1918.

WESTERN AUSTRALIA.

FOURTH EDITION (ABRIDGED).

Western Australian Timber Tests, 1906 (AND SUPPLEMENT).

THE PHYSICAL CHARACTERISTICS OF THE HARDWOODS OF WESTERN AUSTRALIA AND The Principal Timbers of Eastern Australia.

By G. A. JULIUS, B.Sc., M.E.

PERTH:
BY AUTHORITY: FRED. WM. SIMPSON, GOVERNMENT PRINTER.

1918.

L 71/18.

ABRIDGED EDITION, 1918,

With Additional Information.

—o—

The demand for the edition issued last year of this little book has been so great that it has become exhausted, and a new issue is called for. In a prefatory note in the previous edition a hope is expressed that it might be possible to publish shortly appendices to the work embodying tests of timber that have been carried out at the Government Railway Workshops at Midland Junction, Western Australia, on large pieces of jarrah, and also on certain timbers not included in Mr. Julius's work, such as Red Tingle-Tingle (*Euc. jacksonii*), Coolebah, (*Euc. microtheca*), and Powder Bark (*Euc. accedens*), and the results of these tests are now included in appendices. Extensive tests of powellised timbers are still being carried on as well as enquiries into the question of the recovery from treated wood of chemicals used in the course of treatment, but these tests and experiments have not yet been concluded. It is to be hoped that the additional information included in this edition will add to the usefulness of the little book.

C. E. LANE-POOLE,
Conservator of Forests.

August, 1918.

WESTERN AUSTRALIAN TIMBER TESTS.

Abridged Edition, 1917.

NOTE.

Mr. G. A. Julius' *Western Australian Timber Tests* was published in 1906, and attracted a great deal of interest from all quarters. Subsequently a supplement was published in which was given the tests of Eastern Australian timbers. These two volumes together form the most comprehensive and most exhaustive treatise on the strength of Australian timbers; indeed, like Mr. J. B. Johnson's classical book, *Materials of Construction*, G. A. Julius' work stands in the first rank.

It is not surprising that it should have run out of print, considering the wide interest it created.

In reprinting *Western Australian Timber Tests* and the supplement, it was deemed advisable to combine both volumes and reproduce them in a handy pocket volume that would be of more practical use to architects, engineers, and others, than the somewhat large size in which the work was first published. In order to do this it was necessary to leave out a number of interesting plates, which could not be reproduced in so small a size. The present edition will, I think, be found to contain all the essential features of the original books, and though it has been necessary to abridge the text to a slight degree, Mr. Julius' words have not in any way been altered.

It is hoped to publish shortly an appendix to the present work which will embody the tests of timber that have been carried out at the Midland Junction Workshops by Mr. E. S. Hume since 1908. These include tests of very large Jarrah beams, also of certain timbers not included in Mr. G. A. Julius' work, such as Red Tingle-Tingle (*Euc. jacksonii*), Coolebar (*Euc. microtheca*), Powder Bark (*Euc. redunca var?*). In addition to the above, tests of powellised timbers will be included.

C. E. LANE-POOLE,
Conservator of Forests.

5th February, 1917.

WESTERN AUSTRALIAN TIMBER TESTS, 1906.

Prefatory Note.

The rational designing of timber structures of all kinds involves a thorough knowledge of the physical characteristics of the timber to be used. Such information has not been available concerning the timbers of Western Australia, although, as it is hoped this report will show, they are to be classed amongst the most valuable of the world's hardwoods.

The Government of the State having decided that a full investigation was necessary, the matter was placed in the writer's hands, and, with the assistance of the officers of the Railway Department, and particularly that of his Chief, Mr. E. S. Hume, Chief Mechanical Engineer, he has been able to carry out a fairly complete series of tests, the data from which are briefly summarised in the accompanying Report. It is hoped that the information therein contained may be of service in the development of the great timber resources of this State, and to the Engineer in enabling him to make the best use of the materials available.

The writer desires to make a special acknowledgment of his obligation to Mr. E. A. Evans and Mr. Kirkbride, of the Railway Workshops, for the very great assistance rendered by them in the preparation of the timber for test, and especially to Messrs. F. Shaw, G. F. O'Connor, J. M. Limb, E. Goodchild,

and A. Cooper, and to those who worked under their direction, for the whole-hearted and painstaking manner in which they have carried out what has proved a very heavy and arduous work.

Many valuable samples were received from other Government Departments and outside firms.

G. A. JULIUS.

Midland Junction,
21st July, 1906.

THE PHYSICAL CHARACTERISTICS OF THE "HARDWOODS" OF WESTERN AUSTRALIA.

Introduction.

An examination of all hitherto published results of the tests of the timbers indigenous to this State will show records varying to such a wide extent as to render them of little value for practical purposes. Thus the tensile strength of Jarrah is given by three authorities, values of 2,940, 5,000, and 16,407 lbs. per square inch respectively, and similar wide discrepancies occur in the majority of the results, but in no case are sufficient data given to determine the cause of such differences.

