a piece of wood compared to the weight of wood material alone, this usually being expressed as a percentage.

$$\text{i.e. Moisture Content} = \frac{\text{wt. of water}}{\text{wt. of wood substance}} \times 100 \text{ per cent}$$

In the dense Australian hardwoods, the cell walls are quite thick and the cell cavity is fairly small. Hence there is not much room for a large quantity of water, and the wood is fairly heavy. The moisture content of such timbers when freshly fallen lies within the range of 40 to 80 per cent. In softwoods, for example radiata pine, the cell walls are thin and the cavities much larger. There is consequently more water and less wood material in this timber, and its moisture content ranges from 120 to 200 per cent. Thus there can be twice the weight of water in the green timber as there is wood. A very light timber such as balsa may have three to five times the weight of water, i.e. its moisture content is 300 to 500 per cent.

Amongst Australian timbers, very dense hardwoods such as ironbark *(E. crebra)* would have a green moisture content of 40 to 60 per cent; for black-butt *(E. pilularis)* it would range from 60 to 90 per cent; for the ash type eucalypts (e.g. *E. regnans)* 80 to 110 per cent; for rain forest timbers 90 to 120 per cent.

Fibre Saturation Point

The moisture in any cell in timber is considered to be of two forms. The first of these is the water or sap in the cell cavity, which is called "free" moisture, i.e. similar to water in a bottle. The water which saturates the cell wall is called the "bound" moisture. As the cell dries out, the free moisture evaporates first, and eventually a stage is reached when the cell cavity is empty leaving the cell wall still saturated. This is an important stage in seasoning and is called the fibre saturation point. When the free moisture evaporates,

the principal effect is a loss in weight, but as wood dries below the fibre saturation point, the cell wall begins to shrink.

The fibre saturation point for practically all species of wood lies within the range of 25 to 30 per cent moisture content. Note that this term refers only to individual cells and *not* to commercial sizes of sawn timber.

Moisture Gradient

When a log is converted into sawn sections, the saturated interior parts are exposed to the atmosphere. The damp surface of the timber dries, and moisture begins to flow from the inside of the section through to the surface. Because the moisture evaporates faster from the surface than it can travel through the timber, the surface layers have a lower moisture content than layers further in. This difference in moisture content is termed the moisture gradient and is a necessary condition for seasoning. After some period of seasoning there will be a variation in the moisture content from the core or centre of the piece to the case or outer layers, which is the moisture distribution through the section. The moisture gradient would then be the difference between the core moisture content and the case moisture content.

It will be shown later under "Shrinkage" that if this moisture gradient is very steep, then checking may occur, but if it is too small, although degrade is reduced, the rate of drying might be too slow and uneconomical.

Equilibrium Moisture Content

Timber dries essentially because its green moisture content is far too high to be in equilibrium with the moisture content, i.e. the relative humidity, of the air surrounding it. Eventually the timber *will* dry to the stage where it is in equilibrium with the air humidity and no further drying will occur. This is called the equilibrium moisture content (E.M.C.), and at this stage the timber is considered to be perfectly seasoned for that particular location. Unfortunately, this is not the end of the story, because the relative humidity is not constant. It has quite large daily variations, and the *average* relative humidity varies from season to season, and also for different geographical locations. Temperature differences have only a very minor effect on the E.M.C.

Timber is said to be hygroscopic, which means it can pick up or lose moisture with changes in the relative humidity. Table 25 shows the moisture content of timber exposed to various constant relative humidities.

TABLE 25

EQUILIBRIUM MOISTURE CONTENT OF TIMBER AT
VARIOUS RELATIVE HUMIDITIES

R.H. (per cent)	E.M.C. (per cent)	R.H. (per cent)	E.M.C. (per cent)
10	3	60	11–5
20	4–5	70	13–5
30	6–5	75	15–0
40	8–0	80	17–5
50	10–5	90	22–0

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Because moisture moves only slowly through timber, the E.M.C. change with the daily humidity variation is barely noticeable, and it is only after some period of change in the *average* relative humidity that the difference in the E.M.C. of timber can be observed. This is noticeable physically, because a change in moisture content is accompanied by a change in dimensions of the timber, and in prolonged damp weather drawers, doors or windows swell slightly and may be a little harder to open. When the weather returns to normal, this slight difficulty will disappear as the timber dries again and shrinks slightly.

This small change in size is called the "working" or "movement" of timber, and will persist throughout the life of the piece of wood. It is obvious then that the ideal in seasoning is to dry the timber to the middle point of the maximum and minimum moisture content the timber is likely to have in the particular position. Then any change in dimension would be minimised, and in practice would be virtually unnoticeable. Difficulties are usually experienced when the timber is dried to about 3 or 4 per cent too high or too low about the average E.M.C. required.

As a guide to the general trade, the Standards Association of Australia has recommended the range of 10 to 15 per cent moisture content as being the most satisfactory limits for seasoned timber in most areas of Australia. Timber seasoned to 15 per cent M.C. would *not* be satisfactory for use where the E.M.C. is 10 per cent and vice versa. Seasoning to a particular moisture content is most desirable for timber specified for indoor conditions. Outdoor moisture conditions in a similar locality may be a few per cent higher, or lower, depending on the climate of the area.

Petermination of Moisture Content

The end user of seasoned timber is usually not interested in the technicalities of drying, and is only concerned that it will not crack, warp or shrink in service. The best method of checking this is to determine the moisture content of the timber. The two principal means of finding this are by (1) the oven test and (2) the use of the electric moisture meter.

(1) *Oven Test for Moisture Content:* As defined earlier, the moisture content is the ratio of the weight of water compared to the weight of wood substance only. In order to find these weights, a cross cut section of the piece is taken, varying from y_2 to 1 inch in length depending on the size of the board. This section is taken at least 18 inches from an end because of the more rapid end drying which may have occurred. If a parcel of timber is to be tested, then two or three boards are tested from random positions in the stack.

The small sections, after sawing, have their edges scraped free of splinters by means of a sharp knife or sandpapering in order to avoid weight variations from handling. The section is numbered and weighed on a fairly sensitive balance. For greater accuracy the units of weight used are grams, one gram being about one twenty-eighth of an ounce, and the weighings are made to 0-1 gram.

PREPARATION OF SAMPLE BOARDS

Section "a"   Sample Board   Section "b"
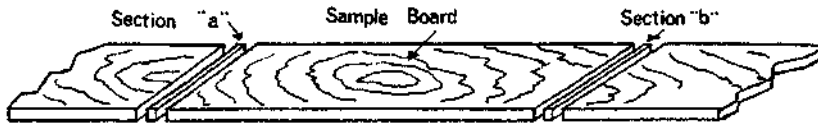
Cut sample board and sections
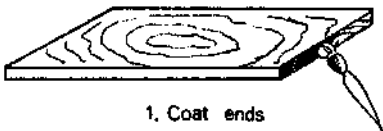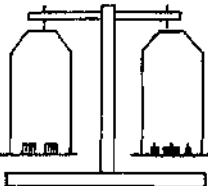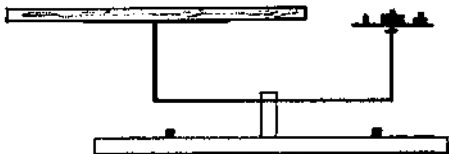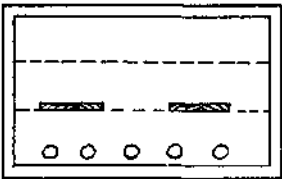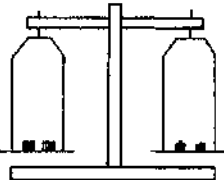
SECTIONS	SAMPLE BOARD
1. Scrape	1. Coat ends
2. Weigh	2. Weigh
3. Dry in Oven	3. Average Moisture Content % = Moisture Content as determined from sections (step 5)
4. Reweigh	4. Calculate Oven Dry Weight $= \text{Weight } 2 \times \dfrac{100}{100 + \text{Moist Cont}}$
5. Moisture Content (%) $= \dfrac{\text{Wt. } 2 - \text{Wt. } 4}{\text{Wt. } 4} \times \dfrac{100}{1}$	Moisture Content at any time (%) $= \dfrac{\text{Weight at Time} - \text{Oven Dry Wt.}}{\text{Oven Dry Wt.}} \times \dfrac{100}{1}$

Figure 21.

This initial weight is commonly referred to as the "green" weight, even though the timber may be fairly dry, because it is the total weight of the wood substance and any moisture that it contains. The section is then placed in an oven which is maintained at a temperature of 102°C to 105°C (215°F to 220°F). Because this is above the boiling point of water, the moisture contained in the timber is evaporated. Higher temperatures are avoided because of possible chemical degradation of the timber (e.g. charring) or loss of volatile components of the timber. After being kept in the oven for 16 to 24 hours, depending mainly on the density of the timber, the section is weighed, returned to the oven for another hour or two and then reweighed. When two such repeated weighings are the same, or vary only by one tenth of a gram, it can be safely assumed that the water has all been evaporated. This constant weight is thus the weight of the wood substance only, and because of its origin, it is called the oven dry weight.

It can be appreciated that the loss in weight between the original (or green) weight and the final oven dry weight (or O.D.W.) is equal to the weight of water in the section of timber.

$$\text{Moisture Content per cent} = \frac{\text{Weight of Water}}{\text{Weight of Wood}} \times 100$$

$$= \frac{\text{Green Wt.} - \text{Oven Dry Wt.}}{\text{Oven Dry Weight}} \times 100$$

Percentages are used because mostly the ratio is a fraction. The above sequence can be followed in the left hand column of Fig. 21, proceeding from top to bottom.

For the record, it should be mentioned that the oven test is universally accepted as being the most accurate method of measuring the moisture content. However, because of the loss of volatile material in some timber (e.g. pine timbers) and for finding the moisture content of timber treated with creosote for example, the distillation method of measuring moisture content is considered to be the most precise technique. For practical purposes, however, most people are only interested in whemer the moisture content is 12 or 20 per cent and not whether it is 12-3 or 12-4, and the oven test is quite accurate enough for practically all purposes.

(2) *The Electric Moisture Meter:* Considering the last statement, and being practical about using timber, it can be seen that there can be a certain tolerance about the optimum required moisture content of timber. This tolerance is about 4 per cent moisture content, i.e. ± 2 per cent about its average E.M.C. This means that if the E.M.C. is about 12 per cent, then timber from 10 to 14 per cent moisture content would give satisfactory results for normal use in furniture, joinery, etc. It is partly for this reason that the moisture meter has become such a valuable tool in the timber industry, apart from its non destructive application and its immediate results.

Green timber is a reasonable conductor of electricity, yet dry timber is used as an insulator (for example in switch blocks). This change in the resistance to the flow of electric current is one of the more spectacular

results of seasoning and is the basis for the design of the moisture meter. Throughout the world seasoned timber has an E.M.C. of from 7 up to 20 per cent, and in this range the electrical resistance practically doubles for each 1 per cent fall in moisture content. It was not difficult to design a meter to measure such a large change in resistance, and the result has been the development of the moisture meter for timber (see photo 23). Essentially it consists of two electrodes spaced an inch or so apart which can be driven into the timber to make good contact with it. A battery voltage is applied to these, and the meter measures the small current which can flow. The higher the moisture content the more current can flow and vice versa. Hence the meter can be calibrated to indicate the moisture content, the meter readings originally having been checked by oven tests.

The following points should be noted in using the moisture meter:

1. The electrodes can be needle points (for softwoods), blades (for hardwoods) or on occasions nails can be used.

2. The meter has been calibrated to indicate the average moisture content of timber only up to about 1 inch in thickness. Over the range of 8 per cent to about 24 per cent, this result is usually accurate to ± 1 per cent moisture content provided the timber is not hot or damp on the surface.

3. The use of nails driven through the surface to the core as electrodes on thicker timber, gives a reading *higher* than the average moisture content. The average M.C. will depend on the moisture gradient through the timber, which of course is not usually known. The use of nails is helpful in finding the maximum moisture content of the core.

4. Given careful handling, the meter itself is highly accurate, the variations between its results and the oven test being due to the chemical constituents of the timber, abnormal moisture gradients or temperature effects. Chemical effects in different species require the use of correction figures which *must* be applied for accuracy. Although these are usually only *± 2* per cent, in the case of brush box *(Tristania conferta)* a reading of 23 per cent is usually obtained on timber having only 15 per cent moisture content. The moisture gradient may cause a wrong result when it is very high, such as on timber kiln dried from the green state, the meter result being higher than the average moisture content of the timber. Temperature has a marked effect on the reading, an increase of 20°F raising the reading by 1 per cent M.C. Timber taken from a hot kiln will soon develop a temperature gradient for which it is impossible to compensate. Such timber should be cooled for some hours before being tested.

5. Timber with a damp surface will naturally give a high result even though the timber may have been dried. This can often be obviated by testing the underside of the board, otherwise it can be crosscut, and a reading taken on the end. Painted or stained timber may lead to a high indicated M.C, and unless the reading shows a low figure, the result could be suspect.

For the sake of completeness, it should be mentioned that other electrical meters are available for measuring moisture content. One such meter depends

on a change in capacitance of a condenser when wood is used as the dielectric, and another uses high frequency radio waves. These have a major drawback to their widespread use, namely their cost, as well as being less portable, more complex electrically and being largely influenced by changes in wood density.

Moisture Distribution

As has been mentioned, a moisture gradient is necessary to cause timber to season. It should be noted carefully that the moisture content of a piece of timber always refers to the *average* moisture content, and includes the drier case as well as the damper core. Hence timber which is seasoned to an average moisture content of 12 per cent may have a gradient of 11 per cent on the surface (or case) to 13 per cent in the core, or it may have (after kiln drying for example) a gradient of 6 per cent case to 18 per cent core, both giving the same average. If timber having the latter gradient is deeply sawn or heavily rebated or machined, timber with the higher core moisture content would be exposed to conditions having a much lower E.M.C. The core will dry out and will shrink resulting in cupping of the section or sections when deep sawn.

Hence, it is essential that properly seasoned timber should not only be at or close to the required E.M.C, but that it should also have a *low moisture gradient.* The moisture distribution in timber can be found best by use of the oven test. A section is taken as for a moisture content test, but it is sawn into layers as shown in Fig. 22. For inch thick timber, two layers—the case and the core—are usually sufficient, but thicker sections can be further
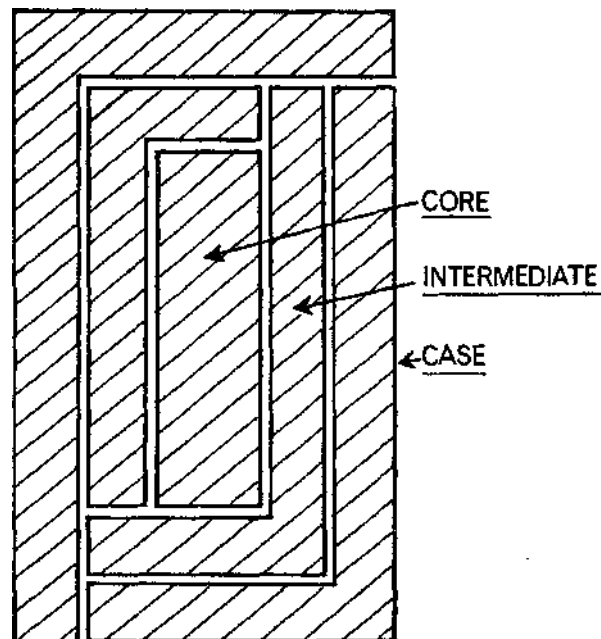
Figure 22. Illustration of the terms "Core", "Intermediate", and "Case" when referring to case hardening of timber.

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divided as shown. Each of these layers is treated as one section and its moisture content determined as previously explained. The results give the moisture distribution, and the gradient is given by the case and core figures. Normally, the core is higher than the case, but after exposure of dried timber to rain, the case may be higher than the core. A little consideration would suggest that the actual moisture gradient through the timber is higher than the results obtained, because of the physical thickness of the sections. This is usually only of concern when the gradient is steep. Such timber can be "equalised", i.e. made more even case to core, by appropriate kiln treatment or by prolonged air drying.

HOW TIMBER IS SEASONED

Factors Controlling Seasoning

No matter by which method timber is dried or seasoned, there are only three factors affecting the process. These are (1) temperature, (2) relative humidity and (3) air circulation.

Temperature: Heat is required to evaporate moisture, hence the higher the temperature the faster moisture is dried from the surface of the timber. A second important factor is that when the moisture content is below the fibre saturation point, higher temperatures increase the rate of movement of moisture from the core of the timber to the surface.

Relative Humidity: This is the most important factor in regard to the quality of the dried timber, especially regarding surface checking. If the relative humidity of the air around the timber is high, the case section of the timber will dry slowly, resulting in a low moisture gradient, a desirable condition when the timber is freshly sawn. If the R.H. is low, then the faster case drying introduces steep moisture gradients which may cause checking or splitting. It is preferable to have a high humidity when the timber is green, falling progressively as the timber seasons.

Air Circulation: As moisture evaporates from the surface of the timber, the humidity of the air immediately adjacent to the surface will rise, and hence the drying rate will slow down. If a current of air flows over the surface it will carry this moisture laden air away and permit drying to continue. Another important feature of air circulation is that the air is the medium used to carry the heat which is required for evaporation and diffusion. The heat taken for moisture evaporation comes from both the timber and the air contact with it, so a constant replacement of the air will improve the rate of drying.

Methods of Seasoning

The aim in seasoning is to dry a parcel of timber to the required equilibrium moisture content in the minimum time and with minimum degrade. Throughout Australia, and even throughout the world where the climate is favourable, there are two principal methods employed for drying timber, namely air drying and kiln drying. Mostly, both methods are employed, prin-

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cipally for economic reasons, by air drying the timber to a moisture content of about 20 to 30 per cent, followed by kiln drying. Naturally there are exceptions and variations on this usual practice, and predryers may be used to replace air drying in some climatic conditions, or the timber may be kiln dried straight from the green state, for example radiata pine.

The Timber Stack

In order to season a parcel of timber, it is first necessary to make up a "stripped" or "stickered" stack. Successive layers of boards up to 6 feet to 8 feet in width are placed above each other, separated by means of small "strips" (also called "stickers" or "tolleys"). The latter are preferably % inch thick and 1¼ inches in width. This thickness is an optimum for most normal Australian conditions, and it is essential that the "strips" be uniform in thickness in order to prevent "bowing" of the boards from a hill and dale effect, and that they touch all the boards and help restrain them from warping. Wider strips may lead to insect attack and strip stains, or even decay in the timber due to slow drying at the contact points. For these reasons the strips should be of seasoned timber. They should be spaced from 12 inch centres for warp prone timber (such as brush box) up to 2 feet centres for straight grained species or thicker sections, e.g. 1½ inch thick tallowwood *(E. microcorys).*

They should also be placed in good vertical alignment to obviate bending moments. The use of a stripping guide is recommended for this purpose. Stacks should be made "box ended", i.e. each end is kept square by aligning each alternate board with the ends of the stack. Long tails at one end of a stack lead to high degrade losses in the form of warping and checking from being unsupported and exposed to severe drying conditions. The long boards should be kept for the outside of the stack and shorter ones may be butted in the body of the stack. Stack sizes depend on the means of handling, being from 3 feet square where mobile cranes are employed up to about 6 feet square for fork lift movement, or even 8 feet square where the lift truck system is operated. The lengths vary from about 20 feet to 25 feet.

Air Seasoning

For the so called "natural" drying or air drying of timber the stripped stacks are exposed to the atmospheric conditions (see photo 24). Consequently the drying factors of temperature, humidity and air circulation (in the form of wind) cannot be controlled. Frequently, Australian conditions are too severe for freshly sawn timber, especially during the summer months, and the percentage of degrade in the form of checking and warping can be quite high for some species.

Generally, the air drying yard should be on a fairly exposed site, clear of trees or large buildings. The drainage should be very good so that pools of water are not left after rain. The stacks should be placed on strong, level foundations, which should be about 18 inches above ground level. Because timber will retain any distortion present during drying, the foundations should be level to keep the stacks flat, and should not sink in parts from the weight

of the timber. When the air evaporates moisture from timber it is cooled, becomes heavier and tends to sink to the bottom of the stack. This is quite noticeable when walking between stacks of drying timber. Since this air contains more moisture it tends to slow down the drying of the bottom layers of the stack, unless the foundations are high enough to allow the wind to carry this cool damp air away. For the same reason good drainage is essential, and the drying area should be kept free of rubbish such as old boards or weed growth.

In the yard layout, the stack spacing should be as wide as possible, being about 2 feet minimum for stacks 6 feet to 8 feet high, and from 4 feet to 6 feet wide for stacks 20 to 25 feet in height. The term used is "air seasoning", and as much air as possible should be allowed to flow through the timber. Where either mobile crane or fork lift handling is used, an excellent drying yard can be set up with pairs of stacks separated by approximately 25 feet wide access ways running both lengthwise and crosswise throughout the drying area, the increased height of the stacks compensating for the loss of area for the roads.

Although the drying conditions cannot be controlled, they can be modified somewhat should they be found to be too severe for certain species. It is possible that in some yards certain positions cause slower drying than others. These positions could be reserved for the more refractive species. Stack covers (see photo 25), consisting of even a layer of old boards, plastic sheeting, tarpaulins or corrugated iron are very effective in reducing the degrade in the top layers of the stacks. Small micro-climates can be formed for individual stacks by enclosing them in hessian, which is quite effective in reducing degrade. The use of protective surface coatings of boards consisting essentially of microcrystalline wax, and more recently the use of sodium alginate (a seaweed extract) have also been shown to be effective in reducing degrade. It should be noted that the most critical period for preventing checking degrade is during the first few weeks of drying. Once the case has dried somewhat it becomes harder and stronger, and more resistant to checking. The most satisfactory means of air drying is that achieved by drying under cover, i.e. in drying sheds. These should be fairly open on most sides with maximum rain protection from the south. Their open nature allows plenty of air circulation, but complete protection from the sun and rain is provided. The combination of wetting and drying is one of the principal causes of degrade, more so when the timber is fairly dry, i.e. below the fibre saturation point.

Kiln Drying of Timber

In a timber drying kiln (see photos 26 and 28), control is effected over all the drying factors, viz. heat, humidity and air circulation. Hence they can be used to control the rate of drying and produce seasoned timber of very high quality. Although there still remains a slight prejudice against kiln dried timber, this is not the fault of the kiln or its potential, but is usually the result of poor maintenance of kilns or unskilled operation. Kilns accelerate drying, and, with satisfactory supervision, production quotas can be programmed and met, enabling future orders to be taken and fulfilled. Timber can be

Figure labels:

VERTICAL FAN BAFFLE WITH CIRCULAR HOLES FOR FANS

WET & DRY BULB THERMOMETERS

VENT

REVERSIBLE PROPELLER FAN

CANVAS BAFFLE

CONTROL ROOM

TRANSFER LINE

FLAT REINFORCED CONCRETE ROOF

COMPARTMENT TYPE KILN
(Cross Shaft-Steam Heated)

DOOR

HEATING COILS

HUMIDIFYING PIPE

CROSS SHAFT FANS

STEAM SUPPLY

CONDENSATE DRAIN

TYPICAL CROSS SECTION OF COMPARTMENT & STACK

CONTROL WALL FOR ONE COMPARTMENT

Figure 23. Cross shaft, compartment-type kiln.

properly seasoned regardless of the weather, for with unfavourable seasons it has been found that it is impossible to produce timber seasoned to the upper S.A.A. limits of 15 per cent, even though the ideal E.M.C. required may be 11 to 13 per cent.

The most popular type of timber drying kiln in Australia is the steam-heated, cross-shaft internal fan compartment kiln, a sketch of which is shown in Fig. 23. Steam is preferred because of its double role in supplying heat as well as humidity and the cross-shaft fan design because of the uniform air circulation and drying which results. The compartment (or batch type) kiln is more suitable for the large number of species of Australian timbers, many of which require careful drying, as opposed to the continuous or progressive type of kiln which is more suited for overseas forests which are predominantly of a single dominant species.

Heating is obtained in kilns by means of closed steam pipes which run full length in the top section of the kiln. These are divided into groups, each of which is controlled by a valve, and consequently a range of temperature is available. The relative humidity is increased by admitting free steam into the kiln chamber through a perforated pipe running the full length of the kiln and it can be reduced by closing this valve off and opening vents placed opposite each fan, usually in the ceiling. These allow the humid air to escape and to be replaced by fresh air, which, when heated by the steam coils, has a low relative humidity. The air circulation is achieved by using several large fans placed in openings in a central fan baffle and driven either by motors

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directly coupled to the fans, or by fan shafts which are driven from outside the kiln. These fans are reversible, and the direction of air flow is reversed every few hours to ensure even drying of the timber stack. Apart from drying the moisture from the timber surface, the air carries heat from the steam coils to the timber. Because of the variation in species, the kilns usually hold from 8000 to 12,000 super feet of 1 inch timber, generally being 40 to 50 feet long.

Modern kilns are automatically governed by air or electrically operated recorder controllers. Both wet and dry bulb thermometers are placed within the kiln and the controller maintains each of these at the required temperatures. The dry bulb shows the actual temperature in the kiln (D.B.D.), while the difference between the dry and wet bulbs—termed the wet bulb's depression (W.B.D.)—indicates the relative humidity. A large depression, i.e. a low wet bulb temperature (W.B.T.), corresponds to a low humidity, and a small depression shows a high kiln humidity.

From work with small representative samples and tiny controlled kilns, "kiln drying schedules" are developed for the various species. This work is carried out by the C.S.I.R.O. Division of Forest Products, and the State Forest research establishments such as the N.S.W. Division of Wood Technology and the Queensland Dept. of Forestry. These show a stepwise increase in severity in drying conditions with the reduction in the moisture content of the timber. When the timber is green, the conditions applied are generally low temperatures and high humidities (110° to 120°F and a 7° to 10° W.B.D.) to introduce a small moisture gradient under a mild drying rate, whereas when the timber is nearly dry (about 20 per cent moisture content) the temperature is high (about 160°F to 180°F) and the depression low, about 30°F.

The fundamental concept of kiln schedules is that the kiln atmosphere produces a certain E.M.C. in the "case" of the timber. Between 120°F and 160°F, there is a fairly constant relationship between the wet bulb depression and the E.M.C. of timber in such an atmosphere. From this it can be seen that at a depression of 7°F, the E.M.C. is about 16 per cent, which means that the surface will not dry to below this figure, and hence only a certain shrinkage will occur. As the timber dries further towards the core, a lower depression causes a lower surface E.M.C, accompanied by a little more shrinkage which can be tolerated because the inner parts of the timber are also shrinking. Finally at high temperature and 30°F depression, the E.M.C. is 5 to 6 per cent, which results in a high moisture gradient, with the high temperature assisting in the more rapid diffusion of moisture from the core to the case. If drying is concluded and the timber is removed from the kiln, it is left with this high moisture gradient of from 5 to 6 per cent on the surface up to 18 to 20 per cent in the core, although the average may be 12 to 13 per cent. Clearly this timber is not satisfactory for dressing or rebating because the machining upsets the moisture symmetry through the section.

The timber should be "equalised" before use by applying a high temperature and humidity to the timber, for instance, 160°F with a depression of 8°F to 10°F. This brings the case back to an E.M.C. of 12 to 14 per cent, while the core will continue to dry out. After about 8 to 12 hours treatment for

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1 inch timber, the moisture gradient should be from 12 to 14 per cent and the timber will be entirely satisfactory for use. This can also be achieved by steaming the timber in a special chamber, but it is not always so precise in operation. Exposure of the stacks to air (preferably under cover) for 2 or 3 weeks also produces this equalising effect.

Returning now to kilns in general; apart from steam heated types, kilns are available which are directly heated. These are principally oil fired, the oil being burned in a furnace and the products of combustion being introduced directly into the kiln. Their advantage is that 24 hour operations can be obtained without the need for an operator such as the boiler attendant needed for steam heated kilns. Humidity is provided by arranging for some of the heat to be used to boil water to give steam, and generally such kilns are satisfactory for the final drying of many species of air seasoned timber. They are not as precise as steam heated kilns for drying from green, and they are slightly more hazardous. Other types of kilns use hot water or hot air drawn from pipes heated in an incinerator as a heating medium, and can give satisfactory results if properly designed.

Predryers

In some areas of Australasia, particularly where the weather is cold and wet and the air drying rate is poor or, conversely where the weatiier is hot and dry resulting in a high proportion of degrade during air drying, pre-dryers are used in place of the initial period of air seasoning. Essentially these are large chambers (holding up to 100,000 super feet of 1 inch timber) where conditions are fixed at a relatively low temperature and high humidity (for example 110°F D.B.T., 100°F W.B.T.). In these conditions, drying is much more rapid than in even good air drying areas, with the added attraction that degrade is significantly reduced—a most important factor in these days of falling timber supplies and higher prices. They are always used in conjunction with kilns, since the rate of drying falls once the timber reaches the fibre saturation point, after which kilns can achieve much faster results. Predryers cause steep moisture gradients, and kilns are a necessity for finally equalising the dried timber.

Sample Boards

Successful kiln operation depends on an accurate knowledge of moisture content of the timber in order to apply the change points. The usual means of constantly checking this is to use some of the timber itself in the form of a sample board. This is prepared according to the right hand side of Fig. 21. Moisture sections are cut from each end of a 2 to 3 foot long section of a representative board or boards from the kiln charge. Their moisture content is calculated as previously described, while the board is painted at each end with a waterproof paint, generally a bitumen paint, in order to prevent end drying. This gives the green weight of the sample board at the moisture content as shown by the moisture sections. Since the moisture content and the green weight are known, the oven dry weight can be calculated as follows:

$$\text{O.D.W.T.} = \frac{\text{Green Wt.}}{1 + \text{M.C.}}$$

or, expressing the M.C. in a percentage,

$$\text{O.D.W.} = \frac{\text{Green Wt.}}{100 + \text{M.C.}} \times 100$$

From this last equation, the calculated oven dry weight of the sample board can be found. If this is known the board can be weighed at any time during drying and its moisture content can be found by reverting to the original equation for moisture content. Obviously, sample boards are very useful during air drying to find the moisture content of the stacks.

Kiln Drying Using a Moisture Meter

One disadvantage with the sample board technique is that boards only show the *average* moisture content. The moisture distribution can only be found by sectioning and oven drying, which may take up to 24 hours. The distribution must be known in order to equalise the timber properly, although trial and error is normally used for 1 inch timber with reasonable success.

For thicker timber, it is more important to know the moisture distribution and this can be found fairly accurately using a potentiometer and a moisture meter.

Two sets of very small electrodes are set in holes drilled in the timber, one pair close to the surface, and one pair in the centre. One of each of these comprises a fine, twin thermocouple wire, while the other is a plain single copper wire. Through fixed wiring in the kiln connected to a multiple switch in the control room, the temperature at the case and core can be found from a potentiometer, while the moisture content across the electrodes can be found using a moisture meter. The relationship between the apparent M.C. at the high kiln temperature and the true M.C. has been developed experimentally, and graphed and tabled into a set of correction figures.

This allows the case and core M.C.'s to be found immediately, and appropriate conditions can be set in the kiln. These results are relatively accurate because the electrodes are close together in the one piece of timber and the true M.C. becomes more accurate as the timber dries towards 12 per cent. This technique is being applied in several kilns in New South Wales with quite good results.

THE EFFECTS OF SEASONING

Seasoning is often accompanied by checking (of both face and ends) and warping. Because both defects are due to shrinkage, an understanding of the reason for their occurrence is helpful in attempts to minimise them.

Shrinkage

Wood is anisotropic, which is to say that its properties (including its shrinkage) are different in the three different directions, length, breadth and height. Boards cut with the wide face parallel to a radial direction are called quarter-sawn, rift-sawn or edge-grained boards. Those cut perpendicular to these,

roughly parallel to the growth rings are called back-sawn or slash grained boards.

Because the cellulose chains are roughly parallel to the tree trunk, the shrinkage along the length of timber is very small, varying from less than 0-1 per cent when straight up to 1 per cent where the timber is very cross grained. Shrinkage in the quarter-sawn direction is roughly half that in the back-sawn direction.

One theory to explain relative shrinkage is that the medullary rays which run parallel to the width of a quarter-sawn board tend to act as "reinforcing bars" and restrict shrinkage. Back-sawn boards are not so restricted (except in their thickness) and therefore shrink more.
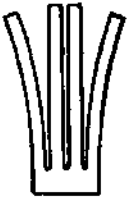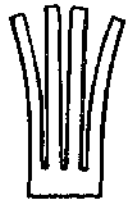
When a piece of timber begins to dry, the outer layers are the first to dry since these are exposed to the air. Individual cell walls only begin to shrink when they dry below the fibre saturation point. In a piece of drying wood, the outer cells dry below 25 per cent and start to shrink before the cells further in even start to lose their "free" moisture. Consequently, soon after drying starts the case is tending to shrink while the core is resisting. The position is similar to a rubber band stretched around a piece of wood—the rubber is trying to shrink back to its original size while the block of wood is resisting it.

In a piece of drying timber the case is trying to shrink and because the core stops it shrinking fully, the case is in a state of tension, with the core in compression. If the initial rate of drying is fast, there is a steep moisture gradient developed across a thin layer of the case, about $\frac{1}{16}$ to $\frac{1}{8}$ inch, with a very large differential shrinkage. The tension developed on the surface may be high enough to cause separation of the fibres. As drying proceeds further, these separations show up as surface'checks. This case tension can be demonstrated by the prong test marked 1 as shown in Fig. 24. Because the shrinkage across the face of back-sawn board is the highest, the surface checks are more prominent on such boards. This then is the reason for the careful drying of certain species on thicknesses during the early stages. Because end drying is usually rapid, the same stresses result in end checking and finally in end splitting.

As drying progresses, the core falls below the fibre saturation point, and then starts to shrink, causing a core tension, which is a "pulling in" effect. It is usually noticeable in timber because the core tension can cause the original face checks to close. It is essential to appreciate that this *is* the final state of dry timber, i.e. it has a core tension, and a corresponding case compression equalling it. This state can be shown by the prong test marked 2 in Figure 24.

These stresses are the direct result of the moisture gradient, but remain in the timber even when the core dries to the E.M.C. Because the case is always drier than the core, especially after kiln drying, the stresses are quite inappropriately given the term "case hardening". Intact, their principal cause is the core tension. If timbers having high shrinkage are rapidly dried this core tension can be sufficient to cause checking in the core of the timber called "internal checking" or, if very noticeable, appropriately termed "honeycombing". They may not be seen until the timber is dressed. Stresses are relieved

TESTS FOR DETECTION OF STRESSES

Prong when Sawn	Prong after Room Drying		

1. Turn Out

Surface in tension and centre in compression.

1a. Turn In

Indication of unequal moisture distribution, surface drier than centre.
Occurrence: Early stages of drying.
Remarks: No need to steam. Raise humidity if checking present.

1b. Do Not Change

Indication of practically equal moisture distribution, surface in tension, centre in compression.
Occurrence: After oversteaming at low moisture content.
Remarks: Steaming treatment has been too severe.

2. Turn In

Surface in compression and centre in tension.

2a. Pinch Tighter

Indication of unequal moisture distribution, surface drier than centre.
Occurrence: After centre dries below fibre saturation point.
Remarks: Advantageous point to relieve stresses by steaming treatment.

2b. Become Straight or Turn Out

Indication of unequal moisture distribution, centre drier than surface.
Occurrence: After steaming but before redrying.
Remarks: Prongs cut after redrying should remain practically straight.

Straight

Timber free from stresses.

3a. Remain Straight

Indication of equal moisture distribution and freedom from stresses.
Remarks: Correct final condition.

3b. Turn In

Indication of unequal moisture distribution, surface drier than centre.
Remarks: A short steaming treatment to balance moisture content should relieve all stresses.

3c. Turn Out

Indication of unequal moisture distribution, centre drier than surface.
Occurrence: During some period of redrying after steaming.

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Figure 24.

by a high humidity or steaming treatment, heat being necessary to allow the stresses to be neutralised. Naturally, the stress relief treatment will also reduce the moisture gradient.

Warping

The most common form of warping is that which occurs during drying. The cells of timber shrink essentially at right angles to their length, but due to the presence of knots, sloping grain (curly or cross grain), and as a result of sawing, the grain of a board is almost never parallel to its length. If the grain direction varies, the shrinkage will not be straight across the board, but at various angles—both in the width *and* thickness. The result is some degree of warping, the extent depending on the shrinkage of the species, the variation in grain and its freedom of movement. The greater the cross grain and the higher the shrinkage of timber, the more it is prone to warping. The need for thicknessed strips and good stripping of timber can now be more appreciated, because if timber is restrained from warping as it dries, it becomes harder and tends to retain its flat condition. The need for close spacing of strips also becomes more obvious. The warping of top boards of an uncovered stack is due to the differential shrinkage of the top and bottom of boards exposed to severe drying by the sun. Cupping is the most pronounced warp, but cross grain or knots can throw the boards into many strange shapes. Hence the need for stack covers and weights.

Warping can occur after dressing. If it happens as the boards leave the machine it is due to severe stresses in the timber (i.e. core tension). Because these are the result of shrinkage, the presence of cross grain can cause uneven warping. If the timber warps some time after dressing—days or even a few weeks—it is due to a large moisture gradient through the board with cupping towards the dressed face being the most obvious form of warping.

Collapse

When the "free" moisture leaves the cells in the majority of timbers, the only change is that of weight. In certain species however, the cells start to collapse inwards, as a canvas hose collapses when the water runs out. The reason for this collapse is still obscure, but it is common in the ash species from N.S.W., Victoria and Tasmania, and sometimes in Western Red Cedar from the U.S.A. It can infrequently occur in practically all species, especially in timbers with shrinkage greater than 6 to 7 per cent. The noticeable effects are a waisting-in of the centre of back-sawn boards or a corrugation of the surface of quarter-sawn ones, due to a very high shrinkage (to 20 or even 30 per cent). This high shrinkage begins right from the green state, even before the fibre saturation point is reached. After that point there is, of course, additional normal shrinkage. This degree of shrinkage markedly increases the checking degrade during seasoning of back-sawn boards, hence the timber is usually quarter-sawn. Honeycombing is also very prevalent.

Although it cannot be prevented, its effects can be largely overcome by steaming the timber when the core moisture content is below F.S. point (25 per cent M.C.). This process (called "reconditioning") restores the timber to

its regular sawn shape, recovering the collapse shrinkage but not the normal shrinkage. Because "reconditioning" also reduces the moisture gradient and reduces stresses, the term is now applied to any steaming treatment after drying even though no collapse is noticeable. A better term for this would be "conditioning".

OTHER FORMS OF SEASONING

It should be noted that kiln drying and air drying (and predrying) are the most common methods of seasoning timber because of their economy. Other means have been tried both in Australia and overseas, and although they have special applications, they are generally more expensive than the above traditional methods.

Chemical Seasoning

It has been found that soaking green timber in certain chemical solutions prior to seasoning can largely prevent degrade, especially checking, during drying. These chemicals are hygroscopic, and tend to draw the moisture from the core of the timber before the case finally seasons. They include sugar, salt, urea glycerine and polythlene glycol. The timber is soaked in a saturated solution of one of the above for a period from a few days to a few weeks— depending on the species and thickness—before it is air or kiln dried. Some of these chemicals, especially the last three of the above, actually reduce the normal shrinkage in timber with consequent reduction in checking and warping, and even in the final working or movement in timber. The treatment naturally adds to the cost of seasoning, but could be economic for certain specialty purposes.

Radio Frequency Drying

It is possible to use very high frequency radio waves to season timber. Because they can penetrate deeply, they can heat timber right through and supply the energy to evaporate moisture. The principle is similar to radio frequency glue setting techniques which are not uncommon in Australia. The seasoning applications are being investigated overseas mainly to make the process more economic.

Vacuum Drying

Because water boils at a lower temperature under low pressures it would appear that applying a vacuum to green timber should be a method of seasoning. The drawback is that heat is still necessary in order to cause evaporation and it is difficult to heat timber uniformly in a vacuum.

Vapour Drying

Investigations by the C.S.I.R.O. have shown that timber can be dried quickly and with little degrade when exposed to the vapour from certain boiling solvents (such as trichlorethlene). Because of contamination of the timber from the solvent and difficulties with the plant apart from its high cost, the process has not proved popular. It is used as a method of drying for preservation in the U.S.A.

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Other seasoning methods include solar drying, using buildings or coverings aimed at picking up heat from the sun's rays. In biological drying, the tree is ringbarked before felling. In the latter process the leaves continue to draw up moisture which now comes from the tree trunk instead of the roots. This leads to drying of the timber before it is sawn but results in higher degrade.

CARE OF SEASONED TIMBER

Once timber is seasoned and as long as it is in use before it is destroyed by fire or fungi, it will change in moisture content and dimensions with changes in its surrounding relative humidity. Provided that timber is sheltered from the elements, its life is indefinite. If it is subjected to rain and sun, it will "weather", that is, it will go grey in colour and gradually disintegrate.

Weathering

If timber is exposed to the weather, the case will absorb moisture during rain and its moisture content, at least close to the surface, will rise to almost the original green value. The surface layers will tend to swell, but will be restrained by the drier core. This will place the case in a state of compression, though to a certain extent this may have already been present. Timber subjected to a compressive stress will shrink more than it normally would, and thus when the sun returns the timber will dry out quickly, which causes shrinkage. Identical conditions exist then as if the timber were drying from green; the case is prone to shrink, but a little more than it originally *would have* because of the compression stress. The dry core resists the shrinkage, causing a tension in the surface layers, and face checking occurs.

The next time the cycle occurs, the rain can penetrate a little further through the checks which become deeper. The moisture dries more slowly out of the checks, and rotting fungi, especially soft rotting fungi, can begin to destroy the timber, so that the surface can be rubbed off even with the fingers. This process can be tried on an old paling fence for example. Hence the timber gradually disintegrates and the process is termed "weathering". This is the most obvious form of loss from the mistreatment of seasoned timber—and it should be noted that it occurs in the top layers of air drying stacks which are not covered. A second and not so noticeable effect occurs where seasoned timber is exposed to high humidities, i.e. over 75 per cent, in which case the moisture content will rise above 15 per cent. Such a situation often occurs under suspended timber floors where the ventilation is inadequate. In this case the bottom side of the floor will increase in moisture content and swell. The top side is exposed to normal conditions and will remain unaltered in size. This differential shrinkage will cause a cupping in the timber or alternatively will cause the whole floor to bow upwards and feel "springy". Cases have been seen where the resultant swelling has pushed out the walls of buildings. Eventually, if the condition is not improved by increasing the ventilation under the floor, the moisture content can rise above 20 per cent, and decay or rotting will occur, with eventual failure of the flooring.

Finally, the exposure of dried timber to high humidity before it is fixed, can result in shrinkage in the finished position, be it in flooring, joinery

furniture or other end uses. It can occur if timber is not properly protected after it has been dried. If dried timber is left in the open with very poor covering, allowing rain to penetrate, then, being in a close stack it retains the dampness for a considerable time. Alternatively, it may be placed on small bearers close to the ground and left completely covered, for some time, for example, with a tarpaulin. The dampness rising from the ground may then increase the humidity under the cover, and cause the timber to pick up moisture. The covering prevents rain wetting, but still may not keep the timber at a low moisture content. The timber appears dry, but has a higher moisture content than is desirable, and shrinkage will occur later.

Therefore, dry timber should be kept in perfectly dry conditions. For the supplier, the best position is in a covered closed shed with some provision for ventilation. The floor should be sealed, but *even then* the timber should be kept about 12 inches off the floor. Deliveries should be made in dry weather, or the timber loaded under cover, and well protected with a tarpaulin in wet weather.

The builder or end user should similarly protect the timber in covered storage with adequate but not excessive ventilation. Generally, conditions suitable for employee comfort are also satisfactory for the processing of timber. Finally, the timber should be adequately protected for its future life by satisfactory finishing for inside use, or a good painting formulation including primer, undercoat and finish for exterior situations.

CONCLUSION

Although some of the details in this chapter may be rather technical for many in the timber trade, they have been included for reference purposes. The bulk of the material should be obvious to all, especially when the reasons for all the techniques have been explained. Once these reasons are generally understood, then good practices should become the rule, permitting timber to be used with complete satisfaction and enabling it to retain its place as one of the most marvellous natural materials to be used by man.

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XVI

TIMBER PRESERVATION

INTRODUCTION

The principal agencies causing deterioration or destruction of timber are weather, fire, fungi, insects and marine borers.

The weather can damage timber in living trees by freezing and by breakages in storms which then permit entry of timber destroying fungi and insects. It can directly face check, split and erode timber by wetting and drying or by wind-driven sand.

Uncontrolled fire destroys both forests and timber structures, while fungi attack in many forms may result in complete destruction through decay, or in unsightly discolourations which depreciate values for many purposes.

Insects, notably termites (or white ants) are a very real worry to many property owners, but serious damage due to decay is very much more prevalent, and favourable conditions for its development often go unnoticed while the attack continues.

Marine borers are very active forms of animal life in many tidal waters and are capable of great damage in submerged timber in a relatively short time. Protection of timber in any locality requires a detailed knowledge of the borers present and their life history.

Adequate protection from the influence of these agents will indefinitely prolong the life of timber. Furniture of an age estimated at four thousand years has been discovered in the dry, sealed tombs of the Pharaohs. The almost perfect state of the woodwork in this furniture was due to conditions which precluded any damaging effect due to the causes mentioned above. Seldom however, does timber in or out of a tomb, enjoy such perfect conditions. Therefore, certain precautions are often necessary to give timber the permanence necessary for it to fulfil its required purpose.

Different species of timber vary considerably in their resistance to one or more of the factors mentioned above. White cypress pine, for instance, is more resistant than most other Australian timbers to attack by termites and certain types of borers. Tallowwood is highly resistant to weathering and decay. Satinay and turpentine char but do not burn readily. Some timbers are resistant to decay, but susceptible to attack by insects and marine boring animals.

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The truewood in most species is more decay and insect resistant than is the sapwood and timber generally is susceptible to deterioration during seasoning, particularly if measures are not taken to control it.

It will be understood therefore, that in guarding against deterioration, one of the most important steps is the selection of timber which, in species and quality, is resistant to those destructive agencies to which, in its final use, it may be exposed. If naturally resistant timbers are not available others less durable can, by preservative methods and attention to conditions of use, be substituted with safety. Furthermore, after treatment with a fixed preservative of known efficacy, the timbers which are readily impregnated can be made capable of outlasting the more naturally durable timbers.

The term "resistant" is used since, in common with most other materials, no timber is of itself entirely proof against destructive agents. The nature of, and measures for combating, these destructive agents will be considered in turn.

DECAY

Decay in timber is caused by species of fungi, microscopic plant organisms which, to exist, require food, warmth, moisture and air. If any one of these factors is absent, or can be maintained in an unfavourable condition for the growth of the fungi, decay cannot develop. If all are present, then conditions conducive to decay exist.

Food is provided by the timber itself; by absorbing it the fungi effect its destruction. As the fungi develop, they produce and liberate minute spores which, on contacting other timber, commence under favourable conditions, a new growth cycle resulting ultimately in decay. This infectious aspect of decay is perhaps not sufficiently recognised. It emphasises the need for preventive treatment in all cases where timber is exposed to conditions favourable to decay even though the timber, when selected, may be perfectly sound.

In felled or sawn timber the sapwood is nearly always more prone to decay than the truewood. In some species the truewood possesses a degree of toxicity to wood-destroying fungi. This is the secret of that resistance to decay which characterises such widely different species as for instance, English oak, Burma teak, Californian redwood and a number of Australian hardwoods. Decay-resistant timbers are termed "durable"; species which are readily prone to decay under favourable conditions are termed "non-durable".* The methods of combating deterioration in non-durable timbers consist of introducing toxic elements, or preservatives, into the timber. These methods will be considered later.

Continuously low temperatures, or the complete exclusion of air, for all practical purposes cannot be effected in the general use of timber. However, where such conditions exist, as in frigid zones, or where timber is used continuously under water to the complete exclusion of air, decay cannot occur.

An excellent illustration of the latter case is provided at the Captain Cook Dock, Sydney. Here the largest crane in the Southern Hemisphere has been erected with a lifting capacity of 250 tons. Timber has been used as one of the

* See page 324.

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main structural elements. Four concrete piers have been sunk into the silt of the harbour and it is on this concrete foundation that the crane is seated. However, to present settling, these piers have been underpinned with large turpentine piles which will finish up about 50 to 60 feet beneath the bottom of the harbour.

Because of their depth and consequent continual covering of silt, no form of parasitic life will feed on them and thus they will stand, possibly for thousands of years, without any deterioration in strength.

Wooden piles which were used by the ancient Romans have been unearthed in this present era and found to be just as sound as the day on which they were driven, some 2,000 years ago.*

Moisture can be controlled to a considerable extent. In the first place, the timber should be effectively seasoned to a moisture content of not more than 20 per cent, since it has been found that wood-destroying fungi are not effective in timber which has dried below this level. In seasoning, proper yard sanitation is important in order to avoid incipient decay (and sap stain) during the early stages of drying.

The next step is to provide ventilation for the timber when in use. Adequate circulation of air will in most cases remove dampness and maintain the timber at a moisture content low enough to prevent fungal attack. One of the principal causes of dampness in houses is due to foundations which arc too low and/or without sufficient ventilation to carry off the moisture rising from the earth. Dripping taps, leaking pipes, broken guttering or downpipes, and so on, can also cause conditions of continuous moisture conducive to decay. In such cases all material below and including the floor will be exposed to decay and should therefore be supplied in durable timber or timber adequately treated.

Modern house design does, or should, provide for sufficient ventilation for the foundations of buildings. Normally, a clearance of 18 inches from the ground is necessary, efficient drainage must be provided, and dampcoiirses fitted in the brickwork. In time, however, the householder may unwittingly interfere with the ventilation of the foundations by stowage of bulky articles under the house, or by growing plants or shrubs over the vents in the foundation walls.

Where wooden stumps are used in building foundations, particular attention must be paid to decay at the ground line since stumps are very often subjected to continuous ground moisture. It is therefore most important that only durable timber, or adequately treated timber, is used for this purpose, and it is advisable as well to apply preservative treatment. Equal importance should be attached to the selection and treatment of fence posts, poles and all timber which is to be set into the ground, and from which a degree of permanence is required.

It is common practice to set the ends of bearers, joists and so on, into brickwork or concrete, which are conductors of moisture. Adequately treated or naturally durable timbers should be used where such practice occurs, and provision made for ventilation of the bearings. Treatment of the contacted

* Division of Wood Technology, Forestry Commission of N.S.W,

surfaces with efficient preservatives is also of some value and insulation from actual contact of the timber with the brickwork or concrete by the use of galvanised iron or bituminous strip is strongly advisable (D.F.P.).

It is interesting to note that in King Solomon's temple, built about 1,000 B.C. in compliance with the God given specification for the building and the first principle of timber preservation, great care was taken to build well ventilated internal "rests" so "that the beams should not be fastened in the walls of the house" where they could absorb moisture and decay.

Wooden joints, when exposed to the weather or other source of moisture, should be given special attention and, where practicable, fully protected. This particularly applies to mortises which may collect and hold moisture.

Conditions favourable to decay are also commonly found in cupboards subject to dampness, such as those under kitchen sinks, where escape water often occurs; and in stair and other cupboards where attention may not have been paid to proper ventilation. Such enclosures should be provided with means for a passage of air by an arrangement of vents above and below the cupboard.

In the fitting out of wooden vessels it is particularly important to ensure that adequate ventilation is provided between the lining (ceiling) and the planking of the hull. This is usually arranged by leaving an open strip at intervals along, and always at the bottom and at the top of the lining.

Notwithstanding these precautionary measures which are desirable and necessary where timber is used under conditions where decay can take place, the introduction of efficient timber preservatives and methods of application has meant that certain timbers, basically those which can be impregnated throughout with fixed chemical preservatives, can be made completely resistant to the various forms of decay and can thus be used in situations and under conditions in which timber was not a suitable material without preservative treatment. This fact has wide commercial implications.

The effect of moisture as a factor in decay cannot be too strongly emphasised, and it is therefore particularly important to consider preventive methods in damp areas. This specially applies to the tropics where conditions of warmth and humidity are constantly present. On the other hand, the dry conditions prevalent in the interior of Australia are not conducive to the growth of wood-destroying fungi, and incidence of decay in timber in these regions diminishes.

It is, however, unwise to discard normal ventilation precautions in such areas. This was proved in Canberra, where the badly ventilated hardwood floor of a telephone cabinet in a comparatively new building on flat ground collapsed as a result of decay.

Under conditions of complete saturation or if maintained continuously below 20 per cent moisture content, timber is not normally subject to any form of decay. The latter is the best and usually the cheapest means of preserving timber in buildings. Neglect of this principle in specifications gives more trouble in correcting damage than any other cause.

The foregoing remarks will illustrate the principles of ventilation, insulation and preservative treatment in combating deterioration in timber wherever

it is subject to conditions favourable to decay. Emphasis is laid on the fact that adequately treated timber can be used with complete success in situations where the use of untreated timber, which has subsequently decayed, has in the past led users and specifying authorities to turn to substitute materials.

Fungus Stain

Certain timbers of both Australian and overseas origin, for example hoop pine, radiata pine, New Zealand white pine and Borneo ramin, are subject to attacks by fungi which are not of the wood-destroying type but which, under certain conditions, can badly stain the timber. In warm and moist weather these moulds form very rapidly on the surface of susceptible timber which has been block stacked or too closely stripped. Staining moulds are of two types: surface moulds and sap-staining moulds.

Surface Moulds: These are commonly found as cottony or fluffy growths on the surface of the timber, they do not penetrate far into the timber or cause any breakdown, and they can be planed off without much loss (D.F.P.).

Sap-staining Moulds: These are usually known as "blue-stain" or "blue mould", though brown stain may also occur. Sap-staining moulds invade the living cells of the sapwood and penetrate much more deeply into the timber than do the surface moulds, and the stains which they cause cannot be planed off. The timber itself is not materially affected other than by the unsightly stain which detracts greatly from the value of the timber for finishing purposes where natural colour is required. If the timber is painted, however, the stain will be no disadvantage (D.F.P.).

Sap-stain, in common with all fungal attack, occurs most rapidly in warm, moist weather and in these conditions can appear within twenty-four hours at the ends and in the sapwood of freshly felled logs or in freshly sawn timber. Susceptible timber should be effectively stripped, so as to dry off the surface moisture immediately after sawing. Sap-stain does not develop in seasoned timber.

Anti-stain Dips: Sap-stain may be prevented by dipping the timber in a chemical solution as it comes from the saw. The principal chemicals used for this purpose as fungicides are sodium fluoride, ethyl mercury chloride and chlorinated phenolates.* Proprietary preservatives of proved value are available from well-known timber preservation specialists in Australia.

In the treatment of logs it is necessary to spray or brush the preservative over the whole surface of the log after the bark has been removed. Particular attention must be paid to the ends, and treatment should be effected immediately after the log is felled. A difficulty in treating logs is that bruising or tearing of the surface during transit leaves the way clear for infection at places so affected.

In treatment for sap-stain it is not necessary to penetrate the timber completely with the preservative but only to provide a continuous outer layer of treated timber.

* A satisfactory dip against blue-stain for pine timbers consists of 4 lb. sodium penta-chlorphenate and 12 lb. borax dissolved in 100 gallons of water.

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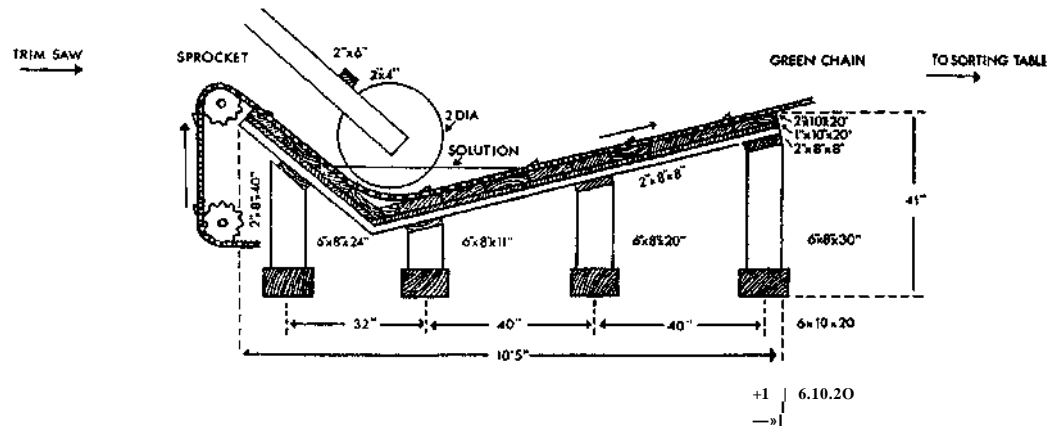
Figure 25. A type of sap-stain bath used in many sawmills.

Treatment against sap-stain described above will afford temporary protection until such time as logs are converted or green sawn timber has dried sufficiently to prevent further action by the staining fungi.

TIMBER PRESERVATIVES AND PRESERVATION PROCESSES

The simple dip or brush treatment with the preservatives mentioned in the foregoing section is generally satisfactory as a preventive against sap-stain and surface moulds occurring during timber manufacture. However, to obtain a more permanent defence against the wood-destroying fungi which cause decay, a wider range of preservatives and other methods of application are necessary. In combating decay, penetration of the preservative into the timber is essential. The requirements of successful decay-resistant preservatives are, toxicity, penetrability, and permanence. But certain other qualities are necessary according to the purpose for which the treated timber is to be used. Under certain circumstances, the preservative must be stainless, or odourless, or non-toxic to human beings. Hence a variety of preservatives have been developed and they may be divided into three principal groups: tar-oil types, water-borne types and organic solvent types.

The wood-preservation industry has grown considerably during the last few years and pressure-impregnated timber can be supplied to most areas. Considerable progress has been made toward an Australian standard for preservative treated sawn timber, veneer and plywood (see SAA 0.113 when published).

In general the timber preservatives mentioned in these pages are commercially most important in the following fields. Creosote oils (both vertical retort and coke oven types) are at present used primarily for transmission poles, piles and posts, in addition to brush applications, for out-of-doors positions. Except for admixture with kerosene for underfloor surface treatment in Queensland against *Calymmaderus incisus* infestation, they are rarely recommended for indoor purposes.

The volume of round and sawn timber now impregnated with water-borne CCA-preservatives (copper-chrome-arsenic) is steadily mounting and the uses to which this treated timber is being put is steadily increasing.

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Organic-solvent preservatives are used principally for topical application by an owner-occupier rather than by a commercial process, although some pentachlorphenol is used in water-repellent preservatives for the protection of some high-class joinery and for some specialty purposes such as the dipping of boxes which have to be exposed to the weather. They are also used for surface treatments for the eradication of some wood boring insects.

Neither copper sulphate nor zinc chloride is now used alone as a timber preservative in Australia and there appears to be little likelihood that either will be recommended for such in the future. Copper sulphate now finds its place as one major component in a number of multi-salt preservatives but these carefully formulated preservatives are so superior in their properties and performance that copper sulphate alone should not be advocated.

Tar-oil Types

Coal-tar creosote is the most common and one of the most efficient preservatives in general use for treating structural timber, fence posts, sleepers and so on. In addition to being an effective fungicide, creosote is highly toxic to timber insects and marine borers. It is also satisfactory as regards penetration and permanence, and can be applied to timber by brushing or spraying, but is much more effective when applied by the well-established vacuum-pressure impregnation. In countries where creosote has been used in effective processes, there are common cases of treated timber serving for periods of forty and fifty years or more and of creosoted marine piles or other heavy constructional timbers being withdrawn after twenty or thirty years of service in such good condition as to warrant their re-use in new structures (R. W. Bond).

Creosote is made up of a number of constituents and may vary in some of its characteristics. Australian Standard Specification no. K55 for creosote has been established as covering the requirements of timber preservation. A disadvantage of creosote is that its dark colour and oily nature makes it unsuitable for use on surfaces which subsequently require to be painted or polished. Its pungent odour, though in time diminishing, also precludes its use for certain purposes. Creosote is sometimes mixed with oil to form creosote-oil mixtures. Petroleum oils, contrary to wide belief, are of low toxic value as timber preservatives against decay and so on, but when certain chemicals such as pentachlorphenol are added at, say, 3 to 5 per cent strength, the mixture then becomes a useful and effective preservative. Some care is, however, needed in the choice of oils, chemicals and creosote, and where the use of such mixtures is contemplated, authorities or specialists in timber preservation should always be consulted.

Water-borne Type

This type consists of chemicals dissolved in water. The preservatives are usually odourless, do not stain, and the treated timber, when dry, may be painted. They also have the advantage of being supplied in powder form. Some, however, are corrosive to metals and some have a tendency to leach out of the timber when in contact with water.

Zinc Chloride: Although relatively inexpensive and as a readily soluble salt used in the past to some extent in a 3 to 5 per cent solution as a fungicide, this has now given place to more efficient "all-purpose" multi-salt preservatives. Zinc chloride is odourless, easy to handle and provided that the timber is thoroughly dry, has no effect on paint.

It does, however, leach easily, and therefore should not be used where the timber is exposed to very damp or wet conditions. In strong solutions it tends to disintegrate timber and has a corrosive effect on metals such as iron. Chromated zinc chloride is effective as a fire retardant.

Zinc-Chrome-Arsenic: For those special purposes where copper is unacceptable as a timber preservative, it is possible to purchase a suitable formulation of zinc, chrome and arsenic under a special trade name.

Sodium Fluoride: Though somewhat more expensive than zinc chloride, this is similar in behaviour. It is not, however, very soluble, a maximum concentration of only 4 per cent being obtainable. Sodium fluoride is one of the constituents of Tanaligh U, sometimes referred to as Wolman Salts. This has been superseded largely by Tanaligh C which is a copper-chrome-arsenate fixed preservative.

Copper-Chrome-Arsenate Preservatives: The combination of these three chemicals, marketed as a single free-flowing dry powder, is now accepted as representing the most well tried and proved and most widely used water-borne timber preservative. Aqueous solutions of between, say 2 and 5 per cent, are used mainly in pressure plants through which carefully controlled preservative salt loadings are applied to the timber.

Copper Sulphate: This has been used for many years in the treatment of poles, but it has the disadvantage of attacking iron and steel and is subject to leaching by the action of water. When combined with chromates, however, as in some proprietary preservatives such as Tanaligh C and Celcure, these defects disappear. Copper sulphate alone is not now recommended for the preservation of poles.