Undoubtedly the most complete and valuable timber tests yet reported are those conducted for the United States Government upon the timbers indigenous to that country, and a study of these tests, which were carried out under the direction of the late Professor J. B. Johnson, and quoted by him in his classical work upon the "Materials of Construction," clearly determines the cause of the great divergency in the results obtained from timber tests, namely, "*variations in the percentage of moisture present in the timber.*" He reports that

> with all the species tested (United States timber) the strength at 12 per cent. moisture is some 75 per cent. stronger than the same sticks are, either green or when wet through, after seasoning.

He further states that

it is the absence of any determination of the moisture condition of the test material that vitiates practically all tests of the strength of timber. Since large timbers require many years to season or dry in the open air, while small test sticks dry out very quickly, it is certain that the difference in the moisture conditions will fully explain the marked differences which have been observed in the strength of identical material in different sizes. It is to be hoped that in future all tests of the strength of timber will be so made as to fully reveal this condition as a definite percentage of moisture across the section near the region of failure.

In view of the necessity for a complete and final determination of the physical characteristics of our timber, owing to the contradictory nature of all existing records, it was decided to conduct the whole of the tests in such a manner as to fully satisfy the conditions laid down by Professor Johnson. As a result it has been found necessary to carry out over 16,000 tests, the data from which are summarised in this report, which "data" completely, and, it is to be hoped, finally establish the timbers of this State in a position at the head of the timbers of Australasia, and in the front ranks of the world's hardwoods.

SCHEME OF TESTING.

When timber is used for constructional purposes, it may be subjected to any of the following stresses:—

(a) "Transverse" or "cross bending" stresses, as in beams which give rise to tensile, compression, and shearing stresses in the material.

(b) Direct "tensional" stresses occurring in the tension members of framed structures.

(c) Direct "end" compression stresses, occurring in the compression members of "struts" of framed structures and in columns, etc.

(d) "Cross" compression stresses occurring wherever a "loaded beam" is supported by a column, or upon a second beam, and also in the case of sleepers where they carry the rails.

(e) "Shearing" stresses along the fibres occurring frequently where timber is used for joints or "keys" in framed structures, and also along the "neutral axis" of beams.

(f) "Combined shearing" and "compression" stresses set up in timber when subjected to blows on end, such as occur in the case of "piles" when being driven, and in "mall" heads, etc., as also to a lesser extent in the case of columns carrying a live load, such as railway bridges, piers, etc.

To satisfactorily determine the "strength," both "ultimate" and "within the elastic limit," of the various timbers of this State, the following tests were conducted:—

(1.) *"Cross bending" tests,* the timber being used as a beam, supported at the ends and loaded centrally.

(2.) *"Tensile" tests.*

(3.) *"End compression" tests,* the load being applied "endwise" upon specimens of various dimensions, and ratios of "length to breadth."

(4.) *"Cross compression" tests,* the load being applied across the fibre of the material.

(5.) "*Shearing*" *tests* along the fibre of the material.

(6.) "*Hardness*" *tests* determined by the resistance to penetration, under both "steadily applied" and "suddenly imposed" loads.

(7.) "*Spalling*" *tests*, which were arranged to record the resistence opposed to splitting and crushing under repeated blows "on end."

In addition to the above, tests were made to ascertain:—

"*Holding power*" of the various timbers upon Railway "dog spikes" both with green and dry timbers, with spikes newly driven, and with those that had been in place in "sleepers" for a varying number of years.

"*Chemical*" *tests* of the sap present in the various timbers and its effect upon metals, etc.

"*Moisture*" *tests* were made in order to comply with the conditions laid down by Professor Johnson, on sections taken from every specimen tested under the above headings, these "sections" being cut immediately after the completion of the "physical" test concerned, and the moisture condition determined in the manner hereinafter described.

Professor Johnson has stated that it has been found sufficiently accurate in the case of the American softwoods to calculate the strength of the large beams from the results of tests on small specimens, this being due to the comparatively low "strength" of these timbers, and the large size and uniformity of the trees from which they are cut.

In the case of the majority of the Australian hardwoods, this assumption cannot be made, as the "direction" of the fibres in the hardwoods is not so uniformly even as it is in the "softwoods"; and since the individual strength of these fibres is very much greater in the former than in the latter, any deviation between the direction of the fibre and the direction of applied stress is felt to a correspondingly greater extent in the hardwoods, and such deviations naturally occur more frequently in large than in small specimens.

For this reason cross-bending tests have been made upon specimens varying in size between 1in. x 1in. and 12in. x 8in. at all degrees of moisture, and the results obtained have fully borne out the above contentions.

As was to be expected the timber that has shown the least divergency between the results obtained with the large and small specimens is "Karri" (*E. diversicolor*), due, no doubt, to the very large size of the trees, and the comparative straightness of the grain.

SUPPLY AND PREPARATION OF TEST SPECIMENS.