Arsenic: In various forms arsenic is used as a preservative, but usually with other substances and principally as a combative against borers and termites.

Organic Solvent Type

Naphthenates: Copper, iron and zinc naphthenates have been used as timber preservatives. The most important of these is copper naphthenate, a green solid almost insoluble in water but easily soluble in kerosene, mineral turpentine, crude oil, solvent naphtha and many other organic solvents. If the preservative is desired in a water base, suitable emulsions are available. The chief advantages of naphthenates as preservatives are: high toxicity to fungi, borers and termites, and satisfactory permanence. They may be used for immunisation pre-treatment or for eradication of existing attack. Good penetration is achieved, particularly with light solvents such as kerosene, thus making an excellent cold dip treatment. Copper naphthenate is often used with creosote which, as with other oil type preservatives, improves the weathering qualities of timber and requires no re-seasoning. When applied

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with a solvent which will freely evaporate, the naphthenates may be used on timber which is to be painted or otherwise surface finished. For Australian conditions the advantages of the wood-preserving naphthenates lie in the light solvents in which they dissolve, assuring reasonable penetration, particularly in sapwoods, without the use of pressure or heat (R. W. Bond).

Chlorinated Phenols: The most generally serviceable preservative under this heading is pentachlorphenol. In general it may be said that its toxicity is higher than that of any other preservative of the organic solvent type so far mentioned. Application of 5 per cent solutions in suitable vehicles will usually give excellent protection against fungi, borers and termites provided the method ensures reasonable depth of penetration. If light oils are used as solvents for cold dipping, spraying, or brush treatment, a small proportion of castor, linseed, or pine oil should be included to ensure solubility and to prevent "blooming".

If water solutions are required, the sodium salts may be used. This sodium pentachlorphenate and sodium trichlorphenate can be most conveniently used for anti-stain treatment of freshly sawn timber in the prevention of sap-stain. A concentration ranging from 1 to 2 per cent is effective, and borax may be added as a protection against wood-destroying insects.

The chlorinated phenols cause no appreciable corrosion of metals, do not colour the timber, have no pronounced odour, may be painted over, and cause no extra fire risk. They can, however, be the cause of skin irritation and manufacturers' instructions regarding their use should be followed. The addition of 1 to 2 per cent borax to the solutions is said to decrease this tendency (R.W.Bond).

Methods of Application

The efficiency of decay-resistant preservatives is largely proportionate to the degree of penetration. It is important, too, for the timber to be treated before any opportunity for infection occurs, since, unless the timber is fully impregnated, decay can proceed in that part not reached by the preservative. Treatment should therefore be effected after all work on the timber (such as scarfs, bored holes and so on) has been completed.

Seasoning is important. Timber cannot absorb preservatives if it is already saturated with moisture. This particularly applies when oil type preservative, such as creosote, is used.

Sapwood is more permeable than truewood, which, in a great many species, cannot be penetrated adequately even under high pressures. This is an important factor in the treatment of round poles, and in the immunisation of timber susceptible to attack by powder-post (lyctus) beetles.

Some species of timber are more permeable than others and this factor of permeability has a bearing upon the method of applying the preservative.

The various methods of application are as follows:

Brushing or Spraying: This is the simplest method but usually the least effective since only a very light surface penetration can be obtained and subsequent abrasion may expose untreated timber. The preservative should be applied

liberally, and preferably hot, and care taken to fill all cracks and holes. Several applications are advisable to get best results.

Dipping: A somewhat more effective method than brushing or spraying is to dip the timber in a tank. This method ensures that all cracks and openings in the timber will be treated, and a better penetration obtained.

The dipping period can vary from a matter of seconds (for example the boric acid momentary dip process) up to fifteen minutes or so. In treating green timber only water soluble salts are likely to be effective and diffusion of salts requires considerable immersion periods. In treating seasoned timber oil soluble preservatives are the most effective.

Steeping: If time is not important, the timber may be left to soak for a considerable period of up to several weeks. Improved penetration may be expected, but it is questionable whether this occurs to any marked extent.

Dip Diffusion: This is a notable improvement on the dipping process and after twelve years field service is now widely and successfully used in the Territory of Papua-New Guinea. When tests using the pressure treatment method indicated that almost 70 per cent of timbers likely to be treated could not be penetrated satisfactorily in the heartwood, that method was rejected. Pressure-diffusion treatment of green timber was also rejected as unsatisfactory because of variable preservative retention between species and between sapwood and heartwood. Dipping in water repellent light oil preservatives was also examined and rejected.

A dip-diffusion treatment of green timber was finally selected, using a borofluoride-chrome-arsenic (BFCA) preservative developed and patented by the Division of Forest Products, C.S.I.R.O., Melbourne. This treatment is simple, reliable and gives reasonably uniform penetration in both sapwood and heartwood, irrespective of species. Control of the treatment is based on a licensing system which permits use of the patented preservative only under conditions approved and supervised by the Department of Forests.*

The treatment involves only the momentary dipping (or spraying) of green timber in a concentrated solution of the preservative followed by block stacking, for a period in excess of three weeks, under plastic sheets or in a sealed room to prevent drying while the preservative diffuses sufficiently into the timber.

The leach resistance of the preservative is considered to be adequate for use in buildings, provided exposed treated timber is kept well painted. All use of this preservative in the ground is prohibited.

A laboratory termite test made by the Division of Entomology, C.S.I.R.O., Canberra, showed that the BFCA diffusion preservative is highly termiticidal and that its toxicity when compared with well-known CCA preservative was approximately proportional to the arsenic content.

Health hazards have not proved serious though no liberties can be taken with the highly concentrated arsenical solution. Gloves and aprons are used

* "Preservative Treatment of Tropical Building Timbers by a Dip-Diffusion Process", Div. of For. Products Rep. no. 725.

by workmen and an extra precaution, the periodic changing of the treatment crew to other work, is recommended and is generally adopted.

Hot and Cold Bath Process {Open Tank): This method consists of immersing the timber (which must be seasoned) for a few hours in a hot preservative, which is then allowed to cool. The hot liquid heats the timber and causes the air in the timber to expand and a certain amount is expelled. On cooling, the air contracts and forms a partial vacuum and the preservative is sucked in. Some control of absorption and penetration can be obtained by manipulating the periods of hot and cold dip and temperature drop. The hot and cold bath process gives good results for the treatment of the sapwood* of Australian timbers, particularly eucalypts.

Butt Treatment of Fence Posts: The following simple method of treating fence posts by the open tank process is suggested by the Timber Research and Development Associated Limited, London, in their booklet *Timber Preservation.* The suggestion should prove of value to Australian property owners, providing, as it does, an inexpensive and effective means of prolonging the life of fence posts.

An ordinary drum is raised on bricks to allow the lighting of a fire beneath it. As many posts as will fit are placed in the drum, which is then filled with creosote preservative to the required height. The fire is lit and the preservative raised to and maintained at a temperature of about 200°F. After from one to two hours' treatment, the posts are removed to a drum or drums containing cold preservative.

This gives a very good protection to the posts at the point where they are most likely to decay, namely, ground level.

However, the heartwood which is exposed in split posts, being refractory (in the case of most Australian eucalypts), cannot be treated effectively by this method. If, therefore, the posts are not of a durable species it is better to use smaller posts wholly in the round and treated in the manner described. The reason for this is that the sapwood of a round post is penetrated relatively easily by the preservative. It then becomes the most durable part of the post.

Methods of treatment and other information relating to the use of round posts are explained fully in C.S.I.R.O. *Leaflet Series* no. 12—"Round Fence Posts: Preservative Oil Treatment".†

Sap replacement takes place when a *freshly cut* and barked piece of round timber is stood up with one end in water. As the sap evaporates from the exposed length of the post or pole, die water is drawn up through the sapwood to replace it. Water solutions of preservative salts can be drawn up in the same way, but preservative oils cannot be used satisfactorily.

* The truewood of most Australian hardwoods is very refractory, and penetration by preservatives capable of outside exposure (that is, not chemicals which are capable of diffusion such as borax) requires the use of the vacuum/pressure impregnation process, involving hydraulic pressures of up to 1,000 lb./sq. inch.

t This method is also described in D.F.P. *Trade Circular* no. 27 and in *Technical Notes,* Feb. 1951, issued by Division of Wood Technology, Forestry Commission of N.S.W.

The C.S.I.R.O. Division of Forest Products has tested the sap-replacement method on a number of eucalypt timbers with most encouraging results. The essential steps in the process are given below (see photo 28).

The sap-replacement treatment cannot be applied to dry posts or to sawn timber. Any green eucalypt timber can be treated, provided that it has at least half an inch of sapwood, but timbers that split badly while drying should be avoided. Other hardwoods such as tea-tree, wattle or scrubwoods have not been tested. Round posts of radiata pine, cannot as yet be recommended for this treatment.

For economy of preservative, fence posts should be as small as possible. A diameter of 3 to 5 inches under bark is adequate for ordinary posts, while a 6 to 8 inch diameter is sufficient for gate and corner posts provided these are sunk at least 3 feet in the ground. Because the treatment maintains the full strength of the sapwood, small diameters can be used.

Posts and poles should be cut only when the bark can be readily removed. Even small patches of inner bark will retard evaporation and replacement of sap and may cause patchy treatment. Avoid cutting the sapwood, as this will interrupt the upward flow of preservative. Knots should be kept above the ground line as they may allow decay or termites into the untreated heart-wood.

Posts should not be pre-bored for wire before treating, and apart from borings should not be cut in any way after treatment.

Preservative salts of the copper-chrome-arsenate type are usually available as a dry powder or a wet mix which dissolves readily in water with a little stirring.

For most eucalypts a preservative solution of 3 to $3^{1}/_{2}$ per cent strength is required to obtain the desired loading of 1 pound of dry salt per cubic foot of sapwood.

Vacuum Pressure Impregnation Process: Vacuum and pressure treatments are carried out in special plants involving the use of a pressure pump, a vacuum pump, a cylinder capable of working at pressures up to 200 lb./sq. inch, a mixing tank and storage tanks for the preservative.

Steam coils are sometimes necessary to maintain the preservative at a suitable temperature. Within the general term "vacuum and pressure", there are however, several operational methods designed to impart preservative treatment to suit different species of timber. The most widely used of these with water-borne salts is the full-cell process.

Vacuum Pressure Diffusion Process: In a review of timber preservation activities in Queensland it was reported* that 80 per cent of the current production of treated timber through cylinders was by the recently developed vacuum pressure diffusion process. At the end of 1968 this figure included four treatment plants approved in New South Wales and nine operating in North Queensland.

Patent rights on the process have been granted for Australia to the Queensland Forestry Department, and when these are finalised detailed reports will be published.

* Forest Products Conference, Melbourne, 1967.

Full-cell Process: This treatment is designed to achieve the maximum possible absorption by impregnating the cell and filling the cellular spaces in the structure of the timber with preservative solution. Subsequent drying-out removes the water, leaving the preservative within the cell structure.

In the treatment cycle, the timber stacked on bogies, is pushed into the cylinder, the doors sealed, and a vacuum drawn which not only extracts air from the cylinder, but also from the cell cavities in the outer surface of the timber. The duration of this vacuum period is varied according to the type of timber being treated. While this vacuum is maintained, the preservative is drawn into the cylinder until it is completely flooded. The vacuum pump is then stopped, the pressure pump is started and pressure is built up to a maximum of 200 lb./sq. inch.

The pressure is maintained until the required absorption has been reached, after which the preservative is withdrawn from the cylinder and a short final vacuum applied to remove surplus moisture from the surface of the timber, making it reasonably dry to handle. Measuring devices on the solution storage tanks enable the actual absorption of the solution into the timber to be measured accurately, and from this, the absorption per cubic foot, and the depth of penetration can be calculated.

Lowry Process: Timbers which are permeable and take up large quantities of preservative are often treated by the Lowry process, particularly if the timber sizes are large or the time allowed for drying is limited. Use of this process avoids raising the final moisture content of the timber to an excessive degree, yet ensures deep penetration of the preservative.

This is achieved by omitting the initial vacuum. After the cylinder is loaded with timber, it is immediately filled with solution and pressure is applied until a predetermined amount of solution has been forced into the timber. In this way such air as is present in the timber is compressed within the timber cells. On the relaxation of pressure prior to emptying the cylinder, the air expands, thereby ejecting up to 40 per cent of the solution originally absorbed. It will be noted that although a large proportion of the timber cells, which had previously been filled with preservative, are in this way largely emptied of liquid, the cell walls still retain sufficient preservative to give the desired net retention of salts. In this way, permeable timbers leave the impregnation plant having been thoroughly treated and deeply penetrated, yet remaining in a comparatively dry state.

Rueping Process: The Rueping process goes a stage further in delivering dry timber after impregnation. Air is forced, under pressure, into the cylinder containing the charge of timber at a pressure of 25 to 100 lb./sq. inch. This results in a certain amount of air being forced into the timber and compressed. The preservative is then pumped under pressure into the cylinder without releasing the air pressure, so that the injected air is retained in the timber. The pressure cycle is continued until the required degree of penetration has been achieved. When the pressure is released, the compressed air in the timber expands and drives out surplus preservative, and this extraction is further assisted by the application of the final vacuum.

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Impregnation by vacuum-pressure (full-cell process) is a most effective method of applying preservatives and gives maximum depth of penetration, besides giving a high degree of control over *the* treatment.

High Pressure Treatments: Treatment of sawn Australian hardwoods, such as railway sleepers and cross-arms for telegraph and electricity poles using creosote and furnace oil, plus pentachlorphenol, represents the most recent development in the industry. Previously, hydraulic pressures to the order of 200 lb./sq. inch had not been exceeded in commercial practice but, following the pilot work carried out by the C.S.I.R.O., commercial treatment for applying pressures of up to 1,000 lb./sq. inch are now being carried out (see photo 29). Specially designed plant is necessary for work of this nature and the requirements of the Australian boiler code are such that, with as small a cylinder diameter as 3 feet 6 inches, the thickness of the cylinder walls exceed 1% inch grade 1 boiler plate. The door sealing mechanism also represents some engineering problems but these have or are being overcome as commercial practice develops.

Incising: Timber that is very refractory, that is, resistant to penetration by preservatives, is sometimes incised before treatment to permit deeper and more uniform penetration. To accomplish this, sawn or hewn timber is passed through a machine having horizontal and vertical rollers equipped with teeth which sink into the timber to a pre-determined depth. The teeth are so spaced as to give the desired distribution of preservative with the minimum number of incisions. The incisions expose end grain surfaces and thus permit longitudinal penetration.*

An example of incising is provided by cricket bats, the blades of which are sometimes perforated with a sharp-pointed knife to ensure better penetration of preservative oil.

THE USEFULNESS OF PRESERVATIVE TREATMENT

The economic advantages of timber preservation are illustrated when we consider that with adequate treatment, using preservatives of known efficacy, a vast quantity of timber which would otherwise go to waste can now be brought into economic service.

There are some striking examples of this, for instance, the case of the telegraph pole. Prior to the installation, in recent years of pressure impregnation plants, the sapwood of the durable pole species was either cut away before the pole went into service or was left on the pole to rot away during the service life of the heartwood. In each case, the sapwood went to waste but now all this valuable timber can be economically used after being preservative treated.

An example is that of spotted gum, where 10 to 20 per cent of the volume of a log, being sapwood, could be cut away and left to waste. Today, this sapwood, treated with creosote or the fixed water-borne preservative applied by vacuum-pressure impregnation, can be put into service alongside the more durable heartwood and will give equal, if not better, service under the

* *Wood Handbook,* United States Department of Agriculture.

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severest conditions of exposure. Such sapwood can also be treated by chemicals which are capable of diffusion, by the diffusion process. The application of these latter chemicals does not require the use of a pressure plant, but the timber so treated is probably better used for interior purpose where there is no fear of the chemicals being leached from the timber.

Creosote oils and copper-chrome-arsenate water-borne salts are now commonly employed to increase the useful service life of transmission poles, round posts and piling for all purposes. Marine piling, with the sapwood carrying a high loading of copper-chrome-arsenate salts is proving successful in resisting marine borers of the *Teredinidae* group. In this regard, timbers such as turpentine, satinay and brush box have an advantage in that they already possess considerable natural resistance in the heartwood.

Other more recent developments in Australia include the preservative treatment of the more permeable timbers such as radiata pine and its quite extensive use in the construction of water cooling tower fill, refrigerated rail cars, refrigerated road vehicles, ship refrigeration spaces and underground cable pits.

Some other examples of situations in which adequately treated timber can be used with advantage and with economic usefulness are: flooring, set direct onto concrete; park and garden furniture; car ports, jetties and slipways; materials handling pallets; packing cases for tropical storage; ammunition boxes; cable drums and wooden conduit; boat building; textile dye vats and so on.

Another notable development in the use of treated timber is in the coal mining industry where treated pit props and sleepers can give a much greater life underground than was the case when timber was used untreated. This is a particularly significant development where the use of small diameter natural round timber is common. Such species as spotted gum have a very short life when used underground without treatment, but, after adequate treatment, can now go into service for greatly extended periods.

The Australian plywood industry has also made great strides towards the introduction of rot-proof plywood and a number of companies are now treating a portion of their range of products to a greater or lesser degree. One major producer in Sydney is impregnating the veneers under pressure with a fixed copper-chrome-arsenate preservative and subsequently bonding these together to produce rot-proof material. Such material can be used in positions of high hazard with complete confidence.

It is, of course, necessary that the correct loading of the preservative is applied to the timber to suit the particular situation in which it will be used and one of the main advantages of the vacuum-pressure impregnation process is that a proper scientific control can be kept over this very important factor. It is also recommended that the Divisions of Forest Products and Wood Technology or those specialising in the application of preservatives are consulted regarding this important point.

THE DECAY RESISTANCE OF AUSTRALIAN TIMBERS

At present, knowledge of the decay resistance of Australian timbers depends largely on the general experience of timber users, combined with data from

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TABLE 26

CLASSIFICATION OF TIMBERS INTO DURABILITY CLASSES

CLASS 1—VERY DURABLE TIMBERS

Broad-leaved red ironbark	Brown bloodwood
Brown touriga	Coast grey box
Crow's ash	Gidgee
Grey box 1	Gympie messmate
Grey gum	Grey ironbark
Narrow-leaved red ironbark	Raspberry jam
Red bloodwood	Red ironbark
Silver-leaved ironbark	Swamp box
Tallowwood	Turpentine
Wandoo	White beech
White cypress pine	White mahogany

CLASS 2—DURABLE TIMBERS

Blackbutt	Carabeen
Cadaga	Celery-top pine
Forest red gum	Grey satinash
Hickory ash	Huon pine
Jarrah	King William pine
Red box	Red mahogany
River red gum	Rose gum
Satinay	Scribbly gum
Southern mahogany	Spotted gum
Sugar gum	White stringybark
Woolly butt	Yellow box
Yellow stringybark	Yertchuk

CLASS 3—MODERATELY DURABLE TIMBERS

Blackbutt	Black peppermint
Brown barrel	Brown stringybark
Brush box	Cadaga
Candlebark	Grey satinash
Karri	Maiden's gum
Manna gum	Messmate stringybark
Mountain grey gum	Myrtle beech
Narrow-leaved peppermint	Southern blue gum
Spotted gum	Sydney blue gum
White stringybark	

CLASS 4—NON-DURABLE TIMBERS

Alpine ash	Bollywood
Brown tulip oak	Brush mahogany
Coachwood	Douglas fir
Hoop pine	Mountain ash
Mountain gum	Myrtle beech
North Queensland kauri	Radiata pine
Rose gum	Shining gum
Silvertop ash	White cheesewood
Yellow carabeen	

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service records and from a small number of field tests. After consideration of all this information, the Division of Forest Products, Melbourne, has drawn up lists dividing Australian timbers into four classes as regards durability (see Table 26).

Several points must be emphasised in connection with this durability classification. It is intended primarily to indicate the expected service life relative to that of other timber species when the timber is used outdoors in contact with the soil, and therefore takes both decay resistance and termite resistance into account. Also, it is based on the durability of the truewood alone. The sapwood is usually much less durable than the truewood and may in fact be classified as "non-durable" for all timbers. Thirdly, some timbers appear in more than one class owing to the wide variation often found within the one timber species.

Information on the durability ratings of a wider range of timbers can be secured from Australian Standard No. Int. 365 for piles from Eastern Australian hardwoods and publications available from the Division of Forest Products, C.S.I.R.O., and Forestry Departments in each of the States. Pamphlets Nos. 3 and 5 of the Queensland Forestry Department cover a large number of timbers in that State.

Timber Durability and Preservation

Properly used, timber has an exceptionally long life. However, like all building materials, it should be used intelligently. A concise paper under the title "Timber Durability and Preservation"—Technical Timber Guide No. 8, setting out the main principles to be observed to obtain long and satisfactory service from timber in buildings is available from the Timber Development Association of Australia.

WOOD-DESTROYING INSECTS

Many species of wood-destroying insects exist, but, so far as the manufacturer and user of timber are concerned, they may be divided, broadly, into five groups:

Group 1—Green Timber Borers. Borers which attack only unseasoned timber and cannot survive in air-dry timber.

Group 2—Green to Dry Pine Borers. Borers which attack only unseasoned or partly seasoned pine timber and complete their life cycle in air-dry timber.

Group 3—Starch Feeding Borers. Borers which attack only sapwood containing starch in timbers other than pines.

Group 4—Dry Timber Borers. Borers which attack fully seasoned soft timbers, pines and others.

Group 5—Termites {White Ants). Insects which under favourable conditions attack almost any timber or other material containing cellulose.

Borers which attack unseasoned timber (Group 1) are primarily the concern of the logger and the sawmiller, since "pin-holes", "shot-holes" and some

larger holes can affect the appearance of timber and hence cause degrade in high-quality stock required for surface finishing. Although activity of most of the pin-hole borers ceases when timber is even moderately seasoned, causing negligible effect upon building scantlings, the resultant degrade of cabinet and joinery timbers becomes economically important.

Borers (Groups 2 to 4) which attack seasoned or pardy seasoned timber (commonly known as powder-post borers, pine borers and furniture beetles), are however, of obvious concern to all those connected with its use. The sale and use of timber susceptible to attack by powder-post borers *(Lyctus spp.)* included in Group 3, are limited in New South Wales and Queensland by the Timber Marketing Acts and Timber Users' Protection Acts in these States.

Termites are of little concern to sawmillers but are very important to engineers, architects, builders and property owners who should understand their habits and economic possibilities.

Borer holes may therefore merely indicate that pin-hole borers have attacked the timber in its unseasoned condition, and that no further activity or re-infestation from this source will occur. Or they may indicate that powder-post borer is active in the timber and, within limitations, may continue its work in the timber affected.

In view of the concern so frequently, and sometimes quite properly expressed when borer holes are discovered in furniture, flooring, house-fittings and so on, it is of the greatest importance that the layman, as well as the expert, should be able to distinguish between borers that do and do not matter.

Unfortunately however, there is a widespread fear that *all* borer attack is dangerous and will lead ultimately to the complete destruction of the whole of the timber and will spread infestation to furniture or other woodwork. This misconception is due largely to ignorance and to the fact that the average householder and timber user has become influenced by advertising propaganda "guaranteeing" some formula to prevent borer attack.

The more important families of timber borers and their habits are briefly described hereunder. For further details the reader is advised to refer to publications listed in the bibliography at the end of this chapter or refer directly to the Division of Forest Products, C.S.I.R.O., or Forestry Department in the State concerned.

Group 1—Green Timber Borers

This is a very large group containing a number of insect families, and the sizes of the tunnels in timber range from small pin-holes to as much as an inch in diameter. The most important fact from the viewpoint of the timber trade is mat they all *must have green timber* to continue to live and bore. *All die when the timber seasons.* There is thus no need to employ any "treatments" or preservation methods to kill the insects and prevent further attack other than to season the timber.

In timber grading their damage is included collectively under the terms "pin-holes", "shot-holes" and "grub-holes" according to the size of the tunnels, and their importance is judged mainly according to their appearance on the

wood surface rather than any serious reduction in strength unless grouped together. The same can be said for minor irregular tunnels in timber from attacks by termites which are not given further opportunity to cause damage.

It is unfortunately true that borer holes in timber, irrespective of the species of timber or type of borer, are often wrongly considered to be sufficient reason for rejecting the timber concerned. Architects and builders who are properly informed know that, apart from surface appearance, this material may be otherwise of first class quality for building construction.

In many hardwoods and softwoods, including pines, small pin-holes frequently occur, both in sapwood and heartwood. These usually measure $\frac{1}{16}$ inch and less in diameter and are the result of attack in the living tree, the log, or wet sawn timber, mostly by borers broadly described as "Ambrosia" beetles. The adult beetles bore into the timber surface to make tunnels in which to lay their eggs.

Fungal spores are introduced into the tunnels on the bodies of the beetles and the resultant fungal growth on the tunnel walls then provides food for the insect larvae when they hatch. The larvae continue to grow and when mature enter the pupal or resting stage before emerging, after a short period, as adult beetles. The holes of this group of insects are often easily distinguished by a dark discoloured zone surrounding the tunnel due to the growth of the fungus. Many of the holes are fairly straight allowing the insertion of a pin to some depth. In this respect they differ from the tunnels made by starch feeding insects hereafter described in Group 3.

Pinworms (Lymexylidae): These insects initially make the smallest of holes in timber and their attack is restricted to *living trees*. They are of importance to the sawmiller because they are found in all parts of the trunk. Most damage is seen in forest hardwoods of the genus *Eucalyptus*.

Eggs are laid into cracks on exposed timber surfaces such as fire scars and other injuries on the trunks, and commonly on broken branches. The young grub is like a thread and the tunnel correspondingly small. Its position can be located by a fine piece of frass extruding from the surface. Tunnelling can take place in any direction, mostly across the fibres.

The grubs travel considerable distances, while their tunnels gradually enlarge with their growth until they are about $\frac{1}{8}$ inch in diameter. The yellow-white grub is then about $1\frac{1}{2}$ inches long and cylindrical in shape. Pupation occurs near the surface of the trunk to allow easy emergence of the beetles. Life cycles may require several years, during which each grub can cause damage over a large volume of timber. Usually the larvae are numerous and this accounts for the large numbers of pin-holes in the timber.

Tunnels of pinworms sometimes resemble those of the pin-hole and shot-hole borers but may be recognised by the occurrence in the one piece of timber of different sized tunnels, all of which are packed with excrement and wood fragments.

Pin-hole Borers (Scolytidae): Scolytid borers are mostly very small beetles, stout in build with a roughened rounded prothorax and light or dark brown in colour. The most common and destructive species is *Xyleborus testaceus,*

a small brown beetle ⅛ inch in length. This borer attacks a wide range of timbers, particularly in the rain forest, but also in the open forest. It is attracted to logs very soon after they are felled.

Adult beetles tunnel through the bark or directly into the timber making extensive galleries well into the heartwood, even to the centre of large logs of softwoods. Eggs are laid in clusters in little offshoots from the main burrow system. The larvae hatching from these are found in various sizes through the whole burrow network. Full grown grubs are white, curved and less than ¼ inch in length.

It is generally considered that all the tunnelling is done by the beetles, and the larvae move along the galleries feeding on fungus on the gallery walls which at the same time causes a dark stain in the timber. The life cycle is completed in a few months and if logs remain in the green condition, subsequent generations can attack the same logs.

Pin-hole and Shot-hole Borers (Platypodidae): Borers of this family are often considered with the Scolytid borers above, and while their habits are somewhat similar, the platypodid pin-hole and shot-hole borers generally are more destructive. Beetles are easily recognised by their elongate form and smooth square-shaped prothorax. The larvae are yellowish white in colour, elongate in shape with a humped prothorax.

Beetles are attracted to freshly felled logs and injured trees, particularly in rain forests. Some species attack through bark, others directly into the timber. In this case the beetles do all the tunnelling. On entering the timber they excavate galleries in all directions more especially across the fibres, even to the centre of the log.

Eggs are laid along the galleries and the grubs move freely through the system feeding on fungus growth which invariably develops on the tunnel walls. It causes a dark discolouration of the timber and this may extend for some distance along the grain.

Most of the species are numerous and very destructive, and the extensive degrade often makes the timber unsuitable for use. The valuable veneer timber, Queensland walnut is an outstanding example. In north Queensland, bruises and other injuries are often made on the trunks of living trees by cyclonic winds. These injuries attract pin-hole borers which extend their tunnels well into the tree. Later injuries become overgrown and the extensive damage is not seen until the log is sawn.

The smaller holes, ⅟₁₆ inch diameter and less, are graded as "pin-holes", and the larger ones as "shot-holes", "grub-holes" or simply "holes" in timber grading rules.

Longicorn Borers (Cerambycidae): In common with the pinworm, pin-hole and shot-hole borer, longicorn borer attack commences on *green timber*. In this case infestation commences only on freshly felled logs. Even round timber with bark on has little or no attraction after a few weeks and barked logs are not normally attacked.

Round timber with bark on such as that used for transmission poles, piles, posts, pit props and mill logs may be seriously damaged by longicorn larvae,

especially if the logs are left in the bush for any length of time or held on millyard skids. If logs are sawn within a few months little loss is incurred, the damage being restricted to surface engravings, but later mature grubs may penetrate a few inches into the timber for pupation.

As the bark dries, some species may soon enter and tunnel extensively into the timber, penetrating deeper still for pupation. Most species die soon after the timber is sawn but a few can continue to tunnel in sawn material until the timber dies. The pupation holes are typically oval in shape ranging up to $^3/_8$ inch in greatest cross section of the tunnel and are known as "grub holes" in timber grading.

Longicorn beetles are so named because of their long incurved, many jointed antennae ("long horns") often much longer than the body. The body itself is elongate, five or more times as long as broad and the legs are comparatively long. They are mostly nocturnal in habits. Eggs are laid in clusters under pieces of loose bark or in cracks or crevices and the young grubs penetrate the bark on hatching. Full grown grubs are fleshy yellowish white in colour and mostly cylindrical in shape, except for a slight tapering toward the tail end.

The family is a large one in which there is considerable variation in size and colour. The predominant colour is brown and the average size of common beetles such as the yellow or gum tree longicorn *(Phoracantha recurva)* and the hoop pine longicorn *(Pseudiotima undulata)is* a little more than an inch in length.

The life cycle varies considerably. The larvae may complete their growth in a few months under favourably moist conditions, but may require about a year if drying of the logs occurs soon after felling. Rubbish from logging operations, ringbarked trees and drying branches normally maintain a reserve of these insects in the forest and should be burned where possible.

Wood Boring Moths (Cossidae, Hepialidae and Xyloryctidae); The larvae of timber moths also attack living trees, and while their damage does not greatly affect the health of the tree, they can cause a considerable amount of degrade, making tunnels in the stem exceeding an inch in diameter.

Giant wood moths (Cossidae): Mostly grey in colour, and amongst the largest moths and grubs in the world, they are pinkish when young but later are creamy white in colour and cylindrical in shape.

Eggs are laid in clusters of hundreds under pieces of bark on the trunks of eucalypts, e.g. forest red gum *(Eucalyptus tereticornis),* but usually only one or two of the grubs from each batch survive. The young grub chews its way through the bark, later penetrating the timber and enlarging the tunnel as its body increases in size. The tunnel turns in an upward direction and ultimately appears as a huge auger hole about an inch in diameter and 6 or more inches long.

Saplings or pole sized trees are most prone to attacks which can occur on the same trees in succeeding years. Normal tree growth covers over the injuries without any sign of internal damage and it is not until logs are sawn that the holes are seen.

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Bent wing wood moths {family Hepialidae): The habits and type of damage from larvae of these moths are somewhat similar to those of the giant wood moths. They are, however, found mostly in rain forests. The tunnels extend in a downward direction sometimes for more than 12 inches and to $\frac{1}{2}$ inch in diameter.

Small wood moths (Xyloryotidae): This type has some of the habits of the giant wood moths but resembles the bent wing wood moths in that the tunnel in the timber is in a downward direction, serves only for shelter and is covered over. The tunnel is not as large and does not penetrate as deeply as that of the other wood moths and also wood destruction is not important. However, the insects can cause gum veins and, if numerous, can seriously affect the quality of the wood.

Wood boring weevils (Curculionidae): These are usually distinguished by the head which is prolonged into a downward pointing trunk, and by elbowed antennae.

Many weevils attack freshly felled logs, eating a small hole into the timber in which to place the eggs. Some directly attack exposed timber. The grubs are stout, more or less cylindrical and curved, and without legs. Destructive species occur mainly in rain forest, and are attracted to freshly felled logs. The grubs of many species tunnel between the bark and sapwood penetrating the timber for pupation.

Elephant weevil (Orthorrhinus cylindrirostris): Although attacking through bark, these grubs tunnel through the timber, and even though the timber dries, they can complete their development. In common with all the wood boring insects which attack green timber (Group 1) the weevils do not reinfest seasoned timber so that the only "treatment" necessary is to dry the timber as soon as possible.

One weevil confines its attack to green pine and this is described in the following Group 2 covering green pine borers.

Group 2—Green to Dry Pine Borers

These borers confine their attention to various species of pine, and in view of the increasing value of improved cypress pine forests and large plantations of native and imported species, are of considerable importance to timber producers and users of timber. All attack freshly felled timber and some are able to continue to destroy timber many years after it is fully seasoned. They do not reinfest dry timber, so that early kiln drying at normal working temperatures is sufficient to destroy the larvae and prevent further damage. Alternatively, early removal of felled logs from the forest will reduce the risk of infestation.

Jewel beetles (Buprestidae) are mostly torpedo shaped and their antennae are saw like. The common name is derived from the brilliant metallic body colourings. Unlike most other wood boring insects they are active during the day time. Eggs are laid into the bark of freshly felled logs, a notable exception being the common hoop pine jewel beetle *(Prospherus aurantiopictus)* which lays its eggs under fragments on the surface or into cracks on exposed timber.

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Grubs are yellowish white, elongate, with prothorax distinctly enlarged and flattened and no legs. Many species tunnel between the bark and sapwood, engraving the timber surface and penetrating into it for pupation. Normally they die after the timber is sawn.

Some species can tunnel into the timber if the bark dries quickly, while the hoop pine jewel beetle tunnels entirely in the timber and continues to do so in sawn and air-dried timber. In this case, the normal life cycle of less than a year may be extremely extended in completely dry timber in position in a building or furniture. Beetles have emerged and caused much concern as long as twelve years after the original fixing of the timber. Considerable damage is inflicted by this borer and the timber may be completely destroyed if many grubs are present.

The cypress pine jewel beetle (Diadoxus erythrurus): This is a greenish yellow and black beetle, attacking felled logs and damaged trunks of various species of cypress pine. Often the grubs are particularly abundant in logs not quickly converted and in a few months the whole log surface is severely tunnelled. If sawing does not occur before pupation, the log is peppered with holes, many exceeding   inch in diameter.

This borer does not attack living trees of native species unless they are injured by some other cause. Attack on living trees of several introduced cypress species four or more years old is common. Usually several larvae work spirally under the bark of branches and trunks, killing the upper parts by ringbarking.

Douglas fir jewel beetles: It is known that a considerable number of species of jewel beetles can attack imported Douglas fir (Oregon pine) *(Pseudotsuga taxifolia)* and are capable of causing severe damage in sawn timber. If this timber is purchased in a kiln dried condition, there need be no worry in regard to possible further damage from the larvae of these destructive insects.

The pine stump weevil (Mitrastethes australasiae) (Curculionidae). The eggs of this weevil are laid on exposed timber and not into the bark. They are placed on freshly felled pine logs and the larvae immediately enter the timber. Normally the larvae are numerous, and extensive damage can be done, especially if logs are held for several months.

While the wood borer tunnels considered so far may range in size from $V32$ to more than 1 inch in diameter, at least they are neatly circular or oval in shape, and, with the exception of the pinworms, normally have no internal filling. The damage inflicted by the weevils is in marked contrast, the tunnelled workings often being very irregular in cross section and ranging in size from less than y_{32} inch to as much as $\%$ inch and often plugged with impacted yellow mud-like excreta.

Although these insects cannot continue to destroy pine after seasoning, their damage can become very severe while the timber is still damp, and the usly form of the attack usually results in total rejection of affected pieces. Heavy attack by stump weevils is sometimes encouraged by the practice of some sawmillers of using wide separating strips in their seasoning stacks which prolong the drying period of the boards where these touch.

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Since infestation of timber by all green timber borers occurs soon after the logs are felled, preventive action must be taken mainly in the forest. The prompt removal of logs from forest to sawmill, and equally prompt conversion, is the best method of avoiding pin-holes. Felling in the winter months will greatly reduce the intensity of attack. The storage of "floaters" in water will protect the immersed portion of the log from attack. Where these measures are unpractical, spraying of the logs, particularly the ends, with creosote, benzene hexachloride (Gammexane) solution, or similar insecticide, will reduce incidence of attack.

Attack by pin-hole or shot-hole borer in freshly sawn green timber can be prevented by immediate stripping. A surface dried condition is sufficient to prevent infestation. *No recurring attack, nor further damage is likely to result from shot-hole or pin-hole borer in seasoned timber.*

From the foregoing remarks it will be understood that the activity of the shot-hole and pin-hole borer is restricted to the living or recently felled tree, or temporarily to unseasoned timber, and that the presence of pin-holes in seasoned timber is *not* an indication that further attack will follow. The rejection of seasoned or partly seasoned timber because of pin-holes is therefore wholly unjustified except on the score of appearance, and here the effect can in many cases be overcome or minimised by the use of an appropriate filler.

The Prevention of Insect Attack in Poles during Seasoning: The necessity for seasoning the sapwood of timber prior to the application of preservative by vacuum-pressure methods has focused attention on the importance of preventive treatments. In northern New South Wales, where many thousands of poles are seasoned annually prior to treatment, spray treatments with benzene hexachloride or dieldrin or similar chemicals are proving most effective. The poles are sprayed as soon after felling as possible and then at regular intervals during the seasoning process. A coating of petroleum wax to the ends of the poles also helps to control any tendency to splitting.

Group 3—Starch Feeding Borers

These borers differ from other groups in that they confine their feeding habits to *sapwood,* the sapwood must contain an adequate level of starch for the nourishment of the larvae, and all pines and some very close-textured non-pines are immune to attack.

The principal wood-boring insects which come under this heading are commonly known as powder-post beetles and belong mainly to the genus Lyctus.

Other fairly common starch feeding borers, known as auger beetles, make much larger holes than lyctus.

The Powder-post Beetle (Lyctidae): The commonest form in Australia is known as *Lyctus brunneus,* and is a somewhat flattened, elongated insect varying from   to 3/16 inch in length, brown to dark brown in colour (see photo 31).

Unlike the shot-hole and pin-hole borers, which attack only green timber, the lyctus borer is found only in seasoned or partly seasoned timber.

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Essential Facts Concerning Attack; Until the following facts are clearly understood, there can be no intelligent understanding of the lyctus borer problem.

1. The lyctus borer confines its attack to the sapwood of certain hardwood* timbers. Its attack is confined exclusively to sapwood and it cannot infest the rest of the timber. Softwood timbers such as hoop pine, radiata pine, firs and so on, are never attacked by lyctus.

The sapwood is the outer ring of timber in a tree which extends from beneath the bark inwards to a thickness of ½ to 1 inch in most eucalypt timbers. It contains starch which provides the food for the lyctus borer. When a tree is cut into scantling sizes, and so on, small strips and edges of sapwood may be included on occasional pieces. Normally, in eucalypt timbers, the percentage of sapwood present is small and its destruction has no significant effect on the strength and stability of a building. An exception to this statement may occur with small dimension timbers such as tiling battens where the percentage of sapwood may be high in relation to the dimensions of the timber.

In some Queensland and New South Wales scrub timbers, for example, white cheesewood and white birch, a band of sapwood many inches in thickness may be present. In certain species, such as spotted gum, starch occurs deeper than the apparent sapwood. In some species, too, the sapwood—the living timber containing starch—occurs right to the heart of the tree. Many of these timbers are susceptible to lyctus attack and are liable to very extensive damage. Unless treated to give complete penetration of the sapwood with a toxic chemical, they should not be used in any permanent construction.

2. The lyctus borer does not attack the living tree or the green log, but almost as soon as timber is cut and surface drying has occurred the sapwood becomes susceptible to lyctus attack.

Because the lyctus borer is very widespread throughout Australia, breeding in dry forest logs, dead trees, sapwood off-cuts, and so on, the chance of infestation during the first year after cutting is high.

In some hardwoods the sapwood is very susceptible to lyctus attack, while in other very similar timbers it may be completely immune from attack.

Two conditions govern the susceptibility or non-susceptibility of the sapwood of any species (or tree); these are (a) starch content and (b) pore size.

(a) Starch is essential for the nutrition of the borer and usually the more starch present the greater the extent of the attack.

(b) The pores in the timber must be large enough to allow the female beetle to insert her eggs into them. Hardwoods (pored timbers) such as alpine ash *(Eucalyptus gigantea)* and mountain ash *(E. regnans)* have a sapwood with sufficiently large pores for egg-laying to occur, but as they

* The term "hardwood" is used throughout this section in its botanical sense. In addition to the eucalypts, hardwoods include timbers which in New South Wales and Queensland are known as "scrub" timbers and also as "softwoods", e.g. silver silkwood (Putt's pine), white cheesewood (milky pine), yellow walnut, white birch, etc. These timbers although soft to work are not, botanically, softwoods. The true softwoods are the pines and firs such as hoop pine, cypress pine and Douglas fir, etc.

are almost completely free from starch they are practically immune from lyctus attack. On the other hand, messmate stringybark *(E. obliqua)* and spotted gum *(E. maculata)* usually have a sapwood of very high starch content and are thus very susceptible to lyctus borer attack.

In certain other hardwood timbers, usually non-eucalypts such as southern sassafras *(Atherosperma moschatum),* the sapwood is never attacked, not always because of lack of starch, but because the pores in the timber are too small for the female lyctus to insert her eggs.

Since they lack pores, all softwoods, for example true pines, firs, spruce and so on, are immune from lyctus attack.

The Iodine Test: The presence of a starch content in sapwood may be detected by means of a simple process—the iodine test. An iodine solution is prepared by dissolving ½ ounce of potassium iodide in a small amount of water. Then ¼ ounce of iodine crystals is dissolved in this solution by constant stirring, additional water being added to make up to 1 quart. To test for the presence of starch, apply a small quantity of the solution with a brush or the tip of the finger to a cleanly cut timber surface. Best results are obtained on a quarter-cut face. The appearance of a dark blue colouration shortly after the application denotes the presence of starch. The reaction is more rapid in green timber than in dry.

Recognition of Lyctus Borer Attack: Most of the damage to timber by lyctus borer is caused by the larvae which, when hatched in the timber, bore in the sapwood forming a network of connected tunnels closely packed with a fine powdery dust.

Lyctus attack is easily identified by the abundant flour-like dust which is packed in the tunnels in the timber and which often forms small heaps beneath the flight holes made by the escaping beetles.

Common Fallacies: There is a widespread belief that once lyctus attack has begun in a piece of timber it will spread throughout the piece until it is completely destroyed. This belief is, of course, quite erroneous because lyctus attack is confined to the susceptible sapwood. Once this sapwood has been destroyed, no further damage will occur, the rest of the timber being completely immune from attack.

Another common fallacy is the belief that if the lyctus borer is present in scantling or other hardwood timber in the house, furniture and other decorative woodwork may be attacked and destroyed. Firstly, if the furniture and so on, is a true softwood such as fir, pine or spruce, the lyctus borer cannot attack it under any circumstances; secondly, if it is a hardwood it can only be attacked if it contains susceptible sapwood.

In general, if untreated hardwood timber shows no sign of lyctus attack after two or three years use then it is probably safe for all time from damage by this borer.

It is sometimes claimed that kiln-dried hardwood will never be attacked by lyctus. Kiln drying will kill all stages of the lyctus borer present in the timber but, if it is unprotected, the susceptible sapwood is again liable to attack.

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Control and Remedial Measures: As mentioned previously, the maximum lyctus attack which can occur in sawn eucalypt hardwood is limited to strips or edgings of sapwood. Destruction of these strips does not significantly endanger the strength of a structure.

It is thus seldom necessary to treat such timber unless a decorative effect is involved or the falling dust is a nuisance.

In special cases such as pergolas or log cabins where round timbers are used, or fence palings which may contain a high percentage of sapwood, treatment is most desirable and in fact necessary if economic use of the timber is to be obtained.

Creosote oil should not be used indoors on account of its odour and the danger of staining. The fixed copper-chrome-arsenate preservatives offer a suitable alternative with the added attraction that they have no odour what-soever and can be stained, varnished or painted. The amount of lyctus borer damage which can occur in eucalypt scantling timbers in Australia is never likely to cause a significant loss in the strength of a structure, unless in small sizes such as tile battens etc. The expense of spray treatments is not justified by minor damage which involves no decorative effect. Douglas fir (Oregon) and cypress pine scantlings, being of non-pored species, are immune to lyctus borer.

It sometimes happens that some timber used for flooring, skirting boards, door architraves, shelving and even furniture will contain susceptible sapwood which is attacked by lyctus. Sometimes the damage to the appearance is sufficient to make replacements of the piece of timber desirable, but in most cases simple remedial measures are sufficient.

Auger Beetles (Bostrychidae): The starch feeding auger beetles are elongate and cylindrical in shape, roughened on the cowl-shaped prothorax and sharply cut away posteriorly, while the colour varies from light brown to black. The number of species is not large, but rather extensive damage can be inflicted by them. The beetles of most species have the shot-hole borer habit of boring irregular galleries into freshly felled logs for egg-laying. These tunnels are made across the grain and may extend several inches, but they never exceed the sapwood.

The curved and fleshy larvae, with three pairs of short legs, tunnel along the grain in the timber subsisting mostly on starch. For this reason their attacks cannot be extended beyond the sapwood. Normally, the grubs are numerous and soon cause extensive damage. Most of the species are widespread and attack a number of different timbers, more particularly those containing abundant starch.

Large auger beetle (Bostrychopsis jesuita): This is the most destructive species and attacks rain forest timbers as well as open forest species (see photo 31). The holes are often irregular and about ¼ inch in diameter and the insect can complete its life cycle in, but not reinfest, seasoned timber.

Small auger beetle (Mesoxylion cylindricus): This beetle is more commonly in sawn timber than the large auger beetle and its presence usually indicates sapwood containing starch. The egg galleries are simple transverse tunnels

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directly into the sapwood. Beetles usually occur in pairs and after egg laying the female dies at the tunnel entrance where the truncated cylindrical body neatly closes the hole.

The larvae tunnel along the grain in the sapwood, and although damage is confined to this, the numerous larvae normally present can cause extensive damage and the large emergence holes, about 1/12 inch in diameter, usually cause alarm.

The life cycle of the large auger beetle requires 11-12 months, but the smaller species can complete development in 6-7 months during summer.

Treatment with Insecticides: Recent work on the control of lyctus has led to the discovery and use of several very effective preservatives for dry timber which may be applied in such cases. Treatment should be made as soon as the first holes are noticed, as lyctus attack develops rapidly. The following methods are recommended.

Treatment with insecticidal solutions should be made with the object of obtaining good penetration of the preservative into the flight holes. This can be achieved by dipping, by liberal brush application, by flood spraying, or by injecting the solution into the holes with a pressure syringe. Pressure syringing is most applicable to decorative work where treatment must be made with minimum risk of affecting the finish.

The following solutions are effective if correctly used. Since they contain organic solvents they may affect painted, varnished or polished surfaces and caution is needed when injecting them into flight holes to avoid spilling. Treated timber may be finished as desired.

Pentachlorphenol: This chemical is a crystalline solid and should be dissolved in kerosene or mineral turpentine at the rate of 1 oz. to the pint of solvent. It may be necessary to add a small amount of methylated spirit or a somewhat greater quantity of linseed, pine, or castor oil to the kerosene or mineral turpentine to obtain complete solution of the chemical. The amount of spirit added should be kept to a minimum to avoid marring polished surfaces. Pentachlorphenol is available as a 5 per cent solution at most hardware stores under trade names.

Zinc or Copper Naphthenate: Both chemicals are readily available as prepared 20 per cent solutions in kerosene or mineral turpentine. They may be diluted to half strength with either of the above solvents. Zinc naphthenate is colourless, but copper naphthenate stains woodwork a deep green and its indoor use is therefore limited to articles which are to be subsequently painted. Zinc naphthenate is about half as toxic to lyctus as copper naphthenate.

Paradichlorbenzene or Orthodichlorbenzene: Paradichlorbenzene is a solid and orthodichlorbenzene is a liquid, and both chemicals may be purchased cheaply at most large chemical warehouses.

Either chemical, dissolved at the rate of 1 oz. to a pint of kerosene is highly effective in destroying lyctus within the timber, but the effect is not permanent unless the treated areas are sealed off to prevent re-infestation. It is therefore necessary to plug the holes and wax, varnish, or paint the surface within a

few weeks of treatment. (This is unnecessary with pentachlorphenol and the metallic naphthenates, but it is an additional precaution which may well be followed in all cases.)

Benzene Hexachloride (B.H.C.): This is a chlorinated hydrocarbon insecticide available in dispersible powder, miscible oil, dust and smoke generator forms, and has been found to give control of termites and of lyctus, anobium, ambrosia and other wood-boring beetles. The crude form of benzene hexachloride has a strong persistent odour, but the purified form, known as Lindane and containing 99 per cent or more of the gamma isomer, the only actively insecticidal form of chemical, is a white odourless powder.

Aldrin and Dieldrin: These are chemically related to the insecticide Chlordane which was developed in 1951. They are both potent insecticides. Data on minimum effective application rates generally show them to be from 1 to 10 times as effective as D.D.T. and Toxaphene, and from 1 to 5 times as effective as Chlordane and Lindane. Dieldrin is generally more effective than Aldrin, not so much because of higher initial toxicity, but because of its longer residual action. The potential use of these materials in approximate order of importance would appear to be the control of soil insects, grasshoppers, flies and mosquitoes, ants and termites, livestock pests, forest insects, army worms, household and stored product pests, flies and timber and fabric pests.

Other Insecticides: Creosote and creosote mixtures are satisfactory for killing most boring beetles and larvae, but as they stain woodwork and adversely affect subsequent finishing with polish or paint they are not suitable for flooring or furniture and should be restricted to application in out-houses, sheds and so on.

Kerosene, mineral turpentine, kerosene-turpentine mixtures or household fly sprays containing D.D.T. may be used if other preservatives are not available, but, while giving good control of insects already present in timber (with the use of a pressure syringe and so on), their effect is only temporary and their general use is not recommended.

Heat Sterilisation: Where applicable, heat sterilisation is quite effective provided temperatures not lower than 120° to 140°F are maintained overnight. However, this treatment will not prevent re-infestation unless flight holes are plugged and the surface sealed as soon as possible with wax, varnish or paint to prevent subsequent egg-laying in the pores of the timber.

Fumigation: Fumigation by reputable firms is an effective treatment for furniture, and so on, but should not be attempted by private individuals. Modern fumigants, applied after preliminary vacuum in closed cylinders, destroy infestation without affecting the finish or leaving objectionable odours. However, it should be stressed that fumigation does not prevent re-infestation unless holes are plugged and the surface sealed as soon as possible after the article is returned. Fumigation of houses to destroy borer attack is not practicable.

Commercial Use of the Boric Acid Process: This treatment has been developed by the Division of Forest Products in co-operation with the New South Wales and Queensland Forest Services as a commercial process for the complete

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and permanent immunisation of veneer and sawn timber against lyctus attack, where such timbers are not subject to leaching in service. The treatment is specially intended for certain Queensland and northern New South Wales timbers such as white birch, yellow carabeen, white cheesewood and so on, which have a wide lyctus-susceptible sapwood. Timbers of this type should not be purchased by timber users, except for temporary use, unless accompanied by a guarantee that the above treatment has been given. In New South Wales and Queensland, legislation has been enacted to control the sale of such timbers unless treated by the boric acid or other authorised process.

In brief, the treatment consists of immersing the green veneer* or sawn timber in a hot or cold solution of boric acid for varying periods according to the thickness and species of the timber. The treatment is non-staining and does not affect animal, casein or urea glues or the finishing properties of the veneer or timber.

The object of the process is to treat the timber completely with the preservative so that the treated material may be machined and worked without exposing any untreated timber. As the preservative is non-volatile, treated timber is permanently immune.

Further advice and information on this process may be obtained from the Division of Wood Technology, Harrington Street, Sydney; the Department of Forestry, Brisbane; or the Division of Forest Products, Melbourne.

Control of Lyctus Borer Attack in Plywood: The use of lyctus susceptible timber in plywood has been made possible as a result of recent research by the Division of Forest Products, Melbourne. Three metfiods are available.

1. The green veneer is immersed momentarily in cold boric acid solution, and then block-stacked to permit diffusion of the chemical in the timber.†

2. Toxic chemicals are added to the cold setting glues used in plywood manufacture. The most promising results obtained have been with D.D.T. and benzene hexachloride ("Gammexane").‡

3. The veneers either green, semi-green or dry are impregnated with one of the fixed copper-chrome-arsenate preservatives. This process not only renders them immune from lyctus attack but, as detailed earlier, provides a complete protection against all known forms of insect attack.

Group 4—Dry Timber Borers

These borers are important because of the ability of one species to destroy unprotected hoop pine and closely allied timbers in the coastal zone situated approximately south and east of the town of Monto in Queensland.

The Queensland pine beetle (Calymmaderus incisus) (Anobiidae): This beetle is particularly destructive to old pine floors of houses particularly in hoop, bunya and New Zealand white pine. Of shining dark brown colour,

* See D.F.P. *Newsletter,* no. 171. "A Momentary Dip Treatment for Green Veneers".
t See D.F.P. *Newsletter,* no. 171 and CSIRO *Journal* vol. 12, no. 1, Feb. 1939.
t See D.F.P. *Newsletter,* no. 180.

oval in shape, about $^3/_{32}$ inch long and nocturnal in habits, this beetle is rarely seen even though it is common.

Eggs are laid in cracks and crevices, on rough surfaces, and on the under surface and in the darkest part of floors. The young grubs tunnel across the grain, and eventually in all directions. With reinfestation the whole timber becomes so severely honeycombed that it may collapse.

The life cycle lasts three years or more. This does not favour rapid breeding, but normally destruction is proceeding slowly for many years before it is suspected. Damage can spread to unprotected pine in other parts of a house, as well as furniture. In no case, however, has re-infestation been found in walls originally and regularly painted, in polished furniture or in enclosed spaces under iron roofs.

It remains to be proved whether this destructive insect can seriously attack the exotic pines *(Pinus spp.)* of which increasing numbers of plantations are being established. In many respects its habits are similar to the Anobium or furniture borer of the same family; the frass of both consists of small, hard, egg-shaped sand like pellets.

Anobium (or Furniture Borer): This beetle is from $^1/_{10}$ to $^1/_4$ inch in length and reddish to dark brown in colour. The head is enclosed in a hood-shaped segment and, looking from above, the head proper is almost invisible. The wing covers appear finely furrowed due to rows of small pits or punctures which are well defined (see photo 31).

As with lyctus the chief damage to infested timber is due to the grub, or larvae, and the presence of a few flight holes of from $^1/_{32}$ to $^1/_{16}$ inch in diameter on the surface may mean extensive attack below.

Anobium attack, though far more uncommon than that of lyctus and confined as it is to certain types of timber* when it does occur, is much more serious because the borer will attack the truewood as well as the sapwood. If unchecked, anobium attack may proceed until the whole of the timber is destroyed or rendered worthless.

Essential Facts Concerning Attack: 1. Anobium borer attack is usually found in softwoods, although a few hardwoods are also attacked.

The principal native timbers in which attack has been reported in Australia are Queensland kauri, hoop and radiata pine. In addition, certain imported timbers are susceptible to attack. These include imported oaks, beech, birch, walnut and so on, and also various pines, firs and spruces such as New Zealand white pine and the so-called Baltic deals.

Except for a very few Australian hardwood timbers and some imported hardwoods, attack is most commonly seen in Australia in true softwoods such as New Zealand white pine, which is particularly liable to attack.

2. Freshly seasoned timber is seldom attacked, preference being shown for old dry woodwork.

As a result of this preference for old timber and the immunity of eucalypts from attack, most damage in Australia is seen in private homes, halls,

* Australian authorities agree that none of the Australian eucalypts and very few of the brushwoods are subject to attack.

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churches, and museums, where old timber exists, and in furniture and other warehouses where wooden articles or pieces of antique furniture are stored for a considerable number of years. Thus attack is commonly seen in old New Zealand white pine shelving or kitchen fittings and so on.

3. Both sapwood and truewood of susceptible timbers are liable to attack which usually occurs in the sapwood first but may spread later to the truewood, causing extensive damage. In most cases, however, the rate and extent of anobium attack is relatively greater in the sapwood than in the truewood.

4. Attack may continue in the same piece of furniture or timber for many years as re-infestation of the timber by each successive generation of beetles occurs, unless remedial measures are taken.

Recognition of Anobium Attack: It is important to distinguish carefully between anobium and lyctus attack, because of the much more extensive damage which may be caused by anobium. With anobium attack, very thorough treatment is always necessary for eradication; with lyctus attack treatment, if necessary at all, is usually simplified by the small percentage of susceptible timber present. The following differences should enable certain identification of these borers in almost all cases.

TABLE 27

ANOBIUM AND LYCTUS ATTACK

Anobium	*Lyctus*
Eucalypt timbers not attacked.	Eucalypt timbers commonly attacked.
Attack more frequently found in true softwoods and in some imported hardwoods.	True softwoods never attacked. (See footnote p. 241)
Attack usually noticed only after woodwork is many years old.	Attack usually commences rapidly in new timber or woodwork.
Damage not restricted to sapwood.	Damage restricted to sapwood usually on the edges of occasional pieces of timber.
Borer dust when rubbed between the fingers feels coarse and gritty.	Borer dust very fine, smooth and flour-like,

It is important to remember that when the first signs of anobium (or *Calymmaderus*) infestation are discovered, active attack may have been in progress for over three years inside the piece of timber; therefore control or remedial measures should be taken as soon as possible after attack is detected. Fortunately, in Australia anobium attack is rarely found in building frame timbers as the majority of such timbers are eucalypt hardwoods, which, as previously noted, are virtually immune from attack by this borer.

Treatment with Insecticides: In general, treatment with insecticidal solutions should be made as for lyctus borer damage, q.v., with the object of obtaining good penetration of the preservative into the flight holes. All woodwork to be treated should be well dusted before treatment, and, if possible, a vacuum

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cleaner should be used to remove all dust and dirt from cracks and joints to provide a clean surface for treatment.

The preservative solutions and methods given for the control of the lyctus borer are also effective against anobium, although several applications may be necessary for complete eradication.

Fumigation ^{an}d Heat Sterilisation: Fumigation by reputable firms is an effective treatment for furniture and so on, but should not be attempted by private individuals. All woodwork which has been fumigated or heat sterilised (as described for lyctus) for the eradication of anobium attack should be treated with one of the permanent preservatives mentioned earlier if it is desired to avoid risk of subsequent attack.

The European house borer (Hylotrupes bajulus) (Cerambycidae): This longicorn menace to pines and softer non-pine timbers was introduced into Australia from Europe in pre-fabricated buildings after the 1939-45 war. So far as Queensland is concerned, it appears to have been eradicated after very heavy expenditure on fumigation, but the position in other States is uncertain. The European house borer attacks dry timber and continues to reinfest until total destruction is achieved. Flight holes are somewhat oval in shape and about y_f inch wide.

Sirex Wasp*: The wood wasps, whose larvae are the boring agents, are not common in Australia but recently have been identified in cargoes of timber imported into this country from Europe and New Zealand. The commonest type is the horntail wasp *(Sirex* tf/#a.v), the female of which is often mistaken for a hornet, its body having bands of yellow and black and the wings being clear and membranous. A long ovipositor projects from the end of the body.

The wood wasp is more the concern of the forester than the user of timber. It usually attacks unhealthy, dying or dead coniferous trees and, occasionally, mill Logs. It docs not attack seasoned timber and will not infest timber in house frames, flooring and furniture. Even if these wasps were found emerging from timber in buildings, and so on, they need occasion no alarm because they represent the final stages of a life cycle which started in the forest or the mill log. Re-infestation in the building will not occur.

*Group 5—Termites (White Ants)^*

Much of the damage caused by termite (white ant) attack in Australian buildings—involving losses of many thousands of dollars every year—could have been prevented if protective measures had been taken when the buildings were designed. The methods of protection outlined in this section, if carefully applied, will ensure that any type of timber used above the foundations is permanently immune from attack.

* See D.F.P. *Newsletter* no. 155: "The Horntail Wood Wasp" and Div. of Wood Tech. Forestry Commission of N.S.W., May 1951, "Siricid Wasps".

t Xhis section has been prepared by the Division of Forest Products, Melbourne for the Commonwealth Experimental Building Station, Ryde. Permission has been granted by the above authorities for its inclusion in this book.

Habits of Termites

Distribution: Most termite attack is found in the northern tropical belt of Australia but the hazard is sufficient in the southern states to constitute a more or less serious problem.

South of the Tropic of Capricorn, the greater part of termite damage to buildings is done by *Coptotermes acinacijormis,* and allied species of the genus *Coptotermes.* This species is almost Australia-wide in distribution; it forms large colonies, and appears to be spreading southwards. A large and destructive termite, *Mastotermes darwiniensis,* occurs sporadically in the tropical belt, and there constitutes a serious hazard. Other species of minor importance are found over a wide area of temperate Australia.

Termite Nests: Practically all the termite species causing serious damage to buildings in Australia are soil-inhabiting, or are always in close contact with the soil. The nest may be visible above ground as a typical termite mound, it may be completely under the soil surface, or it may be inside the hollowed-out butt of a green or dead tree or stump. Except when it is above ground, location of the nest may be extremely difficult.

Although one or two species of "dry-wood" termites, which can attack dry timber out of contact with the ground, do occasionally infest buildings and furniture in parts of Queensland, they are chiefly forest pests.

Colonising Flights: At certain periods of the year when it is warm and humid, flying forms of termites are common, and groups may enter buildings; these forms are reproductives, and, although they will establish a fresh colony if circumstances are suitable, the chances mat this will occur in a properly constructed building are negligible.