As it was of importance that the results obtained from these tests should fairly represent the average qualities of the various timbers, specimens, wherever possible, were taken at random from the contract supplies of timber to the various Government Departments. Other specimens were supplied by various private timber companies, notably the Millar's Karri and Jarrah Forests Co., Ltd., from their stocks. In many cases both dry and green logs up to 4ft. in diameter were supplied, and these were broken down for tests at the Government Workshops and the whole tested, so that the results obtained may with certainty be taken to represent a true average of all the timbers received, which included the following varieties and quantities:—

Local Name.	Systematic Name.	Approximate quantity received for test.
		super feet.
Jarrah	E. marginata ...	3,900
Karri	E. diversicolor ...	2,700
Tuart	E. gomphocephala ...	3,050
Wandoo	E. redunca	3,720
Blackbutt ...	E. patens	4,400
Red Gum ...	E. calophylla ...	3,200
Yate	E. cornuta	1,160
York Gum ...	E. loxophleba ...	1,580
Salmon Gum ...	E. salmonophloia ...	241
Morrell	E. longicornis ...	417
River Banksia ...	Banksia verticillata ...	354
Native Pear ...	Xylomelum occidentale	133
Jam Wood ...	Acacia acuminata ...	40
Sheaoak	Casuarina Fraseriana	262
Swamp Oak ...	Casuarina	197
	Total	sup. ft. 25,354

Each specimen as received was, if necessary, broken down, then machined and planed on all sides, micrometically measured, and weighed, preparatory to being tested transversely. After this test the fractured portions and the requisite moisture sections were cut out of the middle, and the ends of the specimens again machined for other varieties of tests; and after each successive test a further moisture section was taken close to the fracture. No artificial seasoning of any kind was adopted with any of the samples, the beams, after machining, being stacked horizontally under a roof only until required for test. Many interesting samples of timber that had been in service for a great number of years were received for examination and test, some particulars of which are given hereafter.

A very great number of tests were made upon each of the more important timbers, in order to obtain "true" averages. Much of the contradictory nature of previously published test results has arisen from the inadequacy of the number of specimens.

Thus in the tests of W.A. timbers (Jarrah, Karri, and Red Gum) carried out at Sydney University, upon the results of which have been based almost the whole of the condemnatory reports of these timbers, only 14 samples were tested in cross breaking and a corresponding number in each of the other classes of test, or an average of under five per timber.

In the present investigation, the following number of tests have been made, upon the seven timbers of the greatest value:—

——	Totals.	Average per variety.
Cross breaking	1,749	250
Tension	450	64
End compression	2,028	290
Cross compression	713	102
Shearing along the grain ...	654	93
Hardness, etc.	873	125
Moisture	6,467	924
Totals	12,934	1,848

METHODS OF TESTING.

Appliances used.—The greater part of the testing was carried out with a 40-ton horizontal testing machine, specially designed and built in the year 1902 by Messrs. Joshua Buckton & Co., of Leeds, England, to meet the requirements of the Railway Department. Many new appliances have been fitted to it since its erection, and it is now capable of dealing with cross-bending tests on beams up to 30-feet span; tensile tests on specimens up to 40 feet in length; compression and column tests to 12 feet in length; torsion tests up to 45,000 inch lbs., and, in addition, is fitted with special appliances for shearing, and cross compression, etc. To assist in the tests of timbers it was equipped with a specially designed autographic stress strain apparatus, which will accommodate a diagram two feet square, and also with an automatic electric beam balancing mechanism, which has been used throughout the test with complete success. The whole machine was overhauled before testing commenced, and twice during the progress of the work, and the "knife edges," etc., maintained in good condition. The load is applied hydraulically, and the required water, under pressure, is supplied from a special accumulator, which is pumped up between tests, the pumps being stopped during testing to ensure evenness of loading and absence of all shock. In addition to this testing machine, a small 8-ton machine was built to deal with the lighter tests, and the tests with the holding power of dog spikes. In this appliance the load is applied hydraulically from an accumulator and measured by a water balance.

"Impact" and "Spalling" tests were made on a dead-weight apparatus equipped with automatic "lift" and "release," and deflection-measuring gear, the blow being taken on an anvil weighing one ton, carried upon 1in. rubber pads on a solid 4in. floor.

"Moisture" tests were made upon thin sections (1/16in.) cut as close to the fracture as possible, and within 24 hours of testing. These sections were immediately weighed upon a No. 5 "Oertling" Chemical Balance, then placed in sets in a water oven, and there maintained at a constant temperature of 240° F. for a period of four hours, after which they were again weighed, and the loss determined. The oven was specially designed to deal with this work.

Cross Bending tests were carried out on spans varying between 3 feet and 10 feet, depending upon the size of the specimen.

The deflection multiplied by 20 was automatically recorded upon a special scale, from which the moduli of elasticity have been computed. Notes were taken throughout the tests as to the behaviour of the specimens, and the nature and location of the "failure." The loads were applied to produce uniform rates of deflection depending upon the span, that for 5 feet span being ¼-inch per minute.

Tensile tests were carried out on turned specimens, the nominal "reduced" diameter of which was 1in.

These were held in special grips, and an autographic stress strain diagram was taken with each specimen, from which the moduli of elasticity have been calculated. No trouble was experienced in holding the specimens, except that in a few cases where the tensile stress was high the reduced portion pulled through one or both of the enlarged ends, this occurring chiefly in testing "Karri," which has a relatively low shearing strength along the grain. The average rate of loading throughout the test was 1¼ tons per minute.

Tests in End Compression.—These were all carried out between accurately squared steel tables, the ends of each specimen being ground true and square with its axis in a machine specially prepared for this purpose.