Termite Galleries: Most Australian termites attack structural timber from a central nest, through underground and above-ground galleries. If timber is on masonry, the foraging gallery is continued above ground as an earth-covered shelter-tube or rurtway built over the surface of brickwork or concrete or over durable timbers such as wooden house-stumps to make contact with more suitable food-material perhaps many feet above the ground. Extensive termite damage on the third floor of an Adelaide city building has been recorded, the covered galleries being constructed inside the cavity wall.

Such enclosed galleries provide a traffic-way to and from the nest, and maintain the conditions of darkness and humidity essential to all termite castes except the winged reproductives. Once the galleries are broken and contact with the soil and nest severed, termites isolated above the break can do little further damage, and die out unless contact with the soil can be restored.

The Likelihood of Attack: Local knowledge is the best guide to the severity of the hazard in a particular area; the risk, however, is relatively severe in Adelaide, Brisbane and the dry inland and north of the Tropic of Capricorn, moderate in Sydney and Perth, and slight in Melbourne.

Methods of Termite-proof Construction

The Principle Involved: There is no easy method of eradicating termites once established in a building. Measures taken during planning and construction
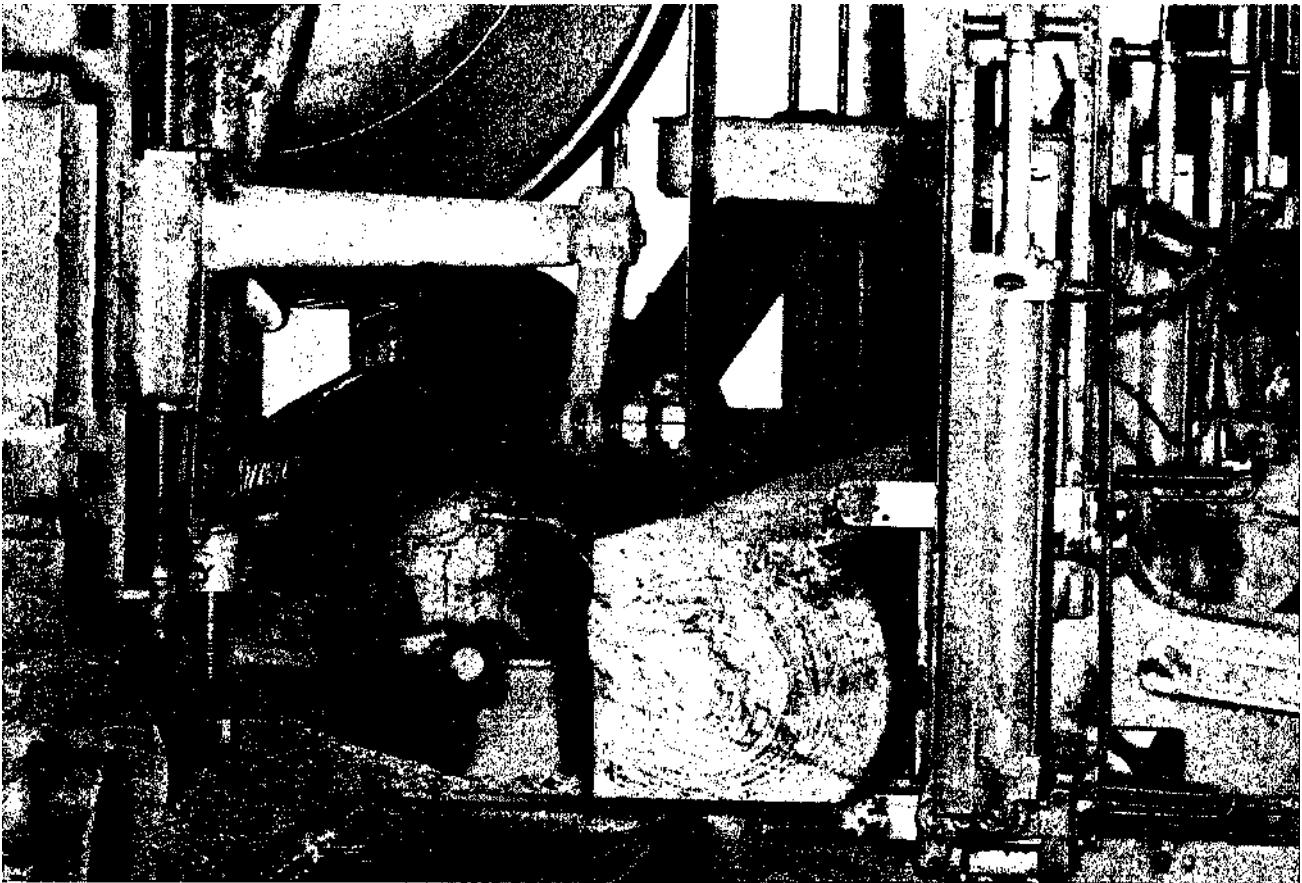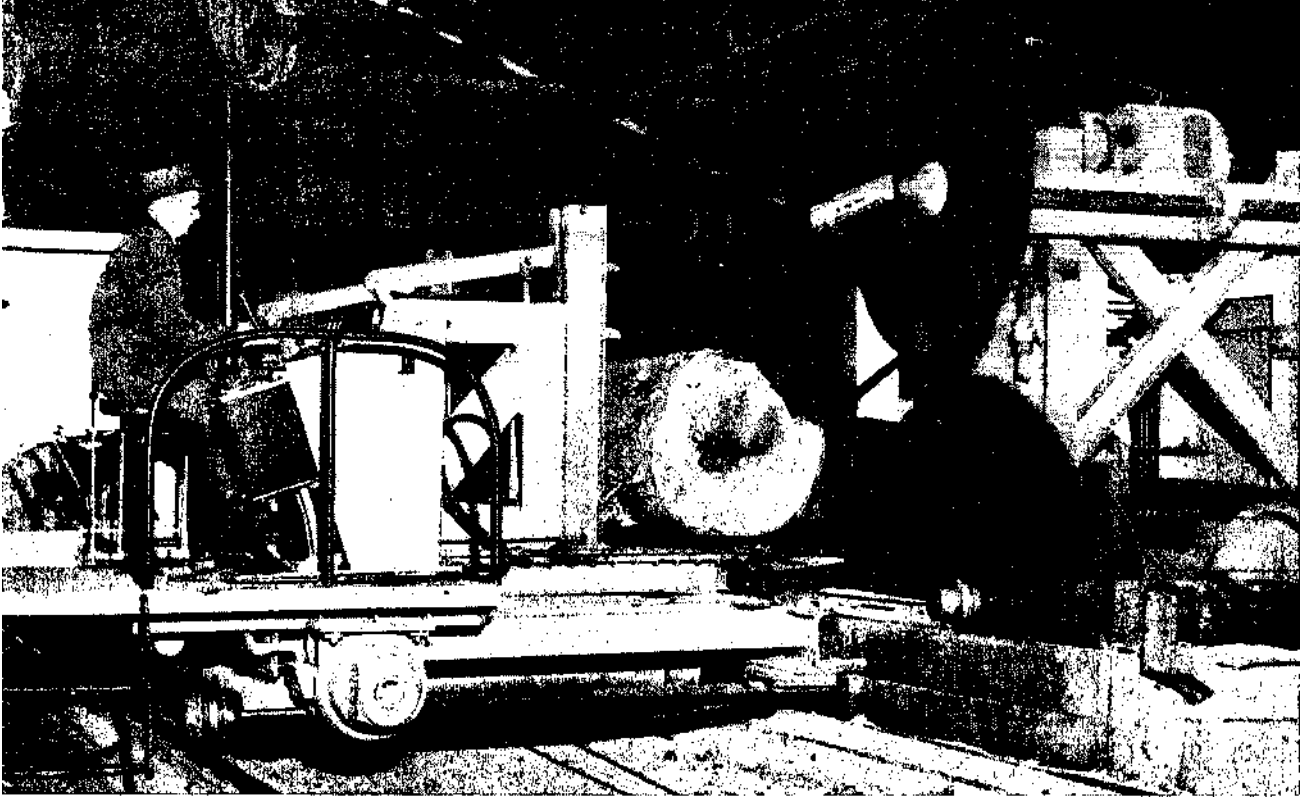
1. ABOVE: twin circular saw breaking-down unit.
2. BELOW: log bandsaw and carriage.
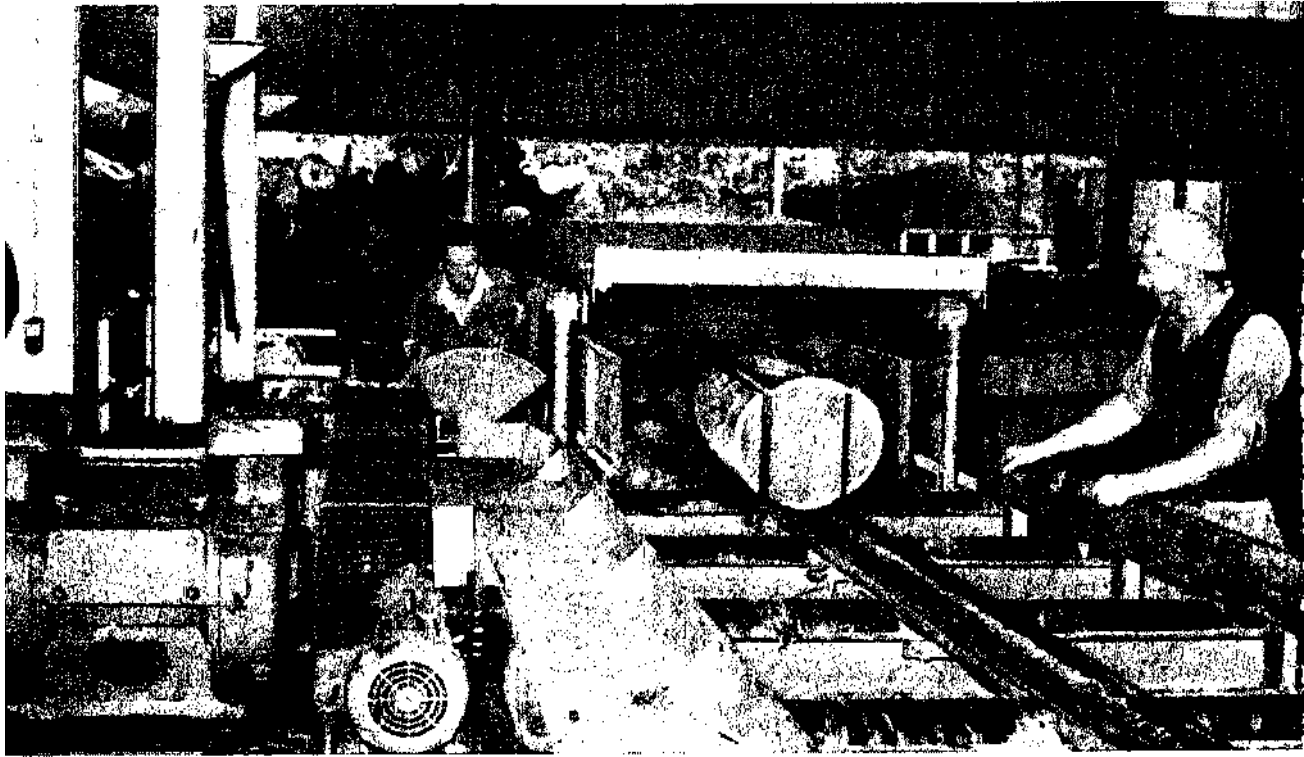
3. ABOVE: the log edger.

4. LEFT: the gangsaw.

5. BELOW: gangsaw sash and cutting blades.
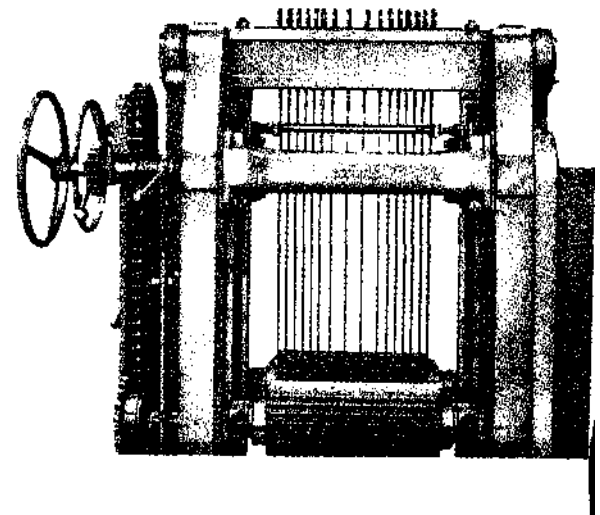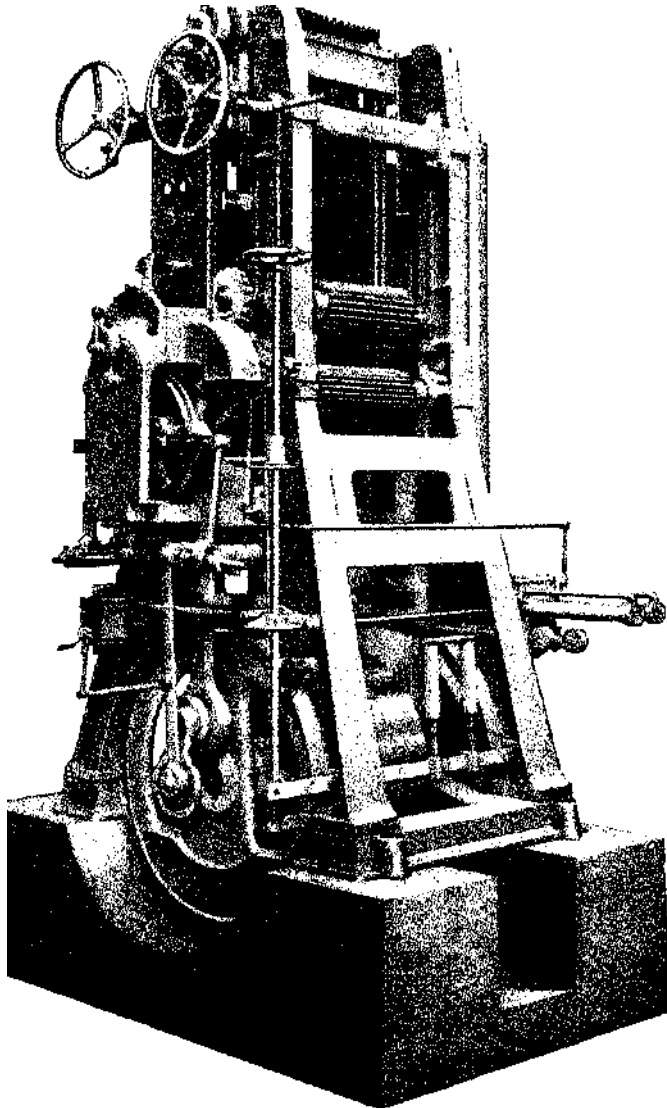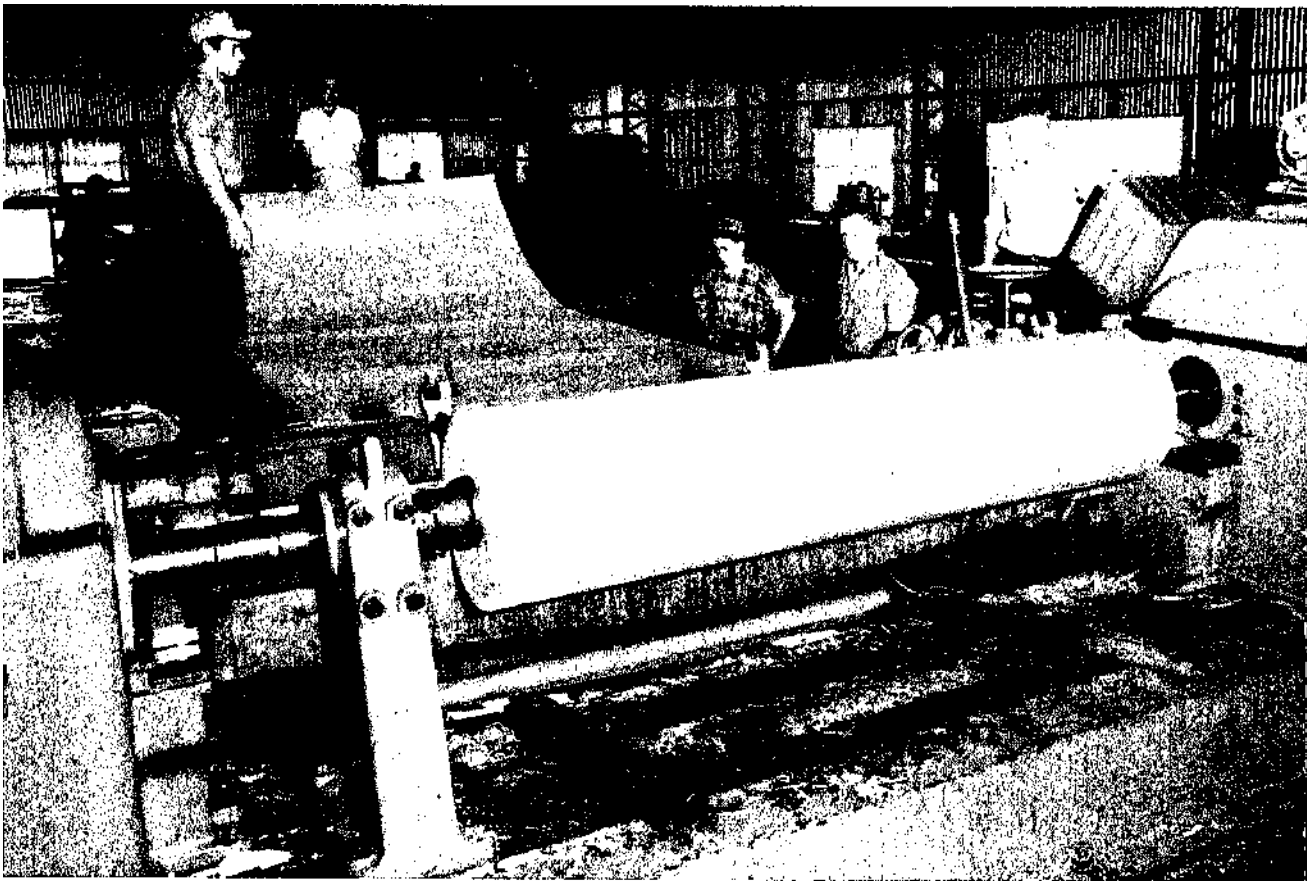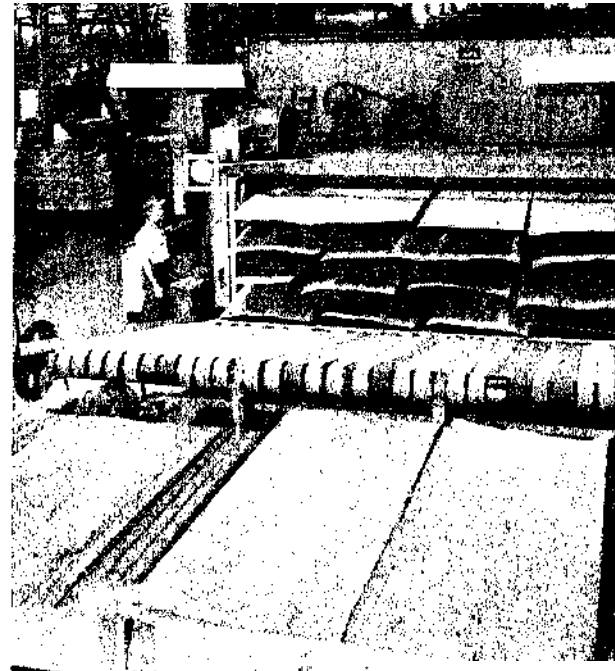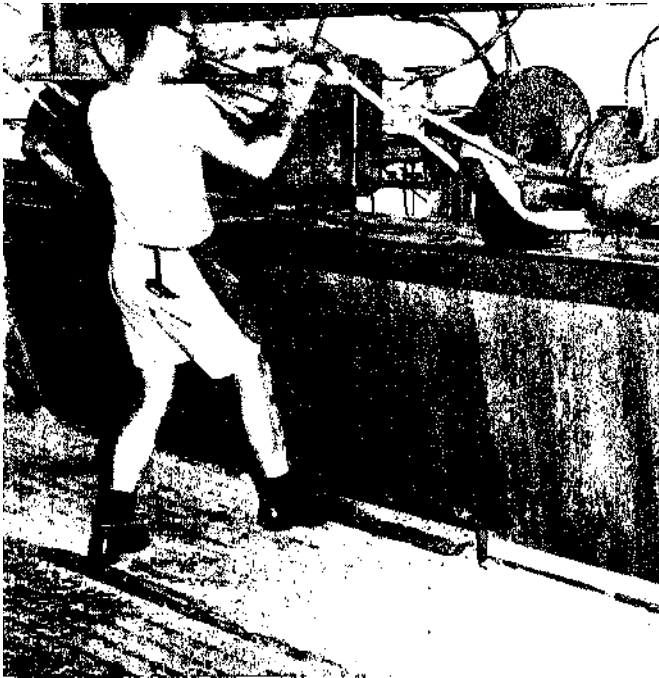
6. ABOVE LEFT: a machinist operating trenching and docking saws.

7. ABOVE RIGHT: modern mechanical drier and veneer sorting area. *{Plywood Association oj Australia)*

8. BELOW: typical lathe used for rotary peeling of veneer logs. *{Plywood Association of A ustralia)*
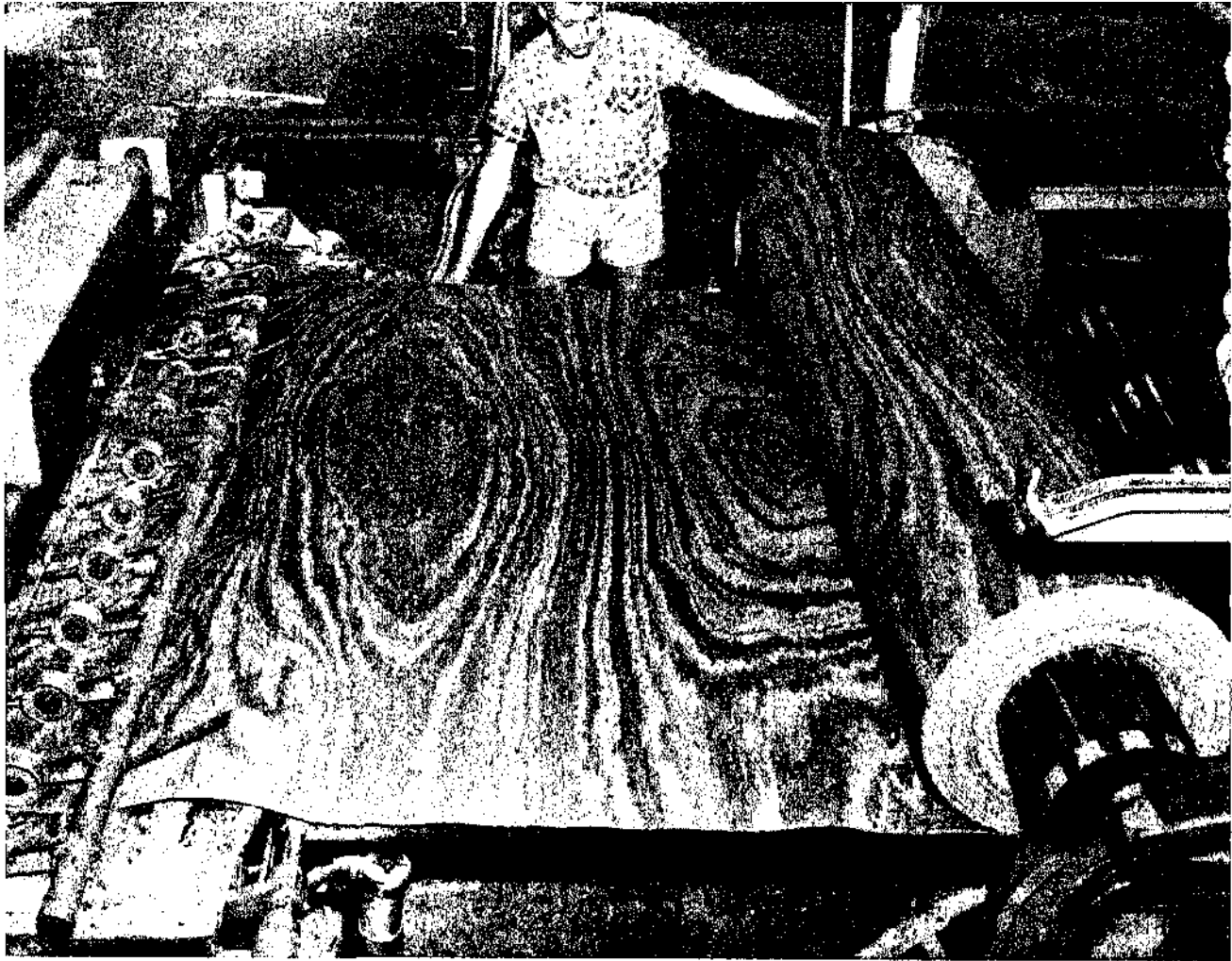
9. ABOVE: unreeling and clipping green veneer. *{Plywood Association of Australia)*

10. BELOW LEFT: the taping machine. *(Forestry Commission of New South Wales)*

11. BELOW RIGHT: glue spreading machine and plywood assembly. *(Plywood Association of A ustralia)*
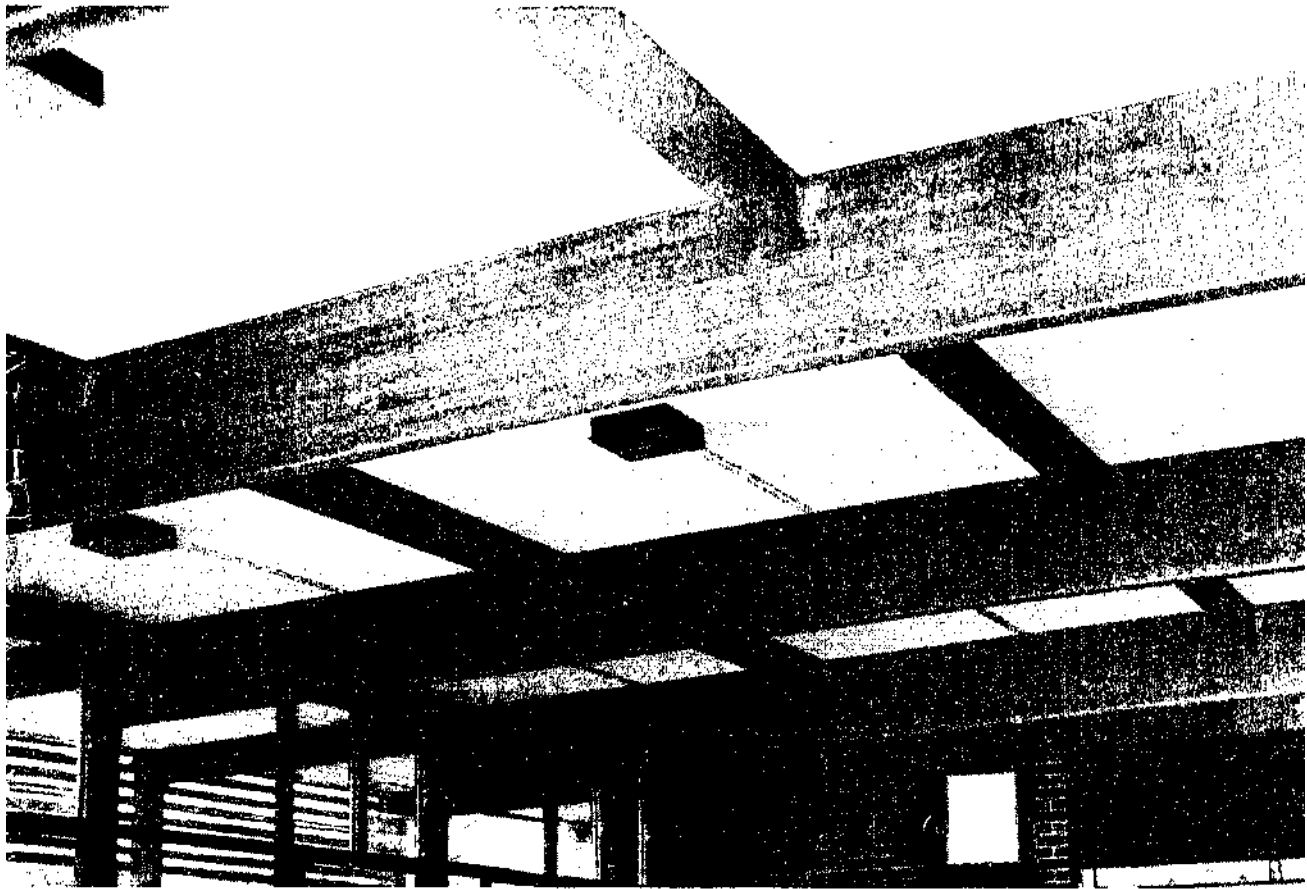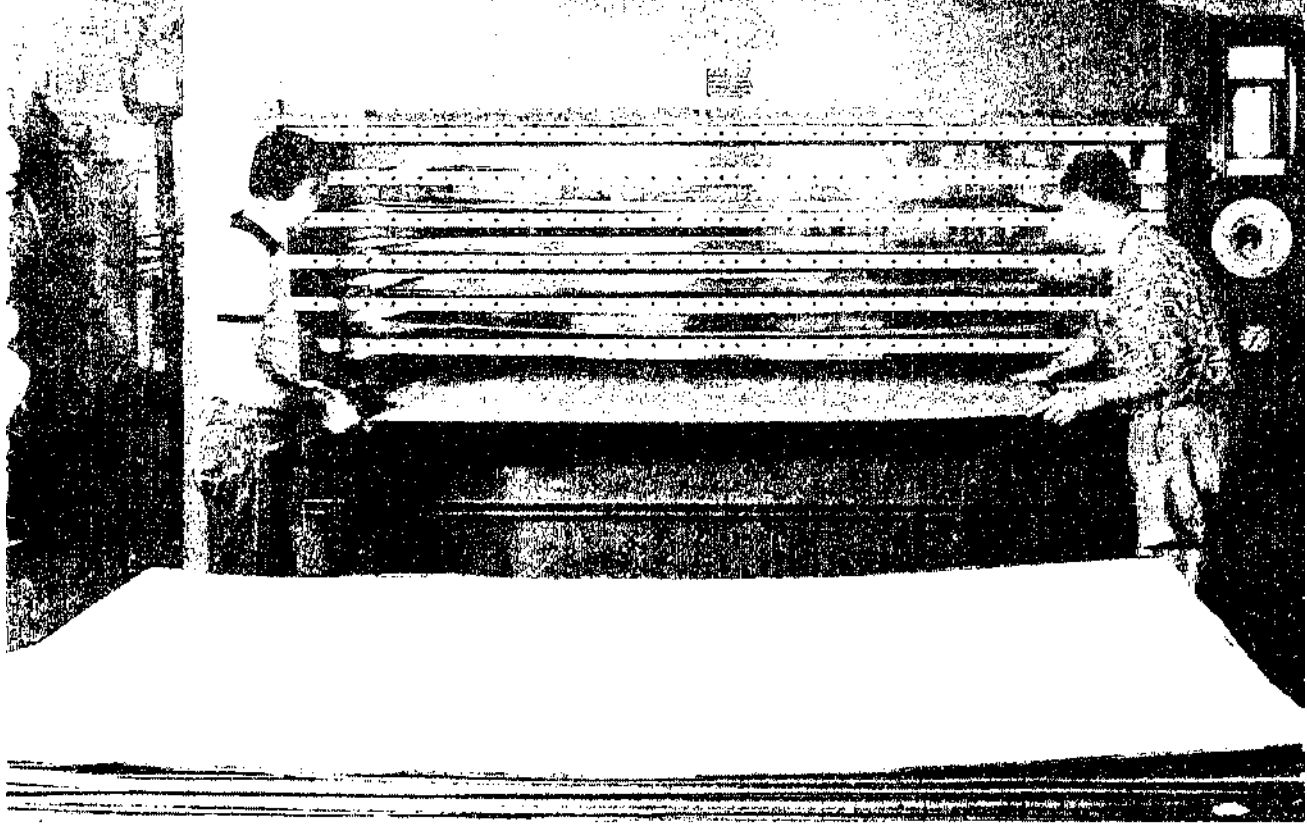
12. ABOVE: hydraulic press. (*Plywood Association of Australia*)

13. BELOW: laminated beams combine high strength with decorative appearance. (*Hancock Bros. Pty. Limited*)
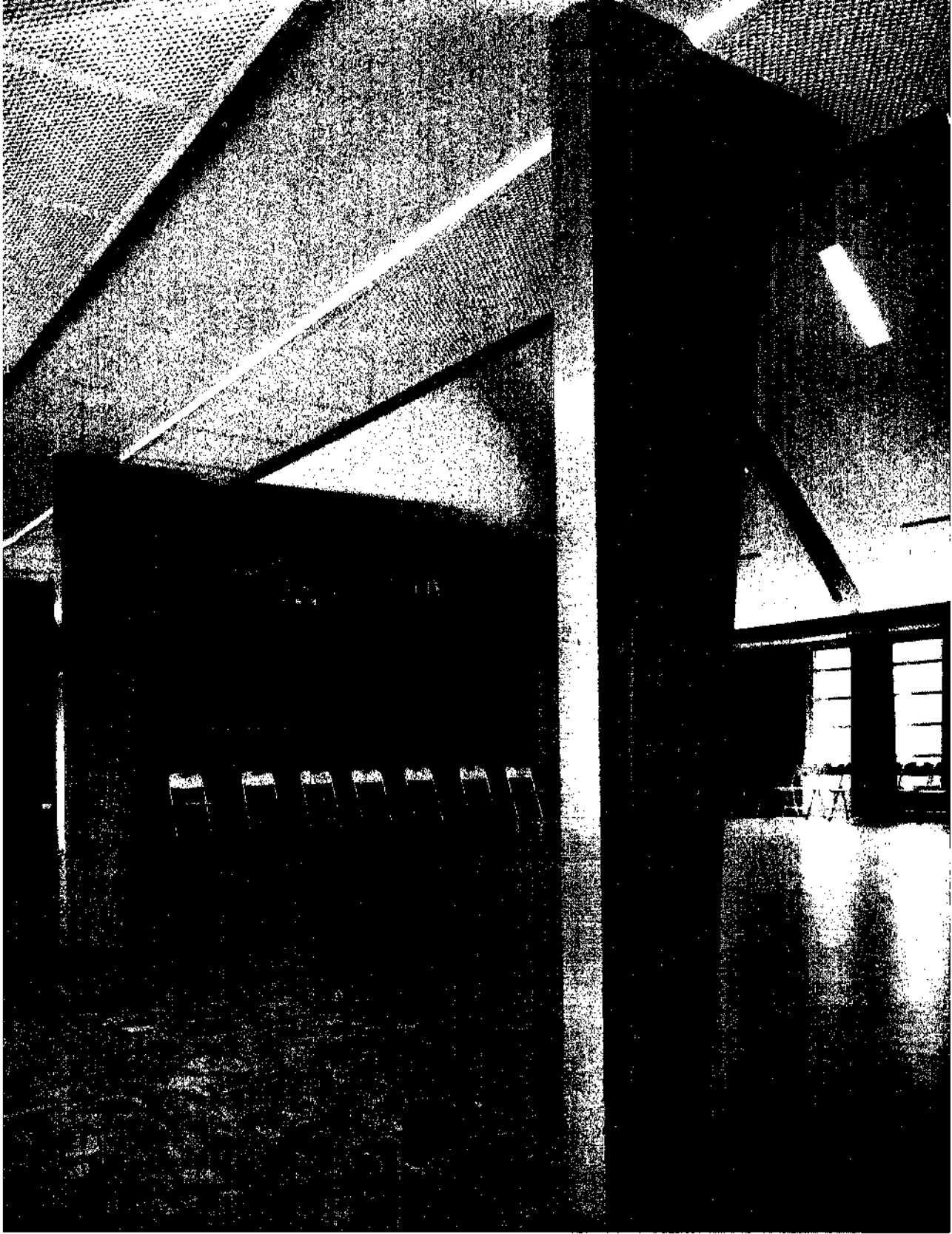
14. Glued laminated arches used in church hall at Janalli, New South Wales.
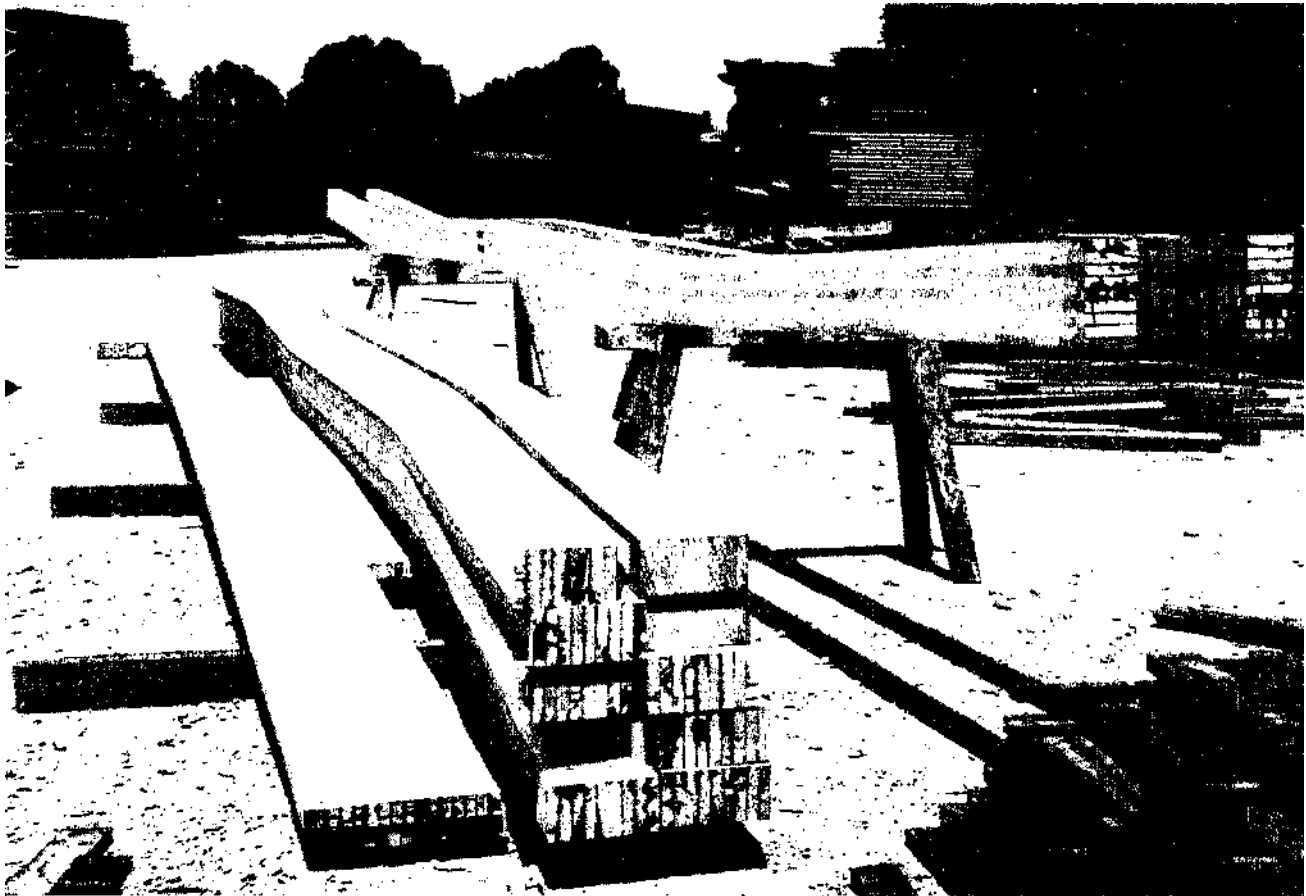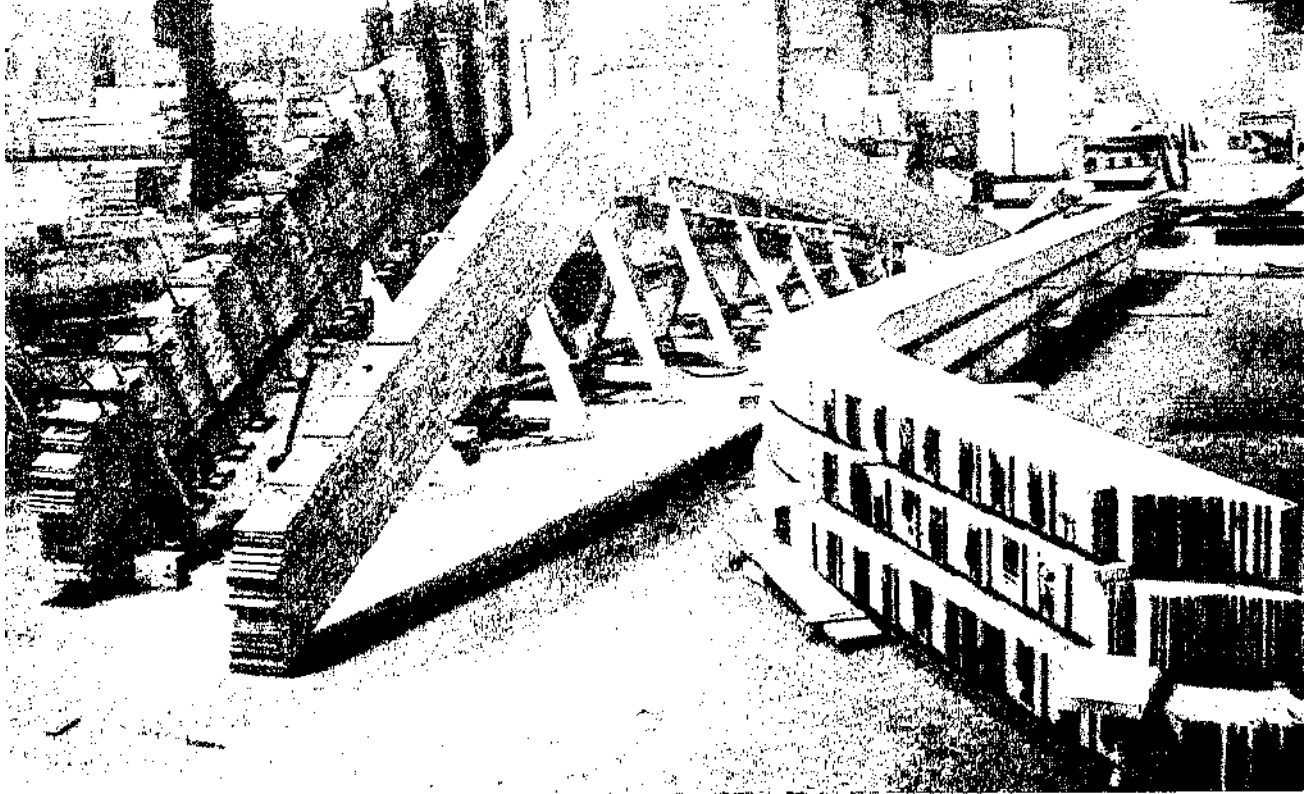
15. ABOVE: production of laminated timber arches.

16. BELOW: custom-shaped laminated cross-arms awaiting finishing stage of manufacture. *(Hancock Bros. Piv. Limited)*
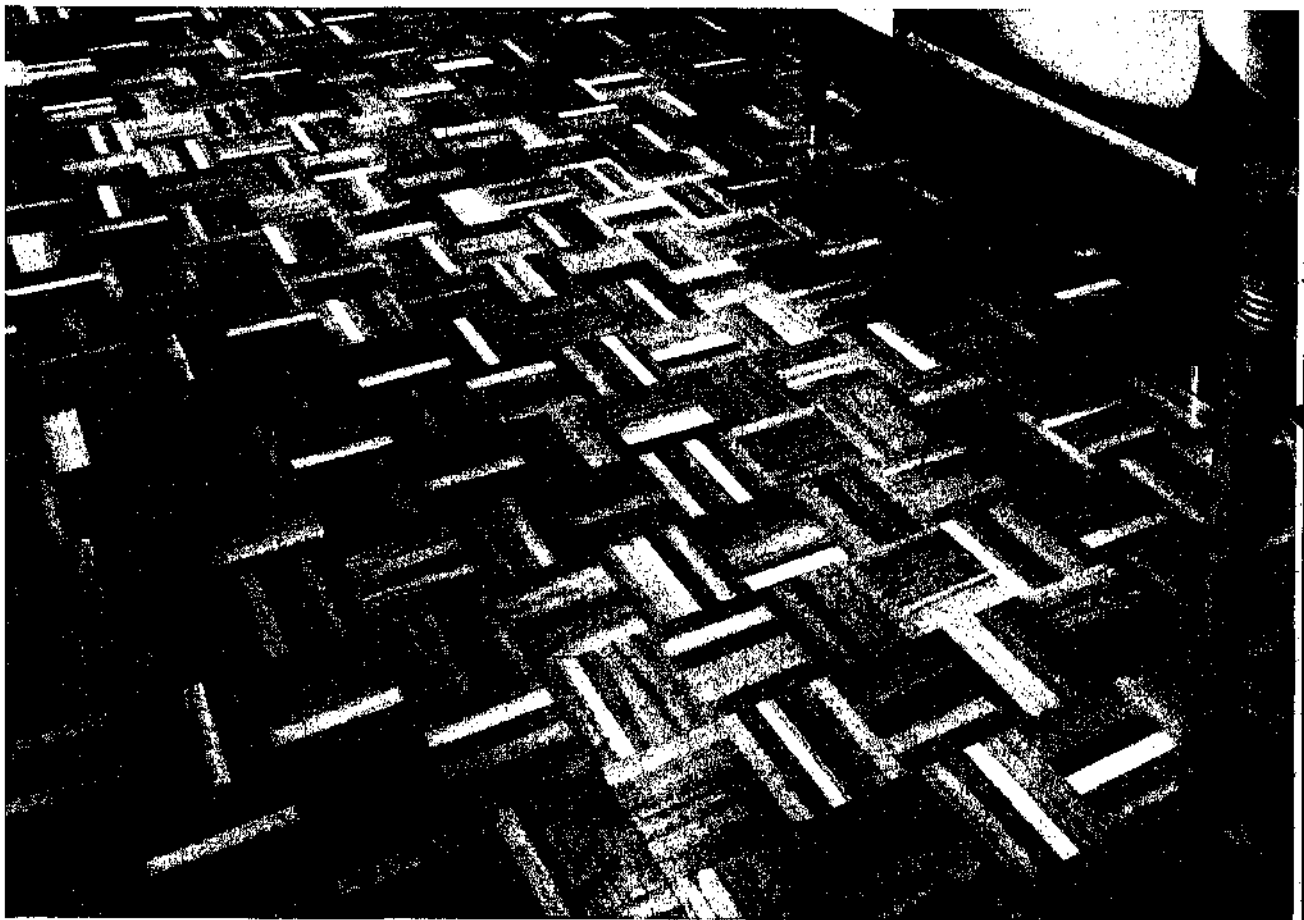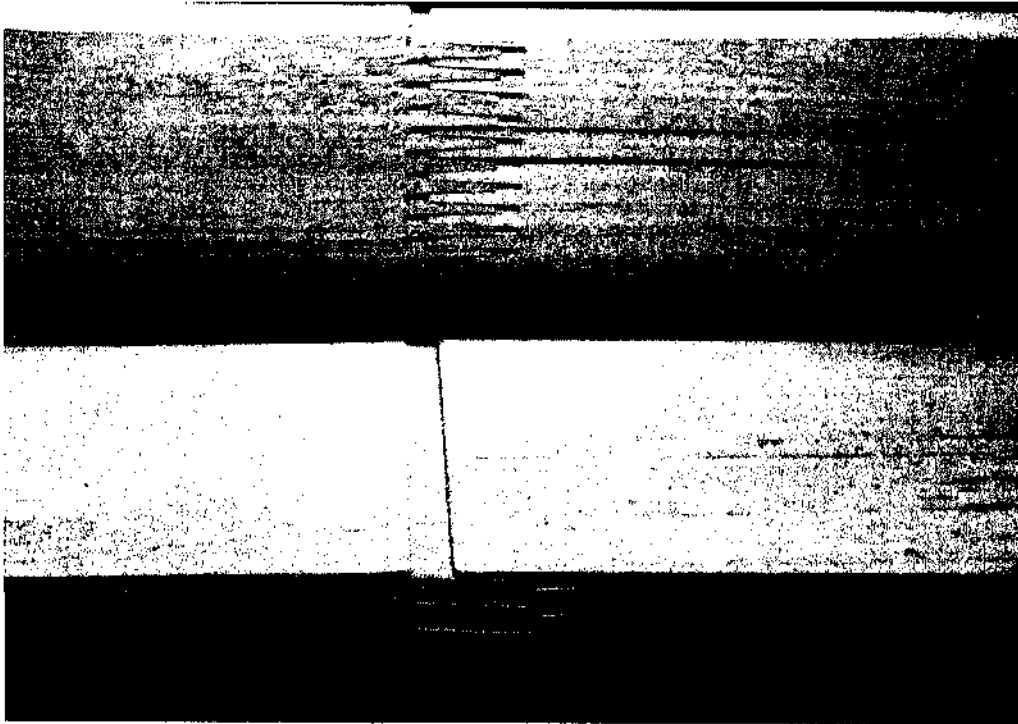
17. ABOVE: examples of horizontally (above) and vertically finger-jointed stock, with joints opened to show fingers.

18. BELOW: mosaic parquetry flooring. *(Timber Development Association)*
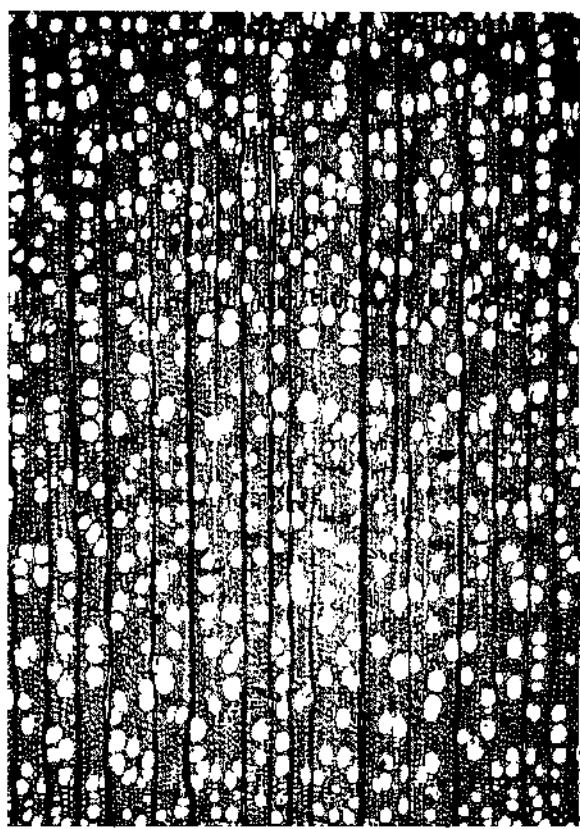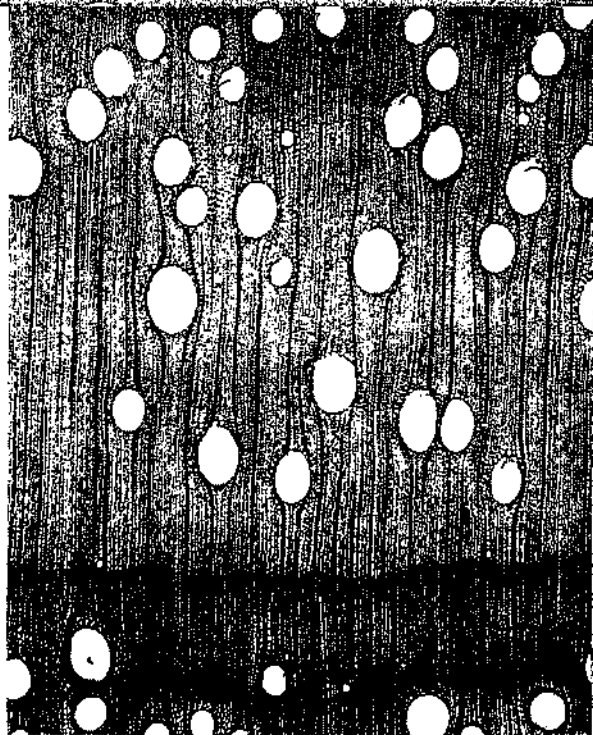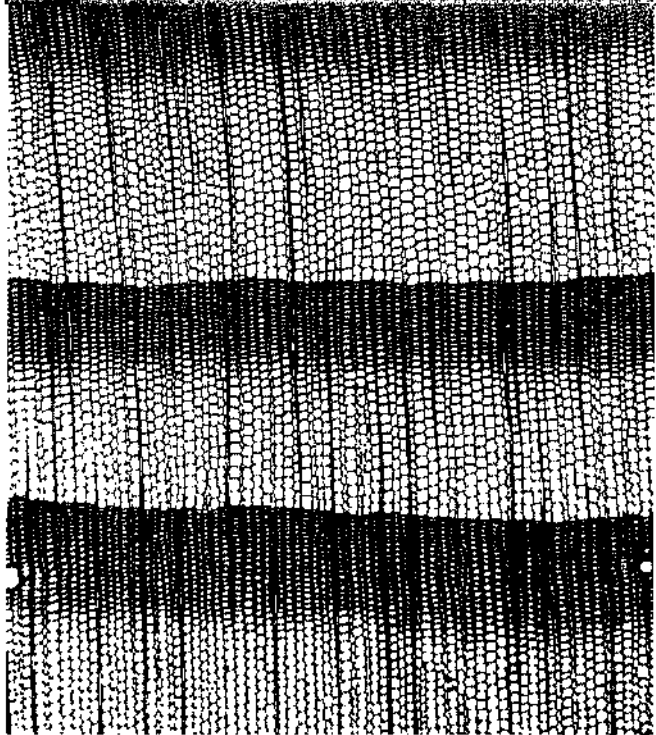
19. ABOVE LEFT: cross-section of a conifer showing complete growth ring. Note open spring wood, followed by more dense summer wood. The larger openings are resin canals.

20. ABOVE RIGHT: cross-section of an Australian hardwood *(E. delegatensis)* showing thinner walled cells of early wood (surrounding characteristic hardwood pores) and the thicker walled cells of the denser late wood.

21 BELOW LEFT: the characteristic figure of coachwood as caused by "soft tissue" or thin walled cells.
BELOW RIGHT: cross-section of coachwood showing horizontal bands of resin-filled soft tissue cells. (All photographs on this page *Division of Forest Products, C.S.I.R.O.)*
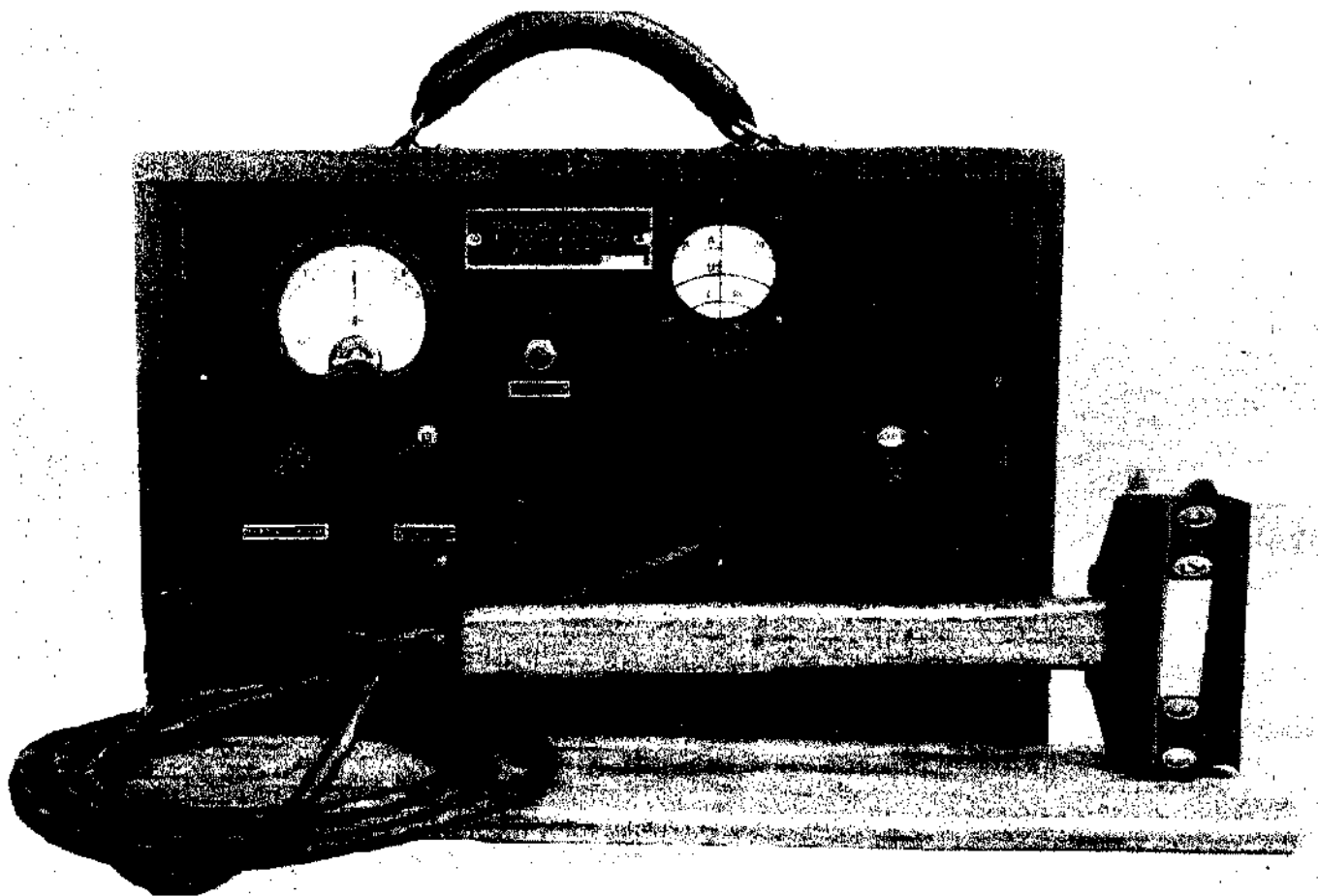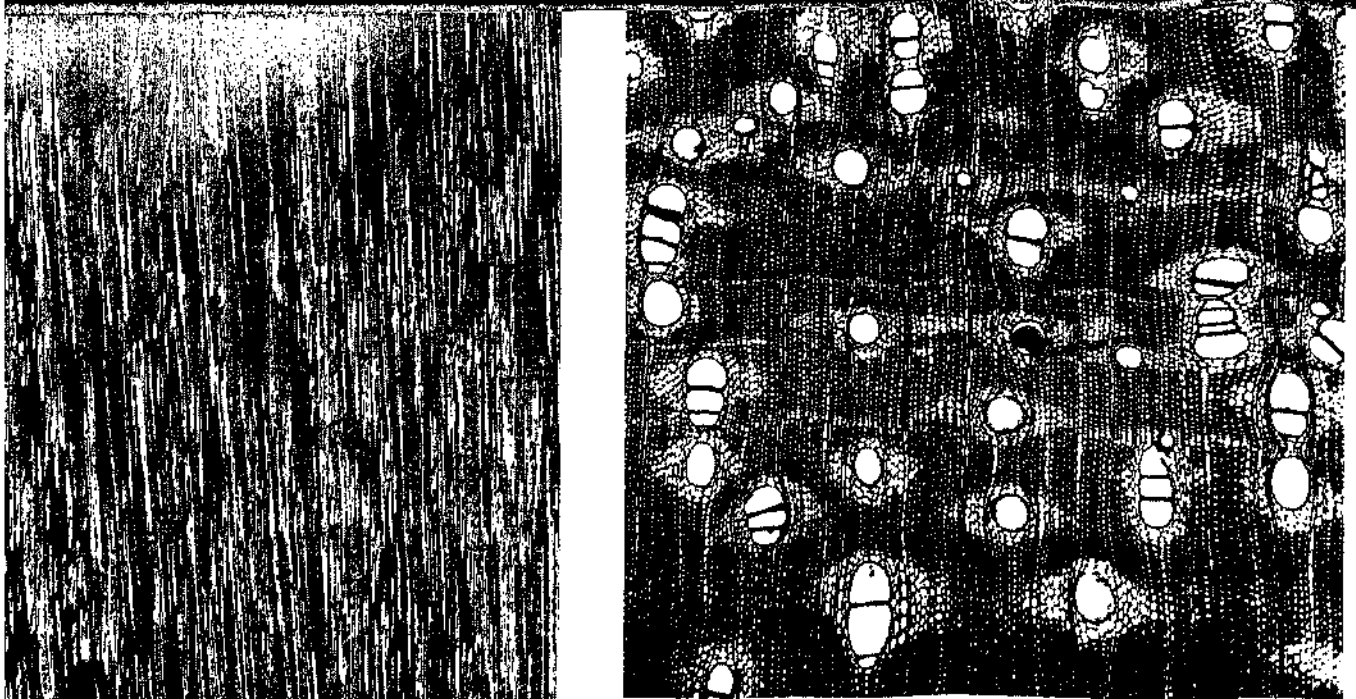
22. ABOVE LEFT: section of a board of black bean showing the prominent and contrasting figure due to the cells of soft tissue surrounding the pores.
ABOVE RIGHT: cross-section of black bean showing the position of these thin-walled cells surrounding the pores. *(Division of Forest Products, C.S.I.RO.)*

23. BELOW: an electric moisture meter, showing recording dials and two-pronged hammer driven into a board. *(Division of Wood Technology, Forestry Commission of New South Wales)*
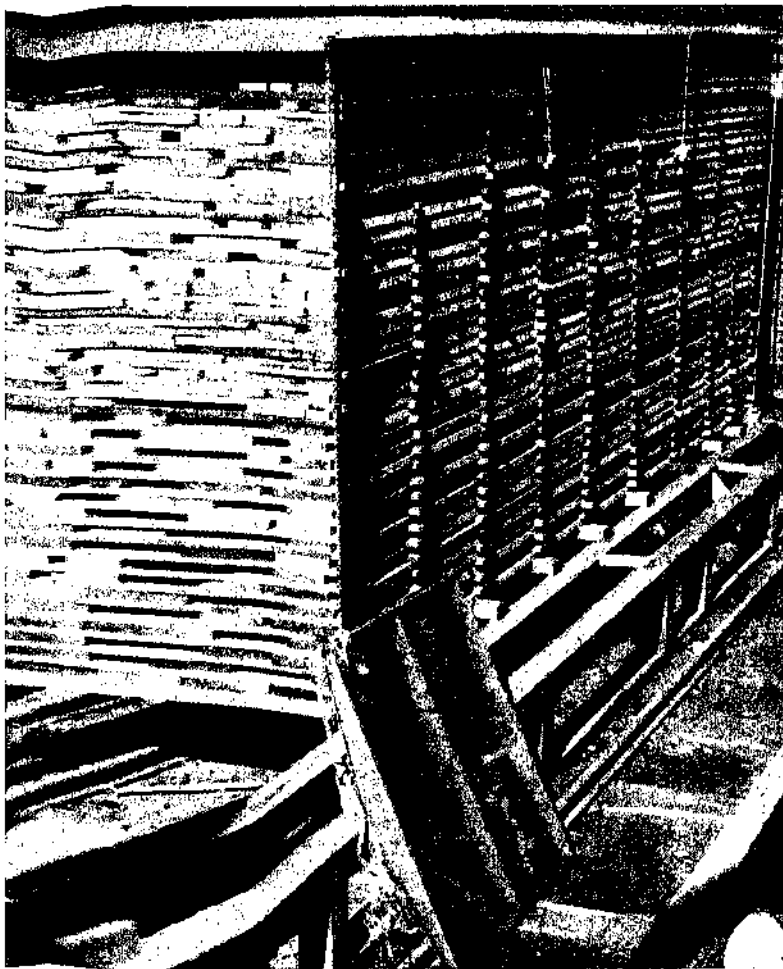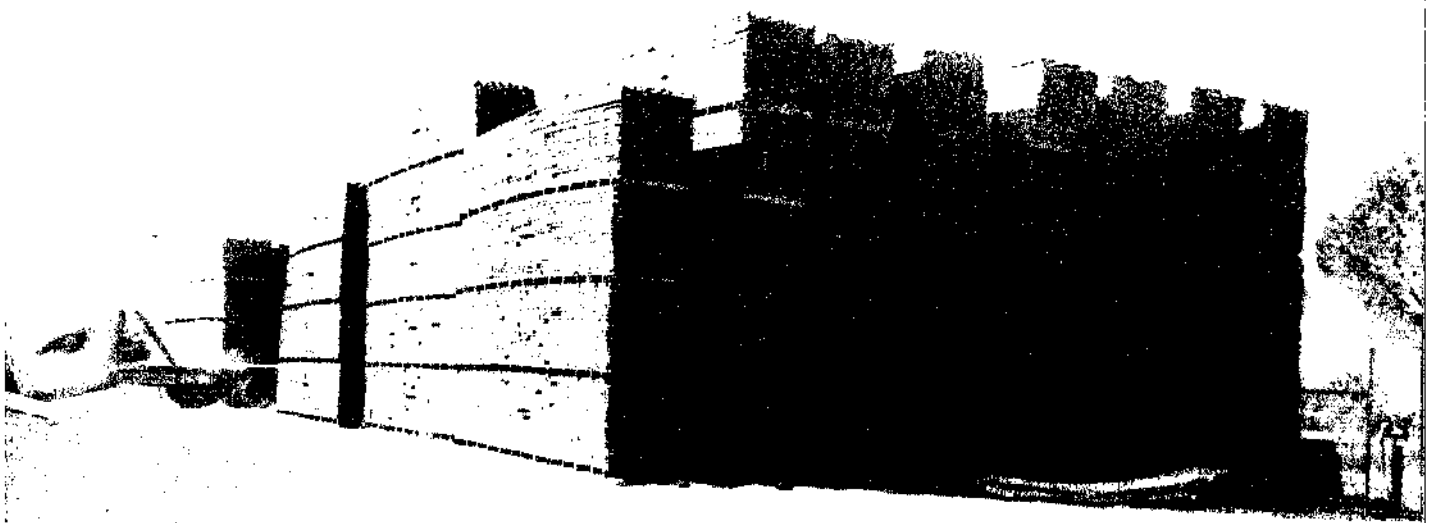
24. ABOVE: stacks of timber during air seasoning.