All columns were of square section, owing to the large amount of labour that would have been involved in turning them to a circular section. The end deflection multiplied by 100 was automatically recorded on a special scale from which, in the case of specimens failing in direct compression, the moduli of elasticity were calculated.

In the case of "long" columns, the "laterial" deformation was autographically recorded relative to the end section of the specimen. This was done to determine the direction relative to the "annual rings" on the section, in which the various timbers tended to deflect laterally. The rates of loading were maintained within predetermined limits depending upon the size and length of the specimen.

Tests in Cross Compression.—These were carried out in two ways, as follows:—

(1.) On specimen squares in section, the length nominally twice the breadth, and the load applied over the whole of one side face.

(2.) On specimens square in section, the length nominally four times the breadth, and the load applied through a steel plate 4in. in width with square corners, which took its bearing upon the specimen on one side face, the opposite side face being supported over its whole surface.

In practice the load is more frequently applied in the latter manner.

In both methods, two arbitrary limits were chosen to determine the points of "initial" and "total failure," the first being that point at which the deformation equalled 3 per cent. of the depth of the specimen, and the latter when 15 per cent. of the depth was reached. These limits are the same as those that were adopted for the United States Government tests. The two "points" were automatically determined by an appliance similar to that used by Professor Johnson, and described by him in his "Materials of Construction." This apparatus dispenses with all calculation in the determination of the two limits, and was found to be both convenient and accurate. The average rate of loading in these tests was 1¼ tons per minute.

Shearing along the Grain.—This test has also been carried out in accordance with two distinct methods, as follows:—

(a) The specimens were prepared and the load applied by means of a "round backed" self-adjusting cotter, which pulls out the "end" of the mortise. In this method the section under test is sustained only by the resistance opposed by the material to "shearing along the grain," and there is no doubt that the results obtained in this manner accurately represent the true strength of the material in this direction.

The specimens were mortised in a "Chain Saw" mortising machine, which cuts the necessary slots "clean" and without shock to the timber. This method is due to Professor Johnson, and is that adopted throughout the United States Government tests.

(b) As the above arrangement gave results uniformly much below those obtained by Professor Warren when testing the timbers of Australia (including Jarrah and Karri), it was considered advisable to also carry out tests by his method. As was to have been expected, very much higher results were obtained, particularly with "curly grained" timber, and an examination of the fracture has shown that the "enforced" failure along the plane defined by the apparatus results in a tensile stress being brought to bear upon many of the fibres, thus greatly raising the ultimate "shearing" stress. Timbers tested in this latter method give results uniformly, from 75 per cent. to 100 per cent. higher than when tested under method "a."

Tests for Hardness.—A "hard" wood has been defined as one requiring a load in excess of 1,000lbs. per square inch to produce an indentation of one-twentieth of an inch.

Tests were made to determine this factor, which is of considerable importance in sleepers, upon specimens 12in. x 3in. x 2in. The load was applied through a circular steel die nominally one square inch sectional area, and the "instant" of obtaining a penetration of one-twentieth of one inch was automatically recorded by a special apparatus.

The relative hardness was also derived by measurement of the penetration produced by a weight of 40lbs. falling from a height of five feet on to the specimen, which was held firmly upon a machined surface that formed portion of an anvil of one ton weight.

The requisite height of drop was previously determined by experiment, and was sufficient to produce well defined differences in penetration, but not so great in the majority of cases as to split the timber.

To afford means for comparison, a number of samples of "American oak" and "Selected Indian" teak were tested for hardness by both methods, and the results are given hereafter.

Spalling tests were made upon turned specimens, three inches in length and four square inches in sectional araa, by allowing a 40lb. weight to fall upon them from a height of five feet, the specimens being placed on "end" on the one ton anvil.

The number of blows required to produce certain "deformations" upon the specimens, as recorded automatically, were taken as a measure of the resistance to "breaking up under shock" by comparison with the results obtained on similar tests of American oak and teak.

Tests to determine the holding power of dog spikes in sleepers were made with both old and new sleepers, the old sleepers being drawn from the "road" by withdrawing two out of the four spikes, thus allowing the sleeper to be removed without disturbing the remaining two spikes. These were then "pulled out" by means of a special apparatus, the "pull" required to "start" the spike being recorded, as also the size and type of spike. New holes were bored in the "old" sleepers and the spikes re-driven, to be again pulled out in order to determine the holding power of the "used" sleepers upon the freshly-driven spikes. Similar tests were also made upon new sleepers. All of the spikes were ⅝in. square, and, with the exception of several of the oldest sleepers, were of the standard pattern, and had been driven into holes bored with a ⅝in. auger.

Chemical tests of Saps were carried out in the Department's Laboratory, the sap being obtained from fairly green samples of the timbers when placed under a 120-ton hydraulic press.

CALCULATION FROM TEST RESULTS.

To ensure a thorough understanding of the methods adopted in arriving at the results, and to assist in the practical application of the data, the following brief statement of formulæ and methods is given:—

Moisture percentages as obtained from sections cut from specimens and dried—

$$\text{Moisture per cent. of total weight} = \frac{W1 - W2}{W1} \times 100$$

where W1 = weight of section before drying and W2 = weight of section after drying.