25. BELOW: timber should be protected from the sun and rain during air season-
ing. This stack has small pre-fabricated plywood covers, one of which is in
the foreground.
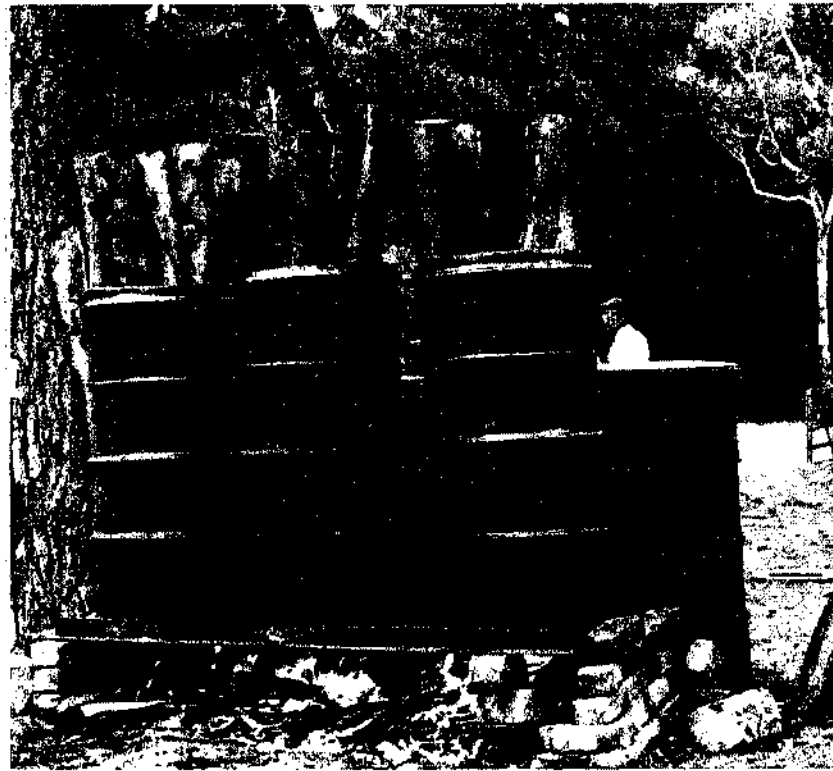
26. ABOVE: a stack (charge) of timber being removed from a kiln drier. *(Timber Development Association)*

27. BELOW: fence posts being preservatised by the hot-and-cold soak method.
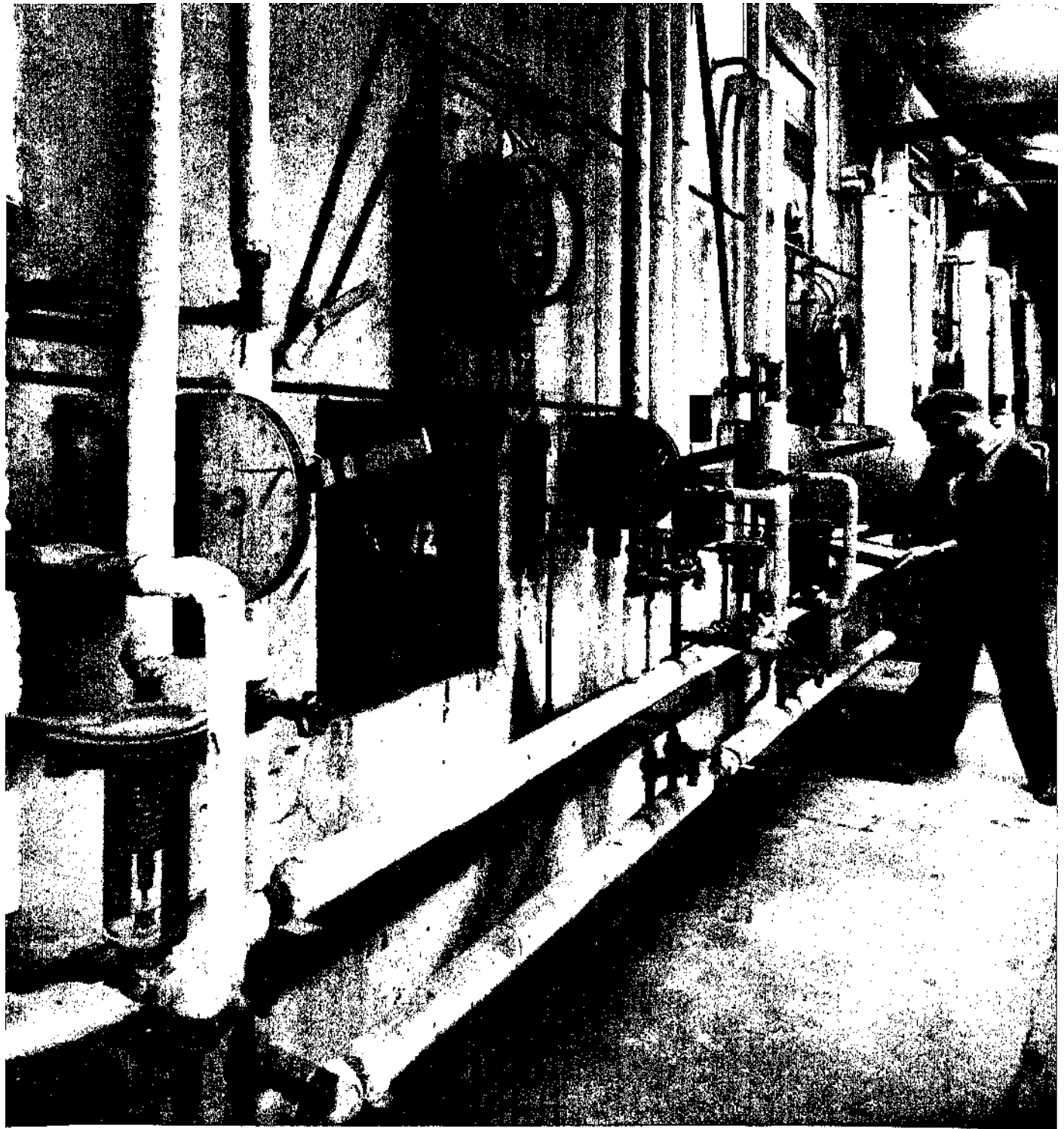
28. The control apparatus of the kiln drier.
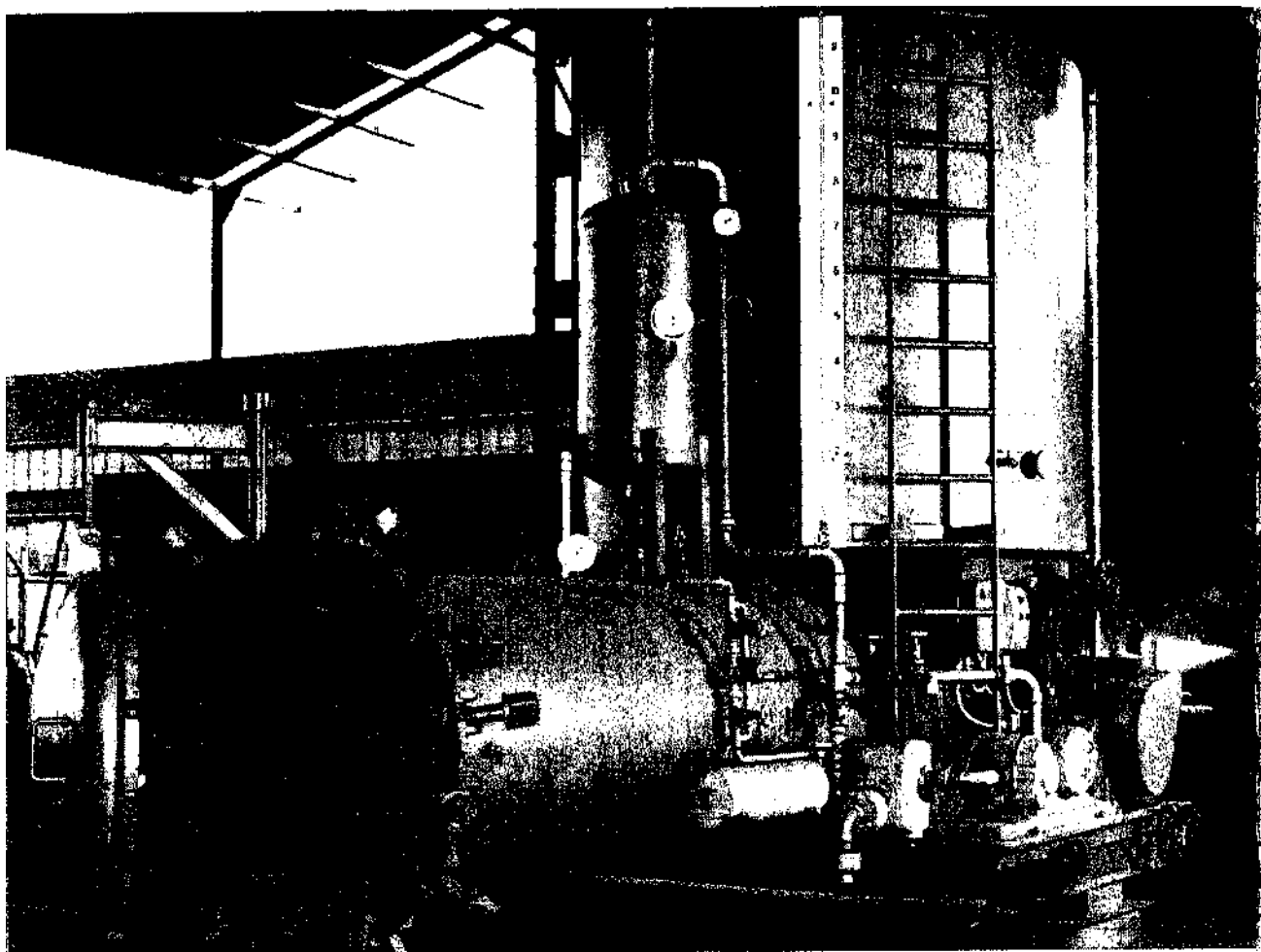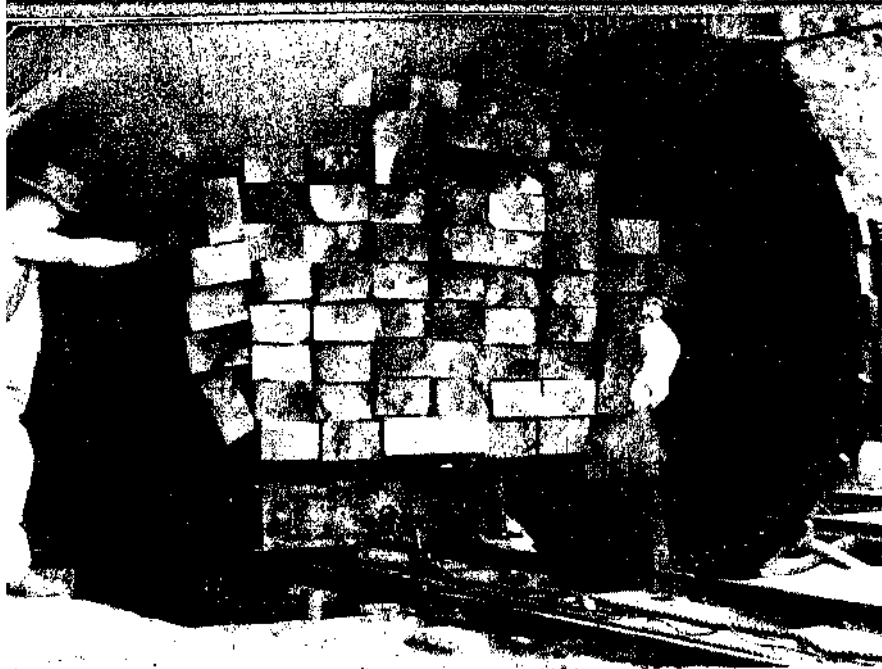
29. ABOVE: a charge of railway sleepers being removed from the pressure impregnation cylinder after treatment. *(Forestry Commission of New South Wales)*

30. BELOW: a small transportable impregnation plant with a capacity of approximately 1,000 super feet of sawn timber per charge. *(Hicksons Timber Impregnation Co.)*

3 1. *Wood boring beetles.*
Auger beetles, *Bostrychopsis jesuita* (Fabr.) (the large beetle) and *Xylohosca bispi nosa* (Macl.).
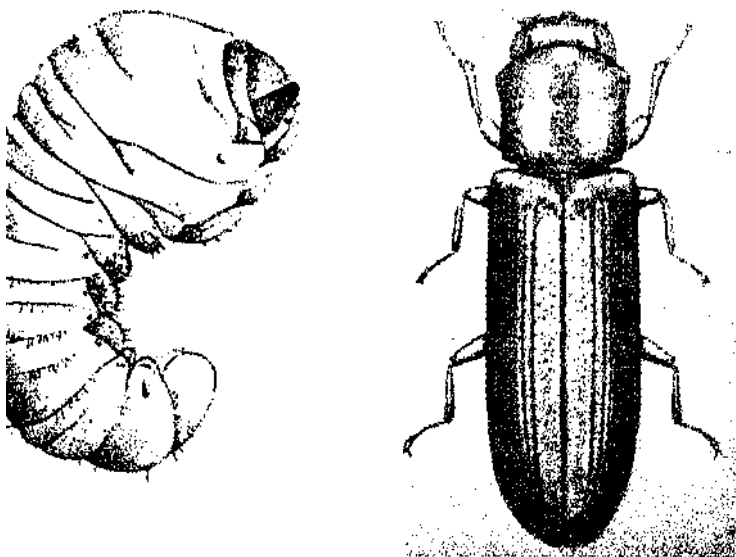
Larva and beetle of the lyctus borer, *Lyctus brunneus.*
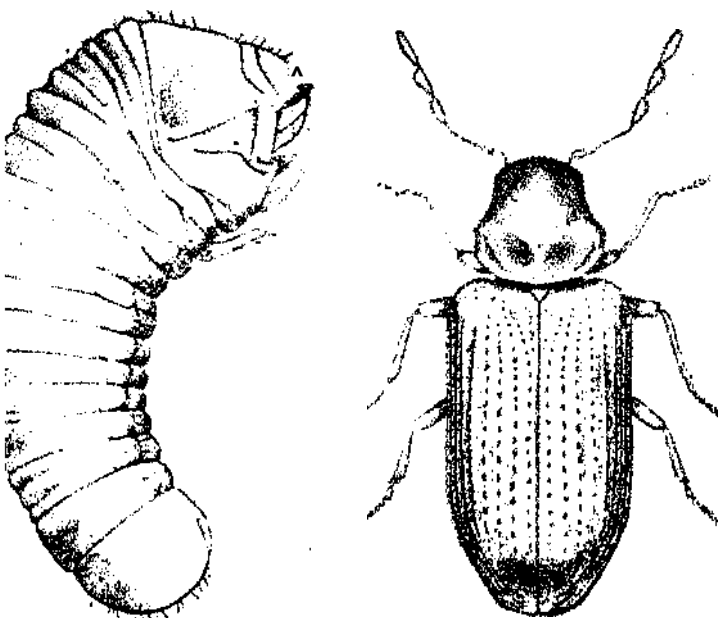
Larva and beetle of the anobium borer, *Anobium punctatum.* (All photographs on this page *Division of Wood Technology, Forestry Commission of New South Wales)*

32. ABOVE: the hydraulic press used in the manufacture of prefabricated timber trusses.

33. LEFT: factory made timber trusses utilising tooth plate connectors. *(George Hudson Holdings Limited)*

are the best means of dealing with the problem. Experience in the use of ant-caps or shields has shown that they give excellent results when properly made and fitted; where termites gain entry in spite of caps and shields, failure is almost invariably due to incomplete protection or poor workmanship.

A bent-over sheet of metal can prevent termites constructing their galleries from a stump or a wall on to constructional timber. Metal turned down at an angle of 45 degrees requires termites to construct a downward gallery and negotiate the edge in order to pass; for some reason termites are very seldom able to do this.

Termite Shields and Caps: Buildings of concrete, brick, brick veneer or timber should be fitted with shields or caps thus:

1. The shield should be constructed of 24- or 26-gauge galvanised iron or copper, and the outer edges should project at least 2 inches from the wall or stump on which the shield is placed.

2. Shields should be stamped out, but if cut from sheet metal all joints should be mitred and soldered.

3. The shield or cap should project horizontally from the top of the wall or the stump for at least ½ inch and should then turn down at 45 degrees for another 2 inches.

4. Where strip-shields are used, or where shields join at wall junctions, all joints should be soldered with a lap of 1 inch.

5. Galvanised iron shields should be laid, on a damp-proof course. Sheet copper can be arranged to serve both as ant-capping and damp-proof course.

Site Clearance: Debris, mortar or timber should not be left under a building to provide access over the metal shield to the timbers above. Timber should be removed from under fireplaces, steps, terraces or porches, where an earth or concrete fill is used.

Ventilation: Ventilation and free air circulation under all floors is essential, and a minimum ground-clearance of 18 inches is desirable. The amount of ventilation required varies with local conditions, but a general rule is to allow 1 ½ square inches of free air-way for every foot of wall-length, with a minimum of two ventilators under each room and one under each passageway or narrow space.

Drainage: Efficient drainage is essential, as moisture attracts colonising termites and often results in persistent termite attack.

Fitting Termite Shields and Caps

Walls: To prevent corrosion, shields in walls should be placed directly on the damp-proof course. The plate or bearer and the brickwork should be laid on the shield, and, in order to prevent sliding, the top surface of the shield may be given a thin layer of tar and sand or bituminous paint.

Caps may be fitted to piers of brick, concrete or timber, but require different methods of holding. Care should be taken not to damage the cap in fixing, or to perforate it so that termites can pass.

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Brick and Concrete Piers: Caps should be placed on the damp-proof courses on brick piers, and the bearers laid on them. Where holding-down is required, a ½ inch bolt may be cast into each concrete pier, the caps perforated, slipped over the bolts, and bedded on cement mortar or tar and pitch mixed to a heavy consistency, in order to seal the caps and the bolt holes.

Wooden Piers or Stumps: If caps are nailed on, the nail-heads must be completely soldered over. It is usual to spikenail bearers to stumps, but this is not desirable; where it is necessary to hold a bearer down, it should be held by a bent bolt, coach-screwed to the stump and passed round the edge of the cap. Experience has shown that these bolts do not provide termites with means of communication to the bearers. As an alternative, caps may be made with hoop iron soldered to the top, to be bent upwards and nailed on either side of the bearer.

Fireplaces, Porches and Terraces: Shields should be inserted above the damp-proof course in brickwork or bonded into concrete; they should be made continuous with those in adjoining walls. In timber buildings, where fireplaces and so on may be isolated, the shield should be fitted all around.

Brick Buildings

Building practice varies among the States, but all buildings may be simply and cheaply termite-proofed by fitting metal termite shields.

Pier-and-Bearer Construction: This is cheaper to construct and to make termite-proof than dwarf-wall construction, and is used in New South Wales, Victoria and Queensland, and less frequently in Western Australia and South Australia. Termite caps are used on free piers and the continuous shield on the walls is mitred to cover engaged piers.

External Walls: The termite shield is laid on the damp-proof course, turned down on the inside edge only and extended about 1 inch beyond the cavity.
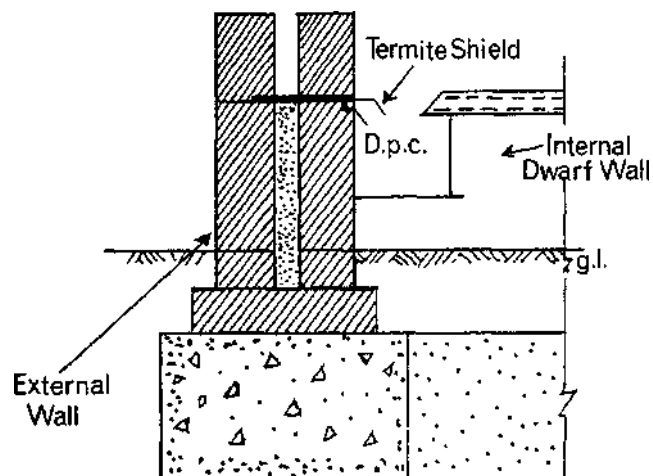
Figure 26. The pier and bearer construction used in brick homes giving adequate shield protection against termites.

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This protection is usually adequate, as termite galleries on the exterior can be seen and destroyed if the base is kept clear of shrubbery, garden soil and debris. If the outside of the wall is likely to become hidden, an exterior shield may be necessary.

Mortar. A mortar consisting of one part cement, one part lime, and six parts sand should be used below the damp-proof course as termites can penetrate lime mortar or mortar of poor quality, and may enter and attack via the cavity. All joints should be well filled.

Weep Holes: The practice of providing weep holes from the cavity in the first course above ground line is not recommended as termites may enter the cavity through them. The cavity should be filled with concrete up to the damp-proof course on which the shield is laid, and the weep holes made above the damp-proof course.

Internal Walls: The shield, 5 inches wider than the wall, is laid on the damp-proof course and projected at least ½ an inch horizontally with a turn down at 45 degrees for 2 inches either side. Where two walls meet, either of two methods may be used.

1. T-junction shields with mitred joints, or

2. Openings left in the internal walls so that the termite shields on the intersecting walls do not meet.

Either method will prevent termite entry, provided that where openings are left, a 6 inch clearance is allowed between the edge of the termite shield and the foundations below.

Brick Veneer Buildings

This type of construction is more common in Victoria and New South Wales than in other States. Termite shields on exterior walls should be placed on the inside of the brick wall, on the damp-proof course. The plate should be laid on the shield and may be held temporarily with a layer of bituminous paint. Shields on the outside of the wall are usually unnecessary (see External walls, page 246). Partition walls and piers should be capped as described in Internal walls, for brick buildings, page 247.

Concrete Slab Floors: If concrete floors are used, it is suggested that a continuous concrete course at least 3 inches thick and projecting 3 inches both inside and outside the walls, should be laid on the foundation walls. The course should be sloped on the outside to allow rainwater run-off and kept clear of soil or debris so that it can be inspected. Concrete floors should be butted to this course and the junction and all expansion joints poisoned with creosote oil or other suitable preservative, at the rate of about 1 gallon preservative solution to 100 linear feet of joint. A 5 per cent solution of pentachlorphenol (colourless) in fuel oil, or a 20 per cent solution of copper naphthenate (green) may be used instead of creosote oil. The junction should be finally sealed with bitumen, pitch and so on.

All timbers should be set after the floor has been placed, and no member should extend through the concrete floor. The timber is then isolated from the
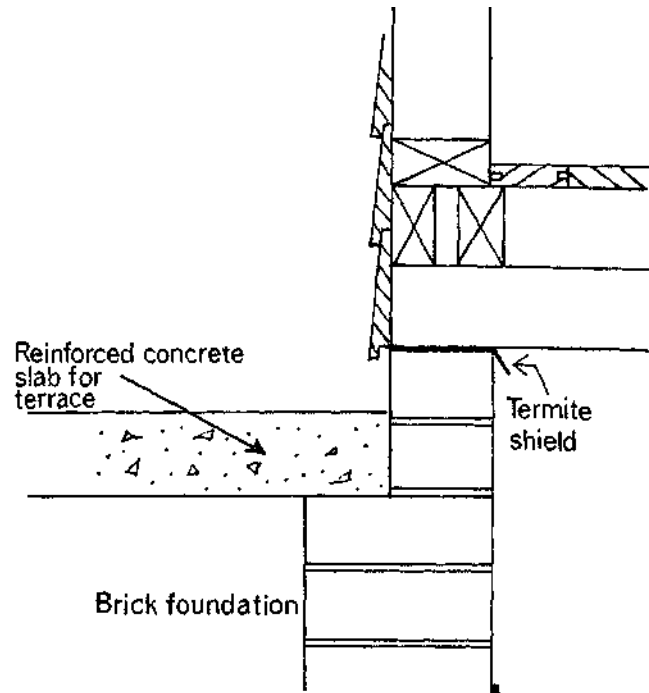
Figure 27. The use of termite shields in the timber frame home. Note the concrete slab is below the shield.

soil, and termite entry can take place only over the external concrete rim or in the expansion joint, where prompt action can be taken. Should it be essential to pierce the slab with timber, creosote should be liberally applied to the hole around the base of the timber, and the area kept clear so that termite attack can be seen.

Creosote Trench: An additional (but not essential) measure is to dig a narrow trench to a depth of about 18 inches around the building, back-filling with successive layers of soil and creosote. The top 2 inches of soil need not be treated. Creosote oil should be used at the rate of 1 gallon for 5 cubic feet of soil. This method of protection may be used for houses, warehouses, factories and other structures with concrete slab floors, and, if regular inspections are made, will be quite effective even in areas of severe hazard, such as northern Australia.

Timber Framed Buildings

The whole superstructure of the building should rest on metal termite caps placed on top of the stumps or piers. A minimum clearance of 18 inches is desirable beneath the building. Stumps may be of termite-resistant or adequately treated timber, concrete or brickwork. (See below, Termite-resistant Timbers.)

Chief routes of attack are fireplaces, porches, steps or terraces, since these usually join the woodwork above the level of the termite shields. All such porches, fireplaces and so on, should be carefully fitted with shields.

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Wooden steps should be either isolated from the main building by a break of about 2 inches or should be constructed on piers or stumps fitted with caps. Out-buildings in contact with the main building should also be protected by shields or caps.

Weatherboards are sometimes carried down to ground level, with the lower boards in contact with soil providing direct access for termites to the timber above. To prevent this, a minimum clearance of 2 inches between the lower edge of the boards and the soil should be carefully maintained, exposing 2 inches of each of the outside stumps. Particular attention should be paid to keeping the nearby area clear of soil or debris. An access door should be provided to allow inspection for the presence of termite galleries on die stumps.

Australian Standard Codes for the Protection of Buildings Against Subterranean Termites

Two very useful Codes have been published by the Standards Association of Australia to enable better protection to be given to buildings from attack by soil inhabiting termites. Australian Standard CA43 (1966) was first issued to cover "Soil Treatments for the Protection of Buildings Against Subterranean Termites" and in all the States, except Queensland, treated soil barriers are more commonly used than metallic shields for termite protection.

Australian Standard CA50 (1968) "Physical Barriers Used in the Protection of Buildings against Subterranean Termites" is now available and generally follows the methods which have given good protection under most Queensland conditions. In some types of buildings, particularly those of concrete slab-on-ground construction, the use of both codes is strongly recommended.

A recent report on Darwin buildings* by officers of the Division of Forest Products and Division of Entomology, C.S.I.R.O., clearly sets out the hazards to timber in buildings in termite infested country, particularly those north of the Tropic of Capricorn in Australia.

Drywood termites are said not to constitute a significant hazard in the Darwin area but it is known that serious damage from these insects is being found quite frequently in unpainted and other unprotected timber in Queensland coastal areas northward from Brisbane. Attack is most common in pine, sapwood of hardwoods and softer timbers and appears to be worst in north Queensland.

Termite-Resistant Timbers

Timber Attacked and Conditions for Attack: Termites attack the sapwood, truewood and heart of most timbers, but show a preference for the sapwood and heart. The truewood of some Australian timbers is, however, very resistant. The following table is a list of some common Australian timbers which have been found after long experience to show considerable resistance to termite attack. They are not listed in order of resistance.

Of imported timbers, Californian redwood *{Sequoia sempervirens)* and western red cedar *(Thuja plicata)* are termite resistant.

* "The Prevention of Termite Attack in the Northern Territory". (See Bibliography.)

TABLE 28

TERMITE-RESISTANT TIMBERS

Botanical Name	Common Name
Acacia acuminata	Raspberry jam
Callitris species	Cypress pine
Eucalyptus acmenioides	White mahogany
E. gummifera	Bloodwood
E. crebra	Narrow-leaved red ironbark
E. moluccana	Grey box
E. leucoxylon	Yellow gum
E. marginata	Jarrah
E. melliodora	Yellow box
E. microcorys	Tallowwood
E. muclleriana	Yellow stringybark
E. paniculata	Grey ironbark
E. polyanthemos	Red box
E, propinqua	Grey gum
E. punctata	
E. redunca var. elata	Wandoo
E. camaldulensis	Red gum
E. fibrosa ssp. fibrosa	Red or broad-leaved ironbark
E. sideroxylon	Red ironbark
E. tereticornis	Forest red gum
Erythropleum chlorostachys	Cooktown iron wood
Syncarpia hillii	Satinay
Syncarpia glomulifera	Turpentine

Timbers listed above should be used for stumps and for other unprotected woodwork in contact with the ground in temperate Australia. In northern Australia, in areas where *Mastotermes* attack is likely, cypress pine should be used for its outstanding resistance to this destructive termite. Most of the light-coloured and light-weight hardwood timbers, and most softwoods, possess little resistance to termite attack. Where permeable species of timber are available, and they have been impregnated with an approved preservative at an adequate concentration, these can be used with complete safety.

Preservative Coatings: Superficial coatings of creosote oil or other preservatives applied to joists and bearers by brushing or dipping will not give permanent protection against termites, although they may act as temporary deterrents. Termite galleries may be built over creosote-brushed timber to reach unprotected timber. Brush treatments are of some value for coating bearing faces where decay is likely to occur. Good impregnation treatment, however, using effective preservatives such as the copper-chrome-arsenate range, can be relied upon to give effective service.

Drainage Pipes and Conduits

These should not be supported on wooden blocks in contact with the ground. Where pipes are inside the main building, and in contact with the ground, each should be fitted with a special metal shield. A study of the

plan before construction commences will indicate possible points of termite entry, all of which should be protected.

Causes of Termite-Shield Failure

In addition to defects in construction of shields, for example, poor soldering or badly cut joints where walls intersect, several other factors may be responsible for termite attack. These include:

1. Edge of shield flattened against the wall or stump, or bent out of shape so that termites can build over the shield.

2. Shield pierced by spike used to hold it to top of stump, or nail holes not soldered over.

3. Foundations too close to ground so that grading of site brings soil into contact with edge of shield.

4. Insufficient clearance between shield and adjacent masonry, woodwork or piping.

5. Faulty bonding between concrete floors of porches, bathrooms, laundries and so on, and adjoining foundation walls.

6. Ill-considered use of shields so that some vulnerable points are left unshielded.

7. Shields constructed of materials which are not durable.

8. The construction of unshielded outhouses or buildings in contact with the main building.

Termite-proof construction is the surest means of preventing termite damage. The cost of termite-proofing is not high, and is an insurance against future damage.

It is emphasised that any timber can be used safely above an efficient and properly fitted termite barrier without danger of termite attack. Termite-proof construction therefore makes available for more general use, timbers which under present conditions are not acceptable owing to the danger of attack.

Measures to render an Infested Timber Structure Immune from further Attack*

Structural Details: It is obvious that it is useless to try to save a building if the upper timbers are entirely unprotected by such guards as termite shields, or if some unprotected structure is allowed to remain in contact with the building timbers, thus providing the termites with means of entry. Where possible, termite shields should be inserted between stumps and bearers, or into the masonry foundations below the bearers. This is frequently very difficult once the building is erected, but it is well worth considerable trouble if attack is likely to be severe or frequent. Once the communication between the timber and the soil is cut off, the termites in the timber do very little damage and die unless they can find a way back to the soil.

Treatment of Soil: Additional security can be obtained by puddling the soil around the foundations with creosote oil or a solution of zinc chloride. This practice is more likely to succeed in the southern portions of Australia than

* Extracted from D.F.P. *Trade Circular,* no. 36.

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in the northern areas where *Mastotermes* is present. Puddling the soil does not guarantee complete safety from further termite attacks, but the puddled soil acts as a barrier and serves to retard the termites if they move towards the foundations. Creosote affects the lime mortar, and for this reason brick-work which will be in contact with creosote-puddled soil should be constructed of cement mortar.

The soil should be puddled to a depth of one foot, and one foot out from the foundations. The preservatives can be easily applied with a watering can. In certain cases, it may be necessary to puddle the soil inside the foundation as well as the outside.

In the case of poles and bridge piling, a certain amount of protection can be obtained by puddling the soil around the butts. This method, however, is not very promising in northern areas infested with *Mastotermes,* and no reliance should be placed on it in such localities.

Extermination of Termite Colonies: The extermination of a termite colony is a difficult matter, because in many cases the nest itself cannot be found. Even if it is found and destroyed, the foraging parties of termites, if they still have communication with the soil, may be able to build up new colonies.

A number of different methods for destroying colonies have been tried. Some rely on the use of the poisonous vapours of carbon bisulphide, benzol, hydrocyanic acid and other substances. In these methods, holes are drilled into die nest or galleries are opened up. Similar treatment of infested poles or posts may have a definite value.

These methods are all rather dangerous, for they employ either highly inflammable or poisonous vapours and, unless they are very thoroughly carried out, are not certain in their effect. In addition, they are laborious, and even in the best circumstances may not result in complete extermination, because, as mentioned earlier, the destruction of the nest does not necessarily mean the destruction of the whole termite colony.

(a) *Treatment of Mounds:* A simple method has been used effectively on the mounds of *Eutermes exitiosus,* a common Australian mound-building termite. These dome-shaped mounds, which have a maximum height of about two feet, are among the commonest found in southern Australia. The outer crust is only a few inches thick and can be penetrated fairly easily. The method of treatment is as follows: a hole is bored into the side of the mound with an auger. The auger is directed to penetrate the centre of the mound at the ground line. After the auger has been forced through the outer wall of the mound, it will slip freely into the loose material of the nursery. It is then withdrawn and half an ounce of white arsenic or paris green, finely powdered, is blown into the centre of the mound. A rubber bulb with a glass or metal tube attached is suitable for the purpose. When the powder has been blown in, the auger hole is plugged up with moist earth. The termites will then continue to work and eventually the poison will be distributed throughout the entire colony. In the course of a few weeks, the colony will die out.

It is not yet certain whether this method can be successfully applied to mounds of other species.

Before attempting to kill out termite colonies by this method, it would therefore be advisable to write for advice to the Division of Forest Products, Yarra Bank Road, South Melbourne, Victoria, or the Division of Economic Entomology, Box 109, P.O. Canberra City (which division was responsible for the development of the method), giving full details of the mounds which require treatment.

(b) *Treatment of Infested Timber:* Infested timber has been successfully treated by blowing poison dusts into the galleries. The attacked timber should be opened very carefully with a sharp knife or chisel, and the galleries exposed sufficiently to allow the end of a fine tube to be inserted. The poison dust is then gently blown in by means of a small rubber bulb, and the galleries are sealed immediately. This procedure should be repeated in several different places, care being taken to treat as many different galleries as possible. More than one treatment in the same board, for instance, would increase the risk of disturbing the termites and all the work may be wasted. Where possible, the tubes leading from the ground should receive attention as these are the main routes used by the termites when travelling from the nest to the wood-work of a building. Any breach in these tubes is usually sealed quickly so that contact with the food supply can be maintained. It is essential that the termites be disturbed as little as possible. A certain amount of the poison will be carried back to the other members of the colony, but it is not yet established that whole colonies can be destroyed in this manner.

If this method is applied in buildings, arsenical poisons should not be used. Sodium fluosilicate is recommended for this purpose, as it is relatively non-poisonous to human beings.

Except in cases where proper protection is impossible owing to structural peculiarities, it is far more satisfactory to deal with termite attacks by the permanent measures already detailed, than to attempt control by applying poison dusts to the galleries in the attacked timber.

Conclusion

In the foregoing remarks, only the essential facts and simple and well-proved methods, as established by the Division of Forest Products, have been definitely recommended. Although many aspects of the problem in Australia are as yet imperfectly understood, it is believed that, with a proper grasp of the facts given, most of the termite damage encountered in Australia can be prevented by the methods which have been advocated.

The publicity given to termite attack in recent years by so-called "White-ant experts", has developed considerable business in the eradication of termites. The assistance of real experts can be of great value, but it is advisable to investigate the qualifications of persons claiming to be such before placing reliance on their services.

MARINE BORERS

The marine organisms principally concerned in damage to underwater structures and to wooden vessels can be classified into two main groups: the Teredinidae and the crustaceans.

Teredinidae

Members of this group, which include various species of *Teredo, Nausitora* and *Bankia,* are commonly known in Australia as teredo or coborah. In the early stages of their life they are minute, free swimming organisms. Upon finding suitable lodgment on timber they quickly develop into a new form and bury themselves in the timber. A pair of boring shells on the head grow rapidly in size as the boring progresses, while the tail part with its two water-circulating syphons remain at the orginal entrance. Thus the organism grows in length and diameter within the timber but remains a prisoner in its burrow, which it lines with a shell-like deposit.

It lives upon the timber borings and upon the organic matter extracted from the sea water that is continuously being pumped through its system. The entrance holes never grow large, and the interior of a pile may be completely honeycombed and ruined while the surface shows very small perforations, often not more than $1/16$ inch across. *Teredo* can grow to lengths of from one to four feet according to species (United States Department of Agriculture). Other genera of the family *Teredinidae* in Australian waters with favourable conditions grow to four feet and more in length. The giant tropical borer, *Bactronophorus subaustralis,* can double this length with a tunnel diameter of two inches.

In Australia, species of teredine borers are responsible for the bulk of the damage to submerged timber. A serious feature of their attack is that, while the only outward evidence of it may be a few small holes on the surface, the interior of a piece of timber may be practically eaten away. The danger from this source to timber vessels and piling can, therefore, be very great unless adequate precautions are taken.

The teredine borers destroy timber at all levels from the mud-line to high-water level, but the greatest intensity of attack upon underwater structures appears to occur in the zone between one foot above and two feet below low tide level (I. H. Boas).

Damage from both teredine and crustacean organisms is more widespread and occurs more rapidly in warm, tropical waters than in the cooler localities, though investigations by the Maritime Services Board of New South Wales and by the Queensland Forest Service indicate that salinity also has an important influence upon the intensity of attack.

Crustaceans

Members of this group include species of *Limnoria* (Gribble), *Sphaeroma* (pill bugs) and *Chelura. Limnoria* are small crustaceans about to 1/16 inch in length and they bore small burrows in the surface of the submerged timber. *Sphaeroma* are somewhat larger sometimes reaching ½ inch in length. Activity of crustaceans is mostly confined to underwater piling and wharf structures, the timber so affected being steadily eaten away from the outside. Attack by *Sphaeroma* is limited to the zone between tidal limits, with the greatest damage close to half tide level (C. J. J. Watson).

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Control and Remedial Measures

No timber is immune to attack by marine borers, but some species are more resistant than others. Australian turpentine, swamp mahogany, and cypress pine *(Callitris columellaris)* have proved to be definitely resistant to teredine borers. The loose laminated barks of turpentine, swamp mahogany and the "paperbark" tea-trees resist penetration by teredine borers which prefer sound timber for boring. These barks have the disadvantage of being easily damaged and also make an attractive home for *Sphaeroma* where these are common. Preservative impregnation of the sapwood of piles, after the removal of the bark, is much more practical than reliance upon bark which is often stripped off.

Permeable timbers such as radiata pine, which are capable of fully accepting treatment, can be impregnated with non-leachable toxic water-borne chemicals and rendered immune from attack. The fixed copper-chrome-arsenate preservatives, applied at the appropriate net dry salt loadings, are currently being tested and are proving very effective in resisting teredine borer attack in south Queensland waters.

Considerable research in the protection of piling and wharf timbers from attack by marine borers has been carried out by the Maritime Services Board of New South Wales, the Queensland Forestry Department and the Division of Forest Products, C.S.I.R.O., and the reader desiring further information in this respect is advised to refer to these authorities.

Protection of yachts and wooden vessels is best ensured by efficient sheathing of the hull with copper sheet or Muntz's metal. Skilled knowledge and craftsmanship in fitting the sheathing is essential since, as explained earlier, entry of the teredo into any one portion of the hull, however small, can be the means of destroying large sections of it. A difficulty always exists in the protection of the rudder post and trunk, since the wear between these fittings tends to destroy the sheathing, allowing the borer to enter. The writer once had to sail a yacht 800 miles without a rudder for this very reason, though the hull otherwise had been maintained in perfect condition. Periodic inspection of the rudder assembly in wooden vessels is therefore strongly recommended (N. K. Wallis).

Temporary protection of hulls by so-called anti-fouling paints can be effective only for limited periods, the effectiveness of such preparations depending upon toxic elements contained in them. The effect of the "working" of the hull, by abrasions, and of sea water itself, quickly tend to reduce the efficiency of this form of protection. Vessels depending upon anti-fouling preparations for hull preservation should be slipped for thorough inspection and repainting at least every three months, and at shorter periods in tropical waters.

As an additional safeguard, wooden vessels, however protected, should be periodically scrubbed down, skin dried and freely brush treated with an anti-fouling preservative in order to destroy any infestation between joints in the woodwork or fittings. In such places initial attack is extremely difficult to detect. A generous brushing of hot K.55 Standard creosote is effective against marine borers on boat underwater planking.

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It is claimed that immersion in fresh water will eventually kill any teredine borers which may have infested the hull, and that by moving vessels to the upper reaches of rivers into fresh water, destruction of the organisms may be achieved. This may be the case under certain conditions, but it should be observed that some species can live in water of very low salinity, and that the period of immersion in non-saline water, to be successful, will depend on the thickness of the hull, species of borer concerned and the degree of attack which may have occurred. Expert biological advice should be secured.

TABLE 29

AUSTRALIAN TIMBERS THAT ARE SUITABLE FOR MARINE PILING*

Standard Trade Common Name	Standard Trade Reference Name	Strength Group	Remarks
IN QUEENSLAND AND NEW SOUTH WALES			
Species			
Turpentine	*Syncarpia glomulifera*	B	Grows in Queensland and New South Wales.
Swamp box	*Tristania suaveolems*	B	Not plentiful.
Satinay	*Syncarpia hillii*	C	Only one source, namely Fraser Is., Queensland.
Brushbox	*Tristania conferta*	B	Grows in Queensland and New South Wales.
Forest red gum	*Eucalyptus tereticomis*	B	Grows in New South Wales and Queensland.
IN VICTORIA AND TASMANIA			
Species			
Messmate stringybark	*Eucalyptus obliqua*	C	Grows in Victoria and Tasmania.
River red gum	*E. camaldulensis*	B	Grows mainly in N.S.W.
Yellow stringybark	*E. muelleriana*	B	Grows mainly in N.S.W.
White stringybark	*E. eugenioides*	B	Grows mainly in N.S.W.
Coast grey box	*E. bosistoana*	A	Grows in southern-eastern Victoria.
Silvertop ash	*E. sieberi*	B	Grows in Victoria.
Brown stringybark	*E. capitellata*	B	Grows in Victoria.
Southern blue gum	*E. globulus*	B	Grows in Victoria and Tasmania. Not plentiful.
OTHER TIMBERS AVAILABLE FROM NEW SOUTH WALES			
Species			
Ironbarks	*Eucalyptus paniculata*	A	*Note:* These timbers are not suitable for use in an untreated condition in the heavily infested waters of New South Wales and Queensland, but will give good service in Victoria, Tasmania and South Australia.
	E. siderophloia	A	
	E. crebra	A	
Grey box	*E. moluccana*	A	
Tallowwood	*E. microcorys*	A	
White mahogany	*E. acmenioides*	B	
Grey gum	*E. punctata*	A	
Spotted gum	*E. maculata*	B	

* Specifications for treated and untreated timbers for piling are available from the Australian Standards Association.

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TABLE 29 (continued)

Standard Trade *Common Name*	*Standard Trade* *Reference Name*	*Strength* *Group*	*Remarks*

IN WESTERN AUSTRALIA
Species

Jarrah	*Eucalyptus marginata*	C	Grows in Western Australia.

For northern Western Australian harbours where severe marine borer attack may have been experienced, see list for New South Wales and Queensland.

IN SOUTH AUSTRALIA
Species

Messmate stringybark	*Eucalyptus obliqua*	C	Small local supply. Plentiful in Victoria and Tasmania.
Brown stringybark	*E. capitcllata*	B	Small local supply.
River red gum	*E. camaldulensis*	B	Small local supply.
Jarrah	*E. marginata*	C	From Western Australia.

Other timbers—Any timber included in the Victorian list.

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XVII

PAINTING AND FINISHING OF TIMBER

The painting of timber serves the dual purpose of protecting exposed surfaces from the effects of weathering, and of providing an ornamental finish, variable in colour and often in texture, to suit requirements of taste and environment.*

WEATHERING

The effect of weathering must be understood in order to realise the importance of sound painting practice. Unprotected timber surfaces exposed to the weather, that is, to alternating conditions of moisture (rain, fog and so on) and dryness (sun, wind), are subject to constant expansion and contraction. The effect of this physical action is to produce firstly a roughening of the surface of the timber followed by checking and subsequent gradual disintegration while the colour of the timber changes to grey. This process of weathering is not, strictly speaking, one of decay, though decay does in many cases supervene owing to "spongy" weathered surfaces being able to retain moisture for long periods, and so maintain conditions favourable to decay. Other effects which can result from weathering are cupping, twisting, splitting and the loosening of joints, resulting sometimes in boards pulling away from fastenings, and fittings coming apart.

Certain species of timber are weather-resistant, and in all species quarter-sawn boards are less susceptible to weather than those that are back-sawn. Closer-textured timber is also less subject to weathering than coarser-textured timber. It therefore follows that where woodwork must be exposed to weather without protective coating, or where paint or similar protection cannot be maintained in an efficient condition, the abovementioned characteristics should be considered in the selection of the timber to be used. Examples of the use of unprotected timber are shingles, boat-decking, exterior stair treads and so on.

The following notes by R. M. Sinclair* will indicate the general effect of the nature of timber on its paint-holding properties.

The ultimate durability of paint films on timber surfaces subject to outdoor weathering is governed to a large extent by the properties of the timber. Initially, the rate of break-down of the film, except in extreme cases, will be governed by the durability characteristics of the paint, but as disintegration of the film proceeds, the effect of the nature of the timber will become predominant.

In the early stages of exposure, dirt collection, loss of gloss and chalking, accompanied or followed by checking, will predominate in the degradation of the film. Continued exposure will probably lead to erosion, cracking, flaking or a combination of these failures, followed by complete disintegration of the film. Initially, the paint is sufficiently flexible to withstand stresses set up by small volume changes in the timber, but as it becomes brittle with age checking or cracking may occur and much of its adhesion is lost.

The results of work carried out in the United States by F. L. Browne showed that the chief characteristic of softwoods that determines the behaviour of the film in the latter part of its life is the proportion of springwood to summerwood. Springwood holds paint better than summerwood and this may be due to the larger cells of the former enabling the film to obtain better mechanical anchorage. Several physical characteristics of timber affect the performance of paint coatings to a degree that is dependent on the proportion of springwood to summerwood.

Timber of light weight (low density) holds paint longer than heavy timber because light timber contains less summerwood. Narrow-ringed wood holds coatings longer than wide-ringed wood because the bands of summerwood are narrower.

Quarter-sawn surfaces hold coatings longer than back-sawn surfaces, also because the bands of summerwood are narrower at the surface. Back-sawn boards may hold paint better on the bark side than on the pith side because, on the pith side, there is sometimes a tendency for the edges of the bands of summerwood to loosen and curl outwards, thus dislodging the coating.

High-grade timber holds coatings better than low-grade because knots and other defects hold paint poorly and because the low grades usually come from the centre of the tree where the timber is likely to be wider ringed.

The effect of extractives is probably less than is generally supposed. Pine resins are usually considered harmful because they tend to exude through the coating after painting. They may also react chemically and cause the film to become brittle. Oily extractives may also retard the drying or cause discoloration of the coatings by bleeding through soon after application. In some cases, however, the durability of the coating may be improved by the presence of extractives.

Excessive moisture will retard the drying of the paint and probably prevent good adhesion of the coating. On the other hand there is evidence that timber

* By courtesy *Paint Notes* issued by Defence Research Laboratories, Maribyrnong, Victoria.

TABLE 30

Timber		Pore Size, microns.	Density lb. per
Trade Name	Botanical Name	(Hardwoods only)	cu.fi.
Blackbutt	*Eucalyptus pilularis*	250-350	53
Mountain ash	*E. regnans*	260-385	39
Jarrah	*E. marginata*	200-400	50
Spotted gum	*E. maculatci group*	210-310	61
Cypress pine	*Callitris glattca*	—	42
Hoop pine	*Araucaria cunninghamii*	—	34
Radiata pine	*Pinus radiata*	—	30
Douglas fir (oregon)	*Pseudotsuga taxifolia*	—	30-34
Californian redwood	*Sequoia sempervirens*	—	28

with its stable moisture content at 12 to 17 per cent holds paint longer than timber with a very low moisture content. In the latter case the oil medium of the paint film is absorbed, leaving a dry pigment on the surface with a poor bond.

The proportion of springwood to summerwood does not affect hardwoods of high density and possessing large pores. The pore size and/or density of the most commonly used Australian timbers is given in Table 30. This table does not include all types but merely gives an indication of the variables likely to be encountered.

Hardwoods with pore sizes ranging from 160 to 430 microns are considered to require the use of a filler in place of the normal priming coat. The filler is composed chiefly of ground quartz mixed with linseed oil and paint drier. Unless a filler is used on hardwoods with larger pore sizes than 160 microns an even film is not obtained and disintegration of the film will be accentuated at the point of weakness located over each pore.

It will be noted that although the Australian hardwoods listed above all fall into the group that benefit by the use of a filler, little attention seems to have been devoted to this aspect in current painting practice.

The Paint-holding Properties of Australian Timbers

Exposure tests of three years' duration have been made on various timbers by the Defence Research Laboratories, Maribyrnong, Victoria. The full results of these tests are embodied in a report issued by this organisation. Table 31 briefly indicates the comparative paint-holding characteristics of the timbers tested.

APPLICATION OF PAINT*

If certain preliminary preparations are carried out before painting is commenced, the task is made easier. The manufacturers' directions should be followed and care taken to adequately mix the contents of the tin. This is best

* *Wood Handbook,* United States Department of Agriculture.

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TABLE 31

CLASSIFICATION OF TIMBERS ACCORDING TO PAINT-HOLDING
PROPERTIES

Group	Paint-holding Properties	Timber
A	Very good	Hoop pine (quarter-sawn) Jarrah (quarter-sawn)
B	Good	Jarrah (back-sawn) American white pine (quarter-sawn) Hoop pine (back-sawn) Blackbutt (quarter-sawn) Spotted gum (quarter-sawn)
C	Intermediate	Mountain ash (quarter-sawn) American white pine (back-sawn) Pinus radiata (back-sawn) Cypress pine (back-sawn) Western red cedar (U.S.A.) (quarter-sawn)
D	Poor	Southern yellow pine (U.S.A.) (back-sawn)

done by pouring off the top layer, then pouring back and forth into another container. Choice and care of brushware are important. For broad areas choose a 3- to 4-inch brush, and a 2-inch brush for painting narrow surfaces such as window sashes and so on.

When using oil paints a new brush may be used, but for enamel type paints a brush which is partly worn should be used, enabling one to spread the paint more easily. After use the brushes should be washed out in turpentine and suspended in a mixture of linseed oil and turpentine rather than stored in water which may be transferred to the painted surface, possibly producing blistering at some future date.

The first step in ensuring success in painting timber is thorough preparation of the surface, which must be clean and free from grease, dirt and water. Its physical condition must be such that the paint film will obtain a good "key". To obtain best results *open-grain* timber, if it is to be finished with a clear varnish, should be filled with a wood filler, or, if it is to be enamelled, with a surfacer applied over the priming coat (see page 267).

Timber should not be painted when it is wet. As long as there is no free water present, however, the moisture content is of minor importance; timber painted at 12 to 17 per cent moisture content holds paint slightly longer than timber painted at 10 per cent moisture content. Paint dries very slowly at low temperatures; painting therefore should not be done at times when the temperature is likely to fall below 40°F. When there is danger of dew or frost at night, application of paint should cease several hours before sunset. In clear, warm weather coatings of paint can be applied within twenty-four hours of each other if necessary, but it is better practice to allow at least two or three

days. On the other hand, it is generally inadvisable to allow more than one or two weeks to elapse between successive coats.

The primary coat on new timber should always be applied by brushing, and should be worked well into the pores and crevices of the timber. On painted surfaces on which the old coating has not yet become deeply cracked, paint may be applied by brush or spray gun with equally serviceable results. Old coatings that have passed into the fissure or flaking stage should be burned off and the timber primed and treated as for new timber. Spray painting is not satisfactory in any sort of wind since considerable waste of paint may result.

The conventional procedure in painting new timber surfaces calls for the application of a three-coat system; a priming coat, undercoat, and finish coat. The formulation of the three coats must be compatible for maximum performance. The current trend is towards the use of "high gloss synthetic resin finishes". The formulation of the paint is generally not known to the private user and under these circumstances it is advisable on any particular job to use primer, undercoat and finish recommended by the manufacturer.

Painting of New Timber

New timber should receive at least three coats of paint; a priming coat to obtain the key to the surface, an undercoat to fill the grain, and a durable finishing coat to provide the protection and decoration of the surface.

Priming. The priming coat is a very important paint film, a feature which is frequently overlooked. It is designed to penetrate the timber and seal the pores thereby obtaining a tight film with a strong key for all subsequent coats of paint. It must also be "elastic" to withstand movement of the timber. A good priming coat will remain an excellent bond for many future paintings, whereas a poor primer adheres to the surface and peels away when the finishing coat weathers. Priming should be applied and worked well into the surface by brush as soon as possible and preferably before the timber is fixed into place. The use of paint remnants without regard to their composition for priming or "first coats" is a frequent but unsatisfactory practice and should be severely discouraged. Such catchpenny methods can lead to premature failure of the paint film or to peeling, with undeserved blame too often laid upon high-grade paints which may have been used for the finishing coats.

Preprimed Timber

Sawmillers and timber merchants take considerable care in seasoning timber to its correct moisture content, but this advantage is readily lost if it is unsuitably stored before being used. Frequently timber is allowed to lie at a building site exposed to the weather for long periods. Under damp conditions moisture is absorbed; if conditions are unusually hot and dry the moisture can cause temporary swelling, with subsequent shrinkage, resulting in gaps opening between joints. As a result the merchant is frequently held by his customer to have supplied unseasoned timber. The priming coat cannot satisfactorily penetrate damp or unseasoned timber and obtain a good bond. This can result in the paint subsequently peeling.

On the other hand, timber with excessively low moisture content may de-

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velop checks, permitting free moisture to penetrate. This also will cause paint to peel. On both counts the timber merchant, the paint manufacturer, or both, are often held responsible for supplying sub-standard material. When timber is seasoned to equilibrium moisture content a relatively stable condition can be maintained by priming dressed or moulded timber before it leaves the mill. Thus protected, timber can be delivered to the job, even during adverse weather, in a satisfactorily seasoned condition and can be maintained in this condition during storage and fabrication.

Machine Priming

An automatic priming machine* is used in Australia for priming ail shapes of dressed and moulded timber. It is so designed that the material may be primed on all sides. The primer is applied by rollers under pressure and worked into the pores of the timber by multiple brushes. The dressed material is evenly coated; overlaps or thin spots that can occur with hand priming are avoided. The machine is capable of applying the priming coat rapidly. Two men working the machine can in a day prime at least five times as much material as could be applied by hand, and at lower cost. A special primer is prepared for this machine to maintain the timber in satisfactory condition during transport, storage and erection periods.

The priming machine can be installed behind a planer or moulder, the latter automatically feeding the former, with a consequent reduction in the cost of the priming process.

The practice of priming dressed or moulded timber after fitting or fixing in position is not recommended since any subsequent shrinkage (such as may occur in weatherboards) will expose unprotected surfaces with consequent risk of deterioration due to weathering, staining or further shrinkage. Freshly sawn or shaped ends, or surfaces exposed during preparatory treatment, should be primed before fitting. Similarly, nailholes, joints, cracks, and so on should be treated with primer before being filled and stopped, this being effected before the undercoat is applied.

Undercoat

This paint coat is designed to fill and to give "body" to the treated surface. It is usually more heavily pigmented than the finishing coat. Undercoats can vary according to requirements. For exterior use and painting of large surfaces the liquid medium must be elastic and free flowing. For exterior enamel work where a very smooth surface is desired the undercoat is prepared as a surfacer which dries harder and has good flow and rubbing qualities. A good undercoat is also designed to offer an effective holding surface for the glossy finishing coat. Undercoats may be tinted to the approximate colour of finishing coats. They should be sanded lightly before the next coat is applied.

Finishing Coat

This coat is the durable film that protects the timber and the previous "building-up" coats from the weather and/or other destructive agencies. Fin-

* Introduced by Lewis Berger & Sons (Aust.) Pty. Ltd.

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ishing coats are prepared from a number of kinds of raw materials, which are combined to impart resistance to weather, mould, chemicals, oil, abrasion and so on.

In some cases two finishing coats may be applied in place of an undercoat and a finishing coat.

Repainting

The essential factor in good paint maintenance is to repaint before serious deterioration of the former coating has occurred. If deterioration has progressed too far, a satisfactory coating cannot be restored merely by painting over the old surface. In such cases the old paint must be entirely removed by scraping or burning off—a laborious and expensive process---and the surface repainted as for new work.

With oil based systems, repainting to obtain the best possible appearance and protection is done at a time when the paint system is at a chalking stage of deterioration and before checking or erosion occurs. Should the old film be dry and absorbent an oil-base undercoat is desirable, followed by a finishing coat. When the surface is sound and non-absorbent, one or two finishing coats should be applied.

If repainting is delayed until the early stages of disintegration occur, that is, when some flaking and cracking has begun, the affected areas should be scraped down and all loose paint removed. Any bare surfaces should be spot primed. Nailholes, wood cracks and crevices should be filled with linseed oil putty. The whole surface should be painted with an oil-base undercoat and finished with a recommended type of finishing coat.

Burning Off Old Paint

If through neglect some surfaces are beyond painting, such as those which are flaking, peeling or show blistering to a greater or lesser extent, then the perished paint should be burnt off. In operation of the blowlamp, the blue part of the flame should be held at right angles to the work. The scraper should follow the flame to avoid softening the blade. The surface should be burnt clean and dry, without charring the timber. Any charred paint should be removed with sandpaper or wire brush. Finally, the surface should be washed down with lime water (using a handful of rock lime to a bucket of water) to remove surface deposits of sap or resinous matter which may otherwise cause blistering of the new paint coatings. After burning off, the timber should be treated as a new surface and when the priming coat has dried, all cracks and holes should be puttied before proceeding with the undercoat and finishing paint.