In all the accompanying diagrams the "strengths" are given for various degrees of moisture expressed as a percentage of the "dry weight" of the material, which is obtained as follows:—

$$\text{Moisture p.c. of ``dry'' weight} = \left(\frac{M}{100 - M}\right) \times 100$$

where M = moisture per cent. of total weight.

Specific Gravity.

Each specimen was weighed and measured before the cross compression test, and its moisture percentage taken immediately after that test.

From this data, the following calculations were made in each case:—

Total weight per cubic foot $= \frac{W}{C}$ lbs.

Where W = weight of specimen in lbs.
and C = cubic contents expressed in cubic feet.

Dry weight per cubic foot = W (1 — M) lbs.

Where W = total weight per cubic foot.
and M = moisture per cent. of total weight.

Cross-bending Tests.

W = breaking load at centre of beam in lbs.

D = deflection in inches per ton of load within the elastic limit as determined by the stress-strain diagram.

We = load (in lbs.) on the beam at the "Apparent Elastic Limit" as determined from the stress-strain diagram.

This "limit" is defined as "the point on the stress-strain diagram of any material, in any kind of test, at which the rate of deformation is 50 per cent. greater than it is at the origin."

B = breadth of beam in inches.

H = depth of beam in inches.

L = span in inches.

Then,

Ultimate extreme fibre stress $= \frac{3\ W\ L}{2B\ H^2}$ lbs. per square inch.

Extreme fibre stress at Apparent Elastic Limit = $\frac{3\ We\ L}{2B\ H^2}$ lbs. per square inch.

Modulus of elasticity $= \frac{L^3}{4D\ BH^3}$ lbs. per square inch.

End Compression Tests.

B = Breadth, or minimum lateral dimension of column, in inches.
H = "Depth" or "maximum" lateral dimensions in inches.
L = Length of column in inches.
W = Load at failure in lbs.
D = Reduction in length (in inches) per ton, of load within the elastic limit for "short columns."

Then "Radius of Gyration" $= \frac{B}{\sqrt{12}}$

Ultimate load per square inch $= \frac{W}{BH}$ lbs.

Modulus of Elasticity for "short" columns $= \frac{2240L}{BHD}$ lbs. per square inch.

Cross Compression Tests.

(a) *Load applied over whole surface*—
W = Total load in lbs.
L = Length of specimen in inches.
B = Breadth of specimens normal to direction of loading in inches.

Ultimate load per sq. inch $= \frac{W}{LB}$ lbs.

(b) *Load applied through steel plate*—
K = Width of plate in inches.

Ultimate load per sq. inch $= \frac{W}{KB}$ lbs.

Tensile Tests.

W = Total load in lbs.
D = Elongation produced by one ton load (within elastic limit).
A = Sectional area of specimen in sq. inches.
L = "Gauge" length of specimens, *i.e.*, length over which the elongation is measured.

Then Ultimate load per sq. inch $= \frac{W}{A}$ lbs.

And Modulus of elasticity $= \frac{2240L}{A\ D}$ lbs. per sq. inch.

Shearing Tests.

Method A.

W = Total load in lbs.
B = Breadth of specimen in direction of "slot" in inches.
D = Depth of material between "slot" and "end" in inches.

Load per square inch $= \frac{W}{2\ B\ D}$ lbs.

Method B.

W = Load in lbs.
B = Breadth of specimen in inches.
L = Length of specimen in inches.

Load per square inch $= \frac{W}{B\ L}$ lbs.

Hardness Tests.

W = Total "static" load in lbs.
D = Depth of indentation = 1/20th inch in these tests.

Load per square inch to produce 1/20th inch indentation $= \frac{W}{A}$ lbs.

Relationship between Direction of Loading and "End Section" of Specimen.—As the position in the tree from which a specimen is cut, and the direction of loading relative to the "annual rings" and "radial lines" as shown on the end section of the sample are of considerable importance, particularly in cross bending, a complete record of these sections was kept for all tests.

RESULTS OF TESTS.

The data obtained from these tests, which exceeded 16,000 in number, are summarised upon the accompanying schedules and diagrams, and may be considered under the following headings:—

(1.) General summary of results expressed in such a form as to be comparable with the information available concerning other hardwoods.

(2.) Detailed description of the general results of the tests, with special reference to the effects of seasoning upon the strength and the relative strength of members such as "columns" and "beams" of varying dimensions.

(3.) Consideration of the results of those special tests which cannot be classed under the general heading, such as the chemical tests of "saps," the holding power of "dog spikes" in sleepers, and the possibilities of the satisfactory treatment of the various timbers to enable them to resist the attacks of dry rot and white ants, etc.

1. General Summary of Results.

Undoubtedly the most satisfactory method of "expressing" the characteristics of our timbers, many of the most valuable of which are yet practically unknown, is by comparison with those of well-known hardwoods indigenous to other parts of the world; and in order that such a comparison may be of value, it is essential that all results should be expressed in accordance with a "common" standard.

This has, as far as possible, been done in the accompanying Schedule (folded sheet at end of volume) in which is given the "strength" of the Western Australian hardwoods, as determined by the present series of tests, and also that of the most important of the "hardwoods" of the Eastern Australian States and of other parts of the world.