Stains*

Brown stains sometimes appear on painted weatherboards after heavy rain. This is usually found to occur when the exterior timber is of hardwood. The stains are caused by rainwater dissolving some of the tannins from unpainted

* Division of Forest Products, C.S.I.R.O.

timber lying beneath the laps of the weatherboard, or from unpainted hardwood battens, and so on, which may be fixed close to painted surfaces.

A priming coat of paint properly applied to weatherboards and fixings *before* fitting will usually prevent the occurrence of brown stains of this nature. In addition to covering the face and ends of weatherboards, the primer should be brushed along the back at the lower edge since a hard driving rain can often affect this portion. Battens and similar fixing which can be permeated by rain should be primed all over before fixing.

Brown stains can best be removed by brushing over with a five per cent solution of oxalic acid in water (preferably warm), and hosing down afterwards. This treatment should be carried out as soon as possible after the stains occur.

Brown stains can best be removed by brushing over with a 5 per cent puttied and painted. These stains are caused by the tannins in the timber reacting with the iron in the nail, producing black iron tannate. This effect is very pronounced when nails in unprotected hardwood are thoroughly wetted. It can often be observed in freshly laid flooring, such as veranda floors, which are exposed to the weather.

Black stains caused by iron fastenings can be removed by brushing over, several times if necessary, with a saturated solution of oxalic acid in warm water. The surface should be allowed to dry between applications. When the stains have disappeared the treated surface should be washed over several times with fresh water. Oxalic acid has a bleaching effect on timber, and, if flooring or similar work is treated as described above, it is advisable to apply the treatment to the whole surface in order to achieve an even finish.

The problem can be prevented by the use of hot dipped galvanised nails or nails manufactured from a non-corroding metal. In marine or industrially polluted atmospheres, careful consideration should be given to the choice of metal. Some timbers such as Californian redwood corrode copper and some aluminium alloys corrode in contact with green hardwoods.

Peeling

Peeling, or failure in adhesion, may be caused by painting over a damp surface, on greasy or non-drying substances, or over old, hard, smooth glossy surfaces which have not been sandpapered to provide a "key" for the paint.

Cracking or Scaling

As timber is not a rigid structure the paints applied to it must have sufficient elasticity on drying to be able to follow movement of the timber due to contraction and expansion. If the coating is too rigid it will crack after a period of exposure allowing moisture to penetrate causing the paint to scale, while the same fault will take place if a hard-drying finishing coat is used over a soft-drying undercoat.

Blistering

Conditions sometimes arise under which paint coatings fail in an unreasonably short time. Blisters form and are followed later by peeling or scaling

of the paint film. Blistering is caused by the presence of a vapour-forming substance which is trapped beneath the coating. The vapours, when released (usually by the warmth of the sun) expand and the new paint film, being elastic, swells under the vapour pressure. It is not a fault of the paint; blisters actually indicate that the film is elastic enough to stand up to the expansion of the vapour and tough enough to prevent the passage of moisture through it. The cause is usually due to entrapped moisture, possibly dew, or solvents from a previous wiping down, or in some cases through painting in hot sunshine causing a too rapid surface drying and the creation of a surface film which imprisons traces of solvent beneath it. Natural resin solvents in some timbers will also cause blistering.

Sheariness or Uneven Gloss

Generally seen on interior surfaces as flat and glossy patches after the paint has dried, this is generally due to insufficient drying of the undercoat or painting too soon over soft-drying undercoats. If grease or wax has not been completely removed there will be flat areas or streaks which will be tacky or partially dry.

If dew falls on an exterior surface before the paint is properly set, the tiny moisture globules create minute indentations in the film with a resulting uneven gloss appearance. Frequently the lower edges of weatherboards are thus affected. Painting should finish early enough to permit the paint film to set before dew falls. Painting should not be carried out if there is a risk of rain falling before the paint is dry.

Wrinkling and Sagging

These faults are closely related and are caused by too heavy an application or to painting in the hot sun and are more prevalent in the faster-drying enamel finish paints if they are not spread evenly.

CHOICE OF PAINT

The variety of colours available for the finishing treatment is one of the features which so highly commend the timber house from an architectural viewpoint. A proper choice of paint colour will ensure that the timber house harmonises tastefully with its surroundings. Also, within certain ranges, the colour may be easily varied or altered in tone as time goes on to suit the varying ideas of the householder or a new owner, or to conform to the changing aspect of the environment. This flexibility with regard to the colour of exteriors enables timber houses to escape the monotony so often observed in built-up areas where houses of other materials predominate. The increasing number of timber houses has, in post-war years, considerably brightened the Australian domestic landscape.

The development of "tailor-made" resins has permitted surface coatings to be produced with special features built into them. The synthetic (alkyd) resins have been modified to give increased durability and gloss retention; new resins such as polyesters, polyurethanes, vinyl and epoxy resins produce coatings with special properties such as resistance to chemical action, and to the effect

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of oils, water and weather. Chlorinated rubber is also made into tough, hard-wearing coatings with excellent water and chemical resistance. Nitrocellulose lacquers have wide use for furniture finishes, and to some extent shellac still holds a position. In the past, most paints were based on white lead but with the introduction of new pigments and vehicles, paint chemists now formulate lead-free paints and enamels which are more durable.

For exterior surfaces, where durability, combined with decorative properties is of major importance, both oil-base paints and synthetic enamels are available in a wide range of light fast colours. Clear synthetic resin varnishes are available where natural timber finish is required.

For interior surfaces, synthetic enamels are available in full gloss, semi-lustre, and flat finishes; and clear varnishes in full gloss or satin finishes.

The main difference between the exterior and interior finishes are that the former are designed to be more elastic in order to withstand the big changes that occur in the weather, whereas the latter are designed for harder drying and produce tough films which resist the effects of cleaning, steam, chemical action and floor wear.

When choosing a paint it is essential to select only the highest quality available. A film of paint only a few thousandths of an inch thick will provide decoration and protection for many years, but this is only possible by the use of good quality products designed by the manufacturers for the particular purpose. The use of low-grade paints or improper preparation is false economy.

During the manufacture of prepared paints, chemists make a thorough study of the raw materials used, and are able to combine the most suitable pigments with the various media in the correct proportions to produce the most durable results. The addition of thinners (other than as recommended) to make the paint go further, will throw the pigment/vehicle ratio out of balance, as well as producing a thinner and less durable film.

Mixing of prepared ingredients "on the job" should only be done by skilled artisans, and then only after full and reliable information has been obtained from the manufacturers. Unskilled or unscrupulous contractors can cause unnecessary trouble by using unsatisfactory mixtures or inferior ingredients.

When choosing the type of finish desired, the building-up coats must be considered. For example, in painting a house, the first coat or priming coat is very important—it must penetrate the grain and provide the key for all future coats. It must remain "tight" for several repaint periods. It is therefore necessary that this coat is well balanced with an oily vehicle that will penetrate, seal and not leave a dry pigment on the surface. The second coat or undercoat is usually more heavily pigmented; its purpose when applied over the priming coat is to fill the grain and provide a smooth, hard surface for the finishing coat. A soft undercoat can cause crazing of a harder-drying finishing coat. The finishing coat protects the undercoats, being designed for durability in a particular environment such as weather or industrial conditions. A properly formulated finishing paint should not crack, craze or erode quickly. It is designed to remain elastic for long periods and gradually weather away by "controlled chalking".

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A wide variety of colours are available in the various types of paints and enamels which, when used judiciously, enhance the architectural features of timber houses, or the woodwork of brick or varnished dwellings. The present trend is for a high-lasting gloss for which the synthetic resin (alkyd) enamels are most suitable. Where high gloss is not important the oil-base paints are preferable, these having proved extremely durable. In areas where mould growth is prevalent, such as in very humid areas, lead-free (zinc oxide base) oil paints are recommended. A good paint system should at the end of a reasonable period be in sound condition for repainting with one or two coats of paint after a thorough cleaning down. No burning off should be necessary.

Oil-based Stain Treatments

The use of pure, raw or boiled linseed oil for an exterior finish is not recommended, as it can cause considerable darkening (on repeated re-coatings) and tends to attract and hold dust.

However, a wide range of formulated linseed oil- and creosote-based stain finishes incorporating pigments, water repellents and timber preservatives etc., are now available.

Inorganic pigments arc generally employed in these finishes, due to their high resistance to fading and weathering. The pigment plays an important dual role in regulating the ultra violet rays of the sun, and masking over any discoloration that might occur.

Radiata pine has a tendency to develop small weathering cracks on northern and western exposure and it is therefore advisable to employ a rough sawn texture if possible, and to stain to a relatively dark shade.

The use of the clear oil-based formulations (i.e. unpigmented) must be restricted to well-protected areas. Although the additions of water repellents and fungicides prevent mildew growth, the timber below is still prone to bleaching and discoloration over a period of time due to the action of sunlight.

Clear Finishes (Varnishes)

Where it is desired that the natural beauty of timber be a feature of house exteriors, clear varnish finishes or oil films may be applied. For exterior work, however, these finishes are not as durable as the opaque pigmented paints, and require more attention and frequent recoatings. This is because the ultra-violet rays of the sun can penetrate the clear pigmented surface. The life of clear varnishes varies according to exposure to, and the intensity of sunlight. Under severe conditions, a fresh coating may be necessary within periods of less than a year. Unless strict attention is paid to clear finishes on house exteriors, their use is not recommended.

The most durable clear varnish films for exterior work are synthetic (alkyd) varnish or marine and spar varnish. The latter are formulated to withstand adverse conditions, wind and water as well as the ultra-violet rays of the sun. However, regular maintenance, by a light sanding of the weathered surface and a further coat of varnish, is essential to keep these finishes in sound condition.

A test carried out by the Timber Research and Development Association* with fifty-six different finishes of various types indicated that two years was the maximum life that could be expected from a good three coat system, under English climatic conditions, before attention was required.

Interior Finishing

The system used for interior painting is similar to that of exterior painting. A priming coat is necessary, followed by the normal puttying of nail holes and crevices. The undercoat, however, is usually designed to be harder drying (less oily) than the exterior undercoat and capable of easy sanding to a very smooth surface.

Some open-grain timber will show the grain pits through to the finishing coat. It is desirable that these be filled, prior to priming, with a wood filler well rubbed into the surface across the grain.

After sanding of the undercoat to a smooth surface, the finishing coat of enamel may be applied in full-gloss or semi-gloss finish to the shade desired.

Varnishing

The timber surface must be well sanded and dusted clean. Open-textured timbers should be filled with wood filler which may be used as a neutral colour or tinted according to the colour of the timber used. The filler is normally reduced with solvent to a slurry condition and applied to the surface allowing adequate time for the solvent to evaporate and the filler to become "floury". This is then rubbed off the surface with coarse cloth or hessian, working across the grain. In this way the filler penetrates the pits and leaves a smooth surface for varnishing.

The surface is sanded smooth when dry and two or three full coats or varnish applied. For interior finishing a number of different types of varnish are available, such as synthetic (alkyd) polyester and polyurethane. The two latter are usually two-package types requiring the addition of a catalyst to the base before using. They produce very hard films and may be used for floors and so on.

Staining

When timber is finished with clear coatings, the object as a rule is to display the natural beauty arising from the grain structure and colour of the timber. The careful use of stains can emphasise the natural grain and improve its appearance. Oil stains have now been superseded by the naphtha-type stains, while water stains still have a use for short work. These latter, however, tend to raise the grain and surfaces must be sanded carefully prior to the application of varnish.

Filling

Open-textured timber should be "filled" to provide a solid base to which lacquer or varnishes may be applied without sinkage. The filling must be opaque enough to reveal rather than conceal the beauty of the grain. Wood

* See *The Durability of Exterior Clear Finishes for Timber,* by V. R. Gray, M.A., Ph.D., Timber Research & Development Association Limited, U.K.

fillers may be obtained in neutral tones or in various tints for staining to a desired tone.

Fillers are applied as a slurry and allowed to remain on the surface long enough to allow the solvent to evaporate. Excess filler is wiped off with a coarse cloth by rubbing across the grain. After drying (usually overnight) a light sanding produces a smooth non-porous surface ready for subsequent finishing treatment.

Sealers are used to prevent undue changes of colour, particularly on light timber prior to filling. These are also known as sanding sealers and used on close-textured timbers when no filling is required. Shellac solution is sometimes used as a sealer but is not quite so pale nor does it seal quite so effectively as properly formulated sealers.

Finishing (Cabinet Work)

A wide range of finishes are now available. French polish and varnish are among the oldest finishes employed, but those most widely used for furniture at present are the nitro-ccllulose lacquers. They are applied by spray methods —either by the normal systems, being "pulled over" with a pad (similar to french polishing) or by hot spray systems. The lacquer used for the latter is the high solids type which is heated to a predetermined temperature by various methods and sprayed with a very full coat which flows out smoothly and eliminates the need for pulling over.

With the introduction of the polyester, epoxy and polyurethane resins, finishes became available with resulting tough, glass-like surfaces. These finishes usually require the addition of a catalyst to promote the hardening of the resin. They are usually applied by spraying. Where quantity production warrants the use of a curtain coater, the articles travel by conveyor belt through a curtain of the varnish. The thickness of the coating is determined by the speed of the belt and the amount of varnish flowing in the curtain. When a catalyst is required, two flow heads are used, the second head containing the catalyst mixture, which combines immediately with the clear base coating.

These catalyst-hardened resin finishes are very resistant to solvents, and are used extensively for table tops, T.V. cabinets, and so on. Stoving synthetic finishes are used both as clear and pigmented coatings curing at low temperatures. They are mainly used in quantity production. The process requires the article to be brought to the required temperature slowly, with humidity carefully controlled.

For small articles such as handles, dipping is most economical. The articles are attached to jigs, dipped into varnish or lacquer, and slowly withdrawn. The quality of the finish is controlled by the rate of withdrawal. A quick withdrawal will leave a thick full coating on the article while a slow withdrawal will result in a thinner coat. The viscosity of the varnish or lacquer used is a determining factor.

Painting of Wallboards

The general trend is to paint wallboards with flat finishes, particularly when used for the lining of walls and ceilings.

Most flat paints such as the plastic, flat alkyd, and flat oil paints may be applied direct to the boards. Two coats of the same paint are usually sufficient.

For enamelling with full-gloss or semi-gloss enamels it is first necessary to seal the boards. Shellac solution is sometimes used but there are general purpose sealers marketed for the purpose. In the absence of these a good wood primer is quite satisfactory.

After sealing, enamelling can proceed in the manner already described, by applying first an undercoat and then finishing with the desired type of enamel.

For clear varnish finishes a clear sealer is essential. Direct application of varnish to wallboards is generally unsatisfactory.

Finishing of Plywood

Plywood lends itself to any type of finishing and may be treated in the same manner as already described for timber surfaces. Open-texture plywood should be filled as already described. When plywood is used in a curved or bent form, (e.g. the roofs of caravans) the convex laminate tends to open the grain and breakdown of the paint film can occur due to stressing. By using a good quality oil primer when dry, and rubbing a ball of putty into the grain of the convex surface, cracking of the paint film can be avoided. Finish with exterior undercoat and an exterior enamel.

For marine work only resin-bonded plywood should be used. At least three coats of good quality marine spa varnish should be applied. Any stopping that may be required should be applied after the first coat of varnish.

Covering Capacity (Spreading Rate) of Paint

The amount of paint required to cover a given surface will vary according to the consistency of the paint and to operative methods. It may be said, however, that for exterior work a gallon of paint will generally cover from 800' to 900 square feet of dressed surface. Undressed surfaces require considerably more.

Fast-drying enamels and varnishes used for interior finish will cover from 500 to 600 square feet.

BLEACHING OF WOOD*

The following procedure has been found to be suitable for bleaching a wide range of timbers. Dark coloured timbers can be made several shades lighter and light coloured timbers can be bleached to a blond finish. There is no record of the bleaching reagents interfering with subsequent polishing operations.

The bleaching should be carried out on timber which has been cut and dressed and is ready for assembly or, alternatively, it may be applied to the assembled article. The bleaching is effected by one or more applications of aqueous ammonia followed by hydrogen peroxide. The details are as follows:—

* D.F.P. *Newsletter,* no. 182. See also *Technical Notes,* vol. 10, no. 1, issued by Division of Wood Technology, N.S.W.

Solution A. Aqueous ammonia—made by diluting one part of 0-880 ammonia with five parts of water.

Solution B. Hydrogen peroxide—this may be used in the concentrated form (100 volumes) or if the material is bleached readily it may be diluted up to five times with water.

Solution A is applied to the timber by means of a swab or mop and is immediately followed by solution B applied in a similar manner. The article is allowed to dry thoroughly and the above process repeated, if necessary. If these two treatments have not produced a marked reduction in the colour intensity the colouring agent is of a type which does not bleach readily and further treatment will have little effect. If the treatment has been effective, further applications of solutions A and B may reduce still further the colour of the timber.

After the article is thoroughly dry it should be lightly sanded to remove any roughness due to the water "lifting the grain" of the timber, and then polished in the usual manner.

Ammonia and hydrogen peroxide may be purchased at most retailers of industrial chemicals. Both chemicals should be stored in a cool place when not in use and as hydrogen peroxide deteriorates on standing it is inadvisable to buy larger quantities than are required for any particular job.

The ammonia fumes make it advisable that the bleaching be done in the open or in a well ventilated room. Care should be taken to avoid undue contact between either of these chemicals and the skin.

CODE OF PRACTICE FOR PAINTING OF TIMBER

A joint technical committee formed by the Timber Development Council of Australia and the Australian Paint Manufacturers Federation has produced a Code of Practice for Painting of Timber in opaque pigmented finishes. This is intended as an authoritative guide on painting practices necessary to achieve satisfactory performance of paint on timber and contains the best advice that technical staff in the two industries can produce at the present time.

The Code is available from the Timber Development Association of Australia under the title "Technical Timber Guide no. 7—Painting of Timber" (January 1968).

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XVIII

TIMBER AND FIRE

Considerable misunderstanding exists with regard to the risk of fire attached to timber and to timber structures. Timber is variously combustible according to species, but is non-inflammable—that is to say, it may be more or less burnt to ashes under certain circumstances, but comparatively speaking, it does not readily ignite (Desch). Before combustion will occur, timber (except in the case of chips, shavings, splinters and so on) must be exposed to a source of considerable heat and flame.

The following figures,* taken from records of the United States National Board of Fire Underwriters, should dispel any popular misconception concerning fire hazard in timber construction. The survey covered 149 cities and 2,623,209 buildings. Over the period of the survey the percentage of fires suffered by the various types of building was as follows:

Reinforced concrete	5.85	per cent
Brick and stone	3.03	per cent
Wood-frame	1.55	per cent

Of the fires covered by the above statistics, only 1 .08 per cent were exposure fires started by the burning of an adjacent building despite the fact that 74 per cent of the total buildings were of wood-frame construction.

It is primarily the contents of the building and not the structure that provides the fire hazard. While many building materials are, practically speaking, non-combustible, few, if any, will withstand the effects of intense and prolonged heat. Steel will twist and bend, and at certain temperatures even become plastic; concrete will disintegrate; brick walls will bulge or fall. Most untreated timbers ignite at about 300°C; steel loses half its strength at about 500°C; concrete fails at about the same temperature. The figures are significant because the temperature of a burning building is usually about 700° to 900°C.f It is therefore important that fires having once started should, within the limits of possibility, be localised, their progress retarded, and ultimate

* Quoted by H. C. Wickett in *The Australian Timber Journal,* Jan. 1945.

t *The Fireproofing of Timber,* Timber Research & Development Association Limited, U.K.

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damage or danger confined to structural non-essentials. The question of building design, whatever the medium of construction, therefore becomes most important.

In certain cases, particularly in warehouse and factory design, timber offers a distinct advantage in what is known as "mill construction". This involves the use of large structural members and heavy, smooth floors designed so as to obtain the necessary amount of strength with the minimum amount of surface and number of exposed projections. A smooth surface does not ignite readily, and large timbers can withstand fire for a considerable period before failure. Timber trusses have good fire resistance if all members are of sufficient size, and if at least 6 X 6 inches in section they will be superior to exposed steel trusses.* Mill construction in the United States enjoys favourable insurance rates and is probably safer in a fire than other forms of construction since it frequently happens that large timber columns and beams will merely char to a small depth and otherwise remain sound. During the initial stage of a fire, the formation of charcoal on the surface of heavy members acts as a fire retardant. Although the building as such may be very severely damaged, it will usually be more safely and easily repaired or, if necessary, demolished, than would be the case in buildings of other construction.

Australia, with its wealth of hardwoods, is particularly favoured in respect of mill construction since research has shown that with many timbers, the heavier the timber the more difficult it is to ignite and the longer it takes to burn.

Timber is a splendid heat insulator and so possesses another advantage in the event of fire. When timber is used for filing cabinets, cupboards and other containers, their contents are not so quickly destroyed as would be the case if metal were used. This is because the heat is rapidly transmitted through metal and chars papers and so on in contact, whereas in a wooden container the contents are unaffected until the timber is burnt right through.

FIRE-RETARDANT TREATMENT OF TIMBER

The following methods have been developed for treating timber to increase its resistance to fire.

Impregnation of Wood With Fire-resistant Chemicals

The efficiency of this method depends upon the chemical used and the degree of penetration. Even with the most efficient fire-resistant chemicals, surface application or a low absorption will not prove very effective. For this reason pressure impregnation into treatable timber is the most satisfactory.

Degrees of Protection. An impregnation process may introduce any required amount of fire-retardant into the timber up to saturation. Hence reference to "maximum fire protection" which implies the highest degree of protection and corresponds to a fire-retardant retention of 4 to 6 pounds per cubic foot,

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* American Factory Mutual Fire Insurance Co. Quoted by United States Department of Agriculture in *Wood Handbook.*

t *The Fireproofing of Timber.* Timber Research and Development Association Limited, London.

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and a "flame-proofing" effect, which corresponds to a retention of $1^{1/2}$ to $2^{1/2}$ pounds per cubic foot. These treatments differ in cost, and the choice will depend on service needs.

Weathering. Although it is difficult to extract from timber a water-soluble fire-retardant with which it has been impregnated, the question of "leaching" must not be forgotten. It is desirable, therefore, that treated timber to be used in the open should be protected from rain by covering it with a paint of low combustibility.

Gluing. If it is intended to glue timber treated with a fire-retardant, the advice of the manufacturers of the adhesive and of the fire-retardant should be sought.

Permeability of the timber is an important factor in successful treatment. Australian eucalypts, the true-wood of which is particularly difficult to impregnate, are in this respect, at a disadvantage. Pressure impregnation, however, is becoming increasingly available in Australia. Recently, Hicksons Timber Impregnation Co. (Aust.) Ltd. and Celcure (Aust.) Ltd. have introduced a fire-retardant treatment which is now available in most capital cities. With the addition of a separate tank to hold the solution, this fire-retardant treatment can be effected in the standard vacuum-pressure plants described earlier.

Work is now in hand on the classification of fire-retardant treatments under Australian conditions. A net dry salt retention of $2^{1/2}$ pounds per cubic foot puts timber so treated into "Class (1) spread-of-flame" under British Standards Specification in Britain. Similar classification is likely in Australia.

The principal chemicals used as fire retardants are monammonium phosphate, diammonium phosphate, boric acid, borax, sulfamic acid* and ammonium sulfamate. Most of these are used as mixtures.

These chemicals act in one or more of the following ways:

(a) By melting at a temperature below that at which timber burns and forming a glaze over the surface, thus excluding oxygen.

(b) By yielding, under the influence of heat, non-inflammable gases which "blanket" the combustion.

(c) By vaporising at a temperature below that at which timber burns and in so doing absorbing sufficient heat to prevent the temperature of the timber rising to combustion point.

Several fire-retardant preparations are available in Australia as proprietary lines. A monammonium phosphate preparation known as Faspos is supplied by Imperial Chemical Industries. Pyrolith is supplied (and used) by Hicksons Timber Impregnation Co. Ltd. for impregnation by vacuum-pressure processes. In addition to fire-retardant chemicals, Pyrolith also contains timber preservatives which are designed to protect the timber from fungal, borer and termite attack. Chromated zinc chloride, which is marketed as timber preservative, also has fire-retardant properties.

* The use of sulfamic acid and compounds as fire-retardants is described in *The Australian Timber Journal,* August 1945. Other treatments are mentioned in the May 1958 issue.

Fire-retardant Surface Coatings

The flame inhibiting ability of surface coatings is much inferior to that of impregnated timber. Nevertheless, certain paints and finishes, by temporarily stopping or retarding the spread of flames, do afford a worthwhile degree of protection. Most of these contain sodium silicate ("water glass") or calcium sulphate. Other ingredients may include powdered asbestos, borax and so on.

In using fire-retardant paints it is important to ensure that the whole of the surface to be protected is thoroughly and adequately coated. For work exposed to weather, paint specially prepared for exteriors must be used. Full directions for the use of fire-retardant paints are supplied by the manufacturers.

The term "fire resistant" rather than "fire proof" has been used in the above remarks since timber, along with most organic materials, cannot be made truly fire proof. These remarks do not seek to convey the impression that timber, whether treated or not, may or should be used in all cases where fire hazard exists. As with other materials, a sensible appreciation of the circumstances must always govern decisions as to how and where timber should be used. It can be stressed, however, that given correct designing and sound technique in construction, together with normal precautions, fire hazard is no

TABLE 32

FIRE RESISTANT TIMBERS

It is generally considered that the high density eucalypts have comparatively high lire resistance. The following Australian timbers* may be regarded as possessing this quality. They are not listed in any order of resistance but in alphabetical order of standard trade names.

Blackbutt	*Eucalyptus pilularis*
Bloodwood, red	*E. corymbosa*
Box, grey, coast	*E. bosistoana*
Box, grey	*E. moluccana*
Box, red	*E. polyanthemos*
Box, white	*E. albens*
Box, yellow	*E. melliodora*
Gum, forest red	*E. tereticomis*
Gum, grey	*E. propinqua*
Gum, grey	*E. punctata*
Gum, spotted	*E. maculata*
Gum, river red	*E. camaldulensis*
Gum, Sydney blue	*E. saligna*
Ironbark, grey	*E. paniculata*
Ironbark, narrowleaved red	*E. crebra*
Ironbark, broadleaved red	*Fibrosa ssp. fibrosa*
Ironbark, red	*E. sideroxylon*
Jarrah	*E. marginata*
Karri	*E. diversicolor*
Mahogany, red	*E. resinifera*
Mahogany, white	*E. acmenioides*
Satinay	*Syncarpia hillii*
Tallowwood	*Eucalyptus microcorys*
Turpentine	*Syncarpia glomulifera*

•Division of Forest Products, C.S.I.R.O. Melbourne.

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greater in timber-framed buildings than in other forms of construction. Experience, and the records of insurance companies, adequately support this view.

Costs of treatment are obviously important, but when the fire hazard is a major issue the minimum safety standards required rather than costs should be the deciding factor.

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XIX

MECHANICAL AND PHYSICAL PROPERTIES OF TIMBER

The phrase "strength of timber" is vague and almost meaningless unless it refers to a definite kind of strength. Loads (or forces) can be, and are, applied to timber, as to other structural materials, in a number of different ways. The measure of resistance by the timber to each kind of force determines the strength value of the timber for that particular force. These strength values, or mechanical properties, vary according to the nature of the force involved. Thus the force required to pull a piece of straight-grained timber apart length-ways (tension parallel to the grain) is immensely greater than that required to crush it in the opposite direction (compression parallel to the grain).

The extent and kinds of load which the various members of a structure will normally have to bear can be calculated. The designing architect or engineer can provide for them if he knows the strength properties of the particular kind of timber, or group of timbers, he intends to use for a specific purpose. He can thus avoid waste due to the specifying of unnecessarily over-size members and eliminate danger due to the specifying of members of inadequate proportions.

The mechanical properties of Australian timbers used for structural purposes have been ascertained by tests at the Division of Forest Products, Melbourne. (Strength grouping of Australian timbers is explained and listed in Chapter XXII). The Division has issued a *Trade Circular* (no. 26) explaining the commoner terms used in the mechanical testing of timber. These are now referred to and will indicate the nature of the various strength properties as applicable to timber.

Stress and Strain

When forces act on a solid body, they change its shape to a greater or lesser extent and there are induced in the body, internal resisting forces which balance the applied forces. The internal resisting forces are called *stresses,* while the change in shape or the deformation is known as the *strain.* Every stress

sets up a corresponding strain. It must be emphasised that, in technical language, "strain" is a deformation or change in shape and is not synonymous with "stress" or "force", in which sense it is often used in everyday language.

The term "unit stress" is used to denote the intensity of the forces acting, and is equal to the force divided by the area over which it acts. For instance, if a load of 1,000 lb. is supported by a column with a cross-sectional area of 10 square inches, the unit stress is $\frac{1,000}{10}$ or 100 lb. per square inch. In practice, the term "unit stress" is usually abbreviated simply to "stress".

The "unit strain" is the deformation per unit length. Thus, if a column 10 inches long when unloaded is 9·99 inches long under load, the total strain is 10 inches—9·99 inches or 0·01 inch and the unit strain is $\frac{0·01}{10}$ or 0·001 inch per inch. As in the case of unit stress, unit strain is commonly abbreviated to strain.

Static and Impact Loading

If a body supports a dead load, for example, a wooden beam supporting a brick wall, it is said to be subjected to *static loading*. This term is also used to cover the gradual and steady application of load to a body. On the other hand, if the load is applied suddenly, as when a weight is dropped on to a body, causing a sudden shock or jar, the body is said to be subjected to *impact loading*.

In structures, the loading is usually a combination of a static load with some degree of impact.

Tensile Stress or Tension

When the applied forces tend to increase the length of a body, it is said to be subjected to tension, and the stress in the body is called a tensile stress.

In timber (see Fig. 28) the forces may act along the grain or at right angles to it, the corresponding stresses being called tensile stress parallel to the grain and tensile stress perpendicular to the grain. If the grain is sloping, there is a combination of tensile stress parallel to the grain and tensile stress perpendicular to the grain.

Compressive Stress or Compression

When the applied forces tend to decrease the length of a body, it is under compression, and the stress is called compressive stress. As with tensile stresses, compressive stresses may be parallel to, or perpendicular to the grain. A compressive stress parallel to the grain is set up in house stumps as a result of the weight of the building, while the floor bearers, where they rest on the stumps, have set up in them a compressive stress perpendicular to the grain.

Shearing Stress or Shear

Shearing stresses are set up when the applied forces tend to cause one part of a body to slip over another part adjacent to it.

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Perpendicular to Grain

1 unit

Sloping Grain

Parallel to Grain

45 units
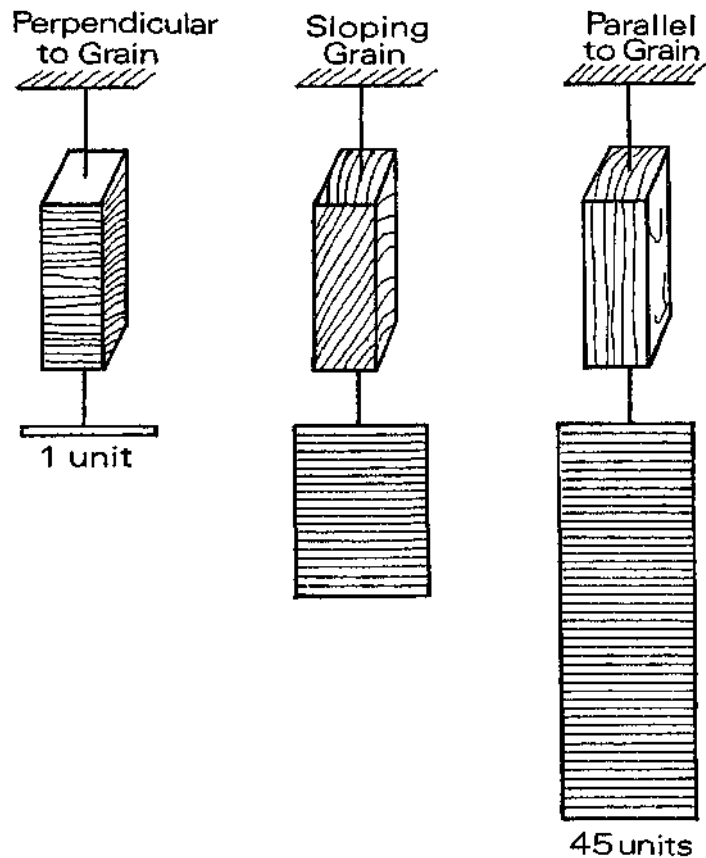
Figure 28.

Shearing stresses may be parallel to, or perpendicular to the grain, but it can be shown that a shearing stress sets up an equal stress at right angles to it. Because timber is much stronger in shear across the grain than it is along the grain, it is extremely difficult to obtain the true shear strength perpendicular to the grain, as failure always occurs by shear parallel to the grain, or by crushing.

Limit of Proportionality or Elastic Limit

If a force is applied to a body, the strain is directly proportional to the stress up to a certain point called the limit of proportionality or elastic limit,* that is, when the stress is doubled, the strain is doubled. Beyond this point, the strain increases faster than the stress.

Fibre Stress at Limit of Proportionality or Fibre Stress at Elastic Limit

If the stress in a body is below the fibre stress at elastic limit, the body will not completely return to its original condition on removal of the stress, that is, it becomes permanendy deformed, or technically speaking, has *permanent*

* Actually the limit of proportionality and the elastic limit are not necessarily the same, but for practical purposes they are so regarded.

set. Thus, the fibre stress at elastic limit is the maximum stress that can be applied without damage to the body.

Modulus of Elasticity

This figure is a measure of stiffness or resistance to deflection; the higher the modulus of elasticity, the less is the deflection or, in other words, the greater the stiffness. For instance, if a timber beam of a certain size under a given condition of loading deflects one inch when the timber has a modulus of elasticity of 1,000,000 lb./sq. inch, it will only deflect half an inch if the timber has a modulus of elasticity of 2,000,000 lb./sq. inch.

Beams and Bending

If a block of rubber such as is shown in Fig. 29 (a) is bent, it will be found that the rubber stretches on the outside face and contracts on the inside face. Midway between the two faces, or at the *neutral plane,* there is no change in length. In Fig. 29 (a), the straight block is marked out with a series of vertical parallel lines half an inch apart. It will be seen that when the block is bent, as at (b), the lines are no longer parallel, but are farther apart at the convex or lower edge, and are closer together at the concave or upper edge. Along the centre line or neutral plane, the lines are still half an inch apart, showing that neither stretching nor compression has taken place. On the convex face, where the lines are farther apart, the material has been stretched, and it is obvious that here there is a tensile force. This gradually

Figure 29.

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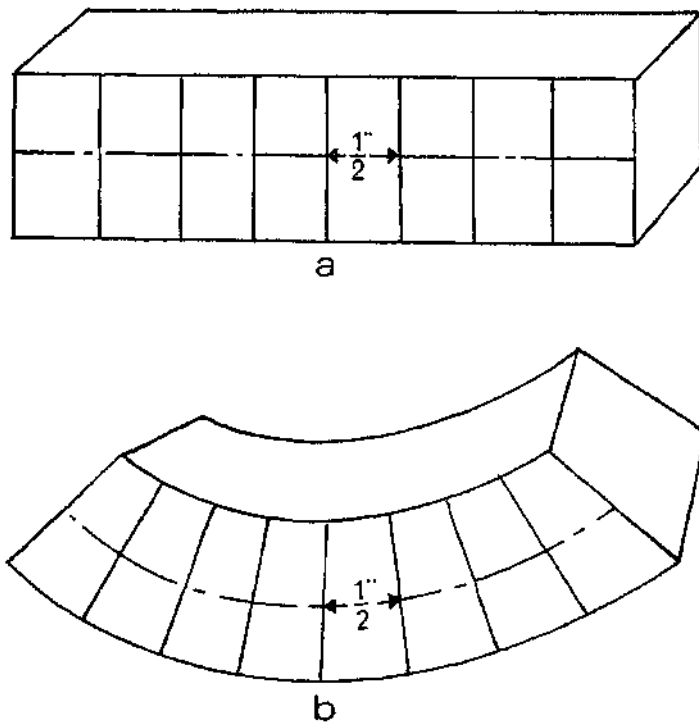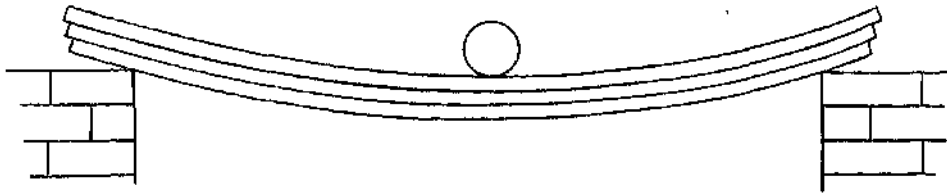
Figure 30.

diminishes as the centre line or neutral axis is approached where it becomes zero. As the opposite or concave edge is approached, the lines become closer together, indicating that the material is compressed. In other words, from the neutral axis to the concave edge there is a gradually increasing compressive force. Exactly the same conditions apply in beams made of any material, although with stiff materials such as timber or steel, the stretching and contraction are not visible to the naked eye.

In addition to the tensile and compressive stresses in a beam, shearing stresses are set up parallel to the long axis; they are at a maximum at the centre line or neutral plane. The presence of these shearing stresses may be readily demonstrated by placing several boards on top of each other and loading them. As the boards bend, they slip over one another so that the bottom corners of each projects beyond the top corners of the one below it (see Fig. 30.) Shear in a beam is called horizontal or longitudinal shear.

Modulus of Rupture

As the load on a beam increases, the tensile, compressive, and shearing forces increase also, until a point is reached when the material fails and the beam fractures. In wooden beams, failure usually occurs first on the compression or concave face, followed by failure in tension on the convex face, though in seasoned timber the initial compression failure is often not visible before failure in tension occurs. (In a short beam, or one containing severe checks or shakes, failure may occur by horizontal shear). The modulus of rupture is a measure of the maximum compressive or tensile stress in the fibres at the point of fracture. For reasons that are beyond the scope of this chapter, the modulus of rupture is not the actual stress in the fibres at fracture, but is approximately proportional to it, and can be used in design. Modulus of rupture is, therefore, a direct measure of the strength of wood in bending.

Thus, a beam of timber having a modulus of rupture of 10,000 lb./sq. inch is twice as strong in bending as one composed of timber having a modulus of rupture of 20,000 lb./sq. inch, provided that failure does not take place by horizontal shear.

*Influence of Dimensions on the Strength and Stiffness of Rectangular Wooden Beam Having a Given Modulus of Rupture and Modulus of Elasticity**

1. *Span.* The bending strength of a rectangular beam varies inversely as its span, that is, if the span is doubled, the strength is reduced to one-half, if the span is trebled, the strength is reduced to one-third, and so on.

*For simplicity, the influence of shear has been neglected.

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The deflection of a beam varies as the cube of the span, if the span is doubled, the deflection is increased $2^3 = 8$ times; if the span is trebled, the deflection is increased $3^3 = 27$ times.

2. *Width.* The bending strength of a beam varies directly as its width, other things being kept constant—if the width is doubled, the strength is doubled, and so on.

The deflection of a beam varies inversely as the width—if the width is doubled, the deflection is halved, or if the width is halved the deflection is doubled.

3. *Depth.* Other things being equal, the bending strength of a beam varies as the square of its depth—doubling the depth increases the bending strength four times, trebling the depth increases the strength nine times, and so on.

The deflection of a beam varies inversely as the cube of the depth— doubling the depth reduces the deflection eight times, trebling the depth reduces the deflection twenty-seven times, and so on.

From the above, we see that for a given span and quality of timber, the strength and stiffness of a beam vary directly as the width, that is, the strength and stiffness are doubled when the width is doubled; but the strength varies as the *square* of the depth, for example, doubling the depth increases the strength four times; while the stiffness varies as the *cube* of the depth, for example, doubling the depth increases the strength eight times. A proper understanding of the above relations is essential for the economical construction of timber structures. Of course, the ratio of depth to width must not be increased too much, or the beam becomes unstable and is liable to twist under load unless supported in some way. A ratio of depth to width of from two to two and a half is about the best compromise where no lateral support (such as that given by flooring nailed to a beam or by herring-boning) is provided.

Concentrated and Distributed Loads

The load on a beam may be applied at one or more points, as, for example, the load applied to bridge beams by the wheels of a locomotive, in which case it is said to be a *concentrated* load. On the other hand, if the load is spread over the length of the beam, as, for example, a brick wall being supported by a beam, it is said to be *distributed.*

A beam can carry twice as great a load if it is uniformly distributed over the full length of the beam than if it is concentrated at the centre of the span.

Toughness

This is a term which is commonly applied to more than one property of wood. Thus, wood which is difficult to split is said to be tough, or again, a tough wood is one that will not rupture until it has deformed considerably, or is one that still hangs together after it has been ruptured and may be bent backwards and forwards without breaking apart. In technical language, however, toughness is the ability to resist shocks and blows and is synonymous with impact strength. A high degree of toughness is important for such purposes as tool handles and sporting goods.

Brittleness

A substance that cannot undergo much change in shape without fracturing is said to be brittle. Thus, glass is a brittle material. Brittleness in timber may be due to defects such as knots or sloping grain (see Division of Forest Products *Trade Circular,* no. 13), or to brittleness of the timber fibres themselves. Brittle timber breaks suddenly with a "carroty" fracture as distinct from the fibrous or splintering fracture of tough timbers. Brittle timber is often spoken of as being "short in the grain", but it is recommended that the use of this term should be discontinued, as it does not distinguish between the different causes of brittleness and is liable to be confusing.

Hardness

The term "hardness" may refer to the difficulty in sawing, planing and so on, to the resistance to wear or abrasion, or to the resistance to indentation. In published tables of mechanical properties, hardness refers to the resistance to indentation, which generally, but not necessarily, goes with difficulty in working or resistance to wear. Such figures, also, are of direct value in determining the utility of timbers for such purposes as mallets.

Working Stresses and Factor of Safety

For several reasons, it is not safe to use the ultimate strength figures obtained by laboratory tests in actual design of structures. The stresses used in design are called *working stresses* and are always considerably less than the average ultimate stresses, being obtained by dividing the ultimate stresses as determined by laboratory tests by a factor known as the *factor of safety.* Thus, if the average modulus of rupture of a certain species is 10,000 lb./sq. inch and the factor of safety of five is decided upon, the working stress to be used in the design of structures would equal $\frac{100,000}{5}$ or 2,000 lb./sq. inch. It must not be thought that because a structure has a factor of safety of say, five, that it is capable of withstanding five times the designed load. Actually, it might only carry one and a half times the designed load for an indefinite period. The factor of safety has to take care of such factors as the variability in the strength of the clear timber, the influence of any defects that may be present, the duration of the load, and any deterioration that may occur during the life of the structure, as well as the possibility of accidental over-loading.

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BENDING OF TIMBER

Bending, as a means of producing curved parts in timber construction, has several advantages over other methods of manufacture, the principal ones being increased strength and economy in material.*

Four main considerations are involved in bending, and unless the bending practice is arranged in accordance with them, the percentage of failures will be unduly high or the resulting bends will be unsatisfactory. The first of these is the selection of stock, the second is the softening of the timber, the third is the stresses produced in bending and the reaction of a piece of timber to them, and the fourth, drying after bending so that the bent piece will retain its shape without failure.

Selection and Preparation of Stock

Timber to be used for bent stock must be carefully selected if the percentage of failures is to be kept reasonably low. It is far cheaper to select only good bending material, rigidly excluding any pieces containing other than permissible defects, than to go to the expense of attempting to bend material which should have been culled, only to be forced to reject it later because of failures.

The first point of importance is selection of the right species for bending. In addition to the ability to bend well, the species chosen must have the other necessary qualifications for the purpose for which it is to be used. Thus, timber for tennis racquet frames must be light in colour, resistant to shock, and fairly light in weight. For skis the timber must be resistant to shock, hard wearing, and retain a smooth surface.

Hardwoods (pored timbers) are in general more suitable than softwoods (non-pored timbers) † also tough timbers bend better than brittle ones. The opinion sometimes held that heavy strong timbers are not suitable for bending is incorrect. Many comparatively heavy and strong timbers, such as karri, spotted gum and the tulip oaks, behave quite well in bending. From the infor-

* See D.F.P. _Trade Circular,_ no. 22.

† For a description of the difference between hardwoods and softwoods, see Chapter XIV.

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mation available, a list of common Australian timbers that have been found suitable for bending is given in Table 41 (p. 323).

There is a tendency to believe that, providing a good bending timber such as blackwood is obtained, this is all the selection necessary. This is far from being the case. Often, it is far more important to select the right material within the species than to select the best species. For instance, the toughness of timber varies considerably within a species, and as brittle timber is unsuitable for bending, such timber should be rejected. A test for brittleness can be made by digging into a surface and prising up a small splinter with a sharp pointed instrument such as a penknife. A tough timber will give a splinter which tends to run along the grain of the timber and resists the prising action. A brittle timber will readily allow short "carroty" pieces to be dug out with the point.

Straight-grained material must be selected for bent stock. Sloping grain inevitably leads to failures in all but the simplest of bends. In general, back-sawn timber bends more readily than quarter-sawn timber.

Faults which are likely to weaken the timber during bending must be avoided. Usually, bending timber is specified to be free from all defects.

The severity of bending possible depends upon the thickness of the timber and the radius of curvature. The thicker the timber and the sharper the bend, the greater is the difficulty of making a successful bend. Hence, timber should be reduced to the smallest possible dimensions before bending. Allowances for final shrinkage and for final dressing should be kept to an absolute minimum. Also, it has been found that slight irregularities in the surface of timber set up danger spots during bending, where failure is likely to take place. For example, the saw marks on the face of a piece of timber will be found (if examined closely) to include a number of more or less sharp-edged hollows. These assist failure. Timber should therefore be dressed before being bent, preferably on all four sides.

There is a difference of opinion as to the correct initial moisture content for bending stock. The higher the moisture content, the greater is the liability to failure by crumpling on the compression or inside the curve, and also the greater is the difficulty in satisfactorily drying the timber after bending. In some timbers, bending at high moisture content will result in collapse. On the other hand, if the moisture content is too low, much greater force is required to make the bend and failures on the tension or outside face of the curve are liable to occur. It is generally considered that timber air-dried to a moisture content of from 15 to 20 per cent is in the best condition for bending.

With some of our hard and strong timbers such as karri, it is possible that the most suitable moisture content may be somewhat higher than 20 per cent.

Softening

The most common method in use for softening timber for bending is by steaming. This is most frequently carried out at atmospheric pressure, although higher pressures are sometimes used. For steaming at atmospheric pressure, the usual time allowance is one hour per inch of thickness, although with

easily bent timber this can usually be reduced considerably. Very long periods of steaming are not desirable because they over-soften the timber and seriously increase the moisture content, thus accentuating difficulties such as shrinkage, checking and warping during re-drying. Also, they are likely to affect the strength of the timber adversely.

Steaming chambers are simply reasonably steam-tight boxes of dimensions to meet the sizes of timber and capacity of the plant. They are built of a variety of materials. Sometimes they are made of timber, but unless carefully constructed, a timber chamber has a short life, and such boxes soon leak and result in steam waste. For metal lining, sheet copper or muntz metal is recommended, joints being sweated in pure tin. Zinc or galvanised iron must be avoided because acids from the timber rapidly attack zinc.

All chambers should be built so that condensed moisture drains away. If bending takes place continuously, it is desirable to build a series of small chambers, which can be emptied and recharged in rotation, thus giving a reasonably constant steaming time to all stock.

Boiling in water is sometimes advocated as a substitute for steaming. This is not usually as satisfactory as steaming, firstly, because it tends to stain the timber; secondly, because re-absorption of moisture is greater, and re-drying difficulties are increased; and thirdly, because a steam chamber heats up much more quickly than the water in a vat can be boiled.

Theory of Bending

In order to understand why failures take place in bending timber, and to realise what precautions must be taken to prevent them, it is necessary first to consider what happens to a piece of timber when it is bent. If a block of rubber is bent, it will be found that the rubber stretches on the outside edge or convex face of the bend and contracts on the inside edge or concave face. Along the centre line, or neutral axis, there is no change in length. The same tendencies occur in the bending of timber. On the convex face there is a stretching or tensile force, and on the concave face a compressive force. These forces diminish towards the neutral axis, at which point they are at zero.

Now, the important feature to remember in timber bending is that heated timber will compress a large amount without fracturing, but it will only stretch a very small amount without tearing apart. Hence, if a piece of timber is steamed and bent without proper precautions, it tends to fail on the convex or outside face, due to the tensile force. The principal problem in the bending operation is how to keep down this tensile force in the timber to such a small figure that the timber will not be ruptured.

Bends in which the ratio of the thickness of the piece to the radius of curvature is less than one-thirtieth can often be successfully made without taking any special precautions, but for more severe bends it is necessary to assist the timber to resist the tensile forces on the convex face. This is done by means of metal straps or bands, which take up the larger portion of the tensile force and greatly reduce the extension of the convex face. If the strap is to be effective in limiting the stretch, however, it must have securely attached to it, adequate end fittings against which the ends of the piece can bear. The success of the
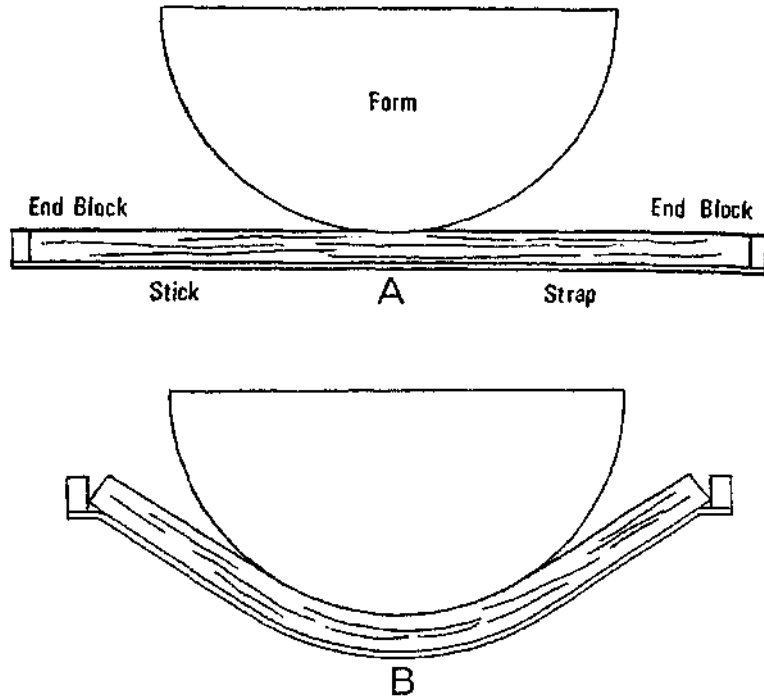
Figure 31.

bending operation will depend on the effectiveness of the straps and end fittings.

Fig. 31 illustrates a common fault in straps. The end blocks are too short in the direction of the strap, and as soon as the load comes on, the end blocks will tip over and slip off as shown at B, and the strap becomes ineffective. The correct type of end fitting will depend on the type of equipment that is being used. In the simple type where the bend is made between two forms, the end blocks may be merely angle irons riveted to the strap, the leg fastened to the strap being three or four times longer than the leg bearing against the timber. In other types of machines and for hand bending, it is advisable to use the reversed lever arrangement of strap and fitting shown in Fig. 32. In this

Figure 32.

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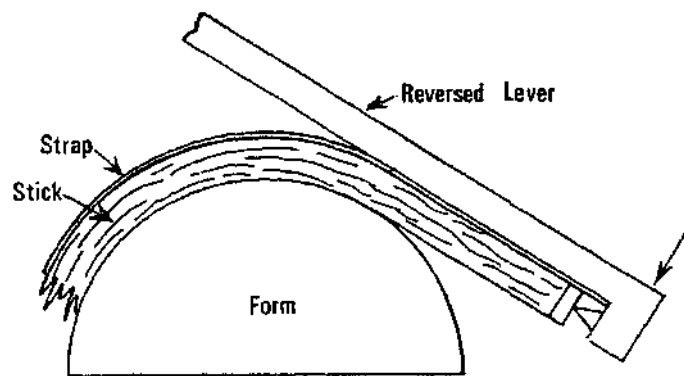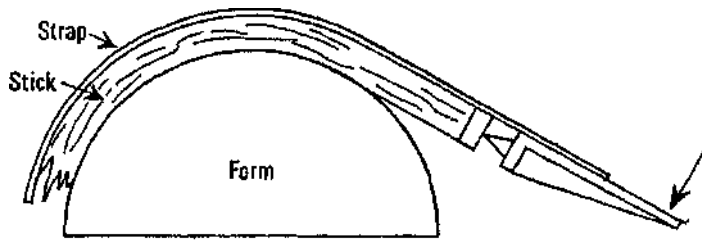
Figure 33.

arrangement the reversed lever must be stiff and about as long as the stock being bent. The type of fitting shown in Fig. 33 is often used, but is inferior to the reversed lever, since, for the best results, the point of application of the load should vary as the bend proceeds.

Frequently, stock is cut too long or too short for the strap. If a piece that is too long is forced into the strap, the lower corner of one or both ends is crushed, thus allowing stretch to occur, with resultant failure. If the piece is too short, a common practice is to fill the gap between the piece and the end blocks with pieces of timber, which are usually placed so that the pressure is taken by the side grain, and, as timber is easily crushed in this direction, the packing pieces fail and allow stretch to take place. The necessity for exact docking is, therefore, apparent. To overcome slight inequalities in length, it is advisable to provide some means of adjusting the length of the strap. This is most conveniently done by having, in addition to the heavy end fittings, loose end pressure bars, the position of which can be adjusted by heavy screws passing through the end fittings. In order to distribute the pressure uniformly over the ends of the stick, the end bars should be pivoted at the middle of their height on the points of the screws (see Fig. 34).

This arrangement also allows the pressure to be relieved a litde as bending proceeds—a considerable advantage in reducing the number of compression failures and in decreasing the forces required in bending.

Another point worth mentioning is that the strap should be strong enough to take up the tensile forces without appreciable stretching. The strap should not be narrower than the width of the piece; a common thickness for small bends is about $^1/_{32}$ inch.

Steel straps are the most satisfactory where corrosion or discoloration is not a difficulty.

With efficient straps, properly used, and with straight-grained, tough stock, there is no excuse for tension failures occurring during bending. Localised compression failures are more difficult to avoid, but they can be minimised by

Figure 34.

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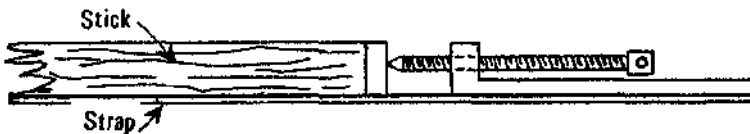
proper selection of the material, by surfacing before bending, and, in the case of hand bending operations, by clamping the piece to the form as bending proceeds.

Bending Equipment

Especially in the case of complicated or reverse curves, a great deal of bending is done by hand. The necessary equipment consists of a form made from timber or other suitable material, over which to bend timber, a means of holding one end securely, and, for the more severe bends, a strap for taking up the tension. In order that the piece may retain its shape, it is usually necessary to leave it on the form for some time after bending. This entails the use of a number of forms and straps.

Special machines have been developed for carrying out all except the most complicated bends.

Re-Drying

After the bend has been made, the timber has to be dried out before it is fit for use. As bent stock is usually used under conditions where it is protected from contact with moisture or high humidity conditions, the ultimate moisture content desired is usually in the neighbourhood of 12 or 15 per cent. If the stock is relatively high in moisture content before being bent, the amount of drying after bending will be great, due to the high initial moisture content and the pick-up during steaming, and there will be the attendant risk of failure of the bends together with warping and checking. Also, high temperatures at high moisture contents affect the strength of some species of timber very seriously, so that the susceptibility to checking is increased.

When the requisite bend has been made in the bending machine or frame, the timber is usually fastened in the bent position by means of a tension piece or clamp. If the clamping is self-contained, it is then removed from the machine and stacked to set and dry. If not, it is allowed to set in the frame. The heat added during the steaming process will assist the drying, and will remove some of the moisture added during steaming. However, except in exceptional cases, further drying is necessary to reduce the stock to a satisfactory condition. If stacked to air-season, it should be placed under cover, because in the open it may re-absorb rain water, with the consequent possibility of deterioration. Individual pieces should be properly spaced by means of spacing strips so that a uniform circulation throughout the stack can be maintained.

Boat Planks and Other Timbers

Boat planks and timbers and so on, are taken direct from the steaming chamber and clamped or temporarily fitted to the hull or to the hull forms. Best practice is to leave the planks or timbers thus temporarily fitted sufficiently long to enable the moisture absorbed during steaming to dry off.

Laminated Construction

As the severity of the stresses in bending varies with the thickness of the piece to be bent, difficult bends can often be facilitated by laminating the

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timber. Such a method is often used in the manufacture of tennis racquet frames, where in place of one piece about ½ inch thick, four or five laminations about $\frac{1}{8}$ inch or $\frac{1}{10}$ inch thick are employed. Such thin pieces are often bent without steaming, but in construction of this type particular care should be taken in the gluing practice.

In addition to tennis racquets, laminated bent construction is now used in a variety of products such as curved decorative portions of furniture, skis, and arched ribs for roof construction. (See Chapter IX "Glued Laminated Construction").

General

It will be realised that in many bending requirements special precautions and special equipment are necessary. It is not possible to consider all such problems here. However, by the application to a particular case of the fundamental principles outlined, it is usually possible to overcome individual difficulties. If further advice is needed, inquiries can be addressed to the Chief, Division of Forest Products, C.S.I.R.O., Box 310, South Melbourne, Victoria.

TABLE 33

List of some timbers reported to be suitable for steam-bending.

Common Name Standard	Common Name Others	Botanical Name Reference
Ash, alpine	Woollybutt, red ash	*Eucalyptus delegatensis*
Ash, silver, northern	Ash	*Flindersia pubescens*
Ash, silver, Queensland	Ash	*Flindersia bourjotiana*
Ash, silver, southern	Bumpy ash	*Flindersia schottiana*
Blackwood		*Acacia melanoxylon*
Gum, spotted		*Eucalyptus maculata*
Karri		*Eucalyptus diversicolor*
Kwila	Johnstone River teak	*Intsia bijuga*
Leatherwood		*Eucryphia billardieri*
Maple, Queensland	Maple	*Flindersia brayleyana*
Maple, Queensland	Silkwood	*Flindersia pimenteliana*
Oak, red tulip	Crowsfoot elm	*Heritiera peralata*
Quandong, silver	Blue fig	*Elaeocarpus grandis*
Stringybark, yellow		*Eucalyptus muelleriana*
Taun		*Pometia pinnata*
Yellowwood	Long jack	*Flindersia xanthoxyla*

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XXI

THE RELATIONSHIP OF TIMBER PROPERTIES TO UTILISATION

GENERAL CONSIDERATIONS

As briefly outlined in the "Introduction" to this Handbook, man has used timbers found suitable for his daily needs since his earliest days. It is evident that for each particular use the essential requirements to be met by the woodwork were carefully considered. Timbers were then chosen which not only possessed the properties necessary for efficient service but also were available in the sizes and quantities required.

Some timbers have become so closely related to particular uses that timber craftsmen have tended to believe that no other timber could be suitable for the work, or at least could not give the same degree of efficiency. When a new timber unlike the old favourite in general appearance is proposed, it is likely to be rejected without trial through unwarranted prejudice. A commonly used group name may prove sufficient to undermine confidence. Lesser known rain-forest timbers, through much past mishandling, may be dismissed as useless "scrubwoods".

In many places, timbers widely accepted and used in the past have become increasingly difficult and expensive to procure and it has been found, necessary to reassess the position, both from the viewpoint of continued availability and of the basic needs in timber for the woodwork to be carried out. Of the latter, workability, natural durability, strength and appearance come Immediately to mind with varying relative values according to use.

In selecting individual timbers for particular uses under present day conditions it is most important, after determining the real needs of the work proposed, to obtain if possible the answers to three questions for each timber considered:—

(1) What is its *correct identity* in standard trade common and botanical names?

(2) What *sizes and quantities* are *available* at economic cost?

(3) What *natural properties* has the timber, good and bad, *relative to the use* proposed?

Correct identification is the key to published literature on the timber and its properties, in addition to related species. If there is any doubt in regard to the correctness of the naming of any timber, a sample can be sent to a competent authority for identification and advice. If botanical specimens in the form of leaves, flowers and/or fruits only are available, the aid of trained foresters or botanists should be sought. They are usually well informed on the question of availability.

Timbers such as red cedar *(Toona australis),* white beech *(Gmelina* spp.) and yellowwood *(Flindersia xanthoxyla)*, highly regarded for special values in workability and natural durability, are now of little economic importance because of scarcity. In circumstances where the manufacturer claims that he "must have" a particular timber in short supply he should, if possible, be given the facts and assisted to make his own inquiries in regard to supply.

A folding chair maker was convinced that yellowwood alone would meet his special needs. After futile efforts in the most likely areas to provide quantities in the quality desired, he gladly changed to boron impregnated tulip oak which, although harder to work, was stronger, of pleasing appearance and readily accepted by his customers in two States.

Urgent wartime demands were received for large keel blocks in "oak" *(Quercus* spp.) and similarly unprocurable lignum vitae *(Guaiacum officinale)* for small power boat stern bearings. The first was supplied in grey ironbark *(Eucalyptus drepanophylla)* and grey gum *(Eucalyptus punctata),* superior both in durability and strength, from northern New South Wales; and the latter in North Queensland saffron-heart *(Halfordia scleroxyla),* not quite as good in wearing ability but available in sufficient quantities and doing a good job in action.

Complete investigation of *wood properties,* particularly of little known timbers, may take some considerable time but most are immediately available for consideration in a broad sense in relation to use. In fact a points score, both for and against, can be made for most timbers provided that the user is able to agree upon the properties which are, and are not essential, and the relative importance of each for the work in hand.

TIMBER PROPERTIES

Density

The most important single use property is *air-dry density,* which indicates the condition in which most timber is normally used, and is expressed in pounds per cubic foot of timber at 12 per cent moisture content. The air-dry and green weights of important Australian and imported timbers are supplied under the heading *"Densities of Some Australian Timbers"* and Table 35 at the conclusion of this chapter. Figures for other species are included in three large groups in Chapter XIII *(Principal Commercial Timbers Used in Aus-*

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tralia) and in publications available from the Division of Forest Products, C.S.I.R.O., Division of Wood Technology, New South Wales Forestry Commission and from State Forestry Departments.

Wood *density* has a close affinity with a number of other properties which have great significance in successful timber utilisation. In the first place it is a reliable general guide to the *"workability"* or ease of working of any timber, but this may be modified by other factors such as the presence of silica, reaction wood, straight or interlocked fibres, open or close texture due to cell size or oily inclusions.

On unit air-dry weight and related workability alone, all timbers can be divided broadly into two main groups: those acceptable as good working "cabinetwoods", and heavier, harder and more refractory "structural hardwoods", the dividing line being in the vicinity of 50 pounds per cubic foot or approximately 4 pounds per super foot. In the 50 pounds and over range, it may be necessary to accept timbers with weights as high as 70 pounds or even more per cubic foot but such higher densities are generally a disadvantage for most building purposes.

Lighter timbers can be further divided for purposes such as rotary peeled veneers which are generally preferred in the 30 to 40 pounds per cubic foot weight range air-dry. Timbers much below 30 pounds per cubic foot may require special arrangements to secure adequate strength and nail holding capacity.

As mentioned in Chapter V (Saws and Saw Fitting) the density of the timber to be sawn is the governing factor in determining the most efficient saw speed in band and other high speed saws. Experienced sawyers can estimate the hardness of timber being sawn by the pitch of the sound coming from the saw.

With greasy timbers such as tallowwood, spotted gum and crow's ash the work required for cutting as determined by density is considerably reduced by the natural lubricants, while in timbers containing abrasive substances, reaction wood, interlocked fibres or very close texture, the difficulty in sawing is greatly increased.

Hardness in working, as indicated by air-dry density, is generally a disadvantage in cabinetwork, joinery and even in building framing as shown by the dislike of builders for the ironbarks. On the other hand, hard, close textured timbers excel in structural members subjected to heavy surface wear such as in bridge and wharf decking and floors of factories and public buildings. Hard timbers resist "rail cut" and reduce the need to distribute the bearing load of steel rails on railway sleepers. There is a very close relationship between air-dry density and surface hardness values, as shown by the Janka test.

Timbers may be described as "hard to work" by machinists, not because of high density, but from the wearing effect on cutting tools caused by natural abrasives in the timber. Queensland walnut *{Endiandra palmerstonii)*, swamp mahogany *(Tristania suaveolens)* and brush box *(Tristania conferta)* are very much more difficult to cut with high speed tools than their air-dry densities would indicate. This is a very great disadvantage in any timber

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usage which requires a considerable amount of cutting, shaping and surface finishing as in joinery, furniture and mouldings. It is less important in the production of veneer where the movement against the cutting edge is relatively slow.

Early determination of the green and air-dry density of any timber under consideration for use is very important because of the close relationship of these to various *factors of strength.* These include *modulus of rupture* and *modulus of elasticity* in bending. The strength groups S1 to S7 for use in working stresses recently introduced by the Division of Forest Products, C.S.I.R.O., can be fairly accurately estimated for an unknown timber from its air-dry density provided that the piece is properly graded for any strength reducing defects present.

A paper on "Sawing Methods in Relation to Stiffness of Studs"* states:— "Specific gravity is a fairly effective index to strength. Most strength properties are more closely related to specific gravity than the width of annual rings or other easily determined indices. Specific gravity therefore is the index of strength used in the survey being made, and is derived from breast high increment cores from sample trees on cruise plots."

In most structural building the choice of a timber member by size, shape and species for use as a beam is governed more by practical limitations in deflection than actual breaking strength. There is, however, a close relationship between modulus of rupture and modulus of elasticity which is used to advantage in modern stress grading machines. The breaking strength of any beam is greatly influenced by the presence of such defects as sloping grain, heart timber, decay, knots according to size and position, and insect damage. These are given due consideration in the limits imposed in the Australian Standard Grading Rules.

There is a useful relationship between air-dry density and the *cleavage strength* of timber along the fibres. This is usually lowest in a radial direction, or along the longer axis of the rays. Timbers with low cleavage values such as cypress pine *(Callitris* spp.) split rather freely when nailed into the tangential face and require a greater thickness in building members such as roof battens for iron. Truncated nails or those with blunted points, which cut rather than wedge the fibres apart, are more efficient than normal pointed nails.

Impact toughness strength also increases with density, and a high value is essential in timber in positions subject to variable, or especially shock loading, as in some tool handles, bridge members and spars. This kind of strength is less important in timber under more or less static loading such as house-framing, sheeting, panelling and much domestic furniture.

In the same way it has been found that strength values in *tension* along the fibres, *compression* parallel to and perpendicular to them, and also *shear,* are closely related to density. These factors are fully considered in designing buildings and other structures required to withstand pre-determined loadings with a wide margin for safety.

* L. H. Reineke, Forest Products Laboratory, University of Wisconsin, U.S.A. Department of Agriculture at the meeting of International Union of Research Organisations, Melbourne. October, 1965.

Finally, air-dry density can be used as a general index to *shrinkage,* and in some botanical families to the *durability* of timber; those of higher density usually being subject to greater shrinkage and slower deterioration due to fungal attack.

Durability

After density, natural durability is probably the next most important timber property to be related to utilisation. It can be shown that certain botanical families such as the *Cupressaceae* (Cypress pines), *Verbenaceae* (teak, white beech), *Myrtaceae* (Eucalypt hardwoods, turpentine, satinay), *Leguminosae* (jam, gidgee, black bean) and *Meliaceae* (red cedar, rose mahogany), contain a high proportion of very durable woods in regard to decay resistance, particularly where the density is high. In other well known families such as the *Sterculiaceae* (kurrajongs, tulip oaks) and *Pinaceae* (*Pinus* spp.), most of the timbers, heavy and light, have relatively low durabiiity.

The durability of timber generally with the wood destroying agents, is further discussed in Chapter XVI (Timber Preservation). Information on particular species is available from the durability class ratings given for commercial timbers described in Chapter XIII.

It is essential for those responsible for preparing timber specifications to know individual timber values on one hand, and on the other the hazards of fungal decay, insects or marine borers to which the structure will be subjected during the service life.

Moisture   Content

It is probably true that for most uses, the three most important keys to successful utilisation of timber are a detailed knowledge of its *density, durability* and *moisture content* both before and after placing a structure.

As explained in Chapter XV (The Seasoning of Timber) the moisture content of timber is a variable property and it is most important to determine it for timber proposed for use in any situation, in order to predict its probable life in service.

The hardness and strength of timber are increased with a reduction in moisture content below the level where it begins to shrink. Below 20 per cent moisture content, or in a continually water-saturated condition, timber is not normally subject to any form of decay and will last indefinitely. If timber is used at a moisture content above the level which is related to surrounding air conditions of humidity and temperature, it will certainly lose moisture and shrink until this level, known as the "equilibrium moisture content", is reached.

It is thus necessary to know what is the normal moisture content to be expected in all timber members of the structure to be built so that timber can be supplied at the correct level, or if unseasoned or partly seasoned timber must be used, so that the extent of shrinkage to the final stable condition can be calculated. A continuously low moisture content in timber is the best insurance against fungal decay.

Moisture content in timber is thus directly related to its stability in dimensions and shape, and a minimum of change is most desirable in all furniture joinery, plywood and other articles such as tool handles, rifle furniture and timber used in precision instruments. Timber is completely dimensionally stable when saturated with water, and at its minimum density when dried free from moisture. These facts are used in calculating basic density as described later in this chapter. Timberwork can also be kept dimensionally stable by conditioning the surrounding air to a uniform relative humidity and temperature, but this is very difficult to achieve in a large building.

As previously noted all timbers shrink appreciably from the green condition to air equilibrium and this varies with the species and the plane of the face measured in relation to its position in the log. Timbers of some botanical families show relatively low shrinkage and also swell and shrink less in response to changes in air humidity and temperature. Others have above average shrinkage and lateral movement across the fibres.

Greasy timbers tend to have below normal shrinkage, and timbers of higher air-dry density shrink more than those which are lower in density. There is also a general trend for timbers of abnormally low cleavage strength to shrink less than would be expected for their density. High durability and minimum lateral movement with weather changes are the two most desirable properties for ships' decking. This accounts for the great popularity of teak and white beech, with several coniferous softwoods, for this purpose.

Shrinkage of 5 per cent or less in a tangential direction across the fibres from green to air-dry may be considered as relatively low, while similar shrinkage of 10 per cent or more is above average. A further consideration is the *differential shrinkage,* or ratio of tangential to radial shrinkage, which causes distortion in drying, particularly in thicker pieces sawn between the "back" and "quarter" positions. A ratio of tangential to radial shrinkage of more than 2 to 1 can cause considerable distortion in the right-angled corners of sawn squares and planks.

In timbers of high shrinkage, the volume yield in seasoned material is considerably reduced. Back-sawn green boards must be cut oversize in width to finish to standard marketable dimensions while quarter-sawn boards require greater thickness to avoid "hit and miss" in dressed timber. All timber finished to a standard pattern should be dried to air equilibrium before machining.

Reasonable stability in timber is a very desirable property. Coniferous softwoods are superior in building work to eucalypt hardwoods used green because they dry more quickly and the smaller movement in framing gives fewer faults in plaster and other wall sheeting. Soft, clean cutting, dimensionally stable woods such as the softer kauris, and even white cheesewood with its latex canals, are preferred for pattern making.

Appearance

The surface appearance of a timber has a considerable influence upon its popularity for furniture, panelling, decorative veneers and other work where

an attractive finish is desired. This may be related to the natural colour of the heartwood, the figure as produced by the fibre and other cell arrangement and the surface texture from the size of the vessels in non-coniferous timbers. See Chapter XIV (The Growth and Structure of Timber).

The figure of some timbers, such as the silky oaks, is produced by large rays, or by abundant soft tissue in regular patterns as in coachwood. In the conifers, the dominant figure comes from the annual rings caused by a reduction of the size of the tracheids (in place of fibres) from the "early" to the "late" wood according to the seasons.

Sometimes the softer tissue can not readily be seen and can be improved greatly in figure by staining. Unfigured woods of pale neutral shades of colour are valued because they can be stained very easily to represent well known and popular timbers. It is here that the art of the decorator and French polisher is seen.

Some timbers, including Queensland maple and satinay, change to popular grey shades when exposed to ammonia fumes, others are sensitive to sunlight during open-air seasoning and after dressing reveal transverse bands from the separating strips. The latter is a disadvantage in timber for decorative work in a natural finish.

Extractives

Many chemical substances may be extracted from timbers which have a bearing upon their utilisation. In general, extractives of any kind are not desired in timbers required for the manufacture of pulp and paper products which are mostly pale in colour.

The best known extractives in Australian timbers are the tannins which in the Eucalypts greatly increase fungal resistance. They may also add to the density without a corresponding increase in bending strength. Acid tannins in damp timber can corrode ironwork and iron fastenings in exposed woodwork not adequately protected by paint and putty. This can be serious in wall cladding, exposed flooring and roof battens to which rain can obtain access through the holes for the nails in galvanised sheeting.

Unpainted scantlings of timbers containing tannins are often the cause of unsightly staining on brick and concrete work during stormy weather while the building is under construction. Splayed hardwood weatherboards painted on the face but not on the backs, often suffer the same fate during heavy rain when any timber face exposed to wetting is liable to stain leaching. Unputtied nail holes and small borer pinholes are particularly troublesome. Fortunately tannin stains can usually be removed as described in Chapter XVII (Painting and Finishing of Timber), but it is much better practice to prevent the stain from developing by means of adequate protection of timber surfaces.

Timbers containing tannins must be excluded from laundry pegs because of staining to wet clothing, and unsightly stains on sheeting hung up to dry under hardwood joists have been known to provide the first evidence of Lyctus attack which has caused powdered timber to be dropped upon it from above. Timbers containing much tannin are also rejected for butchers' chopping

blocks because of the staining caused by steel choppers on the wet surface of the timber.

Resinous and oily substances are found in many coniferous timbers, particularly in the family *Pinaceae,* and are useful for identification purposes. Contrary to a common assumption, naturally occurring resin ducts in certain timbers, the best known species being many true pines *(Pinus* spp.), Douglas fir, larch and spruce *(Picea* spp.), give little evidence of increasing their durability.

Some coniferous timbers frequently have considerable concentrations of semi-transparent, hard and brittle resin impregnating the fibres near the pith and at the junctions of the larger limbs. These considerably lower the timber quality by increasing difficulties in gluing and splitting during nailing. Nail holding power is much reduced.

In the family *Meliaceae,* rose mahogany *(Dysoxylum jraseranum)* at times exudes an aromatic oil from the board surfaces which disfigures it for panelling and the scentless rosewoods *(Synoum muelleri* and *S. glandulosum)* develop an unctuous dirty surface which is very good for identification but spoils gluing. Certain of the *Lauraceae* family develop oil cells in the wood tissue and it is difficult to obtain fast glued joints in the strongly scented timber of rose maple *(Cryptocarya erythroxylon)* for this reason.

The naturally greasy substances in the saffron-hearts *(Halfordia* spp.) and crow's ash *(Flindersia australis)* of the family *Rutaceae* are the secret of their popularity for bearings. Tallowwood, spotted gum, lemon-scented gum and brush box of the family *Myrtaceae* provide greasy or waxy surfaces on dressed boards making them specially good for dance floors.

There is little doubt that the water resistant substances in teak and white beech of the family *Verbenaceae,* are closely associated with their exceptionally high decay resistance and popularity for carved work. A number of species of the olive family, *Olaceae,* are also specially favoured for carvings.

Sandalwoods, family *Santalaceae,* are sold to eastern countries because their greasy timbers both carve well for figures and give out a distinctive odour when burnt. The unrelated sandalbox *(Eremophila mitchellii)* sold for similar ceremonial purposes as "rosewood", has a very pleasant odour, but commands a much lower price, possibly because of its much darker colour. Very small oily spots from ducts on the tangential face of scrub turpentine boards have little utilisation significance but are most useful for identifying timbers of the family *Burseraceae.*

TIMBER PROPERTIES IN MAJOR UTILISATION SUB -DIVISIONS

Turnbull* has reviewed the significance of timber properties in the major sub-divisions of utilisation in Australia as follows:

* "Use Requirements for Sawnwood in Australia". Turnbull, R. F., Division of Forest Products, CSIRO., Proceedings of "International Union of Forestry Research Organisation" at Melbourne, October 1965.

USE CATEGORY	APPLICATIONS	IMPORTANT PROPERTIES
Construction		
In or near ground	heavy construction, mine timbering, sleepers, foundation timbering, fencing, poles, piles.	*strength:* high *durability:* high
Above ground, exposed	superstructures, decking, cladding	*strength:* moderate to high *durability:* high relative to decay, flying termites, wood borers *shrinkage:* low
Above ground, sheltered	framing	*strength:* moderate *durability:* low to moderate *shrinkage:* low to moderate *density*: to suit ease of handling, fitting and fixing
	finishing	*machining:* moderate density consistent with wear resistance *shrinkage:* low *grade:* high for display, moderate for painting or covering *figure:* decorative if displayed
Manufacturing		
	furniture	*density:* low to moderate *shrinkage:* low *colour:* varied, pale for staining *figure:* decorative to plain texture: fine and even *machining:* high *grade:* high
	handles	*density:* moderate *texture:* fine and even *strength:* high impact for strikers, high in relation to density *machining:* high *grade:* high

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USE CATEGORY	APPLICATIONS	IMPORTANT PROPERTIES
Manufacturing (cont'd)	turnery	*density*: moderate to high *figure:* decorative *machining:* high for turning *grade:* high
	sporting goods	*density:* moderate to low *strength:* high impact *special properties:* according to use
Packaging		
	cases and crates	*colour:* pale *density:* low to moderate *strength:* moderate *grade:* common

It is difficult to assign numerical values to such terms as high, moderate, medium, low etc., but it is not impossible to devise scales which would allow the words to be used fairly consistently in connection with the properties of wood.

An interesting table of the sawn output in Australian timbers in 1965 was supplied, clearly showing the present dominance of Eucalypt hardwoods. A significant trend in future timber availability is shown by the figure for the principal plantation species, good working radiata pine, already the second largest single species producer of timber with 14.4 per cent of the Australian total. It is certain that this proportion will increase greatly as existing plantations mature and larger areas now in the planning stage are planted.

The figures shown in Table 34 are extracted.

DENSITIES OF SOME AUSTRALIAN TIMBERS*

The density of timber when expressed in pounds per cubic foot is usually referred to in the trade as its "weight". While this is not strictly correct, the practice is well established and causes little confusion.

The density of timber varies with species. There is also some variation within the species itself depending on moisture content (for example, whether green or seasoned), age of tree, position in tree and general conditions of growth. The greatest variation in density of a particular species is, of course, that due to change in moisture content.

Table 35 gives the weight per cubic foot of various species at 12 per cent moisture content. It gives also the density of green timber, the weight per 1,000 super feet and the super feet per ton of both green and air-dry material. These figures are useful in connection with the transport of green and seasoned timber.

* Condensed from *Pamphlet* no. 2, issued by the Division of Wood Technology, N.S.W. Forestry Commission.

TABLE 34
PRINCIPAL TIMBERS IN AUSTRALIAN SAWN OUTPUT

Timbers	Millions of Super. Feet	Group Total Millions of Superfeet	Per Cent of Total Sawn
EUCALYPTS			
Messmate stringybark	206 ⎫		
Blackbutt	161 ⎪		
Jarrah	156 ⎬	659	52
Alpine ash	136 ⎭		
Red gum, mountain ash, karri, spotted gum tallowwood, silvertop ash (all between 20 and 30 millions)		169	14
Other eucalypts (15 and under millions)		54	4
Total Eucalypts		882	70
OTHER BROAD-LEAVED TIMBERS			
Queensland maple, silky oak, and other Queensland cabinet timbers	13 ⎫		
Satinash, alder, cheesewood, sassafras, quandong, butternut, brush box, turpentine and other rain forest timbers	57 ⎬	70	6
CONIFERS			
Radiata pine	179 ⎫		
Other plantation pines	17 ⎪		
Cypress pine	69 ⎬	293	24
Hoop pine, bunya pine, kauri	25 ⎪		
Tasmanian native pines	3 ⎭		
Total		1,245	100

The Table also gives green timber figures for the super feet per ton and the weight of 1,000 super feet in Hoppus log measure. The Hoppus system is usually employed for the measurement of logs and arbitrarily allows for the loss of timber in conversion. Thus:

100 sup. ft. actual equal 78.54 sup. ft. Hoppus.
100 sup. ft. Hoppus equal 127.3 sup. ft. actual.

Table 36 gives similar figures for some imported timbers.

Basic Density and Green Moisture Content

The basic density of any timber is the oven dry weight of a specimen divided by the green volume. It is usually expressed in pounds per cubic foot. The basic density figure is useful for two reasons. Firstly, it is a measure for any timber of the amount of actual wood substance present compared to void space such as pores, and so on. Secondly, it enables us to calculate the weight of a timber at any moisture content above fibre saturation. This is possible because green timber shrinks very little until its moisture content reaches fibre saturation (25 to 30 per cent—depending on the species). An example

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TABLE 35

DENSITIES OF SOME AUSTRALIAN TIMBERS

Standard Trade Common Name	Standard Trade Reference Name	Air-Dry Weights 12% m.c.			Green Weights						
		lbs. per cu. ft.	lb/1,000 sup. ft.	sup. ft. per ton	lb. per cu. ft.	lb/1,000 sup. ft.	sup. ft. per ton	lb/1,000 sup. ft. log measure	sup. ft. per ton log measure	Green moisture content %	Basic density lb./ cu. ft.
alder, brown	*Ackama paniculata*	37	3,080	730	57	4,750	470	6,050	370	96	29
ash, alpine	*Eucalyptus delegatensis*	38	3,170	710	65	5,420	410	6,900	320	119	30
ash, crow's	*Flindersia australis*	58	4,830	460	64	5,330	420	6,800	330	31	49
ash, mountain	*Eucalyptus regnans*	44	3,670	610	64	5,330	420	6,800	330	101	32
ash, silvertop	*Eucalyptus sieberi*	52	4,330	520	75	6,250	360	7,970	280	80	42
ash, southern silver	*Flindersia schottiana*	43	3,580	630	57	4,750	470	6,050	370	63	35
ash, white	*Eucalyptus fraxinoides*	42	3,500	640	65	5,420	410	6,900	320	93	34
bean, black	*Castanospermum australe*	48	4,000	560	68	5,670	400	7,220	310	92	35
beech, white	*Gmelina dalrympleana*	32	2,670	840	56	4,670	480	5,950	380	107	27
blackbutt	*Eucalyptus pilularis*	56	4,670	480	68	5,670	400	7,220	310	52	45
blackwood	*Acacia melanoxylon*	36	3,000	750	49	4,080	550	5,200	430	62	30
box, brush	*Tristania conferta*	56	4,670	480	73	6,080	370	7,750	290	63	43
box, coast grey	*Eucalyptus bosistoana*	68	5,670	400	74	6,170	360	7,860	280	34	55
box, grey	*Eucalyptus microcarpa*	69	5,750	390	72	6,000	370	7,650	290	32	55
box, yellow	*Eucalyptus melliodora*	69	5,750	390	82	6,830	330	8,710	260	46	56
brownbarrel	*Eucalyptus fastigata*	51	4,250	530	70	5,830	380	7,430	300	85	38
carabeen, yellow	*Sloanea woollsii*	38	3,170	710	54	4,500	500	5,740	390	71	32
cedar, red	*Toona australis*	26	2,170	1,030	40	3,330	670	4,250	530	81	22
coachwood	*Ceratopetalum apetalum*	39	3,250	690	54	4,500	500	5,740	390	75	31
gum, forest red	*Eucalyptus tereticornis*	71	5,920	380	74	6,170	360	7,860	280	26	59
gum, manna	*Eucalyptus viminalis*	46	3,830	580	67	5,580	400	7,120	310	100	34
gum, mountain grey	*Eucalyptus cypellocarpa*	60	5,000	450	68	5,670	400	7,220	310	55	44
gum, river red	*Eucalyptus camaldulensis*	53	4,420	510	70	5,830	380	7,430	300	61	41

TABLE 35 (continued)

DENSITIES OF SOME AUSTRALIAN TIMBERS

Standard Trade Common Name	Standard Trade Reference Name	Air-Dry Weights 12% m.c.			Green Weights						
		lbs. per cu. ft.	lb/1,000 sup. ft.	sup. ft. per ton	lb. per cu. ft.	lb/1,000 sup. ft.	sup. ft. per ton	lb/1,000 sup. ft. log measure	sup. ft. per ton log measure	Green moisture content %	Basic density lb./ cu. ft.
gum, rose	Eucalyptus grandis	44	3,670	610	62	5,170	430	6,580	340	78	35
gum, southern blue	Eucalyptus globulus	58	4,830	460	74	6,170	360 ·	7,860	280	73	43
gum, spotted	Eucalyptus maculata	58	4,830	460	69	5,750	390	7,330	310	51	46
gum, Sydney blue	Eucalyptus saligna	57	4,750	470	72	6,000	370	7,650	290	68	43
ironbark, broad-leaved red	Eucalyptus fibrosa ssp fibrosa	72	6,000	370	76	6,330	350	8,070	280	34	57
ironbark, grey	Eucalyptus paniculata	70	5,830	380	75	6,250	360	7,970	280	36	56
ironbark, narrow-leaved red	Eucalyptus crebra	68	5,670	400	71	5,920	380	7,540	300	25	57
ironbark, red	Eucalyptus sideroxylon	73	6,080	370	79	6,580	340	8,390	270	37	58
ironbark, silver-leaved	Eucalyptus melanophloia	68	5,670	400	77	6,420	350	8,180	270	37	56
jarrah	Eucalyptus marginata	54	4,500	500	73	6,080	370	7,750	390	—	—
karri	Eucalyptus diversicolor	56	4,670	480	73	6,080	370	7,750	390	—	—
kauri, South Queensland	Agathis robusta	30	2,500	900	—	—	—	—	—	—	—
mahogany, miva	Dysoxylum muelleri	43	3,580	630	68	5,670	400	7,220	310	101	34
mahogany, red	Eucalyptus resinifera	60	5,000	450	72	6,000	370	7,650	290	50	49
mahogany, rose	Dysoxylum fraseranum	45	3,750	600	66	5,500	410	7,010	320	82	36
mahogany, southern	Eucalyptus botryoides	58	4,830	460	74	6,170	360	7,860	280	65	45
mahogany, swamp	Eucalyptus robusta	50	4,170	540	70	5,830	380	7,430	300	80	39
mahogany, white	Eucalyptus acmenioides	62	5,170	430	74	6,170	360	7,860	280	54	49
messmate, N.S.W.	Eucalyptus phellandra	51	4,250	530	72	6,000	370	7,650	290	96	37

TABLE 35 (continued)

DENSITIES OF SOME AUSTRALIAN TIMBERS

Standard Trade Common Name	Standard Trade Reference Name	Air-Dry Weights 12% m.c.			Green Weights						
		lbs. per cu. ft.	lb/1,000 sup. ft.	sup. ft. per ton	lb. per cu. ft.	lb/1,000 sup. ft.	sup. ft. per ton	lb/1,000 sup. ft. log measure	sup. ft. per ton log measure	Green moisture content %	Basic density lb./ cu. ft.
oak, silky, southern	Grevillea robusta	38	3,170	710	70	5,830	380	7,430	300	120	32
oak, tulip, blush	Heritiera actinophylla	53	4,420	510	67	5,580	400	7,120	310	64	41
oak, tulip, brown	Heritiera trifoliolata	53	4,420	510	64	5,330	420	6,800	330	52	43
pine, cypress, black	Callitris endlicheri	39	3,250	690	40	3,330	670	4,250	570	23	33
pine, cypress, white	Callitris columellaris	43	3,580	630	48	4,000	560	5,100	440	26	37
pine, hoop	Araucaria cunninghamii	34	2,830	790	42	3,500	640	4,460	500	49	28
pine, radiata	Pinus radiata	26	2,170	1,030	58	4,830	460	6,160	360	167	22
quandong, silver	Elaeocarpus grandis	34	2,830	790	48	4,000	560	5,100	440	70	28
sassafras	Doryphora sassafras	37	3,080	730	57	4,750	470	6,050	370	86	30
silkwood, silver	Flindersia acuminata	38	3,170	710	48	4,000	560	5,100	440	71	28
stringybark, mess-mate	Eucalyptus obliqua	52	4,330	520	74	6,170	360	7,860	280	80	41
stringybark, red	Eucalyptus macrorhyncha	56	4,670	480	66	5,500	410	7,010	320	56	43
stringybark, white	Eucalyptus eugenioides	56	4,670	480	68	5,670	400	7,220	310	43	43
stringybark, yellow	Eucalyptus muelleriana	54	4,500	500	69	5,750	390	7,330	310	60	43
tallowwood	Eucalyptus microcorys	62	5,170	430	77	6,420	350	8,180	270	54	50
turpentine	Syncarpia glomulifera	57	4,750	470	71	5,920	380	7,540	300	66	42
wandoo	Eucalyptus redunca	68	5,670	400	79	6,580	340	8,390	270	—	—
yellowwood	Flindersia xanthoxyla	44	3,670	610	57	4,750	470	6,050	370	57	36
yertchuk	Eucalyptus consideniana	56	4,670	480	73	6,080	370	7,750	390	73	42

TABLE 36

DENSITIES OF SOME IMPORTED TIMBERS

Standard Trade Common Name	Standard Trade Reference Name	Air-Dry Weights 12% m.c.			Green Weights						
		Weight in lb. per cu. ft.	Weight in lb./1,000 sup. ft.	Sup. ft. per ton	Weight in lb./cu. ft.	Weight in lb./1,000 sup. ft. sawn timber	Sup. ft. per ton sawn timber	Weight in lb./1,000 sup. ft. log measure	Sup. ft. per ton log measure	Green moisture content %	Basic density lb./cu. ft.
baltic, red (European redwood)	Pinus sylvestris	33	2,750	810	50	4,170	540	5,310	420	85	27·0
baltic, white (European whitewood)	Picea abies	27	2,250	990	42	3,500	640	4,460	500	80	23·3
cedar, Borneo (Pacific maple)	Seraya spp.	28	2,330	960	47	3,920	570	4,990	450	73	26·2
cedar, western red	Thuja plicata	23	1,930	1,170	27	2,250	990	2,870	780	37	19·4
dacrydium (New Zealand rimu)	Dacrydium cupressinum	37	3,080	730	61	5,080	440	6,480	350	102	30·6
fir, Douglas (Oregon)	Pseudotsuga taxifolia	34	2,830	790	38	3,170	710	4,040	550	36	28·1
hemlock, western (Canada pine)	Tsuga heterophylla	29	2,420	930	41	3,420	660	4,350	520	74	23·7
kauri, New Zealand	Agathis australis	36	3,000	750	51	4,250	530	5,420	410	80	28·3
ramin	Gonystylus spp.	41	3,420	660	—	—	—	—	—	—	—
redwood, Californian	Sequoia sempervirens	24	1,990	1,130	45	3,750	600	4,780	470	123	20·4
spruce, Sitka	Picea sitchensis	28	2,330	960	33	2,750	810	3,510	640	42	23·1

of the use of basic density for calculating green density is given on page 194. It is important to note that while the density figures given are "means", there is considerable variation in the weight of samples from different trees of the same species, and also for different samples of the same log; thus for a timber with a mean density of 40 pounds per cubic foot, individual samples may vary between 35 to 45 pounds per cubic foot, and occasionally even greater variation occurs. Although there are many exceptions, in general wood is heaviest from slowly grown trees and is lightest in weight nearest the heart. There is usually no marked difference in density between the truewood (heartwood) and sapwood.

The green weights have been calculated from the basic density and the green moisture content, which is shown. The green moisture content has been obtained for each species by taking the mean of a number of tests for the species. The moisture content between different species will show a wide variation, for example, sassafras and scented satinwood (coachwood) may contain as much as 140 per cent moisture content when freshly sawn, cypress pine heartwood (truewood) may not contain more than 35 per cent, while the moisture content of the sapwood may exceed 120 per cent.

In general, the denser the timber, the less moisture it contains when green. However, individual trees of the same species vary in their moisture content, and variation also occurs within different zones of the same log, and the position may be further complicated by seasonal alteration of the water content within these zones. The old, yet very prevalent, superstition that the sap rises in spring and summer and falls in winter, thus increasing or decreasing the moisture content of the wood, has been proved to be definitely fallacious; actually the moisture content may be higher in winter than in summer.

Calculation of Density

There are several ways of determining the weight per cubic foot, but for those without special equipment a close approximation can be readily obtained by the flotation method. This consists of placing a small, evenly dimensioned, square-ended sample, for example, 8 in. long x 2 in. x 1 in. (the size is immaterial) in a container of water and measuring the depth to which it sinks. It is essential, of course, to keep the sample vertical. If the eight inch sample sinks to a depth of six inches then the weight per cubic foot can be calculated as follows:

$$\frac{\text{Depth to which sample sinks}}{\text{Total length of sample}} \times 62.4$$

In this case density is $^6/_8$ x 62.4 = 47 lb. per cu. ft.

Shipping Weights of Timber

In shipping timber, the table giving weights of sawn timber and timber in the log will be found useful. It is important to remember that there will be variation in practice from the figures quoted. This is due to local species variation, errors in sawing, partial drying out of timber, errors in measuring round timber and so on. For this reason the figures given in the tables for

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sawn and round weights, and so on, are approximated to the nearest ten pounds.

Where weighing is used to determine rough tallies of timber, it is most important to remember that an error will arise if the actual sawn size differs from the nominal or assumed size of the timber.

A considerable error occurs when milled lines such as flooring are measured in this way. One way of coping with this problem is to determine the actual cross-sectional area of the moulding by tracing it on squared paper and counting the number of squares. Actual lineal feet determined from the tables and the nominal cross-section is then multiplied by the nominal cross-sectional area and divided by the actual cross-section of the moulding.

Another method, where weighing scales are available, is as follows:

A typical batten about six feet long with square docked ends is taken, weighed and the weight recorded. This piece is then run through the moulding machine and again weighed. The ratio of the two weights is the same as the ratio of the cross-sectional areas of the batten and the moulding.

For example, if we assume that a 4 x 1 inch batten of green tallowwood weighs 12½ pounds before and 7 pounds after moulding, then in 1 ton of green mouldings we will have:

$$\frac{1,050 \times 12\frac{1}{2}}{7} = 1,870 \text{ lineal feet. (Approx.)}$$

Calculation of Green Density of Wood Above "Fibre Saturation Point", Using Basic Density

$$\text{Basic density} = \frac{\text{Oven dry weight—lb.}}{\text{Green volume—cu. ft.}} \text{ lb./cu. ft.}$$

To obtain the density at any moisture content above about 30 per cent, the basic density is multiplied by 100 plus the moisture content and the result so obtained is divided by 100, thus:

$$\frac{\text{Basic density} \times (100 + \text{m.c.})}{100} = \text{density}$$

For example, the density of *Tristania conferta* at 50 per cent moisture content is:

$$\frac{43 \times 150}{100} = 64.5 \text{ lb./cu. ft.}$$

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XXII

THE SPECIFYING OF
TIMBER FOR STRUCTURES

The technical approach to timber design in Australia is made compara-
tively simple because the essential data required has been compiled and pub-
lished in *Timber Engineering Design Handbook* by Pearson, Kloot and Boyd
(C.S.I.R.O. in conjunction with Melbourne University Press). This work is a
development of the earlier *Handbook of Structural Timber Design**.

The *Timber Engineering Design Handbook* is invaluable to engineers and
others responsible for the design of timber structures. The subject matter of
the earlier volume has been extensively revised and its presentation altered.
Much new material has been added including chapters on the design of ply-
wood and glued laminated construction.

To assist architects and builders, a publication known as "Building Frames,
Timbers and Sizes" *(Pamphlet 112)* has also been issued by the Division of
Forest Products. This lists the recommended sizes of the various members
such as bearers, joists, studs, rafters and so on, as are used in normal house
frame construction, and is based on the *Handbook of Structural Timber
Design.* The recommendations are based upon a vast amount of scientific
study and are endorsed after practical tests by the Commonwealth Experi-
mental Building Station. The recommendations have been taken into account
by the Standards Association of Australia,† and incorporated in "Australian
Standard Schedule of Dimensions of Structural Timber for Use in Domestic
Building Construction (A.S.0.56—1948)".

Tabular arrangements covering the several Australian strength groups and
indicating the stiffness and load carrying capacities of beams and columns of
various sizes and lengths are set out in Division of Forest Products *Newsletter,*
no. 271. This data may be used in place of the charts provided in the *Timber
Engineering Design Handbook.*

The classified properties of "durability", "strength" (in bending) and

* Prepared by Ian Langlands, B.E.E., M.Mech.E., A.M.I.E. Aust. and A. J. Thomas,
Dip.For.

† See Chapter XXV *Technical Standards in the Timber Industry.*

"hardness" for a wide range of Queensland and New South Wales timbers are tabled in "Queensland Building Timbers and Specifications for their Use", *Pamphlet* no. 5 of the Queensland Department of Forestry. Timbers recommended for "Joinery and Mouldings" are described in *Pamphlet* no. 3 of the same Department.

The Division of Wood Technology of the New South Wales Forestry Commission has published a number of papers on building timbers of that State including those recommended for scantling, external cladding and flooring.

It should be the serious concern of all connected with the building industry to take advantage of the information offered in the abovementioned treatises.* Unfortunately, and particularly with regard to house building, this concern is not apparent. Despite the high cost of timber and a none too prodigal supply, economies made possible by the acceptance of authoritative recommendations are not being widely effected. The fault would appear to lie with architects and builders in continuing to apply conservative "rule of thumb" policies based on long-standing custom established when there was no detailed knowledge of Australian timbers such as exists today, and equally with sawmillers and timber merchants in adopting similar laissez-faire policies. But a large share of blame for this state of affairs is also attributable to local shire councils and similar building authorities and to certain financial institutions which refuse to revise their building ordinances and regulations in the light of the advanced knowledge available. A case in point refers to a New South Wales municipality which insisted upon 4 x 2 inches hardwood rafters, 10 feet in length at 2 feet 6 inch centres, to support a galvanised iron roof. Clearly, rafters of smaller dimension would have sufficed.

Too often in the past, and, fortunately to a lesser degree at the present time, there have appeared in architects' specifications and in various official ordinances, requirements detailing the minimum allowable sizes for structural members in "hardwood or Oregon", without any regard for the respective values of the two classes of timber on a basis of strength. It is a challenge to logic, and to economic sanity, to suggest the substitution of, say, a 4 x 2 inch hardwood for its softwood counterpart of $3^7/_8$ x $1^7/_8$ inches (or less). Broadly speaking, and for most purposes, it may be taken that Australian hardwoods are much stronger than softwoods, and in the general run of cases where hardwoods have been used in house-frame construction, a smaller dimension than those specified would have sufficed. In recent years, thanks largely to the efforts of the Divisions of Forest Products and Wood Technology, some improvements in this situation have occurred. However it is suggested that the timber trade generally, in pursuit of a policy of cost reduction, should do its part through publicity and technical education, in making the user of timber cognisant of the principles laid down in the *Timber Engineering Design Handbook.*

To illustrate the respective strengths of hardwood and Douglas fir (oregon) the following table, compiled by the Division of Wood Technology, New South Wales, shows a comparison in bending strength of hardwood with scant sawn Douglas fir of various dimensions. The first column lists Douglas fir

* See also D.F.P. *Newsletters,* nos. 165 and 174.

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sizes, sawn $^1/_8$ inch scant. In the second column the sizes given are proportionately equivalent to the Douglas fir sizes, in the third column the same depth is maintained, and the equivalents are given on a basis of thickness.

These sizes do not take account of the reduction in stiffness due to the reduction in sizes, but are given as sizes necessary to safely carry equivalent loads. It is not suggested that the sizes shown above should be those necessarily adopted in the substitution of hardwood for softwood equivalents, but the figures given furnish an indication of how costs in the utilisation of hardwood could and should be enormously reduced.

The above remarks have concerned structural timbers, but a few words in this regard might be applied to floorings.

TABLE 37

COMPARISON OF SIZES FOR DOUGLAS FIR AND A GROUP HARDWOODS, BASED ON THE STRENGTH IN BENDING

Sizes in Douglas fir All cut $^1/_8''$ Scant.		Equivalents in Hardwood (proportionate dimensions)	Equivalents in Hardwoods, maintaining same depth	
3×1	braces	$2 \cdot 09 \times 0 \cdot 70$	$1 \cdot 04 \times 1$ inch	Depth taken
4×1	battens, etc.	$2 \cdot 79 \times 0 \cdot 70$	$1 \cdot 39 \times 1$ inch	as $1''$
2×2		$1 \cdot 45 \times 1 \cdot 45$	$0 \cdot 76 \times 2$	
3×2	studs	$1 \cdot 36 \times 2 \cdot 04$	$0 \cdot 79 \times 3$	
4×2	rafters, etc.	$1 \cdot 51 \times 3 \cdot 02$	$0 \cdot 81 \times 4$	
10×2	joists	$1 \cdot 50 \times 7 \cdot 48$	$0 \cdot 84 \times 10$	
6×3	purlins	$2 \cdot 25 \times 4 \cdot 49$	$1 \cdot 25 \times 6$	

Working stress used for Douglas fir (oregon): 1100 lb. per sq. inch.
Working stress used for hardwood: 2400 lb. per sq. inch.

A comparison with overseas standards shows a tremendous and certainly unnecessary margin in the Australian practice as regards thickness. Apparently the minimum finished thickness of stock floorings in Australian hardwoods and softwoods is in the region of $^{13}/_{16}$ inch, a thickness determined by the Standards Association of Australia. Some merchants specify $^{27}/_{32}$ inch. The British Columbia Standard finish for 1 inch Douglas fir or western hemlock is $^3/_4$ inch. European flooring supplied to the Australian market finishes to a $^3/_4$ or $^7/_8$ inch standard. Looking at Table 37, does it not seem that our flooring dimensions are unnecessarily full, and consequently costly? Or, that the market could be offered a satisfactory cheap hardwood floor to finish $^9/_{16}$ inch, as has been suggested by the Division of Forest Products?* Such a dimension would lower costs at five points: 1. In the rough green state, 2. seasoning, 3. freight, 4. cartage, and 5. handling.

It seems relevant to this discussion† to refer also to the lack of uniformity in dimension in the supply of hardwood and softwood, particularly Douglas fir for structural purposes. The customary practice, in Australia, is to supply hardwood sawn to the nominal sizes specified, but respective sizes in

* See D.F.P. *Newsletters,* nos. 140 and 157.

† See also: "Sawdust or Sovereigns?" by N. K. Wallis *(Proceedings,* All Australia. Timber Congress 1938).

Douglas fir, which is used so extensively as a structural timber in New South Wales (and to a lesser degree in other States), are supplied in at least $1/8$ inch less than the nominal size.

The reason for this, of course, is the necessity for allowing for the saw kerf in accounting for the full measurement of a Douglas fir flitch. Is it not equally desirable, however, to maintain the highest possible output from a hardwood log? In any case, it frequently occurs that hardwood is supplied to retailers in flitches for re-cutting to trade sizes, in the same way as is Douglas fir. In such cases the resawn product will be "less the saw kerf", whereas trade sizes sawn directly from the log will be supplied "full to size". So we have, in the industry, the illogical situation of an indiscriminate supply to the building trade of both full and scant sawn "dimension" stock.

In order to illustrate the extraordinary and unnecessary loss which is taking place in every sawmill through this illogical practice of sawing hardwoods full to size alongside the successfully established practice of sawing Douglas fir scant, the following table is set out to show the percentage increase of timber involved in the one case as against the other. The saw kerf involved is taken as $1/8$ inch.

TABLE 38

Scant Size inches	Full Size inches	Increase in Section per cent
$7/8 \times 7/8$	1×1	30·61
$1^3/8 \times 7/8$	$1^1/2 \times 1$	24·68
$1^7/8 \times 7/8$	2×1	21·90
$1^7/8 \times 1^7/8$	2×2	13·78
$2^7/8 \times 1^7/8$	3×2	11·30
$3^7/8 \times 1^7/8$	4×2	10·11
$5^7/8 \times 2^7/8$	6×3	6·57

Added to whatever effect the above figures must have in regard to out-turn costs, there remains their highly important effect on freights. It can be safely asserted that freight and/or cartage is in nearly all cases applicable twice to sawn timber between mill and consumer. And we have only to take the case of one of the commonest sections, that of 4 x 2 inch, and consider the saving here of ten per cent in price cost, and again in freight and cartage, to realise how important this matter of saw kerf becomes.

Before leaving this point it might be in order to comment upon the customary reference to scant sawing. "Resawn timber" runs the legend in some official catalogues, "shall be the saw-cut less than the nominal size". As saws engaged in the remanufacturing of flitches vary in gauge from, say, 18 to 10, and the sawcut therefore from $1/8$ to $1/4$ inch, this definition is very loose. In view of the increasing demand for precision in all things technical, it is possibly time that a more exact phrasing were used so that the accepted dimensions of resawn timber may be more properly determined. The accepted allowance of $1/8$ inch has been mentioned for sawcut, but in practice it will be found in many cases to be considerably greater. Improved standards with

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regard to the timber-framed house may yet demand that structural grades be supplied surfaced to dimensions.

In the meantime, sawn timber must necessarily be subject to variations in size partly for the reasons indicated above, partly because sawing itself is not a thoroughly accurate process, and partly because in supplying structural timber in a more or less unseasoned condition, the element of shrinkage arises. None of these causes seems altogether avoidable, and the question naturally arises as to whether this situation should not be governed by some remarks in the official catalogues under the heading of "Tolerance". Understandings with regard to this matter do, one imagines, exist, but except in some government specifications, no definition of such understandings is officially laid down. If conditions of sale governing timber are to be in any way complete, it does seem that this matter should be cleared up.

Selection of Species*

Strength Groups. Timber cannot be used to advantage if all species are regarded as one, namely the weakest, but on the other hand, it would be an unnecessary refinement to consider each timber separately. A compromise which meets most practical requirements is to classify timbers into groups according to mechanical properties. The classification adopted in Australia is set out in Table 39† below, the groupings being designated A, B, C and D. The *average* properties of each group are approximately as listed:

TABLE 39

Group	Modulus of Rupture lb per sq. in.		Modulus of Elasticity lb. per sq. in.	
	Green	12 per cent moisture content	Green	12 per cent moisture content
A	15,000	24,000	2,400,000	3,000,000
B	12,000	20,000	2,100,000	2,600,000
C	10,000	16,000	1,700,000	2,200,000
D	7,000	12,000	1,500,000	1,900,000

Group	Crushing Strength Parallel to Grain lb. per sq. in.		Shear Strength lb. per sq. in.	
	Green	12 per cent moisture content	Green	12 per cent moisture content
A	7,500	12,000	2,000	2,500
B	6,000	10,000	1,500	1,900
C	5,000	8,000	1,200	1,600
D	3,500	6,000	800	1,100

{Note: The above figures apply for defect-free timber and are given as a basis for comparison only).

* See also "Selection of Timber" D.F.P. *Newsletter* no. 203.

t *Handbook of Structural Timber Design.*

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The properties of any particular species in a group may vary somewhat from the figures given, and in some cases it is difficult to classify a species correctly. For instance, river red gum is very low in bending strength and stiffness because of its exceedingly irregular grain; its other properties, however, are comparatively high. It has, therefore, been placed in Group D for bending, tension and stiffness, and in Group B for the other properties.

For the most practical purposes, no distinction is drawn between Groups A and B. In normal constructional practice the two are grouped together.

A list of the important structural timbers used in Australia, with their strength grouping under the above classification, is set out in Table 40.

Generally, the imported softwoods are appreciably inferior in strength to any of the hardwoods commonly used in Australia. Table 41 shows important strength properties of freshly cut or green material calculated as a percentage of the strength of Douglas fir.

Grading. Apart from the exclusion of low quality timber, it is not yet regular practice throughout Australia to grade our structural timbers for building framework. As has been pointed out earlier, the existing practice generally is to specify sizes in Australian hardwoods which provide an unnecessarily wide margin of safety at the expense of economy. This margin is certainly wide enough to ensure that even very low quality timber will be strong enough for its purpose. While the utilisation of this lower quality timber is in itself highly commendable and desirable from the standpoint of our economy and resources, it is, on the other hand, wholly uneconomical not to take full advantage of the superior properties of the higher grades.

In Western Australia structural grading of jarrah, karri and wandoo has been adopted (see Australian Standards nos. 0-10 to 0-45) and it is hoped that the rest of Australia will soon adopt the same good practice.* The necessary data is available and provisional standards enabling this to be done have been established. (See Emergency Standard no. (E) 0-54 (Australian Standard Grading Rules for Sawn and Hewn Structural Timbers)).

Australian Standards nos. 024, 034, 035 and 038-1964 are available for "Milled Products from Western Australian Hardwoods" including "Flooring", "Lining", "Siding Boards" and "Mouldings", in addition to 036-1965 for timbers used in "The Manufacture of Joinery" and 046-1960 for "Round Section Stringers from Western Australian Timbers".

Other standards now available include those for "Dimensions of Structural Timbers" in "Domestic Building" (056-1948), "Sleepers" in 24-in. and larger railway gauges (057-1949 and 097-1963), "Crossarms" (061-1965), "House Stumps" (070-1958), "Wood Blocks for Parquetry" (071-1960), "Door Frames" and "Jamb Linings" (076-1967), "Decking" (080-1963) "Plywood" (086 to 088), "Timber for Marine Craft" (096-1964), "Seasoned-Framing Timber from Hardwoods" (098-1966), "Wooden Doors" (099-1966), "Mechanical Stress Grading of Timber" (MP18-1966), "Standard

* See "Strength-graded Scantling and Engineering Timbers" by J. D. Boyd, M.C.E., A.M.I.E.(Aust.), Officer-in-Charge, Timber Mechanics Section, Division of Forest Products, C.S.I.R.O. "Building and Decorating Materials" Nov./D 1960. See also D.F.P. *Newsletter,* no. 270.

TABLE 40

CLASSIFICATION INTO STRENGTH GROUPS OF STRUCTURAL TIMBERS
USED IN AUSTRALIA*

	Wt. lb./cu. ft.		Percentage Shrinkage	
	Green	Air-Dry	Radial	Tangential
GROUP A:				
Box, coast grey	80	69	4	8
Box, grey	80	70	3·5	7
Gum, grey	80	66	5	6
†Gum, spotted	75	63	4	6
Ironbark, broadleaved, red	80	71	4	6
Ironbark, grey	80	69	4	6
Ironbark, narrowleaved, red	80	67	4·5	6
Tallowwood	75	62	4	7
Wandoo	80	68	2·5	3·5
GROUP B:				
Ash, hickory	75	62	3	4·5
Ash, silvertop	75	53	5	12
Blackbutt	70	55	4	7
Blackbutt, W.A.	70	54	—	—
Bloodwood, red	70	55	3	4
Box, brush	75	56	5	10·5
Box, yellow	80	65	3	6
Gum, forest red	75	61	5·5	9
Gum, maiden's	75	60	5·5	11
†Gum, river red	75	56	4	8·5
Gum, southern blue	75	56	5	11
†Gum, spotted	75	63	4	6
Gum, Sydney blue	70	52	5·5	8·5
Gum, yellow	75	64	3	6
Karri	75	56	5	10
Mahogany, red	80	59	4·5	6
Mahogany, southern	75	57	4·5	9
Mahogany, white	80	59	3	5·5
Messmate, Gympie	80	62	—	—
Stringybark, brown	70	56	5	10·5
Stringybark, red	75	55	5·5	9
Stringybark, white	70	52	5·5	10
Stringybark, yellow	75	55	4	7
Turpentine	75	59	6·5	12

(continued)

*Reprinted from *The Commercial Timbers of Australia, Their Properties and Uses,* by I. H. Boas.

†*Note:* The properties of any particular species in a group may vary somewhat from the figures given, and sometimes it is difficult to classify a species correctly. For instance, river red gum is very low in bending strength and stiffness because of its exceedingly irregular grain; its other properties, however, are comparatively high. It has, therefore, been placed in Group D for bending, tension and stiffness and in Group B for the other properties. Spotted gum has been placed in both Group A and Group B because of its variability, the timber from Queensland and northern New South Wales being much stronger than that from southern New South Wales.

TABLE 40 (continued)

	Wt. lb./cu. ft.		Percentage Shrinkage	
	Green	Air-Dry	Radial	Tangential
GROUP C:				
Ash, alpine	65	41	5	8·5
Ash, mountain	65	44	7	13·5
Gum, manna	75	51	2·5	9
Gum, mountain grey	70	54	5	11
Gum, rose	65	49	4·5	7·5
Jarrah	70	51	5·5	8
Peppermints (various)	70	49	—	—
Satinay	75	52	4·5	10
Stringybark, messmate	70	47	6	13·5
GROUP D:				
Douglas fir (oregon)	40	35	2·5	4
†Gum, river red (bending only)	75	56	4	8·5
Pine, hoop	55	33	2·5	4
Pine, radiata	53	32	2·5	3·9
Pine, white cypress	60	42	2	2·5

t See *Note* previous page.

Nomenclature of Commercial Timbers Imported into Australia" (Int. 363-1954), "Milled Products from South-Eastern" and "North-Eastern Australian Hardwoods" (062 to 065-1956 and 066 to 069-1960), "Radiata Pine for Sawn Qualities for Dressing and Milled Products" (072 to 075-1960), "Engineering Timbers from Eastern and South-Eastern Australian Hardwoods" (081-1966), "Sawn Eastern Australian Hardwoods" and "Southeastern Australian Eucalypt Hardwoods" (082-1965 and 083-1963), "Cypress Pine" boards, milled products and light scantlings (091 to 095-1964), "Australian Rainforest Timbers", sawn and milled products (084-1967 and 0100 to 0103-1967) and "Sawn Douglas Fir (oregon) and western hemlock (Canadapine)" (0106-1969 Int.).

Other standards are under consideration or review. See Chapter XXV.

TABLE 41

Timber	Bending Strength	Stiffness	Compression Strength	Shear Strength
IMPORTED				
White Baltic	70	69	67	67
Sitka spruce	75	79	69	82
Red Baltic	79	80	78	81
Hemlock	80	79	77	87
Douglas fir	100	100	100	100
AUSTRALIAN				
Mountain ash	120	121	110	112
Jarrah	130	95	133	142
Messmate	137	115	141	144
Blackbutt	160	141	171	157

Durability. The word "durability" here refers to the resistance of the timber to attack by fungi and termites and not to its resistance to mechanical wear or attack by marine organisms. There are four durability classes, Class 1 includes the highly durable timbers such as the ironbarks, which have an average life of say, 20 years as a pole and 40 or 50 years when used in outdoor structures, while Class 4 includes the timbers having very low durability when used under adverse conditions, having a life of say, 3 to 8 years as a pole and 8 to 10 years when used in outdoor structures without preservative treatment. It must be noted that if they are kept thoroughly dry and protected from attack by termites, the timbers in Class 4 will last indefinitely. So far as durability is concerned, they are therefore quite as suitable as Class 1 timbers for indoor construction. When a timber is listed in two classes, it is either very variable or else is intermediate in durability between the two classes (see Table 42).

TABLE 42

CLASSIFICATION OF TIMBERS INTO DURABILITY CLASSES*

Class 1. *Very Durable.*
Bloodwood, red
Box, coast grey
Box, grey
Gum, grey
Gum, yellow
Ironbark, grey
Ironbark, red
Mahogany, white
Pine, white cypress
Tallowwood
Turpentine
Wandoo

Class 3. *Moderately Durable.*
Blackbutt
Blackbutt, Western Australian
Box, brush
Gum, maiden's
Gum, rose
Gum, southern blue
Gum, spotted
Gum, Sydney blue
Karri
Mahogany, red
Stringybark, brown
Stringybark, messmate
Stringybark, red
Stringybark, white

Class 2. *Durable.*
Ash, hickory
Bangalay
Blackbutt
Box, red
Box, yellow
Gum, forest red
Gum, river red
Gum, spotted
Jarrah
Mahogany, red
Satinay
Stringybark, red
Stringybark, white
Stringybark, yellow

Class 4. *Non-Durable.*
Ash, alpine
Ash, mountain
Ash, silvertop
Douglas fir
Gum, rose
Pine, hoop
Pine, radiata

*Reprinted from *The Commercial Timbers of Australia, Their Properties and Uses,* by I. H. Boas. *Note:* The species in each class are listed alphabetically, not in the order of their durability. A few species are listed in both Class 2 and 3 because it is so difficult to divide these classes by a sharp line and opinions of authorities vary.

The division into durability classes is somewhat uncertain because of the variability within a species and the lack of technical information on the relative durability of Australian timbers.

Another point to be remembered is that the durability classification applies to truewood only; the sapwood of all timbers is non-durable under adverse conditions.

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XXIII

MECHANICAL JOINTING
OF TIMBER

Nailed Joints

Ease of fabrication is one of the many favourable characteristics of timber and there is no doubt that the traditional nailed joint exploits this advantage to the full. Nailed joints are normally associated with conventional timber frame construction. However, more sophisticated structures may also employ nails. For example, nailed trusses have been designed which employ nailed joints. Typical designs are illustrated in the *Timber Engineering Design Handbook*.

However, the capacity of nailed joints to transmit stress is limited by the comparatively small surface area and low withdrawal resistance of these fastenings. One method of overcoming this problem is by using gussets and increasing the number of nails. Metal gusset plates may be used, and hard board gussets are becoming very popular, especially for trusses for domestic construction. For all but pure compression, the load between the jointed members is bridged across the gussets which therefore must have sufficient strength to carry the full joint load, as well as to transmit the bearing loads through the nails.

Clinching and riveting of nails, especially copper nails in boat building, is a well known method of improving the withdrawal resistance of nails.

Angle plate connectors (available under the name of "Trip-L-Grip Framing Anchors" manufactured by the Timber Engineering Company) also improve the strength and stiffness of nailed joints. (See Fig. 35). They are commonly used in light frame construction. Special nails are supplied for use with these connectors.

Design data for nailed joints is given in the *Timber Engineering Design Handbook,* while figures for special fasteners such as a Trip-L-Grip are available from the manufacturers.

Bolted Joints

Bolts may be used to connect two or more members. A considerable amount of design information for various types of bolted joints is available, much of which is detailed in the *Timber Engineering Design Handbook.*
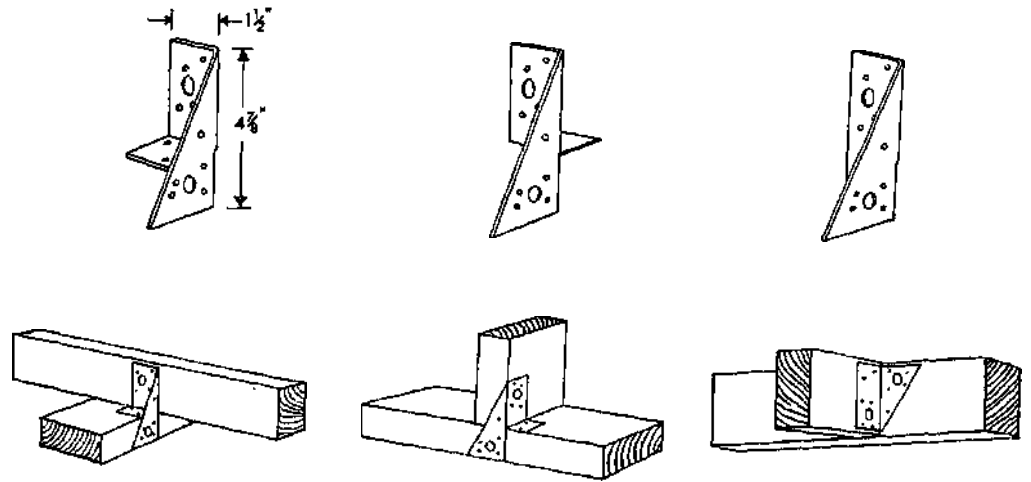
Figure 35. Types of framing anchors and their uses.

Most bolted joints suffer the same disadvantage as nailed joints, the surface area of the bolts being relatively small. Larger bolts, or more of them, will provide more bearing area, but this solution is limited by the size of the timber members being joined and by the high cost of large bolts.

Timber connectors provide an excellent solution to this problem by transmitting stress over a comparatively large surface area. Several types of timber connectors are available, the most important of which arc illustrated in Figure 36. With shear-plate connectors the shear is transmitted from the wood through the plate into the bolt. The bolt itself is therefore a load-bearing member in shear and must be designed as such. On the other hand, with the split-ring and bull-dog connectors the shear is transmitted directly from the wood into the connector and the principal function of the bolts is simply to hold the joints together. The split-ring connector has the added advantage that it has variable diameter and can adjust itself to shrinkage of the joint. Thus, splitting is not as likely to take place.

Timber connectors eliminate the costly and cumbersome array of plates,

(a)   **(b)**   (c)
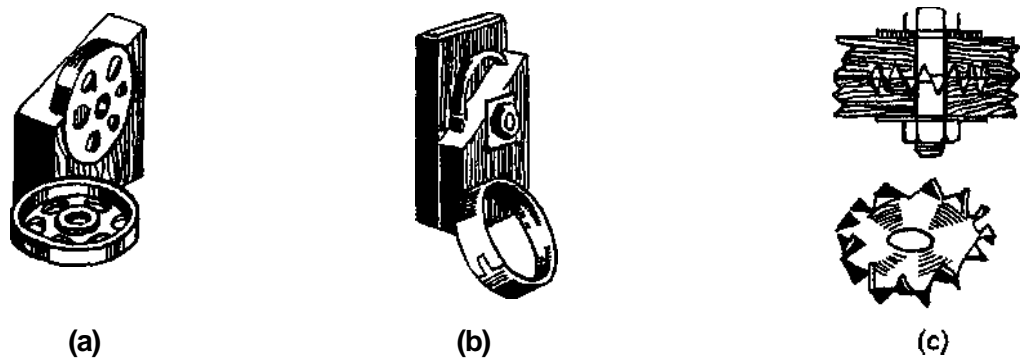
Figure 36. The various types of Teco connectors, *(a)* shearplate, *(b)* split-ring and (c) "bulldog" connector.

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angles and straps often associated with bolted joints. They usually allow member sizes to be determined on their load carrying capacity rather than upon the size necessary to develop sufficient joint strength, and this usually achieves significant economies in member sizes. They therefore provide much larger scope in the design of timber structures, allowing larger spans than would otherwise be possible. Also, the stiffness of joints is increased.

Ample data for the design of connector joints is given in the *Timber Engineering Design Handbook,* and also by the manufacturers of the connectors. One of these is the Timber Engineering Company which manufactures "Teco" connectors.

Toothed Plate Connectors

These connectors consist of punched toothed plate which in one piece combines the attributes of a nailed steel gusset joint (See Fig. 37). The joint is formed by pressing the toothed plate into each side of the joint simultaneously in a hydraulic press.

Toothed plate connectors are excellent for the factory fabrication of timber trusses (see Photo 32) and it is in this field that they have enjoyed increasing popularity in recent years. One manufacturer of toothed plate connectors, producing the "Gang Nail" plate, has established truss fabrication plants in many parts of Australia. Trusses for saw-tooth, gable or hip roofs can be ordered to almost any span and pitch.

This manufacturer supplies a design service, and design data is also available for engineers or architects requiring to do their own design work. While their greatest utilisation has been in domestic construction, toothed plate connectors are not at all limited to this field (see Photo 33). Industrial trusses of 200 ft. clear span are quite practicable.