The whole of the figures given for the Western Australian timbers represent their "strength" when containing an amount of moisture equal to 12 per cent. of the dry weight of the wood, this being the standard adopted in the United States Government tests.

The results of the tests of the American Oak and Hickory and of "Djatti," are also expressed in accordance with this standard, which is probably the fairest that can be adopted, although higher results are obtained from still drier timber.

The data given in this schedule may therefore be accepted as accurately representing the strength of the timbers of this State, both directly and by comparison with the results quoted for other hardwoods.

On the plate at the end of this book is shown a graphical summary of the strength of 24 of the most important of the Australian hardwoods, and it is to be remarked that six out of the first eight places are held by Western Australian timbers, and that two of them, and one to a most marked degree, are superior to the New South Wales Ironbark, which comes third on the diagram.

Against each timber is given the number of specimens tested, and the large number of such tests in the case of Western Australian timbers entirely precludes the suggestion that "picked" specimens only have been dealt with as does also the method in which the samples were obtained.

2. Detailed Description of the Results of the Tests.

From the figures given on the Schedule the following deductions have been made:—

A.—Specific Gravity and its relation to Strength.

The heaviest of the Western Australian timbers, and of all the Australian timbers of note, are Yate and Wandoo, which when first cut both average 79lbs. per cubic foot, Tuart and York Gum following closely with weights of 78 and 77lbs. respectively. When seasoned, *i.e.*, at 12 per cent. moisture, Yate and Wandoo are still the heaviest, with Tuart, York Gum, Salmon Gum, and Morrell following in that order.

It has been stated that the *weight and density of a seasoned timber* is to a certain extent a *measure of its strength,* and this is borne out in the case of Yate, which is the heaviest and very much the strongest of the Australian hardwoods; and although Wandoo and Tuart do not come next in order of strength, yet both are well to the front.

It is more nearly correct, however, to state that the *greater the density* and therefore the weight, the greater is the strength to *resist Compressive strain,* whether applied edgewise or crosswise; and this is fully borne out by the results of the tests, in which the relative positions are, Yate, Wandoo, Morrell, Tuart, Salmon Gum, and York Gum.

It has been found that the *"density" is no criterion as to the "Tenacity"* or tensile strength of the material, and hence, therefore, affords no guide as to the relative strength of beams which largely involves the tensile strength of the timbers. Thus, Karri, which when seasoned is lighter and less dense than any of the above-mentioned timbers, is very much stronger in tension and as a "beam" than all others, excepting Yate and Salmon Gum.

Red Gum also, which is comparatively light when seasoned, is very strong in tension, although not so high when used in beams, due to its lower compressive strength.

Generally speaking, the following deductions as regards density and strength may be accepted:—

(1.) *Timbers in which the grain is closely twisted and interwoven* are in general very hard, dense, and heavy; high in compressive strength both edgewise and crosswise, and also in shearing strength along the grain; comparatively low in moisture, and, relatively to the straight-grained timbers, are lower in tensile strength, and therefore to a certain extent less strong where used as "beams." Such timbers are Wandoo, Tuart, and York Gum.

(2.) *Timbers in which the fibres are straight and even,* are relatively less hard and dense, and are lighter; considerably higher in moisture percentage when green; stronger in "tension," and therefore generally stronger as beams, but are correspondingly lower in compressive strength and in shearing strength along the grain. The straight-grained timbers are to be found in districts with a heavier rainfall, and particularly in soils that hold the water. Such timbers are Karri, Red Gum, Blackbutt, and Jarrah.

(3.) *Timbers lying midway between these two conditions,* although not so "dense" and "hard" as those coming under the first heading, are in general stronger than either; such timbers being Yate, Salmon Gum, and Morrell.

(4.) *Timbers coming under the first and third headings* in general are to be found either in districts where the rainfall is comparatively light (such timbers being Wandoo, York Gum, Salmon Gum, and Morrell) or in localities where the soil is porous and does not retain the moisture, such as the sandy country to which Tuart is almost wholly confined.

(5.) *Timber grown in the dry districts*—viz., Wandoo, York Gum, Salmon Gum, and Morrell—in every case the moisture percentage is very low, the average of the four, when green, being 28 per cent., and the sap is of a thick viscous nature. These timbers, when cut, season very slowly, and shrink to a comparatively small extent in seasoning.

Timbers growing in loose "porous" country, such as Tuart and Yate, the moisture percentage is higher, averaging 37 per cent., and the sap is of a more fluid nature. These "season" more rapidly, but shrink very little in the process, this being markedly the case with Tuart.

In the straight-grained timbers—Karri, Jarrah, Red Gum, and Blackbutt—the moisture percentage when green averages 60 per cent., the sap being very fluid; and these timbers season more rapidly and shrink to a greater extent than those with lower initial moisture.

B.—Cross Bending Tests.

The general results of these tests on beams of various sizes are clearly shown when plotted in curves. The curves clearly demonstrate the very great variations in strength at different degrees of seasoning, thus fully bearing out Professor Johnson's contentions in this respect.

From such curves and other data obtained in testing, the following information has been derived:—

(1.) The ultimate extreme fibre stress for beams of various sizes at 12 per cent. moisture lies between an average of 22,500lbs. per square inch for small Yate scantlings (up to 10 square inches sectional area) and 12,600lbs. per square inch for heavy Blackbutt beams, the actual figures being summarised on Table No. 1. It is seen that at 12 per cent. moisture, small beams up to 10 square inches section are from 10 per cent. to 16 per cent. stronger than beams of sizes between 20 and 25 square inches section, whilst heavy beams (30 to 40 square inches) are from 8 per cent. to 22 per cent. weaker.

As was to be expected, the least variation (8 per cent.) was obtained with Karri, owing to the large size of the trees and the evenness of the grain, Tuart and Blackbutt following next for the same reason; and the greatest variation (22 per cent.) occurred in the case of Red Gum, due to the presence of gum veins in the larger beams.

(2.) At 12 per cent. moisture the strength at the Apparent Elastic Limit lies between 89 per cent. and 69 per cent. of the ultimate extreme fibre stress, Tuart and Jarrah occupying the extreme positions respectively.

(3.) At 12 per cent. moisture the average modulus of elasticity lies between 2,800,000 (Yate) and 1,800,000 (York Gum).

It was found that in those timbers with high moisture percentages, *i.e.*, Jarrah, Karri, Red Gum, and Blackbutt, the modulus of elasticity was equal to 150 times the Ultimate Extreme Fibre Stress.

In the case of Yate and Tuart, this ratio fell to 136, and for the dry timbers—Wandoo, Salmon Gum, York Gum, and Morrell—its value was 131.

(4.) For average size beams (25 square inches section), the percentage reduction in strength between "seasoned" and "green" timber varies from a maximum of 33 per cent in the case of Karri and Tuart to a minimum of 14 per cent. for Wandoo.

(5.) As the percentage of moisture increases, the relationship between the strength of beams of various dimensions remains fairly constant.

(6.) In general, the strength of beams cut on the "quarter" was 12 per cent. less than that of square cut beams.

In carrying out the cross bending tests an endeavour was made to test an equal number of specimens cut square, partly on the quarter and wholly on the quarter, so that the results obtained might be true averages, it being impossible, commercially, to entirely avoid the use of ''quarter cut'' timber except in the most important works.

(7.) It is to be noted that the strength of the weakest of the West Australian ''Eucalypts'' is equal to that of Hickory, and is 20 per cent. greater than that of the best Oak.

C.—Shearing Strength along the Grain.

The results of tests carried out are given in the Schedule.

The average value of the true shearing strength (as determined by Professor Johnson's method) is 58 per cent. below that obtained by the Sydney University method, the difference being more marked in the case of "curly-grained" timber.

As previously pointed out, the "shearing" strength of the hard, dense, dry timbers is generally higher than that of straight-grained, moist-grown wood.

D.—Strength in Cross Compression.

In the results of this test it is to be noted that when the load is "confined" to a portion of the specimen only, as is usually the case in practice, the strength in cross compression is, on the average, 12 per cent. higher than is the case when the load is applied over the whole surface.

In illustration of the relationship between the cross compressive strength and "seasoning," one feature is particularly noticeable, namely, that although Wandoo, Tuart, and Yate are very much stronger in cross compression, yet with these timbers an increase in moisture is followed by a considerably greater reduction in strength than in the case with the comparatively weaker timbers, Karri and Jarrah, etc.

E.—Tensile Strength.

The tensile strength was, in general, higher than the ultimate strength in cross bending, the average increase being 5 per cent.

The average value of the Modulus of Elasticity in direct tension was also 5 per cent. higher, and varied between 120 and 170 times the tensile strength—the average being 150, thus showing the relationship existing between the tensile strength and moisture percentage of various timbers.

F.—Strength in end Compression.

Tests to ascertain the relative strength of columns of different lengths were made with specimens in which the ratio of length to minimum lateral dimensions ranged between 2/1 and 36/1 at 12 per cent. moisture.

From these tests the following data were obtained:—

(1.) Up to and including ratios of 12/1 the strength in end compression in all the timbers was fairly constant, and the specimens invariably failed in direct compression.

Under this condition the average strength varied between 11,600 and 8,450lbs. per square inch.

The Modulus of Elasticity in direct compression was in all cases below that obtained in the Cross Bending and Tensile Tests.

Karri, as in other tests, shows the greatest difference between the strength "green" and "dry," the former being 46 per cent. below the latter. The corresponding figures for the other timbers are—Yate 43 per cent., Blackbutt 40 per cent., Tuart 35 per cent., Jarrah 31 per cent., Red Gum 29 per cent., York

Gum and Wandoo 23 per cent., Morrell 22 per cent., and Salmon Gum 21 per cent.

(2.) At a ratio of approximately 18/1 the strength in end compression falls to an extent of 2.9 per cent. in the case of Karri, and in that of Tuart 6.1 per cent. (these being the two limits), and the failure in 60 per cent. of the tests was by "side flexure."

The strength is quickly reduced as the "column ratio" is increased, and at a value of 36/1, which was the limit tested, the reduction in strength below that, at a 12/1 ratio, varied between 39 per cent. (Karri) and 47 per cent. (Wandoo).