The use of well designed mechanical joints is effecting significant changes in some of the traditional methods of timber construction. This is most evident in domestic construction. For example, light weight timber trusses of great strength and rigidity are beginning to replace the massive and complex roof structures normally associated with timber frames. Their rigidity eliminates sagging roof lines. Since all roof loads are transmitted through the external
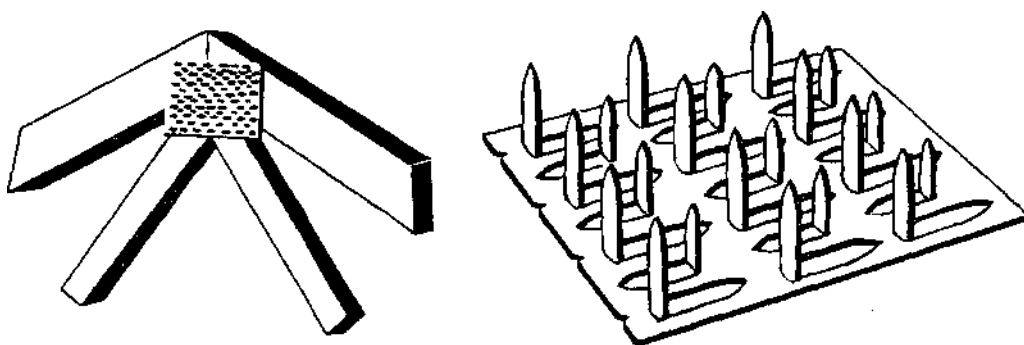
Figure 37. Typical toothed plate connector.

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walls, interior partitioning can be of light construction, moveable if desired. Interior foundations can be reduced or eliminated. Thus, overall economies can usually be achieved.

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XXIV

TIMBER HOUSE CONSTRUCTION

The subject under the above heading is far too wide to be covered adequately in this volume.* In recent years, however, there has been a dramatic increase in the demand for the better class of timber house and the suppliers of timber for domestic buildings, along with architects and builders, have sought with increasing interest information relative to the technique of building in timber. Responding to this demand and to this interest, the Division of Forest Products of the C.S.I.R.O., South Melbourne, and the Commonwealth Experimental Building Station at Ryde, New South Wales, are engaging in continuing research, much of which is devoted to the field of modern house construction.

Results of this research are published in pamphlets, newsletters, bulletins and technical treatises, most of which are available on application to the authorities concerned, † Many of these publications, particularly those issued by the Division of Forest Products, have been quoted from, or referred to, throughout this volume. The reader is also referred in particular to the following publications of the Commonwealth Experimental Building Station from which much of the information in this chapter is drawn:

Technical Studies
    No. 29 Timber Roof Trusses for Domestic Buildings.
    No. 39 Rationalised Traditional Roof-framing.
    No. 40 Rationalised Traditional Timber Wall-framing.

Notes on The Science of Building
    No. 19 Light Timber Roof Trusses.
    No. 25 Thermal Insulation.

* For notes on domestic flat roof construction see *Newsletter* no. 224.

t See also "The Development of Modern Methods of Timber House Construction" by J. D. Boyd, M.C.E., A.M.I.E.(Aust.)—*Australian Timber Journal,* December 1958 and January 1959.

No. 34 Timber in Domestic Building.
No. 37 Domestic Roofs.
No. 42 Claddings for Small Buildings.
No. 44 Traditional Roof-framing for Tiled Roofs.
No. 45 Timber Floors in Dwellings.

Australia is endowed with many timbers. Some are plain, many are figured; some are pale, others are richly coloured; some are light, readily machined, and comparable with the finest cabinet timbers, others—heavy, strong and durable—are among the best structural timbers of the world. If chosen with due regard to their properties, and if suitably prepared for use, local timbers can satisfy almost any building requirement.

The principal timbers available in various parts of Australia are listed in Chapter XIII. Other timbers may be important in certain localities. Forest officers and timber traders may be consulted regarding the availability and properties of timbers generally in any particular locality.

Differing characteristics are required in the various timber components of buildings. Durability is most important in foundation timbers, posts and all pieces placed near or in the ground; strength, resistance to deflection, and nail-holding qualities are important in all framing; good appearance is required in flooring, mouldings and fixings that will not be covered; workability and good appearance are desirable in timber to be used for joinery and internal fittings.

For joinery, flooring and other items that are jointed or fitted together, it is important that timber completes its shrinkage before being machined or fitted. This condition is ensured if the timber is seasoned. When seasoned timber is required, a moisture content appropriate to the locality should be stipulated, and vague terms such as "thoroughly dry" or "fully seasoned" avoided. Moisture content cannot be determined by appearance or odour, or by feeling. It is determined by a weighing procedure or by means of electrical moisture meters. The tests are simple, but need to be carried out scientifically; some forestry authorities render service in this connection (see Chapter XV, The Seasoning of Timber).

Strength (See Chapter XIX)

Most Australian hardwoods are stronger than the timbers used in Europe and America for building purposes. For convenience the structural timbers generally have been classified in Australia into four groups based upon their strengths.

Rational dimensions for constructional work can be chosen if the strength-group to which a timber belongs is recognised. Strength-group A includes the strongest hardwoods, such as ironbarks and wandoo; Group B includes black-butt, karri, brushbox and many others; Group C includes alpine ash, mountain ash, messmate stringybark, jarrah and many other well-known timbers; Group D includes hoop pine, Douglas fir, cypress pine and many rainforest timbers.

Grading

Timber is produced in grades intended for different purposes. No advantage is gained from using a grade intended for joinery in building frames. Conversely, grades admitting defects not important in relation to strength, but detrimental to appearance, are not suitable for panelling, mouldings and the like. The user should choose the right grade for the particular use.

The main timbers and their major products are covered by Australian Standard Grading Rules or by Australian Standard Specifications published by the Standards Association of Australia.* In the milled products (flooring, lining, weatherboards, mouldings) "select" grade is suitable for clear finishing, "standard" grade for painted or covered work. Standard-grade scantling or structural timber is the most readily available, and it is recommended for all framing. A "common" grade can be supplied for purposes where strength or appearance is not important. The Division of Forest Products, C.S.I.R.O., the Forest Services, and the Standards Association of Australia, can advise on grades appropriate for building timbers.

Decay (See Chapter XVI)

Decay in timber, usually termed dry rot, is caused by wood-destroying fungi, the spores of which are always present in the atmosphere and which in the presence of sufficient moisture and air establish themselves in the timber. Decay is likely to develop when timber is maintained at a moisture content appreciably above 20 per cent; timber will not decay if it is kept constantly dry (that is, at a moisture content not higher than 20 per cent) or constantly saturated with water. In practice, non-durable timbers under favourable conditions may show signs of considerable decay in one or two years.

Those timbers which are to be used in situations of high decay hazard, and unprotected by preservative treatment, should be chosen from the more durable species or from those of lower durability which can effectively be impregnated with recommended fungicides. Situations in which a high decay hazard exists are in those portions of posts set in the ground, in ground-floor timbers where there is inadequate sub-floor ventilation, and in the joints, mortices and like positions of joinery exposed to the weather. The life of timbers used in positions of high decay hazard can be greatly and almost indefinitely extended by suitable preservative methods.

The simplest protection for sub-floor timbers is to install durable damp-proof courses, and to ensure that ample ventilation is provided beneath the floor, particularly in those positions where there are likely to be air-pockets. It is believed that carefully located ventilation openings calculated at the rate of not less than 1½ square inches per foot run of wall are necessary to provide proper ventilation.

Timbers used in Australia for joinery are usually softwoods, and they are frequently of non-durable species. The usual protection afforded is regular painting and stopping-up of any cracks. Particularly, the end grain of sashes,

* See Chapter XXV, *Technical Standards in the Timber Industry.*

doors and the like should be well painted. All mortices and tenons, where not glued, should be well-primed before assembly and put together while the paint is wet. Where glue is used it is preferable that it should be moisture-resistant.

Insect Attack—termites (See Chapter XVI)

Practically all of the termites destructive to building timbers are soil-inhabiting, and attack timbers in buildings through enclosed galleries built of earth. The most practical way of coping with such attack is to provide efficient termite shields and caps of metal between the timber and the ground. Another method, ground poisoning, is also used. This process is valuable where concrete slab floors are constructed on the ground, as it is then usually difficult to use termite shields effectively. The life of ground poison however, is not indefinite, and the poison must be renewed from time to time.

Insect Attack—borers (See Chapter XVI)

The borers which attack seasoned and semi-seasoned timbers are those which principally concern architects and builders. Of these the lyctus or powder-post borer is the principal one causing damage; this borer will attack only the sapwood of certain timbers which contain starch.

Usually the sapwood of the eucalypts used for structural purposes is insufficiently wide in the sawn piece for its destruction to be significant structurally, but occasionally lyctus attack may be serious in small timbers such as battens, woodwork, trim and flooring.

The following sketch plans and elevations are intended to indicate *conventional methods* of construction in the framing of timber houses. The dimensions of the members and fittings, as shown, are not necessarily those most suitable under all conditions* (see Chapter XXII). The sizes of structural timbers used in buildings are usually controlled by local building regulations; otherwise, three useful references, already mentioned, are: AS 0.56-1948 Australian Standard Schedule of Structural Timbers, published by the Standards Association of Australia, *The Handbook of Structural Timber Design,* and Pamphlet no. 112, "Building Frames, Timber and Sizes", both published by the Division of Forest Products, C.S.I.R.O.

ILLUSTRATING CONVENTIONAL METHODS OF CONSTRUCTION IN THE FRAMING OF TIMBER HOUSES

Explanatory Notes—Figures 38 and 39

Plan. The plan sets out the horizontal dimensions and location of all walls, foundations, doors, windows, fireplaces, equipment such as sanitary fittings and any special items such as cupboards.

Elevations. The elevation drawings set out the vertical dimensions and locate the heights of doors, windows, chimneys and roof pitch. They also indicate the position of all materials used in wall and roof covering.
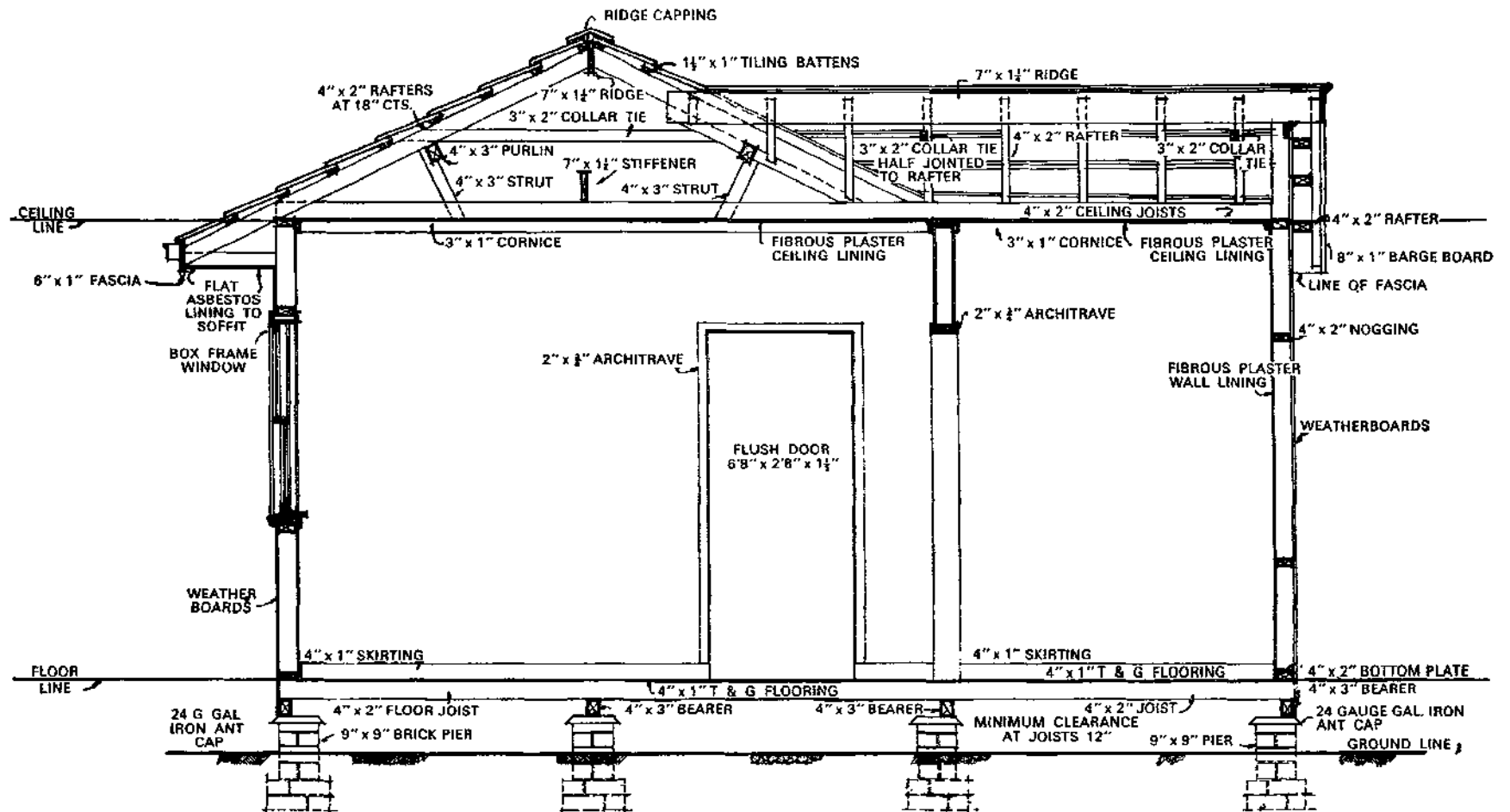
Sections. The section drawings reveal the construction generally. They also contain elevations of internal walls.

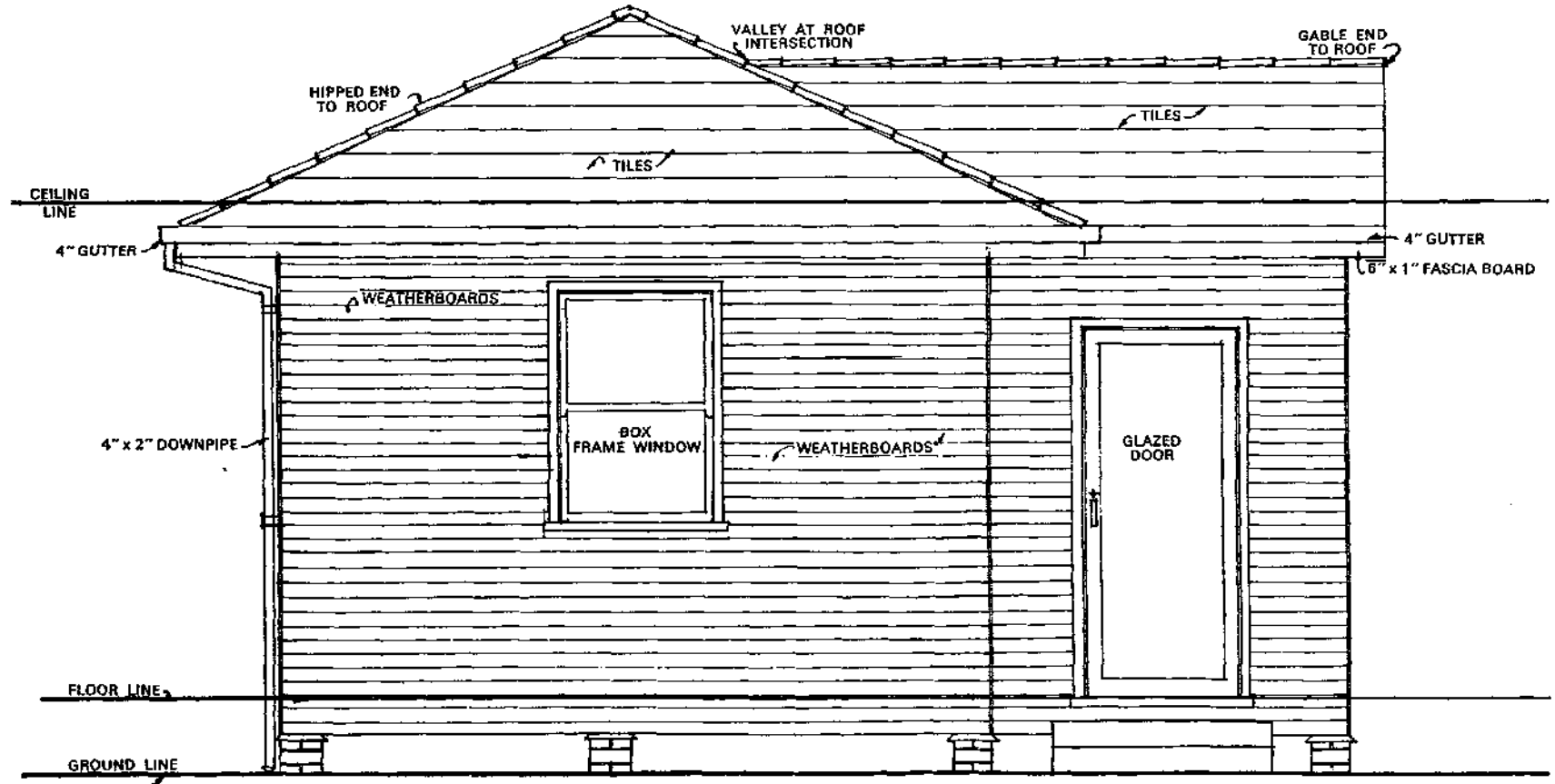* External wall studs in Queensland are usually 3" x 2".

PLAN

Figure 38.

335
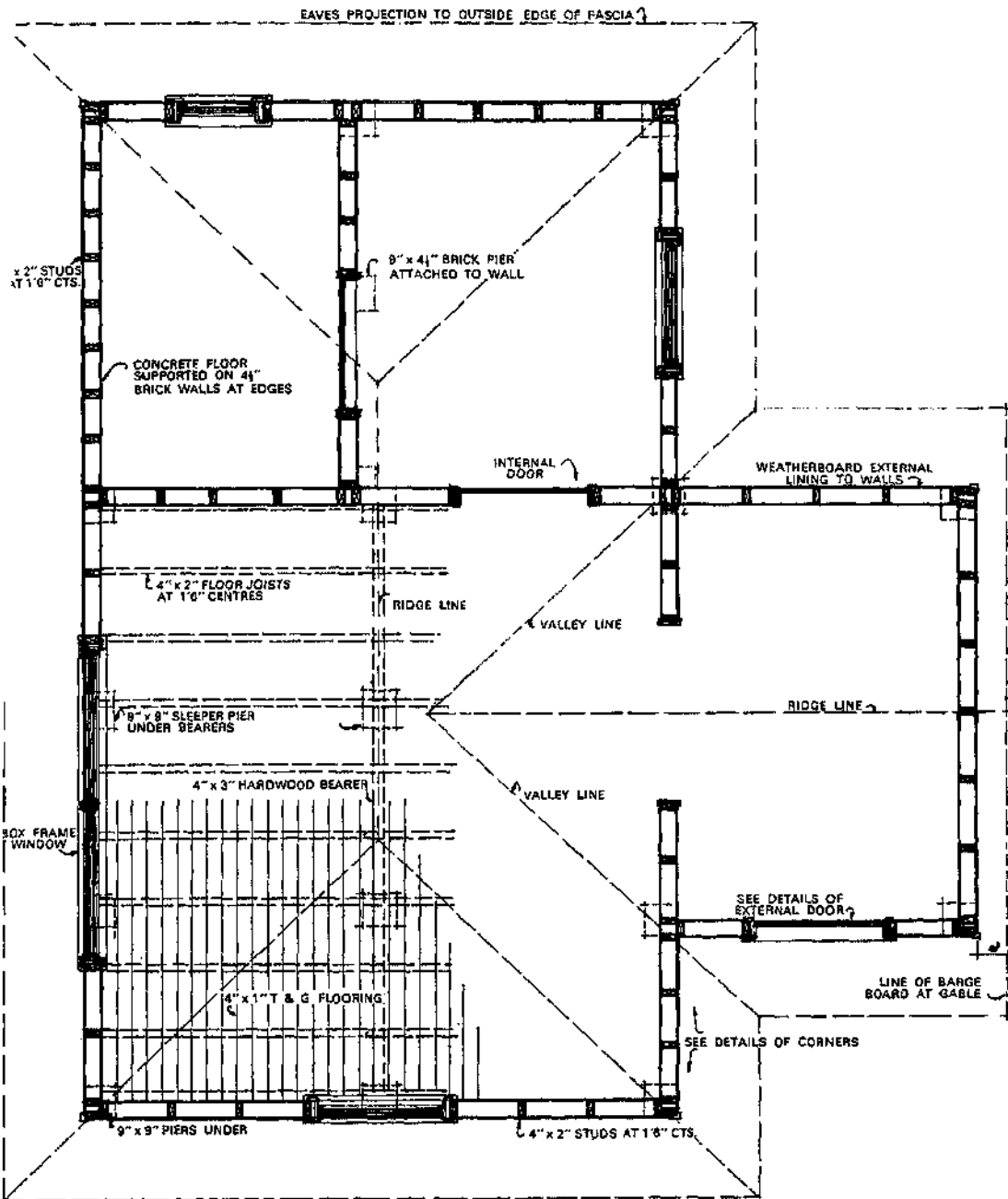
"CROSS SECTION

Figure 39, No. 1

VALLEY AT ROOF INTERSECTION

GABLE END TO ROOF

HIPPED END TO ROOF

TILES

TILES

CEILING LINE

4″ GUTTER

4″ GUTTER

6″ x 1″ FASCIA BOARD

WEATHERBOARDS

BOX FRAME WINDOW

WEATHERBOARDS

GLAZED DOOR

4″ x 2″ DOWNPIPE

FLOOR LINE

GROUND LINE

END ELEVATION

Figure 39, No. 2

Measuring Quantities of Materials. The plans, sections and elevations together with a specification give all information necessary to "take off" quantities of materials for ordering purposes.

These drawings give the complete shape and design of the building and provide the key for all general setting out. For this purpose drawings to inch = 1 foot scale are usually adequate. However, construction of a carefully detailed and complex nature requires further explanation by means of special detail drawings to a larger scale.

Explanatory Notes—Figure 40

Foundations. May be of continuous walls or pier type and are often a combination of both. To avoid cracks the foundations should be carried down to a depth where the soil is fairly free from seasonal moisture change.

Wall-type foundations are generally confined to external walls where they are used to screen off the space under the building as well as support the structure above. In places where grass and bush fires are a hazard, continuous wall foundations provide the best protection against the danger of underfloor fires starting. Pier type foundations are used for economy.

Foundations may be constructed of brick, concrete, stone and where the ground is free from termites, durable type timber posts are suitable. The spacing of foundation piers is regulated by the dimensions of beams or bearers they support and vice versa. For example, for domestic type floor loading using 4 x 3 inch hardwood bearers, the maximum spacing of foundation supports is 6 feet.
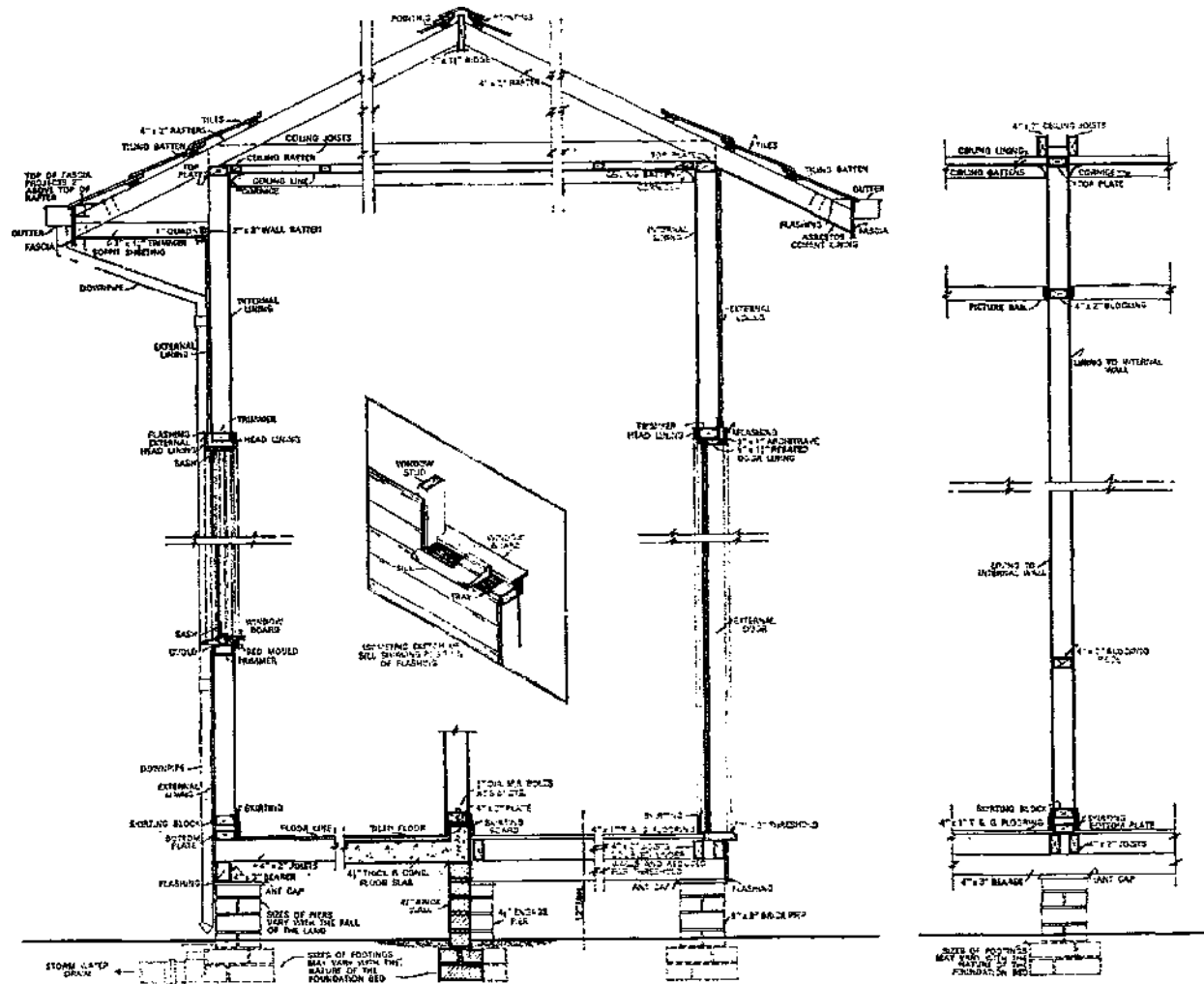
Ant Caps. These serve the double function of a barrier to rising damp and to ground termites.

Concrete Floors. These are generally used for wet areas such as laundries and bathrooms. It is best practice to construct a concrete kerb with a damp-proof course under timber wall plates to ensure that water on the floor will not penetrate under the plate and cause decay in the timber structure.

Window Flashing. The joint under window sills is particularly vulnerable to entry of water, consequently it is necessary to construct a flashing out of galvanised sheet iron, aluminium or such, with the outer edge turned down over outside weatherboards and the inner edges turned up around the window sill. Also, to drain off any water entering from side joints of the window, the flashing must be let into a saw cut groove in the side face of studs, and all joints at the corner of the flashing must be sealed. Care must be taken not to puncture the flashing with nails. To prevent water entering at the head of doors and windows, a flashing must be provided with its inner edge turned up inside weatherboards and the outer edge turned down over the top of the architrave.

Ceiling Battens. These are required for the fixing of fibrous plaster ceilings and are run both ways. Where the ceiling joists are not perfectly level underneath, the ceiling battens are packed to provide a perfectly level nailing ground.

Roof Tiles. To prevent the row of tiles at the gutter from sagging out of line with the remainder of the roof it is necessary to fix the fascia, or batten against

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TYPICAL SECTION THROUGH INTERNAL WALL

TYPICAL SECTIONS THROUGH EXTERNAL WALLS

Figure 40.

339

Measuring Quantities of Materials. The plans, sections and elevations together with a specification give all information necessary to "take off" quantities of materials for ordering purposes.

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TYPICAL SECTIONS THROUGH EXTERNAL WALLS

TYPICAL SECTION THROUGH INTERNAL WALL

Figure   40.

the fascia, higher than the roof battens generally to compensate for the omission of one tile thickness.

Explanatory Notes—Figure 41

Floor Structure. First the bearers are placed on the foundations over the ant caps and damp proofing, and are made level by packing with cement mortar or small notching. Floor joists are then laid over and skew nailed to the bearers. The spacing of floor joists, 18-inch centre to centre, is regulated to the need to support and nail the wood flooring. Where joists are parallel to walls it is necessary to fix two joists, one with its outer face flush with the outside surface of wall studs, and the other one inch in from the inner face of studs to provide support and nailing for the ends of floor boards.

Figure 41.

340
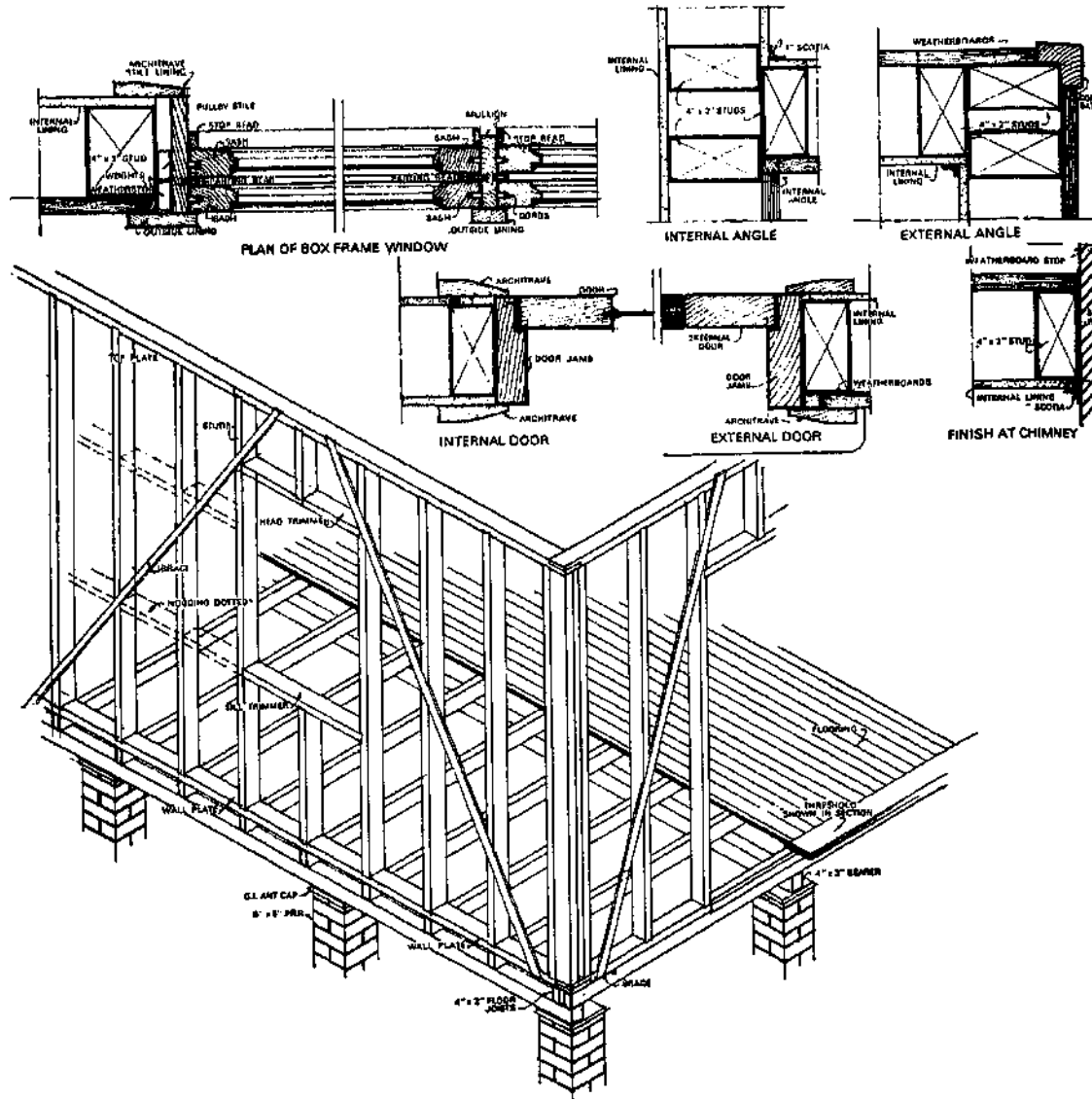
Wall Framing. Studs and plates are best framed together on a level surface, in man-handleable lengths, and then lifted up, fitted in place and nailed together at corners and to floor joists. All joints in wall plates, including corners, should be halved together to provide maximum continuity of structure. The studs should be tightly housed into top and bottom plates to prevent the studs twisting and to make a firm joint.

Bracing. It is essential to diagonally brace all wall frames, and bracing should be let in flush with the face of studs, checked into top and bottom plates and securely nailed at all studs. Bracing is located to clear doors and windows but is most effective in long lengths.

Corners. To provide nailing ground for internal and external wall linings it is necessary to use three or four studs at the corners as indicated. Owing to possible movement in timber it is difficult to avoid the cracking of plaster sheeting at the corners, but this trouble may be overcome by fixing a timber moulding in the internal corner.

Trimming Around Doors and Windows. This is necessary for both the fixing of doors and window frames and to provide nailing ground for wall linings.

Nogging. Nogging between studs serves the double function of stiffening the studs and providing fixing grounds for wall linings and fittings, and may be located at the joint in the wall sheeting and where required to fix fittings.

Explanatory Notes—Figures 42 and 43

Planning. Two-way pitched roofs as indicated only fit over parallel walls. In cases where the plan is irregular, i.e. with converging walls, a flat type of roof would be more suitable.

Ceiling Joists. These should be in single lengths where possible to provide maximum binding and stiffening to the wall framed against wind pressure.

Hanging Beams. Where unsupported lengths of 4 X 2 inch ceiling joists exceed 6 feet, the joists must be supported by means of a hanging beam as indicated. The hanging beam is supported at the ends on the walls and intermediately by galvanised-iron straps or wood-batten hangers fixed to the rafters. The hanging beam is also used to level and stiffen the ceiling joists.

Rafters. These are spaced to provide adequate support of the roofing material. For heavy material, such as tiles, rafters are spaced at 18 inch centres and for lightweight materials, such as corrugated galvanised iron, they are spaced at 2 feet 6 inch centres. To provide firm abutment, the joists should be birds-mouthed jointed over top plates and securely nailed.

Collar Ties. To prevent either spreading or sagging of rafters, collar ties should be provided with a half joint to every second rafter.

Purlins. When rafters exceed 8 feet lengths, 4 X 3 inch purlins are necessary to support and stiffen the rafters, and to ensure maximum rigidity they are best fixed directly under the collar tie as indicated on the detail drawing. The purlins are supported by struts of partition walls.

Ridge. This acts as a stiffener to roof ridge and transmits and distributes wind loads to all rafters.
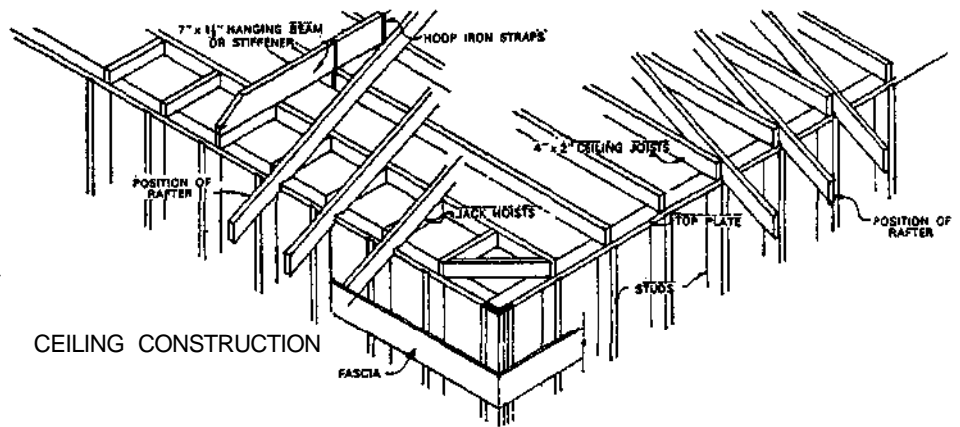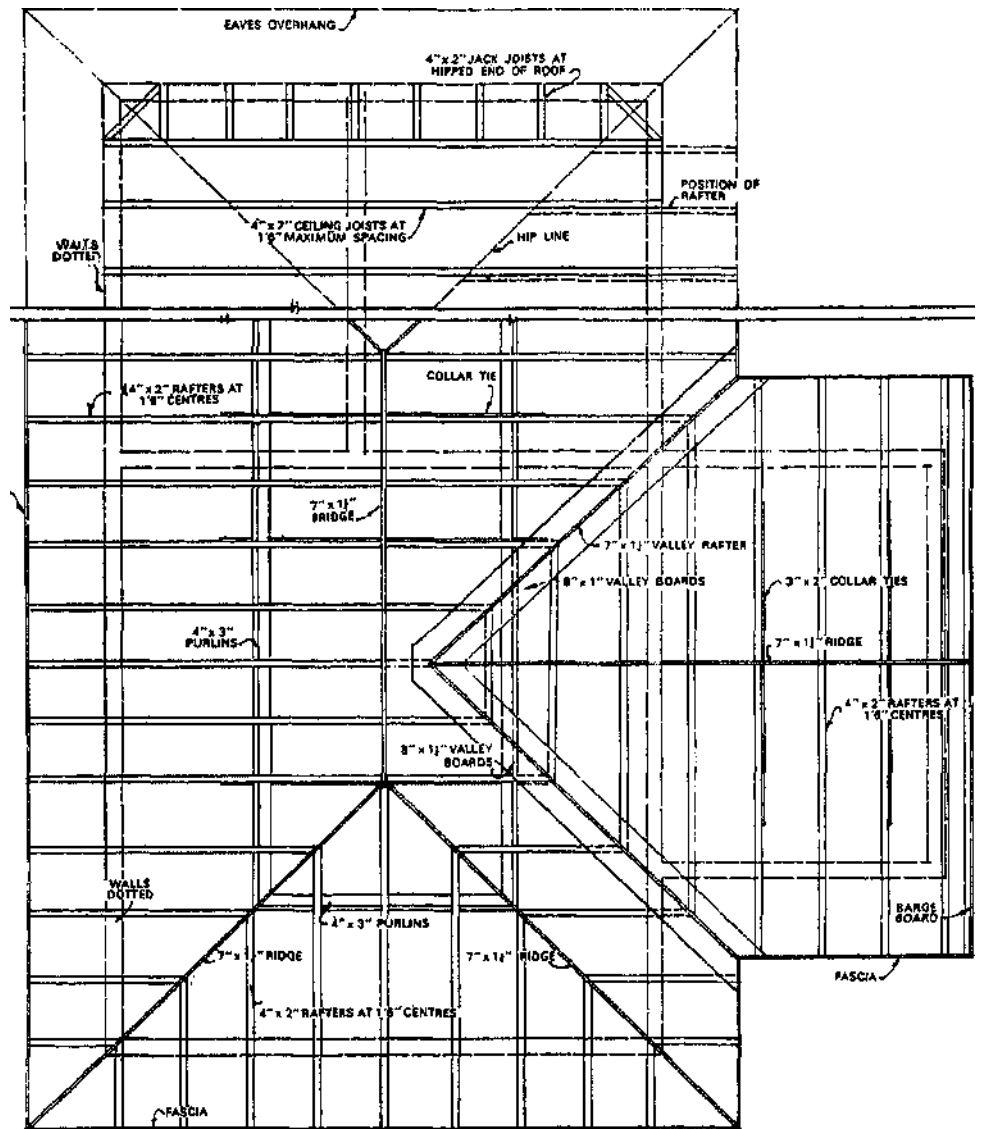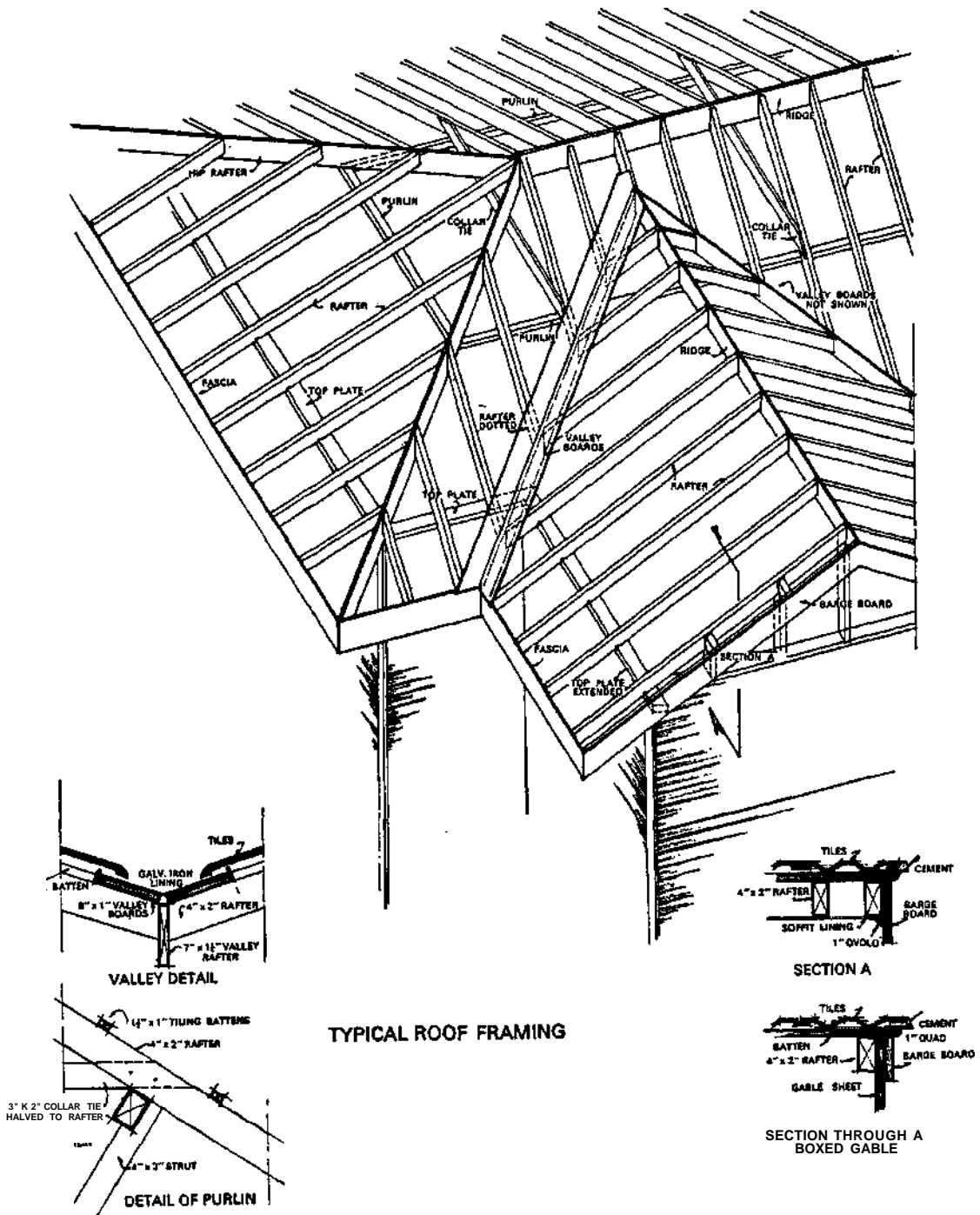
M

EAVES OVERHANG

4" x 2" JACK JOISTS AT HIPPED END OF ROOF

POSITION OF RAFTER

4" x 2" CEILING JOISTS AT 1'6" MAXIMUM SPACING

HIP LINE

WALLS DOTTED

4" x 2" RAFTERS AT 1'6" CENTRES

COLLAR TIE

7" x 1½" RIDGE

7" x 1½" VALLEY RAFTER

8" x 1" VALLEY BOARDS

3" x 2" COLLAR TIES

7" x 1½" RIDGE

4" x 2" RAFTERS AT 1'6" CENTRES

4" x 3" PURLINS

8" x 1½" VALLEY BOARDS

WALLS DOTTED

BARGE BOARD

4" x 3" PURLINS

7" x 1½" RIDGE

7" x 1½" RIDGE

FASCIA

4" x 2" RAFTERS AT 1'6" CENTRES

FASCIA

7" x 1½" HANGING BEAM OR STIFFENER

HOOP IRON STRAPS

4" x 2" CEILING JOISTS

POSITION OF RAFTER

JACK JOISTS

TOP PLATE

POSITION OF RAFTER

STUDS

CEILING CONSTRUCTION

FASCIA

Figure 42.

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VALLEY DETAIL

DETAIL OF PURLIN

TYPICAL ROOF FRAMING

SECTION A

SECTION THROUGH A BOXED GABLE

Figure 43.

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Valley Rafters. These provide support for roof rafters, and long lengths should be supported with struts off the partition.

Valley Boards. These support the galvanised flat-iron valley flashing as indicated on valley detail drawing.

Roof Bracing. Gable roofs should be braced against wind loads by means of diagonal timber braces nailed to the bottom of the rafters and carried from the apex of the gable to the wall plates.

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Pearson, Kloot & Boyd. *Timber Engineering Design Handbook*—1958, C.S.I.R.O. & Melbourne University Press.

Standards Association of Australia. A.S. no. 0.56-1948. Australian Standard Schedule of Dimensions of Structural Timbers.

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XXV

TECHNICAL STANDARDS IN THE TIMBER INDUSTRY

The Standards Association of Australia (S.A.A.), through its Timber Industry Sectional Committee, determines the standards applicable to timber and timber products throughout the Commonwealth. The extent and progress of the programme of standardisation is, to a great extent, dependent upon the support for this work provided by the timber industry itself.

The importance of standards in the timber industry cannot be overstressed. Standardisation simplifies the understanding and the application of timber and building practice from architect and draughtsman right along the line to sawmiller and artisan. It increases design efficiency, reduces risk of costly errors, limits the number of "lines" for stocking by merchants and helps to establish confidence and understanding between producer, merchant and consumer.

Monthly Information Sheet

The SAA each month publishes an information sheet in which new work and the progress of work in hand is briefly outlined. It also carries a list of recently published Australian and British Standards, with references to issued standards of other countries.

Membership of SAA is open to all industrial and commercial firms and to professional firms and individuals.

The following list* indicates the Australian Standards and Interim Standards that have been prepared in respect of timber and plywood. The Interim Standards have been issued to meet an urgent need and represent the best available knowledge at the time of their preparation. Experience gained by their use will indicate where revision is required.

Publications listed may be obtained from headquarters of the Association, 80-86 Arthur Street, North Sydney, or from branch offices in each State.

*Brief descriptions of each standard specification are given in the *Timber Industry Sectional Catalogue* issued by the Standards Association of Australia.

Nomenclature

0.2—1965	*Nomenclature of Australian Timbers.*
Int. 363 (1954)	*Nomenclature of Commercial Timbers Imported into Australia.*

Grading Rules

0.1—1964	*Glossary of Terms Used in Timber Standards.*

STRUCTURAL TIMBERS

0.14—1948	*Structural Timber—Jarrah.* Select Grade.
0.16—1948	*Structural Timber—Jarrah.* Standard Grade.
0.17—1948	*Structural Timber—Karri.* Select Grade.
0.19—1948	*Structural Timber—Karri.* Standard Grade.
0.72—1960	*Sawn Radiata Pine Graded on Face Appearance.*
0.80—1963	*Decking Timbers From Eastern and South-Eastern Australian Hardwoods.*
0.81—1966	*Engineering Timbers From Eastern and South-Eastern Australian Hardwoods.*
0.82—1965	*Sawn Eastern Australian Hardwoods.*
0.83—1963	*Sawn South-Eastern Australian Eucalyptus Hardwoods.*
0.84—1967	*Sawn Australian Rainforest Timber.*
0.95—1964	*Cypress Pine Light Scantlings.*
0.98—1966	*Seasoned Size-matched Framing Timber (including Finger Jointed Pieces) From South-East Australian Hardwoods.*
Int. 360 (1952)	*Rough Sawn Eastern Australian Hardwood.* Describes select, standard and common grades.
Int. 361 (1952)	*Rough Sawn South-Eastern Australian Hardwoods.* Select and standard grades.
Int. 362 (1952)	*Rough Sawn Eastern Australian Brushwoods.*
Int. 366 (1953)	*Heavy Engineering Structural Timbers—Eastern Australian Hardwoods.* Graded on a strength basis into select and standard grades.
Int. 371 (1954)	*Sawn Radiata Pine.* Provides for dressing quality, merchantable quality and common quality.
Int. 376(1959)	*Sawn Radiata Pine for Structural Engineering Applications.* (Amndt. 1, Dec. 1967).
Int. 377 (1959)	*Sawn Radiata Pine for Use as Light Framing Material.*
(E)0.54—1942	*Grading Rules for Sawn and Hewn Structural Timbers.*
0.106—1969	*Sawn Douglas Fir (Oregon) and Sawn Western Hemlock (Canada Pine).*

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MILLED PRODUCTS

0.24 and 0.25—1948	*Flooring—Select and Standard Grades—Jarrah.* (Partly superseded by 0.24—1964).
0.32—1948	*Flooring—End Matched Jarrah.*
0.34—1964	*Lining From Western Australian Hardwoods.*
0.35—1964	*Siding Boards From Western Australian Hardwoods.*
0.36—1965	*Timber Used in the Manufacture of Joinery in Western Australia.*
0.38—1964	*Mouldings From Western Australian Hardwoods.*
0.39—1948	*Wea therboards—Jarrah.*
0.62 to 0.65—1958	*Milled Products From South-Eastern Australian Hardwoods.* (Flooring, lining, weatherboards and mouldings).
0.66 to 0.69—1960	*Milled Products From North-Eastern Australian Eucalypt Hardwoods.* (Flooring, lining, weatherboards and mouldings).
0.73—1960	*Radiata Pine Milled Flooring and Decorative Lining.*
0.74—1960	*Radiata Pine Milled Weatherboards, Fascia, Door Jambs and External Sheathing.*
0.75—-1960	*Radiata Pine Milled Mouldings.*
0,76—1967	*Wooden Door Frames and Door Jamb Linings.*
0.91 to 0.94—1964	*Unseasoned Cypress Pine Sawn Boards and Milled Products* (Boards, milled flooring, milled weatherboards, milled lining) -
0.111 to 0.103—1967	*Milled Products From Australian Rainforest Timber* (Flooring, lining, weatherboards (chamferboards) and mouldings).

RAILWAY MATERIALS

0.10--1948	*Railway Sleepers—Jarrah, Karri and Wandoo.*
0.11--1948	*Railway Crossing Timbers—Jarrah.*
	Sleepers for 24-in. Gauge Railway Track (Sugar Cane Industry).
0.57--1949	*Rail Track Sleepers, Lead or Crossing Timbers and*
0.97--1963	*Bridge Transoms From Eastern Australian Hardwoods.*

MISCELLANEOUS TIMBER PRODUCTS

0.20—1948	*Cross-arms of Jarrah, Karri and Wandoo.*
0.22—1948	*Mine Guides—Jarrah and Wandoo.*
0.44- -1948	*Piles—Jarrah.*
0.45- -1948	*Poles—Jarrah and Wandoo.* Describes dimensions in terms of length, crown and butt diameters, as well as taper, straightness and general grade description.

0.46—1960	*Round Section Stringers From Western Australian Timbers.*
0.61—1955	*Cross-Arms—Eastern and South-Eastern Australian Hardwoods.*
Int. 364(1952)	*Wooden Poles for Telecommunication and Power Lines* (arndt. 1, Nov., 1963). Generally of eastern Australian hardwood origin, but some pinus species are included.
0.70—1958	*Sawn House Stumps, Soleplates, Fence Posts and Struts.*
Int. 365 (1952)	*Piles (Eastern Australian Hardwoods).*
0.71—1960	*Wood Blocks for Parquetry Flooring.*
0.96—1964	*Timber for Marine Craft.*

PLYWOOD

0.6—1953	*Plywood for General Purposes.* (Highly moisture resistant, medium moisture resistant and non-moisture resistant).
0.59—1952	*Waterproof Plywood.* Marine and Standard grades.
0.86—1964	*Plywood for Marine Craft.*
0.87—1963	*Plywood for Exterior Use.*
0.88—1963	*Plywood for Interior Use.*
0.90.1 to 0.90.5-1964	*Methods of Testing Plywood* (Moisture content, bond quality of plywood (knife test), resistance of glue-lines to micro-organism attack, quality of scarf joints, depth of peeler checks in plywood and veneers).

ADHESIVES

K.77, 78 and 79-1941	*Joiners' Glue.* Dry forms, jellies and liquids, and casein.
K.88—1952	*Synthetic Resin Adhesives for Plywood* (Phenolic and Amino-plastic).
K.89—1953	*Protein Adhesives for Plywood.*
K.90—1957	*Synthetic Resin (Phenolic) Moulding Materials.*
Int. 370(1953)	*Adhesives for Fruit Case Labels.*
CA.31	*Australian Standard Code of Practice for the Laying of Parquetry Flooring.*
0.71	*Australian Standard Specification for Wood Blocks for Parquetry Flooring.*

MANUFACTURED ARTICLES

S.l—1951	*Household Furniture.* Provides a minimum standard of construction for the general run of household furniture.

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Int. 305 (1952)	*Kitchen Fitments.* Mainly cupboards and benches for general prefabrication.
Int. 314 (1949)	*Bathroom Cabinets.* Sizes and constructional details.
Int. 316 (1949)	*Clothes Line Posts.*
Int. 321 (1952)	*Doors.* Included are panel, framed and ledged, ledged and braced, and flush hollow core doors.
Int. 318	*Wood Windows of Double Hung and Casement Types.*
Int. 322	*Wooden Door Frames and Door Jamb Linings.*
Int. 328 (1954)	*Roof Tilers' Ladders.*
N.33	*Australian Standard Specification for Wooden Cheese Crates (for Export Purposes).*
0.99—1966	*Wooden Doors.*

MISCELLANEOUS

0.56—1948	*Schedule of Dimensions of Structural Timbers for Use in Domestic Building Construction.*
0.60—1956	*Wood Treated With Lycticides.* Specifies the degree of concentration of certain recognised lycticides.
N.21—1952	*Fibreboard Containers for Butter (for Export Purposes).*
Int. 180	*Grading and Selection of Timber for the Construction of Small Craft.*

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' II

Glossary and Index

TIMBER TERMS, PHRASES AND ABBREVIATIONS

I. TERMS USED IN SIZE CLASSIFICATION

*STRIP: Under $^a/_4$ inch thick and up to 3 inches wide.

*BATTEN: $^3/4$ inch and under 1½inch thick and from 1 to 3 inches wide.

*BOARDS: $^3/_8$ to 1½ inch thick and 3 inches and over wide.

*PLANKS AND SHEETING: Over 1½ inch and up to 4 inch thick and over 6 inches wide.

*SCANTLING, HEAVY, FLITCH AND BAULK: Over 4 inch thick and/or over 6 inches wide.

Scantling, heavy scantlings, generally 4 inches and greater thick and 6 inches and greater wide.

Scantling, small scantlings, generally less than 4 inches thick and less than 6 inches wide.

Baulk, a piece of sawn or hewn timber of large rectangular cross-section, usually more than 4 inches thick and more than 6 inches wide and intended for re-sawing.

II. TERMS USED IN MANUFACTURING CLASSIFICATION

*SHOP AND FACTORY TIMBER: Timber to be used for further manufacture, and graded on the basis of the percentage of the area which will produce cuttings of a specific quality, or a given minimum size.

*ORDINARY BUILDING TIMBER: Timber to be used for general building purposes, and graded upon the use of the entire piece.

•STRUCTURAL TIMBER: Timber to be used in construction and graded upon the strength of the piece and the use of the entire piece. Timber for applications where strength is the essential element in its selection and use.

*ROUGH TIMBER: Timber as it comes from the saw.

•DRESSED TIMBER: Timber that is dressed by running through a planer; dressed on one side (D1S), two sides (D2S), or (DD), one edge (D1E), two edges (D2E), or a combination of sides and edges (D1S1E), (D2S1E), (D1S2E), or (4S), etc. DAR means "dressed all round", i.e., on four sides.

*As defined in C.S.I.R.O. Division of Forest Products *Trade Circular* No. 15, "Draft Terms and Definitions".

fBritish Standards Institution, 565, 1949, "Glossary of Terms"; Standards Association of Australia, Australian Standard 01-1964, "Terms Used in Tmber Standards."

*MILLED TIMBER:	Timber which has been run through a machine and moulded, tongued and grooved, or worked to make a "rabbetted" or lapped joint.	

III. GLOSSARY AND INDEX

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	(2) Manufactured products supplied as rigid or semi-rigid sheets, e.g. blockboard, fibreboard, particle boards.	
†BOARD, PARTICLE'.	A board made from particles of timber and/or other ligno-cellulosic material bonded with synthetic resin and/or other organic binder.	.99
BOARD FOOT: (or Board Measure)	A unit used in the measuring of timber, the equivalent of 1 square foot and 1 inch thick. (See *Superficial).* . . .	.31
†BOLE:	The main stem of a tree.	.177
BONE DRY:	Thoroughly seasoned. (See *Seasoning).*	
BOOM:	*A* long pole or spar.	
†BORER:	Wood-boring insect in the larva (or beetle) stage which tunnels into wood or between bark and wood. (Principal species: ambrosia, anobium, auger, lyctus. (See also Borer Marine and Chapter (XVI).).	.227
* BORER AMBROSIA:	See *Borer, Pinhole.*	
* BORER ANOBIUM:	Larva of a beetle of family Anobiidae, commonly the species *Anobium punctatum De Greer,* which causes damage in some well-seasoned timbers, e.g. in old furniture panelling, etc. Syn. furniture borer.	
*BORER AUGER:	Beetle of the family *Bostrychidae* which makes auger-like holes in the surface of the wood and whose larvae cause internal damage mainly in the sapwood of hardwood timbers.	
*BORER LYCTUS:	Larva of the family *Lyctidae,* commonly the species *Lyctus brunneus Steph.,* which attacks starchy sapwood of some seasoned or partially seasoned, pored timbers. The adult beetle makes the flight hole. Syn. Powder-post borer.	
* BORER MARINE'.	A marine crustacean or mollusc which tunnels into timber submerged in salt or brackish water, e.g. *Limnoria, Bankia, Teredo.* (See Chapter XVI)	
* BORER PINHOLE:	Ambrosia beetle of the family *Nansitora, Platypodidae, Scolytidae* or *Sphaeroma* which bore "pinholes" in green timber where they cultivate an ambrosia fungus upon which the larvae feed and which dark-stains the perimeter of the tunnels.	
*BORER POWDER POST:	See *Borer, Lyctus.*	
*BORER SHOT HOLE:	Beetles of the families *Bostrychidae* and *Scolytidae,* which make holes 1/16- inch diameter.	
†BOTTOM RAIL:	The horizontal bottom member of a door, casement or lower sash.	
* BOW :	A curvature from the plane of the wide face (i.e., flatwise), in the direction of the length only.	
BOX TIMBER: (or CASE)	Timber used for the manufacture of boxes or crates.	
BOXED FRAMES:	Window frames built up with hollow sides to receive the balance of weights for vertically sliding sashes.	341
†BOXED HEART:	The pith and the adjacent timber contained within the four surfaces of a piece of timber anywhere in its length.	.431
BOX THE HEART:	Cutting boards from the outside of a log leaving the heart in the centre piece.	.431
BRANCH KNOTS:	See *Knots.*	
†BRASHNESS".	A condition that causes timber to be relatively low in shock resistance (brittle). When stressed, brashy timber fails abruptly at comparatively small deflections with little or no splintering.	
BREAKING DOWN:	The initial sawing processes in converting logs to timber at the head saw. (See Chapter III).	.36
BREAKING STRENGTH:	The measured load or force necessary to overcome the resistance of the structural member and break it.	

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CASINGS:	Cabinet framing. Coverings in timber for the concealment of rough work, pipes etc.	
CEILING BOARDS:	Linings or building boards, fixed to the ceiling joists, used as surface covering for the top of a room.	
CEILING JOISTS:	Light horizontal beams for carrying the ceiling	341
CELL:	A unit of plant tissue	117
CELLULOSE:	A major constituent of the cell walls of timber. A derivative used in the manufacture of celluloid, cellophane, explosives, lacquer, synthetic fibres, etc.	
CHAIN SAWS:	Portable, power driven, saws in which a toothed chain is fitted as the sawing element. Used for cross-cutting logs or large timber sections	55
†CHAMFER:	The surface produced by the removal of an arris. (See also *Bevel*).	
CHATTERING :	Vibration of poorly fitted saws or cutters causing ridges on the timber surface.	75
†CHATTER MARKS:	Ridges on the surface of milled timber caused by the faulty operation of a planing machine. (Also known as *Shudder Marks*).	
†CHECK:	A separation of the timber extending longitudinally and formed during drying. Commonly caused by the immediate effect of dry wind or hot sun on freshly sawn timber. (As compared with longitudinal shakes, checks have an order of magnitude of inches in length). *End Check:* One occurring on the end of a piece. *Internal Check:* One having its origin in the interior of a piece. *Surface Check:* One occurring on the surface of the piece. *Through Check:* One extending from one surface through the piece to another surface.	204
†CHECK, HEART:	A check extending from the pith outwards in any direction but not reaching the surface of the piece.	
†CHECK, SEASONING:	A check occurring on the surface during seasoning.	
CIRCULAR SAW:	A circular steel blade with cutting teeth on the circumference and power driven. (Also refers to the machine using a circular blade).	48
CLEAR AND BETTER:	Marketing term defining upper grades in the grading of north American timbers, particularly Oregon (Douglas fir).	
CLEAR TIMBER:	Timber free from defects.	
CLEATS:	Small battens, nailed or fitted, serving a temporary purpose. †A member nailed across a number of boards to hold them together.	
CLOSE GRAIN:	Wood with narrow growth or annual rings.	
COARSE GRAIN:	Wood with wide growth or annual rings.	
COFFIN BOARDS:	Boards used for coffin making and usually specified 13 inches and wider, multiples of 7 feet in length, and 1 inch thick.	
COLD PRESS RESINS:	Urea-formaldehyde resins which do not require heat for setting	111
COLEOPTERA:	See *Bark Beetle*.	
*COLLAPSE:	Flattening or buckling of wood cells during drying which becomes manifest in excessive and/or uneven irregular shrink-age	206
COMMONS:	A marketing term used to denote lower grades.	
COMPRESSION: (or COMPRESSIVE) STRESS)	When applied forces tend to descrease the length of a body it is under compression and the stress is called compressive stress.	284
*COMRESSION WOOD:	Abnormal wood which may occur in non-pored timbers, characterised anatomically by short thick-walled cells showing spiral markings, the timber being denser, more brittle and prone to greater longitudinal shrinkage than normal wood.	

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CONCAVE SAW:	A circular saw concave in form, used for cutting cooperage and such-like stock.
CONCENTRATED LOAD:	A load applied to a very small part of a beam.
†CONDITIONING:	(1) (In timber) a term loosely used for any process designed to ensure that the moisture content of the timber is suited to the conditions and purpose for which it is to be used.
	(2) (In seasoning) a treatment applied at the conclusion of the seasoning schedule so as to bring the moisture content to the desired value or to reduce moisture gradients.
	(3) (In wood preservation) the preliminary treatment of un-seasoned or partially seasoned timber for the removal of air and moisture to improve penetrability and absorptive properties of wood.
CONIFEROUS:	Applied to wood derived from conifers, i.e., softwoods or non-porous woods.
†CONVERSION or CONVERTING:	The process of sawing timber from the log. (See Chapter III) 36
†CONVBRTED TIMBER:	Timber sawn from the log. (See Chapter III) 36
CORD:	A unit of measurement equalling 128 cubic feet.
†CORE:	(1) The central ply or plies in a plywood sheet.
(CORESTOCK)	(2) The inner layer of blockboard.
	(3) (In rotary veneering) the portion of the peeler block remaining after available veneer has been cut.
	(4) (In timber seasoning) the inner portion of the cross-section of a piece of timber, the middle-third of the width and thickness 82
CORNICE:	A moulding of fairly large section fixed in the corner between wall and ceiling.
CORNICE MOULDING:	A moulding applied to the top of a piece of furniture.
CROOKED GRAIN:	Irregular grain due to varying growth rings, trunk bend, intersection of branches etc.
CROSS-ARMS:	The arms fixed to the top of poles carrying telegraph and power lines.
†CROSS-BAND:	As a general term, one of the transverse layers of veneer that distinguish plywood and allied material from laminated timber, in which the grain of adjacent pieces is parallel 82
*CORRUGATION	A condition of collapse in which the surface of the piece assumes a rippled appearance. 208
CROSS-CUT:	To cut across the grain. A circular saw for cutting boards sectionally.
CROSS GRAIN:	See *Grain.*
CUBIC:	Measurement of volume. Cubic foot is standard timber measure in some British countries 33
CULLS:	Degraded timber, or logs.
CUNTT:	A unit of measurement (usually applied to round-wood for pulp manufacture) equalling 100 cubic feet true measure.
†cup:	A concave curvature across the grain, i.e. across the width of the face.
CUSTOM SAWING:	Sawing of logs or timber under contract.
CUTTERS:	The knives or blades used in planing and moulding machines. *Cutter Block:* The blocks fixed to spindles in woodworking machines and which carry the cutters, (See Chapter VI) 79
C.V.J. :	Centre vee jointed. Lining boards with a V finish at the joint and also with a V machined at the centre of the board.
CYCLONE:	Funnel-shaped, collector of air and wood waste located at the end of an exhaust system.

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D, DO, DAR, etc.	D: Dressed. DD: Double dressed. D1S: Dressed one side. D2S: Dressed two sides, (or double dressed). DAR: Dressed all round. D1S2E: Dressed one side, two edges, etc.
DEAD KNOT:	See *Knots.*
DEAD LOAD:	A steady load due to force of gravity.
DEAD ROLLERS:	Rollers that are not power-driven.
DEAL:	Applied to softwoods between 2 and 4 inches thick 9 and 11 inches wide. Applied loosely to European softwood.
*DECAY:	A partial disintegration of the timber substance due to the action of wood destroying fungi. *Incipient Decay:* The early stage of decay which has not proceeded far enough to soften the wood perceptibly. (It is usually accompanied by slight discolouration or bleaching of the wood. See Chapter XVI) ... 212
DECAYED KNOT:	See *Knots.*
DECIDUOUS:	Applied to trees subject to annual shedding of leaves. Deciduous trees are nearly all classified as hardwood.
DECKING:	Timber hewn or sawn used in working platforms or forming the floors of ships' decks, wharfs, etc.
†DEEP CUTTING:	The resawing of timber parallel to its broad surface.
*DEFECTS:	Any irregularity occurring on or in timber, that may lower its strength, durability or utility value.
DEFLECTION:	The sagging, bending or distortion of structural members through the action of forces on the structure.
DEFIBRATOR:	Machine for disintegrating wood into fibres.
tDENSITY:	The weight per unit volume, usually expressed in pounds per cubic foot.
DESICCATION :	Artificial drying of timber by controlled heat in special chambers.
DETRUSION:	Shearing of the fibres along the grain of the wood.
DIAGONAL GRAIN:	See *Grain.*
*DIAMOND:	Distortion to a more or less diamond-shaped cross section due to seasoning or imperfect manufacture.
†DIMENSION STOCK:	Timber converted to specified widths, thicknesses and lengths.
(or TIMBER)	In structural design. (See Chapter XXII) 316
DIMENSION:	Any change in the normal colour of wood.
DISCOLOURATION:	A load spread over an area or length; not necessarily uniform.
DISTRIBUTED LOAD:	Division of Forest Products (Commonwealth Scientific and
D.F.P. :	Industrial Research Organisation).
D.W.T. :	Division of Wood Technology (Forestry Commission of New South Wales).
DOG:	(1) A piece of bent steel sharpened at one end and with a ring or hook at the other, used in logging. (2) Steel projecting teeth attached to a log carriage-knee used to hold the log against the head blocks. (3) A term used for loading heavy timbers by hoisting with steel grips.
DOOR FRAME:	A strong solid frame for a door, usually from 5 x 3 inch stock.
DOORS:	Principal types are framed and ledged, ledged and braced, panelled, flush faced. Principal sizes: 6 feet 6 inches X 2 feet 6 inches; 6 feet 8 inches x 2 feet 8 inches; 6 feet 10 inches x 2 feet 10 inches.
DOOR SILL:	The piece holding the feet of door posts and serving as a threshold.
DOZY or DOSY :	Decayed q.v.
DOUBLE-BOXED:	A boxed mullion for receiving two pairs of weights for sliding sashes.

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DOUBLE CUTTING: A band saw which is toothed on both edges and can cut logs on the return of the carriage as well as in the normal way.

DOUBLE HUNG: Sash and frame windows in which both sashes are balanced by weight.

DOUBLE SAPWOOD: Sapwood which has not been converted into heart wood due to causes such as severe frost, but through which the cambium survived to continue growth.

DOVETAIL: A method of joining pieces of timber at right angles. Types of dovetail joints are: common, lapped and secret.

DOWEL: A wooden pin, very often used in various kinds of joints, or in place of a mortise and tenon joint.

DRAG SAW: A portable, power driven, reciprocating saw used for cross cutting logs or large timber sections 56

DRESSED: Planed Surfaces. (See II, Terms Used in Manufacturing Classification).

DRESSED AND MATCHED : Boards dressed to the same thickness and width, tongued and grooved.

DROP SIDING: Exterior covering for timber building. Weatherboards.

DRUM SANDER: A machine with one or more sandpaper-covered drums for finishing wood surfaces.

DRUNKEN SAW: A circular saw running out of truth on its axis. The "wobble" thus induced causes the cut to be greater than the thickness of the saw. Used for plough grooves etc.

DRUXY or DRUXINESS : A disease in timber caused by the attack of fungus in the cambium layer.

DRYING: Seasoning q.v.

DRYING STRESSES: Stresses in timber caused by variations in shrinkage 204

DRY JOINTS: Joints which are not glued.

DRY KILN: A compartment in which timber is dried by artificial heat and humidity 199

†DRY ROT: A general term applied to the decay of timber caused by the attack of certain fungi (especially *Merulius Lacrymans)* as a result of which the timber becomes light in weight and friable. (Chapter XVI) 211

†DUNNAGE: Timber usually of poor quality, used for supporting cargo in ships or stacks of timber in storage.

DURABILITY: The natural resistance of timber to its various diseases and decay 225

DURAMEN: Heartwood (q.v.)

E: The symbol for modulus of elasticity 286

ECCENTRIC LOAD: A force not acting along the axis of a column or through the centre of gravity of a section.

†EARLY WOOD : The less dense, larger celled, first formed part of a growth ring. 181

EDGE GRAIN: Quarter-sawn (q.v.)

EDGER: A machine used for squaring waney timber. It is also used for cutting wide boards into several narrow boards. It has several circular saws on the same arbor, and feed rolls 52

†EDGiNGs: A strip of wane, usually carrying bark, which is cut from the edge of a piece in the course of cutting to width.

ELASTICITY: The property that allows material to regain its original condition following distortion.

ELASTIC LIMIT: The limit to which material can be distorted and still regain its original condition 286

EMPTY CELL PROCESS: Cellular impregnation with preservative followed by vacuum
(Open Cell process) treatment to withdraw surplus preservative from the wood ... 223

ENCASED KNOT: See *Knot.*

ENCLOSED KNOT: See *Knot.*

END CHECK:	Seasoning checks in the end of a board.	
END GRAIN:	The transverse section of a piece of wood.	
END MATCHED:	Applied to flooring which is tongued and grooved on the ends to fit.	
†END SPLIT:	A split at the end of a log or piece.	
†EQUILIBRIUM MOISTURE CONTENT:	See *Moisture Content.*	
EUCALYPTUS:	The principal hardwood species in Australia. (See Chapter XIII).	138
EXIT HOLES: (Flight Holes)	Holes from which wood-boring insects emerge as beetles from the timber.	227
EXPANSION:	An increase in the volume of wood usually due to increase of moisture content. (In contrast to shrinkage).	203
f:	Symbol denoting maximum intensity of stress. (Used in structural design).	
FACE:	(1) The wider and better surface of a piece of timber. (2) The lower concave part of a saw tooth.	
*FACE CUT:	A piece produced in straightening up a log, flitch or piece.	
FACE MEASURE:	Surface measure. See *Superficial.*	
FACE VENEERS:	Those used on the surface of plywood.	
FACINGS:	Finished timber covering rough work or inferior surfaces.	
FACTOR OF SAFETY:	(FS). In engineering design the number by which the breaking strain is divided to give the safe working load. The factor of safety for timber lies between 4 and 10 according to type and quality of the wood	289
FALSE HEARTWOOD:	Dark wood in the interior of a log caused by disease, or unnatural conditions.	
FALSE RING:	A ring additional to the normal annual ring formed during the year's growth usually due to unusual growth conditions.	
FALSE WORK:	The framing and casing for setting concrete.	
FASCIA OR FACIA:	A flat wide board with or without moulding as used to finish eaves in a building.	336
FASTENINGS:	Various forms for securing finished work together such as nails, bolts, screws, dowels, etc.	
FATIGUE:	Breakdown in strength of materials due to continued over-strain.	
f.b.m.:	Foot board measure.	
FEATHER EDGED:	Tapered in thickness across the width of the face.	
FEED: (Rate of)	The speed expressed in feet per minute at which timber is fed into saw or planing machine.	
FELLING SHAKE:	A longitudinal or transverse shake caused during the felling of a tree.	
†FIBREBOARD:	Board (sheet) manufactured from fibres of ligno-cellulosic material with primary bond deriving from the felting of the fibres and their inherent adhesive properties. Bonding or impregnating agents may be added during manufacture.	
†FIBRES:	The main body of cellular units of which timber is composed	177
†FIBRE SATURATION POINT:	The hypothetical moisture content at which the cell walls are saturated without there being any free moisture in the cell cavities. *Note:* Above the fibre saturation point the strength and dimensions of timber remain approximately constant, and below it they change as the moisture content varies. Fibre saturation point varies considerably between species but for practical purposes is assumed to be 25-30 per cent moisture content. (See Chapter XV).	188
FIDDLE BACK:	See *Grain, Wavy.*	

†FIGURE: The appearance of a timber surface due to its anatomical features or variation in colour, grain and texture.

FILER: Saw doctor (q.v.) See also *Hammering*. "Filing and hammering" generally refer to all phases of the conditioning of saws. (See Chapter V).

FILLER: A paste of the required colour used for filling the grain of timber before polishing   272

FINISHED SIZE*,   The exact size required *after* machining.

FINISHINGS: The joinery and dressed or moulded work used in a building as distinct from the frame work. (See Chapter XVII)   274

FIRSTS: A qualitative term in grading timber denoting the best quality.

FIXINGS: Fixed mouldings in the interior of a building such as architraves, skirtings, etc.

FLAKEBOARD: See *Board, Particle.*

FLAT-SAWN or

FLAT GRAIN: See *Back-Sawn.*

FLIGHT HOLES: Exit holes (q.v.)

fFLITCH: A large piece of sawn log intended for further cutting. A flitch is sawn on two surfaces at least.

FLOOR JOISTS: The timbers in a building carrying the floor board   340

FLOORING Or

FLOOR BOARDS: Dressed, tongued and grooved, boards nailed to floor joists to provide the floor of a house. Usually in 3-inch, 4-inch and 6-inch widths and 1-inch thick.

†FLOORING, END

MATCHED: Boards or blocks for use in floors, profiled on ends as well as edges.

†FLOORING, PARQUETRY: Flooring of matching small pieces of timber usually laid in geometrical patterns, the latter sometimes being enhanced by using timbers of various colours..   129

FLUSH: A surface level with another. A smooth unbroken surface.

FLUSH DOORS: Doors with smooth level faces usually framed and faced with plywood or consisting of a core with veneered facings.

FLUSH PANEL: A panel level or flush with the framing.

FORMS :   (1) The casings in which concrete is cast. (2) Long low benches.

FORM WORK: Temporary structure used in the casting of concrete. See *False Work.*

FOUR HEADER: A machine which planes or moulds the four sides of timber in
(Five Header,   one operation. (See Chapter VI)   74
Six Header)

FOX WEDGES: Wedges used to fasten sub-tenons in their mortises.

FRACTURE CROSS :   Fibres broken across the grain or ruptured by compression.

FRAME: Built-up sections prepared for finished coverings, or for the fitting of doors and sashes   340

†FRAMING TIMBER: Timber used to form the basic structure of a building.

FRAMED and LEDGED: Applied to doors fitted with stiles, top rails, ledges and vertical boarding.

FRAME SAWS: - Power saws in which one or more blades are fixed in a frame which moves in a vertical direction   49

FRASS: The dust made by wood-boring insects.

tFREE MOISTURE: The portion of the moisture content of timber which is contained in the cell cavities.

FRENCH POLISHING: See *Polishing.*

FRET SAW: A very fine saw used for fret work.

FRET WORK: Thin timber perforated and cut into various patterns.

FULL: Up to or slightly oversize. As opposed to "bare".

FULL CUT: (Overcut)	Timber which is sawn in excess of dimensions specified within denned limits.	
FUNGICIDE:	Any preparation for destroying fungi or fungus	232
FUNGUS:	Plant life of the mushroom variety that produces mildew, mould, blue-stain, etc. and depending upon suitable moisture and temperature. Preventatives are proper seasoning and preservatives. (See Chapter XVI).	215
FURNITURE BEETLE!	The Anobiidae. Destructive insects which attacks easoned and mature timbers, often found in old furniture, panelling, etc. Treatment by fumigation or injection of insecticides into flight holes	240
† **GALLERY, TERMITE:**	A passage or burrow, bored or excavated by termites in the bark or timber.	
GANG MILL:	A frame saw (q.v.) with a number of saw blades	49
GAUGE:	A usual method of denoting the thickness of a saw blade. It is commonly measured according to the Stubbs Birmingham Wire Gauge.	59
GIRTH".	A measurement around a log normally taken under bark and at the centre.	24
GLUE:	Animal, mineral or vegetable adhesive. Common glues are chiefly of animal gelatinous substances. Cold water glues are derived from dextrines or caseins q.v. Albumin glues or cements are derived from blood and/or egg sources. In addition there are many proprietary synthetic glues available. (See Chapter VIII).	107
GNARL:	A twisted knot.	
GRADING :	Sorting timber in order of quality. The principal timbers have their own special grading rules agreed upon by buyer and seller	321
*GRAIN:		
Chipped Grain.	A part of the surface is chipped or broken out in very short particles below the line of cut. (This should not be classed as torn grain).	
Cross Grain.	The fibres have a varying inclination to the axis of the piece due to cutting from timber in which the straightness of the grain is imperfect. (This usually occurs in restricted areas of the piece).	
Curly Grain.	See *Wavy Grain.*	
Diagonal Grain.	The fibres do not run parallel with the axis of the piece although the piece has been cut from straight grained timber. See *Quarter-Sawn.*	
Edge Grain, interlocked Grain.	The fibres of adjacent layers are spirally inclined in opposite directions.	
Loosened Grain.	A small portion of the timber has become loosened but not displaced.	
Raised Grain.	A roughened condition of the surface of dressed timber in which the hard portions of the growth rings are raised above the softer portions, but not torn loose from them.	
Ribbon Grain.	A striped effect produced by sawing timber with an interlocked grain.	
Spiral Grain.	A simple spiral inclination of the fibres.	
Torn Grain.	A part of the timber is torn out in dressing.	
Wavy Grain.	A wavy arrangement of the fibres. (This may be known as wavy, curly or fiddleback, depending upon the fineness of the wave. The fineness should be specified by the number of waves per inch).	
†**GREEN:**	A term applied to freshly felled timber, or to timber which still contains free water in its cell cavities. Unseasoned.	

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*GROWTH RINGS:	Rings on the transverse section of a trunk or branch, which mark successive cycles of growth.	.180
†GRUB HOLE:	A hole over one-eighth inch in diameter, oval or circular, sometimes darkly stained, with or without coarse or fibrous boredust.	
GULLET:	The concave space or throat between two consecutive saw teeth.	.59
*GUM VEINS:	A ribbon of gum or kino between growth rings which may be bridged radially at short intervals by woody tissue.	
*Loose Gum Veins.	One associated with extensive discontinuity of wood tissue.	
*Tight Gum Veins.	One not associated with extensive discontinuity of wood tissue.	
HALF-ROUND:	A moulding in the shape of a semicircle.	
HALVING:	Jointing by removing part of the timber in each piece of a cross-joint so that both surfaces are flush.	.340
HAMMERING.	Conditioning a saw by use of a special faced hammer.	.63
HAMMER MARKS:	Distinguishing marks impressed in timber by a hammer embossed with the required design	
HARDBOARD:	A wallboard of timber fibre pressure treated to produce a hard smooth and usually waterproof surface.	
†HARDWOOD:	A conventional term used to denote the timber of broad leaved trees belonging to the botanical group Angiosperms. (Porous woods).	.182
HEAD:	A cutter block carrying the knives in planing machines ...	79
HEAD BLOCK:	The arrangement on a saw carriage which holds the log and consists of the base, knee and dogs, with a device for advancing or withdrawing the knees to or from the saw line.	
HEADSAW: (or Headrig)	The principal breaking-down saw in a saw mill. (See Chapter IV).	48
*HEART:	That portion of the centre of the tree affected by decay or of no appreciable strength.	.179
HEART SHAKE:	A shake radiating from the heart of a log.	
†HEARTWOOD: (Truewood) (Duramen)	Wood in which the growing tree has ceased to contain living cells and in which the reserve materials (e.g. starch) have been removed or changed into more durable substances.	
†HEWN TIMBER:	Timber, with or without wane, finished to size by axe or adze; the ends are sometimes sawn.	
HIGH HUMIDITY TREATMENT:	Raising the humidity of air in a dry kiln as a special method of conditioning.	.206
†HIT AND MISS:	A series of surfaced areas with skipped areas between.	
HOG:	(1) Machine for chipping or grinding sawmill refuse. (2) Bevel filed on circular saw teeth, against the set.	
*HOLES:	Holes in timber may extend partially or entirely through the piece and be from any cause. (When holes are permitted, the average of the maximum and rninimum diameters measured at right angles to the direction of the hole shall be used in measuring the size unless otherwise stated.)	
*HOLES, INSECT.	Holes in the timber caused by the attack of wood-boring insects.	
*HOLES, KNOT,	Holes caused by the removal of knots by any means.	
*HONEYCOMB :	A group of internal checks, often caused by case hardening in seasoning.	.204
HOOK:	The angle made by the face, or inside line of the tooth nearest its point, and a line drawn from the tooth point to the centre of a circular saw, or perpendicular to the back of a band or reciprocating saw.	.59

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HOPPUS MEASUREMENT:	A method used in measuring round logs, also known as the quarter girth system. The formula is (¼ girth)^2 in inches X length in feet÷12 = measurement in superficial feet. The formula allows about 27 % for waste in conversion as against the solid contents or Brereton Measurement (q.v.) (See Chapter II).	
HOT PRESS RESINS:	Thermo-setting resins that require heat for setting	I11
*IMPERFECT MANUFACTURE:	Includes all defects or blemishes which are produced in manufacturing, such as chipped grain, loosened grain, raised grain, torn grain, skips in dressing, hit and miss, variation in sawing, miscut timber, machine burn, machine gouge, mismatching and insufficient tongue or groove.	
IMPREGNATION :	Treatment of timber to increase its durability. Chemical solutions are soaked or forced into the timber to increase resistance to attack by insect or fungi, etc..	222
IMPROVED WOOD:	Timber that has been specially treated to prevent shrinkage or expansion due to variations in moisture content. Methods include impregnation with synthetic resins. (See Chapter XII)	133
*INCLUDED SAPWOOD:	Patches of sapwood included within the truewood, usually on the pith side of a gum vein or ring-shake.	
INCIPIENT DECAY:	The early stage of dry rot (q.v.) usually identified by slight discolouration.	
INDIGENOUS:	Applied to timber or trees native to a particular country.	
INITIAL ABSORPTION:	In the use of timber preservatives the amount absorbed before pressure is necessary to complete impregnation	222
INITIAL VACUUM:	In timber preservation the vacuum applied to the timber prior to the introduction of the preservative.	222
INSERTED TOOTH:	A hardened saw tooth, or bit, capable of being inserted in and removed from the saw blade. Use of inserted teeth avoids the necessity for gradual wearing down of the diameter of the blade due to grinding in the normal way.	
INTERLOCKED GRAIN:	See *Grain.*	
IN THE ROUND:	Applied to logs before sawing.	
IN THE WHITE:	Applied to finished furniture or fixings before polishing.	
†JAMB:	A vertical outer member of a window frame, door frame or lining.	
JIG SAW:	A small saw with a reciprocating motion usually used for cutting frets or scrolls.	
JOINERY:	The timber fixtures of buildings in the form of finished work such as doors, windows, panelling, framing etc.	
JOINT CONNECTORS:	See *Timber Connectors.*	
JOINTER:	A planing machine for facing and edging timber.	
JOINTS:	Prepared connections in the fitting together of two or more pieces of woodwork	86
JOISTS:	Horizontal pieces of timber used for bridging, or spanning, as for the carrying of floor and ceilings. (See Chapter XXIV).	
JUNK:	See *Flitch.*	
k.d.:	Kiln dried. See *Seasoning.*	
†KERF:	A saw cut.	60
†KILN:	A chamber used for drying timber, in which the temperature and humidity of the circulating air can be suitably varied and controlled	199
*KILN BURN:	Incipient charring of timber due to excessive temperatures in kiln and drying or reconditioning.	
KILN DRIED:	See *Seasoning.*	
KILNS:	See *Dry Kilns.*	

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KNOT: A branch or limb embedded in the tree and cut through in the process of manufacture. (Knots are classified according to form, quality and occurrence.)

* *Branched Knot.* Two or more knots branching from a common centre.
* *Decayed Knot.* One softer than the surrounding timber and containing decay.
* *Encased Knot.* One whose growth rings are not intergrown and homogeneous with those of the surrounding timber. (The encasement may be partial or complete.)
  Enclosed Knot. One buried in the timber and not visible from the surface.
* *Hollow Knot.* An apparently sound knot with a relatively large hole in it.
* *Insecure Knot.* One which under ordinary circumstances will hold its place in a dry board and yet under pressure can be started, but not easily pushed out of place.
Intergrown Knot. One whose growth rings are completely intergrown with those of the surrounding timber.
Knot Cluster. The grouping of two or more knots together as a unit with the fibres of the timber deflected around the entire unit. (A group of single knots is not a knot cluster.)
* *Loose Knot.* One not held firmly in place by growth or position, and which cannot be relied upon to remain in place in the piece.
Pith Knot. One which is sound, with a pith hole not more than one-inch in diameter.
* *Round Knot.* One which is oval or circular in form with a ratio of surface length to breadth of not over 3 to 1. (The average of maximum and minimum surface diameters shall be used in measuring size unless otherwise specified).
Single Knot. One with the fibres of the timber in which it occurs deflected around it.
Splke Knot. One sawed in a longitudinal direction, and of a greater ratio of surface length to breadth than 3 to 1.
* *Sound Knot.* One solid across its face, as hard as the surrounding timber, and free from decay.
Tight Knot. One so fixed by growth or position that it will firmly retain its position in the piece.
* *Unsound Knot.* One solid across its face, but containing incipient decay.
* *Watertight Knot.* One whose growth rings are completely intergrown with those of the surrounding timber on one surface of the piece, and which is sound on that surface.

LAMBS TONGUE: A flat ogee moulding.

LAMINATED: Material built up by thin layers to a required size. (See Chapters XII and IX)

†LAMINATED WOOD: An assembled product made up of layers of timber and adhesives in which the grain of adjacent layers is parallel. (See Chapters XII and IX) 120

LAST CUT: The last piece to come from the saw after converting a log.

*LATE WOOD: The denser timber with thicker cell walls formed during the later stages of the growth of each growth ring 181

†LATH: A piece of sawn or riven timber 3/16 to inch thick and 1 to $1^{1}/4$ inch wide.

LINEAL: Applied to measurement of length only. (Linear measurement. Running measurement). **33**

LININGS: Thin boards, usually tongued and grooved, used to cover rough work or to provide a finished surface. Interior finishings in furniture.

LIGNIN: One of the principal chemical constituents of timber cellular tissue.

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LIVE ROLLS:	Power-driven rollers for conveying sawn or partly sawn boards and for feeding them to machines	54
LOAD:	(1) A quantity of timber ready for conveyance.	
	(2) In European timber markets, 50 cubic feet cargo space or 600 super feet. A load is generally assumed to be about 1680 lb. in weight	34
	As a factor in design. (See Chapter XIX)	
LOG BAND MILL:	See *Band Mill.*	
LOG CARRIAGE:	The carriage upon which the log is placed for passing to and fro through the saw.	
LOG DECK:	A platform in a sawmill upon which logs are placed prior to and ready for sawing.	
LOG DOG:	A spiked plate fixed to an endless chain for drawing logs up to the log deck.	
LOG RULE Or SCALE:	Tables giving the quantity of converted timber that may be obtained from logs of given sizes. (See Chapter II)	24
LOG RUN:	See *Mill Run.*	
LOG SAW:	The saw for converting logs. Three principal types are twin circular, band and frame.	
LOG HAUL-UP:	An endless chain, fitted with log dogs and power-driven, set at an incline to the log deck, and for hauling logs thereto. A winch and wire serve the same purpose. See *Bull Chain.*	
LOG LIFT:	A method of lifting logs vertically from water to the log deck.	
LOG TURNER:	A mechanical device for turning logs on a saw carriage or log deck. Principal types include overhead winch and wire, steam operated arms and pusher (Simonson q.v.) and a toothed arm operating vertically from below the log deck as a nigger.	
LOOSE KNOTS:	See *Knot.*	
LUMBER:	North American synonym for Timber	24
LUSTRE:	The reflection of light on the surface of timber varying according to the undulation of fibres and to cell contents.	
LYCTUS:	A family of boring beetles very destructive to the dry sapwood	
(Powderpost beetle)	of certain timbers. (See Chapter XVI)	234
*MACHINE BURN:	A darkening or charring of the timber due to overheating by machine knives.	
*MACHINE GAUGE:	A groove across a piece due to the machine cutting beyond the desired line of cut.	
MACO GAUGE:	A templet capable of adjustment to the contours of mouldings	
(or Templet)	etc.	
MARGIN LIGHT:	Narrow panes of glass surrounding a central pane or panes in/around a sash or door.	
MARINE BORERS:	*See Borer, Marine.*	253
MATCHER:	A machine for preparing jointed boards such as floorings and linings	74
MATURITY:	The age, varying with the species and conditions of growth, at which a tree attains its prime and after which the heartwood begins to deteriorate.	
m.b.m.:	Abbreviation for 1,000 feet board measure	31
MEASUREMENT:	See Chapter II	24
MECHANICAL		
PROPERTIES:	The principal mechanical properties determining the value of timber used structurally are: Strength in compression, tension, bending, torsion, crushing and shear; elasticity, deflection, durability, cleavability, etc. Most of these are established by laboratory test. (See Chapter XIX)	283
MEDULLARY RAYS:	Ribbons of tissue extending radially across the growth rings. They allow the radial flow of sap. True quarter-sawn wood is	

cut with or parallel to the rays producing a beautiful flecked figure. (Medulla: The pith of a tree)   182

MEETING RAILS: The rails of sliding sashes that meet when the sashes are closed.

MERCHANTABLE OR MERCH.: A grading of timber usually applied to that of sound quality free from major defects, suitable for structural work, but not of a quality high enough for joinery, furniture or panelling. Selected merchantable is a higher grade suitable for dressing.

MILLED TIMBER! See II, Terms Used in Manufacturing Classification.

MILL RUN: (or Run of the Log) All the saleable output of timber from a log or parcel of logs.

MILL WORK: Completely manufactured joinery ready for fixing.

*MISCUT TIMBER: That which has a greater variation in thickness or width throughout or at different places on the piece than specified.

†MiTRE: An angle joint between two members in which each is cut to a corresponding angle at their intersection.

*MISMATCHED MATERIAL: Worked material that does not fit at all points of contact between adjoining pieces or in which the surfaces of adjoining pieces are not in the same plane.

MODULUS OF ELASTICITY (E): A measure of elasticity or the power of recovery of material, after strain or distortion, determined by laboratory test   286

MODULUS OF RUPTURE: A constant used in structural design denoting the equivalent fibre stress at maximum load determined by laboratory test...   287

MODULUS OF SECTION (Z): The value of a structural member of a given size and shape of cross-section to resist a load.

*MOISTURE CONTENT: The weight of moisture contained in a piece of timber expressed as a percentage of the oven-dry weight.
(Unless prefixed by an indicative term such as core, intermediate or case, the term "moisture content" will be taken as referring to a complete cross-section of the piece of timber under consideration)   192
Percentage moisture content =
$$\frac{\text{original weight—oven-dry weight}}{\text{oven-dry weight}}$$

*Case Moisture Content, The moisture content of the outer layers or case of a piece of Timber. (See *Moisture Distribution.*)

*Core Moisture Content. The moisture content of the central portion of a cross section of a piece of timber. (See *Moisture Distribution).* (Wet Spot)— Where there is reason to believe that a core cut from the centre of a piece will not show the highest moisture content of the internal portion of that piece, an additional core shall be cut from the spot of supposed higher moisture content, and the higher of the two shall be taken as the maximum core moisture content

*Equilibrium Moisture Content: The moisture content at which timber neither gains nor loses moisture when subjected to a given constant condition of humidity and temperature   191

*Intermediate Moisture Content: The moisture content at which timber neither gains nor loses between the core and the case. (See *Moisture Distribution)*

* Moisture Distribution: The limits of moisture content of a piece as determined by core, intermediate, and case moisture content tests   196

†MOISTURE GRADIENT: A gradation in moisture content between successive layers of timber   191

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†MORTISE Or MORTICE:	A hole or slot to receive a tenon or dowel of corresponding size.	
MOULD:	The shape to which a piece of timber is planed. More common types are known as beads, chamfers, lambs tongue, nosing, ogee, quadrants, ovolo, scotia and so on	74
MOULDINGS:	Lengths of timber which have been shaped to the various moulds	74
†MULLION:	(1) A vertical member dividing the lights of a window frame. (2) A vertical member between the door and sidelight of a door frame.	
NATURAL DRAUGHT KILNS:	Dry kilns in which the current of air depends on natural flow and not on mechanical control.	
*NEAT CUT:	Timber which is sawn exactly to dimensions specified.	
NIGGER:	A mechanical device for turning a log on the carriage working vertically from below the log deck.	
NOG:	A small block of timber. A block projecting from a wall to carry a shelf. Nogging pieces: the stiffeners fitted between studs	341
*NOMINAL SIZE:	An arbitrary term used for indicating the approximate size of green, dry, rough, or dressed timber, and usually based on the rough size cut to allow for shrinkage and sometimes machining.	
NON-POROUS WOOD:	Wood, usually coniferous, which does not contain pores.	
†NOSING:	The projecting edge of a tread or board usually rounded.	
OFF-SET:	An automatic device which moves the log carriage away from the saw line when it is returning after a cut.	
OFF THE SAW:	Applied to the size of timber when freshly sawn.	
OGEE (O.G.):	A moulding consisting of convex and concave arcs.	
ON THE BACK:	See *Back-Sawn.*	
ON THE QUARTER:	See *Quarter-Sawn.*	
OPEN CELL PROCESS:	Impregnation of timber under pressure. The preservative is retained in the cell walls and the cells left empty	222
OPEN GRAIN:	Coarse or porous grain.	
†OVEN DRY:	A term used to describe timber which does not lose moisture when placed in a ventilated oven at 100 °C. (212° F.)	192
OVERCUT:	See *Full Cut.*	
OVERRUN:	In conversion, the amount by which the actual output exceeds the calculated output.	
OVOLO:	A convex moulding in the form of a quadrant with listels.	
PANEL: (Panelling)	Thin wide boards fitted into framing, or suitable for similar purpose. Plywood finished to given sizes. (See Chapter VII)…	82
PARASITE:	A destructive organism living on the tissue of another, such as timber.	
PARCEL:	A loose term used to cover quantities of sawn timber or a number of logs.	
PARQUETRY:	Small pieces of timber sometimes of different species fitted together to form geometrical designs; usually applied to floors.	
PARTICLE BOARD:	See *Board, Particle.*	
PARTING BEAD:	A thin moulding separating sliding sashes.	
PEEL: (Peeling)	The process of cutting veneers from a log by turning the latter in a lathe. (Rotary cutting)	83
PEELER:	The lathe for cutting rotary veneers (q.v.)	83
†PEELER LOG:	A log suitable for the manufacture of rotary cut veneer	83
PENDULUM SAW:	See *Swing Saw.*	
PENETRATION:	A term relating to the impregnation of timber by preservatives. Timbers vary in their resistance to penetration according to structure. Cellular arrangement and type governs the amount of preservative absorbed.	222

PICTURE RAIL:	A moulding fitted to walls and from which pictures are hung.	
PILES:	Long wooden poles driven into the sea-bed as part of wharf construction, and so on, or into the ground to provide foundations for a structure.	
PIN HOLES:	Small holes in timber not more than one-sixteenth inch diameter due usually to attack by ambrosial borers q.v.	230
*PIPE	Absence of timber in the centre of a log.	
PITCH:	In a circular saw, the distance between the points of two consecutive teeth.	59
	*An accumulation of resin in the timber cells of coniferous woods.	
*PITCH POCKET:	A cavity which has contained or contains pitch. (Bark also may be present in the pocket).	
*Closed Pitch Pocket:	One that does not show an opening on both sides of the piece.	
*PITCH SEAM:	A crack which is filled with pitch.	
*PITCH STREAK:	A well-defined accumulation of pitch in a more or less regular streak.	
*PITH:	A small soft core occurring in the structural centre of a log ...	177
prr PROPS:	Small round timber used in mining to support the roof of a tunnel.	
PIT SAW:	A long two-handed saw used for sawing logs in a pit or on a raised deck where one sawyer is above and one below the log.	
PLAIN SAWN:	See *Back-Sawn.*	
PLANING MACHINE: (Planer)	A machine used for planing the surface of wood. (See Chapter VI).	74
PLANK:	A loose term applied to boards usually wider than six inches and two inches or thicker. Boat planks: the outer covering of a wooden vessel.	
PLASTIC GLUES:	Resin-bonding glues used in laminated construction, plywood, stress skin construction, and so on. The several groups are thermo-setting resins, thermo-plastics, casein plastics and natural resin glues.	
PLASTICITY:	The opposite to elasticity. A property that allows materials to retain their shape when bent or distorted.	
PLASTIC WOOD:	A paste composition used as a filler for open joints, holes, cracks and so on.	
PLOUGH:	To machine a groove.	
PLY:	A thin slice of timber or a veneer as used for plywood. (See Chapter VII)	82
†PLYWOOD:	An assembled product made up of plies and adhesives, the chief characteristic being the cross layers which distribute the longitudinal timber strength. Boards formed of more than three plies are usually designated "multi-ply". (See Chapter VII.)	82
POLE:	The trunk of a straight, slender tree or rounded piece of timber.	
POLISHING":	Applying the final finish to prepared timber. French polish: shellac dissolved in methylated spirit. (See Chapter XVII) ...	272
PONY BAND MILL:	See *Band Mill.*	
*POPPINESS:	An inherent condition of timber manifest in a tendency to form excessive splits.	
†PORES:	The vessels, i.e. the principal vascular or water-conducting elements of hardwoods; these are sometimes visible on the cross-section (end grain) as small round holes.	
POROUS WOODS:	Woods usually from broad-leaved trees containing vessels or pores.	

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PRECONDITIONING:	The treatment of collapsed timber to reduce excessive and/or irregular shrinkage and to improve the texture	196
†REJECT:	A piece of timber rejected because it is below the specified grade.	
RIBBON GRAIN:	See *Grain.*	
RIM SPEED:	The speed of the perimeter of a circular saw, usually expressed in feet per minute.	
RITSTG ROT:	Decay in logs in the direction of the growth rings.	
R-TNG SHAKE:	See *Shake.*	
jtrpSAW:	A saw specially used for sawing along the grain and usually for flat boards	53
RHVING KNIFE:	A thin steel blade placed behind a saw to prevent the timber from closing on the back of the blade.	
HOCK SAW:	A circular saw working on a long arm in front of a breaking-down saw to remove a wide kerf on the upper surface of the log before it enters the headsaw. The object is to remove stones or gravel which would otherwise injure the headsaw.	
HOT:	See *Decay.*	
ROTARY CUTTING:	See *Peeling.*	
H.OTARY VENEER:	Veneer cut or peeled from a round log by means of a lathe as distinct from that sliced off by means of a knife	**83**
* ROT POCKET:	Decay which appears in the form of a hole, pocket, or area of soft rot, usually surrounded by apparently sound timber.	
ROUGH TIMBER:	Timber as it comes from the saw.	
ROUND TIMBER:	Logs, as distinct from sawn or hewn timber.	
ROUTER:	A machine for shaping, grooving or trenching timber.	
RULE: (Ruler)	A strip of timber or metal graduated for measuring.	
RUMBLER:	A machine for smoothing small wooden articles such as turnings.	
RUMBLER: (Tumbling Drum)	A machine for testing boxes or cases.	
RUN OF THE LOG:	See *Mill Run.*	
RUN OF THE MILL:	See *Mill Run.*	
RUNNING FEET:	Linear measurement. See *Lineal.*	
RUPTURE:	Tearing of the fibres across the grain.	
s.1.s. or s.2.s:	Sanded one side or sanded two sides. Usually applied to ply-wood.	
SAFE LOAD:	A proportion of the breaking or ultimate strength of a structural member. The proportion depends upon the factor of safety used (q.v.).	
SANDER:	A machine for sand-papering woodwork. There are several varieties using belt, drum or disc.	
SAP:	The fluid which passes from cell to cell in the tree upon which life and growth depend	179
*SAPWOOD:	The outer layers of the timber of a tree in which food materials are conveyed and stored during the life of the tree, and which are usually of lighter colour than the truewood	184
SAP STAIN:	Stain due to the action of fungi in sapwood, probably due to oxidation or fermentation. Dipping in preservative solutions is a preventive.	215
SARKING:	Boards fixed close together not usually tongued and grooved; used as an undercovering for shingles, roofing and so on.	
SASH:	(1) A frame, in particular the frame to a window holding the glass. It may be sliding, hinged or fixed. (2) The frame in which gang saws are stretched.	
SASH BAR:	The intermediate members of a sash dividing the glass into smaller squares.	

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SASH BEAD: (Stop Bead)	A moulding serving as a guide or stop for a sash.	
SASH DOOR:	One with a glazed upper panel.	
SASH GANG:	See *Frame Saw.*	
SASH LININGS: (Window Linings)	Facings to the box frame of a sash and frame window.	
SASH SAW:	The saw stretched in a sash used in a frame saw.	
SASH STOCK:	Timber prepared for the manufacture of sashes.	
SATURATION POINT:	See *Fibre Saturation Point.*	
SAWING METHODS:	See Chapter HI.	
SAWS:	Steel blades, discs, or bands with toothed edges for cutting timber. Used by hand or machine. When used in machines, saws are known as circular, frame or band saws. (See Chapters IV, V).	48
SAW DOCTOR:	A skilled mechanic who keeps the blades of saws in condition.	
SAW HAMMERING:	See *Hammering.*	
SAW KERF:	See *Kerf.*	
SAWMILL:	The plant and buildings in which logs and/or timber is sawn...	36
SAW PIT:	Pits or raised decks used for converting logs or squared timber by means of a double-handled saw operated vertically by two men, one above and one below. See *Pit Saw.*	
SAW SET:	An appliance for setting saw teeth	59
SAW TEETH:	Many types of teeth are used in machine saws, the design depending on the nature and size of the timber to be sawn and the direction of the grain. Tooth speed is also an important factor. (See Chapter V.)	
*SCANT CUT: (Bare)	Timber which is obtained by re-sawing without making allowance for the thickness of the saw cuts.	
SCANTLINGS:	Timber sawn to dimensions of up to about 6x4. *Heavy Scantling:* Dimensioned over 6x4 inches. (See I, Terms Used in Size Classification).	
SCARF:	A joint used to connect structural timbers lengthways but which does not increase the cross sectional area.	
SCOTIA:	A concave moulding.	
*SEASONING :	The drying of timber. (The degree of seasoning cannot be stated in terms of period of kiln or air drying, but must be expressed by moisture content to which the timber is dried.) (See Moisture Content, Chapter XV).	188
*Air-dried Timber:	Timber that has been dried by stacking in the air. (The term cannot be taken as implying the suitability of the timber for any particular purpose).	
Air-Seasoned Timber:	See *Air-Dried Timber.*	
*Kiln-dried Timber:	Timber that has been dried in a kiln. (The term cannot be taken as implying the suitability of the timber for any particular purpose).	
*'Kiln-seasoned Timber:	See *Kiln-Dried Timber.*	
SEASONING CRACK:	See *Check.*	
SECOND GROWTH:	Natural regeneration in a forest after felling or fire.	
SECTION MODULUS:	See *Modulus of Section.*	
SELECTED MERCHANTABLE:	See *Merchantable.*	
SET:	The projection of teeth on the blade of a saw to ensure clearance when sawing	59
SET WORKS:	The mechanism for advancing or withdrawing the knees on a sawmill carriage.	
*SHAKE:	A partial or complete separation between adjoining layers of timber, due initially to causes other than drying.	

Cup Shake:	See *Ring Shake.*
*Falling Shake:	A longitudinal or transverse shake caused during the felling of the tree.
Felling Shake:	See *Falling Shake.*
*Heart Shake:	One extending from the pith of a tree and existing in the log before conversion.
*Longitudinal Shake:	One running parallel to the length of the fibres. (As compared with checks, shakes usually have a magnitude of feet in length).
*Ring Shake:	One occurring between two adjoining growth rings.
*Star Shake :	A number of heart shakes more or less in the form of a star.
*Transverse Shake:	One running across the fibres.
Water Shake:	See *Ring Shake.*
* Wind Shake:	One caused by wind action on the growing tree.
*Shatter:	A multiplicity of long splits or shakes. (It is usually caused by falling or lightning; in the former case it is usually confined to the end of a log; in the latter it usually occurs throughout the length of the piece).

*SHAVING MARKS:	Indentations on the planed surface of the board due to imperfect clearance of shavings from cutters.	
SHEAR: (or Shearing Stress)	Shearing stresses are set up when the applied forces tend to cause one part of a body to slip or slide over another part adjacent to it	284
SHEATHING:	Protective covering in timber.	
SHELLAC:	The shell of the lac insect, dissolved in methylated spirit and used for French polish and in certain varnishes.	
SHINGLES:	Thin, oblong pieces of timber used in covering roofs and outer walls. Usually of redwood, western red cedar or "forest oak". The latter are the commoner indigenous variety and usually split while the two former imported species are usually sawn.	
SHIPPING DRY:	A stage in seasoning, usually of about sixty days' air-drying, sufficient to prevent fungi attack or deterioration when stacked as ship's cargo.	
†SHOOKS:	(1) A piece of casemaking timber of a required size. (2) A set of boards for a box. (3) A split stave for a barrel.	
SHOP AND FACTORY TIMBER:	See II, *Terms Used in Manufacturing Classification.*	
SHORT GRAIN:	Carroty or cross-grain q.v. The fibres fracture with a minimum of splintering.	
SHORTS:	Applied generally to timber less than six feet in length.	
SHOT HOLES:	Holes due to wood borers. The term is usually applied to holes above $^1/_{16}$ inch diameter and up to $^1/_8$ inch. Holes less than 1/16 inch diameter are termed pin holes (q.v.)	230
SHRINKAGE:	Decrease in dimension due to decrease in moisture content. Tangential (back cut) shrinkage is approximately double that of radial (quarter cut) shrinkage	203
*SHUDDER MARKS:	See *Chatter Marks.*	
SIMONSON LOG TURNER!	A steam-operated twin cylinder appliance equipped with a hook arm and pusher arms for loading and turning logs on the log carriage. It is operated by the head sawyer.	
SIDING:	The exterior sheathing of timber houses. Weatherboards.	
SILICA:	A mineral secretion in timber. It oftens causes difficulty in sawing and offers resistance to attack by teredine borers. With timber preservatives it may cause trouble by fusing in fire boxes and gas producers.	
SILL:	The bottom horizontal members of a frame or other structural work.	

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SINKER:	A log which will not float.	
SIZE:	A powdered glue used to seal the surface of timber in order to prevent absorption of moisture.	
SKIN:	Timber surface.	
SKIN STRESS:	The stress acting in the outer edge or surface in a structural member.	
*SKIP:	An area on a piece that failed to dress.	
*SLAB:	A piece of timber with one flat cut from the outside of a log.	
SLASHER:	A machine used to cut slabs, edgings, and other waste timber into lengths suitable for firewood. It consists of several saws mounted on one arbor.	
SLASH GRAIN:	The grain or figure resulting from back sawn timber.	
SLASH SAWN:	See *Back Sawn.*	
SLATS:	Narrow, thin pieces of timber.	
SLEEPER :	A strong piece of timber laid on the ground to support loads, structures and so on applied in particular to the transverse timbers carrying railway lines.	
SLICER:	A machine for slicing veneers and thin boards	**84**
SLOPE OF GRAIN:	The angle between the direction of the grain and the edge of the piece.	
SMALL DIMENSION STOCK:	Wood in small special sizes for specific repetition work.	
SNAKY:	Irregular edges due to wavy saw cuts.	
SNUG:	A good tight fit.	
†SOFTWOOD:	A conventional term used to denote the timber of trees belonging to the botanical group Gymnosperms. Commercial timbers of this group are practically confined to the class Coniferae or Conifers..	183
SORTING TABLE:	A long platform in a sawmill along which chains slowly move carrying the sawmill output for sorting by graders stationed along the platforms	55
SPARS:	Strong round pieces of timber used for hoisting purposes or for carrying the sails of a vessel.	
SPECIES:	In the classification of trees, species is a subdivision of a genus.	
SPIKE KNOT:	See *Knot.*	
SPIRAL GRAIN:	See *Grain.*	
SPLAY:	A bevel or large chamfer.	
SPLICE:	A splayed joint.	
*SPLITS :	Cracks extending from one surface to another and located at the ends of a piece.	
*SPOONDIF:	A depression on the tangential surface of a piece caused by a gouging out of the timber along a growth ring.	
*SPRING :	(1) A simple curvature of the edge of a piece of timber, not affecting the face. (2) The bend in a log or large flitch which occurs during sawing.	
*Total Spring:	Is measured by the maximum deviation from a straight line joining the ends of the board.	
*Unit Spring:	Is measured by the maximum deviation from a strainght line joining two points ten feet apart.	
SPRING SET:	The set of saw teeth when they are sprung (bent) alternately to right and left	59
SPRING WOOD:	The early growth or inner portion of the annual rings. Early wood (q.v.).	182
SPRUNG:	(1) Distortion of a curved member. (2) Applied to a fractured spar.	
SQUARE:	A measurement of area of 100 sq. feet used in reference to the	

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	area of the floor space in a building. Also used in reference to the quantity of flooring necessary to cover a specific area.	
*SQUARES:	Any timber square in section.	
SQUARED LOG:	A log which has been roughly squared up with axe or saw.	
STACK:	A quantity of timber neatly arranged for storing or for seasoning.	
STACKER:	A machine for supplying timber at varying heights to a stack of timber in process of building up for seasoning.	
*STAIN:	A discolouration occurring on or in timber of any colour other than the natural colour of the piece.	
*Blue Stain:	A blue discolouration caused by fungi	215
*Brown Stain:	A stain which is brown in colouration caused by fungi or chemical reactions in the timber.	215
*Iron-Tannate Stain:	A bluish-black stain of tannin-bearing timbers (eucalypts, oaks, etc.) caused by chemical reaction between iron and tannin acids on surfaces in contact with nails, wedges, mill machinery etc.	
*Sap-stain:	A discolouration of sapwood caused by fungi	215
†STANDARD : (Petrograd)	165 cu. ft. of timber. *Note:* Originally known as the St. Petersburg (Petrograd) Standard Hundred (P.S.H.)	33
STANDING TIMBER:	Trees suitable for commercial use, prior to felling.	
STAR SHAKES:	See *Shakes.*	
†STAVE:	A piece of sawn or split timber of a definite dimension, intended to form part of a barrel.	
STICKER:	See *Strip.* (Also a simple moulding machine).	
STILES:	The vertical members of a frame, door or sash.	
STOCK SIZES:	The standard common sizes in constant demand by the consumer and usually kept in stock by retailers.	
STOP BEAD:	See *Sash Bead.*	
STOPPING :	Plastic materials for filling pores, cracks and so on in timber. See *Plastic Wood.*	
STRAIN:	Deformation of a member under load	283
†STRENGTH.	The term in its broader sense embraces collectively all the properties of timber which enable it to resist different forces or loads. In its more restricted sense, the term applies to any one of the mechanical properties, in which case the name of the property under consideration is stated; e.g. strength in compression parallel to grain, strength in bending, hardness, and so on. (See Chapters XIX and XXII)	283
STRESS:	An internal resistance to an external force, e.g. tension, compression, shear and so on. In structural design, stress = load ÷ sectional area	283
STRESS GRADE:	A grade of timber selected for its estimated value of "f" for structural work. The grading applies for joists, beams, columns and so on. The method is of overseas origin and the grading is designed to ensure the economical use of timber for structural purposes.	
STRING MEASURE:	See *Hoppus Measurement.*	
STRIP:	(1) A narrow piece of timber. (See I, Terms Used in Size Classification).	
	(2) The separators, usually of 1 or ¾ inch thickness, used in stacking timber for seasoning. Sometimes called stickers	198
STRIPPING:	The stacking of timber in preparation for seasoning. The boards are laid above each other on strips so that a free passage of air can pass across the faces and edges of all the boards	198
STRUCTURAL WORK:	The essential framing of a building or other structure.	

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STRUCTURAL TIMBER:	See II, Terms Used in Manufacturing Classification. (Classification into strength groups.) (See Chapter XXII). The vertical timbers forming a wall or partition. (See Chapter XXIV).
STUMP:	The base of a tree after felling. The stumps of some trees contain valuable timber of an ornamental nature owing to a high proportion of quilted figure, sometimes called a stump figure, or butt figure.
SUPERFICIAL: (Super. Sup.)	A superficial foot is the equivalent of a square foot one inch thick. (It is sometimes called board measure). If, however, the measurement is less than one inch in thickness, the measurement is called superficial face, (super face) and is based on the square or surface measure. (See Chapter II). 31
SUMMER WOOD:	The later growth of an annual ring. It produces in most species harder, denser, and darker timber than the spring wood ... 182
SURFACE CHECK:	See *Check.*
SURFACED:	Planed or dressed. (See Chapter VI). 74
SURFACER:	A planing machine. (See Chapter VI). 74
SWAGE:	The spread of a tooth on each side of a saw to provide clearance for the blade. 59 A tool for spreading the points of saw teeth.
SWING SAW: (Pendulum Saw)	A circular saw suspended by an arm which swings in pendulum fashion and is used for cross-cutting.
TAILER-OUT: (Puller Out)	The operative behind a circular saw who draws out the timber as it passes through the saw.
TALLY:	A record of the number of pieces, size and grading of measured timber.
T & G:	Tongued and grooved.
TANGENTIAL SAWN:	See *Back-Sawn.*
†TANGENTIAL SECTION:	A lengthwise (longitudinal) section in a plane tangential to a growth ring, i.e. at right angles to the radius.
TARE:	The weight of a vehicle as distinct from that of the load.
TECO:	A proprietary timber connector.
TEETH:	See *Saw Teeth.*
TEMPLET:	A pattern made of thin material to a required contour and used for marking out (or shaping up a mould).
TENON:	The end of a piece prepared for jointing by a reduction in section so as to fit snugly in a recess or mortise of the other piece to be jointed.
TENONER:	A machine for preparing tenons.
TENSION Or TENSILE FORCE:	A force acting along the length of a member with a pulling or stretching effect. .284
TENSION: (Saw)	A condition of a saw in which the body is expanded so that the cutting edge will remain taut, or in tension. (See Chapter V)... 59
†TENSION WOOD:	Reaction wood formed typically on the uppersides of branches and leaning or crooked boles of hardwood trees, and characterised anatomically by little or no lignification and by the presence of an internal gelatinous layer in the fibres. It has abnormally high longitudinal shrinkage, tending to cause warping and splitting, and the machined surface tends to be fibrous or woolly especially when green.
TEREDINE BORERS: (Coborah or Cobra)	Tidal water molluscs highly destructive to timber. They resemble very soft worms from a few inches in length to as much as four feet and more, and honeycomb wood usually in a direction parallel to the fibres, making tunnels from one quarter to two inches in diameter, the latter in the tropics. Pro-

tection methods include metal sheathing, concrete jackets, sand-filled concrete collars and impregnation with creosote or copper/chrome/arsenate salts. (See Chapter XVI).

TERMITES: See *White Ant.* (See Chapter XVI) *243

TEXTURE: It is described variously as fine, coarse, even, hard, soft, harsh, smooth, uniform, uneven and so on. Variation in texture is conditioned by the relative size and distribution of the respective timber elements and the rate of growth. The various species have a characteristic general texture.

THERMOPLASTIC RESIN: Resin which can be made plastic by heating. (See Chapter VIII). 113

THICKNESSER: A planing machine designed to dress timber to required thicknesses. (See Chapter VI) 74

THROUGH AND
THROUGH: Describes the process of converting logs by cutting board after board full width and not necessarily turning the log. 36

TIES: Railway sleepers.

TIGHT KNOT: See *Knot.*

TILE BATTENS: Battens usually of a size 2 x 1 inch upon which roof tiles are laid 339

TIMBER: The general term covering wood suitable for building and structural purposes. (See II, Terms Used in Manufacturing Classification). In North American countries the term refers to sawn material with a least dimension of five inches.

TIMBER CONNECTORS: Metal fasteners used in structural work and designed to prevent lateral movement in the joints. (See Chapter XXIII) ... 327

TIMBER FRAME: Applied to buildings in which the structural part of the building is of timber. (See Chapter XXIV) **331**

TIMBERING: Temporary timbers used for scaffolding, buttressing, excavations, shafting and so on. Timbering is removed prior to the completion of the work.

†TOE: (Of pile or pole) the small end.

TOLERANCE: An amount allowed less than a quoted dimension.

TONGUED AND
GROOVED: A term used to describe boards in which one edge is moulded to a tongue and the other with a groove. When laid side by side, the tongue fits into the groove of the adjacent board, e.g. flooring, lining, and so on.

TOP LOGS or TOPS: The uppermost log to be cut from the tree.

TOUGHNESS: That property of timber enabling it to bend more or less, without breaking. **288**

TRASH: Sawmill waste, dead and broken trees remaining on an area after logging.

TRUEWOOD: That portion of the tree existing between the sapwood and the heart or the pith. **178**

TRUSS: A framework fitted with triangular bracing and designed to carry a load.

TUMBLING DRUM: A machine for testing boxes and cases.
(Rumbler)

TURNERY: Wooden articles turned in a lathe, e.g. chair and table legs.

TWIN SAW: Two circular saws mounted one above the other and cutting in the same plane enabling a greater depth of cut than could be made with a single saw.

TWIN FEED: A twin-cylinder steam engine used in driving a sawmill carriage.

†TWIST: A spiral distortion along the length of a piece of timber.

ULTIMATE STRENGTH: See *Breaking Strength.*

UNIFORM LOAD: A load evenly distributed along a beam or similar member.

WOOD:

Because of its many and varied properties including the combination of lightness and strength, ornamental appearance, workng Qualities insulation, elasticity, durability, resonance and so on,wood is practically universal in its application.

WOOD ELEMENTS:

The structure of wood comprises the following cellular units: fibres tracheids vessel cells (pores on transverse section) and parencyma cells (wood and pith, both axial, and ray cells horizontal in tree).

WOOD PULP:

Wood chips, shavings and so on reduced to pulp for making

WOOD FLOUR:

paper,cardboard and so on.

WOOD TAR:
WOOD WOOL:

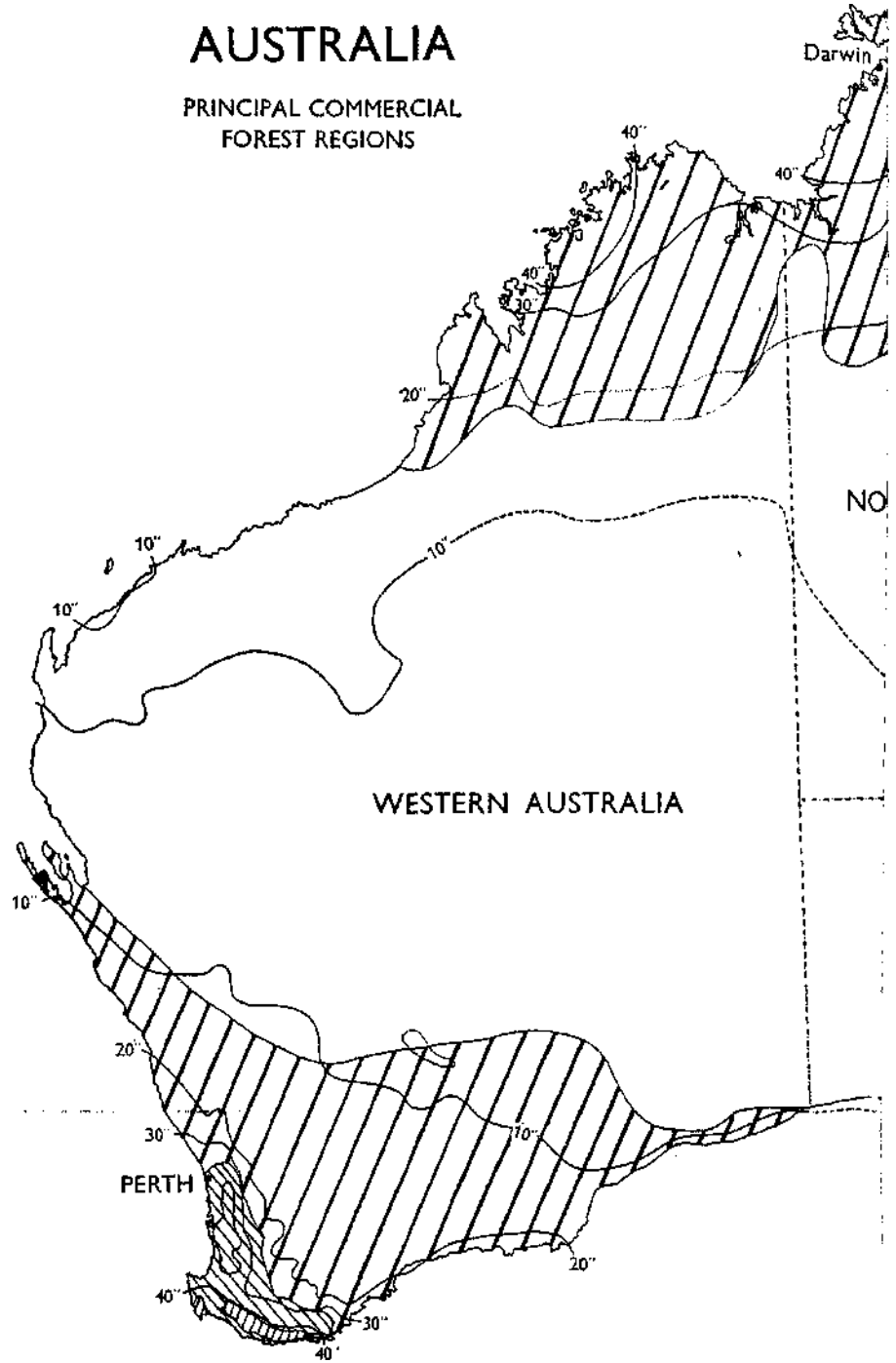Waste wood,usually sawdust, ground to the consistency of flour and used in the manufacture of many synthetic materials such as plastics, linoleum, wallboards and so on. It is also used extensively in the manufacture of explosives.

†**WOOLLY GRAIN:**
†**WORKING:**

Very fine thin shavings specially manufactured for packing, insulation and so on.

Sawn elements frayed out in sawing and planing.

Alternate swelling and shrinkage which occurs in seasoned timber, due to moisture content changes caused by variations in the surrounding atmospheric conditions . . . .

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AUSTRALIA

PRINCIPAL COMMERCIAL
FOREST REGIONS

Darwin

40"

40"

20"

10"

10"

10"

10"

NO

WESTERN AUSTRALIA

10"

20"

30"

10"

PERTH

20"

40"

30"

40"

Rain Forest g==g   Cypress Pine Forest 1T~H
Eucalypt Forest (high rainfall) VZZi,   Riverain Forest M i l
(low rainfall) g^   Woodland 7771

Isohyet   10"-