It was found that the same percentages of reduction were closely followed at higher moisture values; hence, from the data given, the strength of any column at any "moisture percentage" can readily be computed.

(3.) In all cases where the failure occurred in direct crushing, the fracture was of a sliding nature, and this "sliding" *invariably took place in the direction of the annual rings.*

In turned specimens, and in rectangular specimens wherever sliding occurred in a direction parallel to one of the sides of the specimen, the angle of sliding was always close to 45°.

In nearly all other cases the angle of sliding lay between 40° and 45° when measured directly in the direction of movement.

Where the specimens failed as "long columns," *i.e.,* by lateral flexure, in the majority of cases failure occurred in the direction of *the annual rings,* rather than radially; but in many cases this was not so, apparently due to local inequalities in the specimens.

G.—Hardness.

This was experimented upon by the measurement of both "static" and suddenly applied loads, and the former was found to more accurately represent the hardness of the material.

Where the load was suddenly applied, the "very moist" timbers generally gave higher results when they were partially seasoned than when dry, due probably to the elasticity of the specimens, the "cells" closing upon receiving the blow, and reopening immediately and before the depth of indentation could be measured—this being particularly noticeable with Karri and Red Gum.

For this reason, therefore, the static pressure required to produce a given penetration is the more accurate of the two methods, and as was to be expected, the "dry," "dense," "curly" grained timbers gave considerably higher results than those that are straight grained.

Natural Seasoning.

Table No. 2 shows aproximately the percentage of moisture that may be expected after various periods of "seasoning," both for large and small sizes, based upon the experience obtained with the timbers held in stock by the Government Departments for ultimate use in rolling-stock construction and other works.

Sleeper Tests.

One of the most important uses of the hardwoods is as railway sleepers, for which some of the Western Australian timbers have been used for many years.

Certain special tests were therefore made to determine the relative suitability of the various timbers for this class of work, and also the physical state of the material after a varying numbers of years' service in the track.

In determining the value of a timber for use as a sleeper, three important items have to be considered:—

(1.) The durability of the timber, and its capacity for resisting dry rot and white ants, etc.

(2.) The hardness and toughness of the material to enable it to resist indentation by the rail without tendency to "split" or break up in service.

(3.) The requisite capacity for retaining the "dog spikes" in place.

Many specimens both of old and new timbers were examined and tested to determine the above points, from which examination the following data were obtained:—

Durability.

Sleepers drawn from the road for examination after a varying number of years' service, and without any special selection, show, particularly in the case of the Jarrah and Wandoo, the remarkable durability of the timbers.

The Jarrah and Wandoo sleepers had been in service for over 19 years, and were still sound. Several of the Wandoo sleepers were cleaned, machine planed and then tested in "Cross Bending," and the results obtained were only 6 per cent. below the average for thoroughly seasoned unused timber of the same dimensions, notwithstanding the fact that this timber had been in dirty gravel "ballast" for 19 years, and during that period had been exposed to moisture on the one face and two sides, and to the hot sun on the top face, and had also been subjected to all the wear and tear of railway traffic, and, further, in a district with a 20-inch rainfall in four months, the remainder of the year being very hot and dry.

There were no signs of dry rot upon any of these old Jarrah and Wandoo sleepers, which, prior to being tested, were sound enough to have continued in use for many years.

Two Karri sleepers had been in service in a damp position for 19 years, and although there were many signs of dry rot, yet they still retained their hold upon the dog spikes to a degree quite sufficient to render them safe in the road.

Blackbutt and Red Gum sleepers were tested after four years' service, and although this period is insufficient for test, the sleepers were absolutely sound and free from all signs of dry rot and white ant borings, although the country in which they were used is much infested with these pests.

Red Gum sleepers were machined and tested in "cross bending," giving results from 3 per cent. to 5 per cent. below the average for unused seasoned timber.

As further examples of the durability of Western Australian timbers, the following results of examination and test may be quoted:—

(a) Two jarrah telegraph posts that were known to have been in use for a period of at least 20 years were tested in "cross bending" and "end compression," etc., and gave results from 5 per cent. to 7 per cent. only below the average for unused seasoned timber.

(b) Two Wandoo slabs or face-cuts that had been in use in the decking of a road bridge for a period of 25 years were cut up and examined, and were found to be thoroughly sound throughout.

(c) Four Jarrah posts that had been in use in building construction for eight years were cut up and tested, and the results obtained were up to the average for unused seasoned timber.

(d) Two *hewn square* Jarrah piles were drawn from the Swan River for test, after having been in use for a period of 72 years, and were found to be sound, although completely saturated with salt water. They were both entirely free from signs of attack by the "marine borers."

(e) A section through a Jarrah pile after 18 years' service, show holes bored by marine insects in the *sap wood only*, the body of the pile being thoroughly sound.

(f) Tuart, American Oak, and Teak bogie wagon bolsters were examined after a varying numbers of years' service.

The Tuart bolsters were put into the trucks when green, 14 years ago, and are absolutely sound in every way, although in each case they were "heart wood," which is much more liable to crack and decay. The bolt holes still showed the auger marks, and were free from any signs of corroded ironwork; the bolsters had not shrunk to any measurable extent, nor had the ironwork resting upon them cut into the timber, although bearing a very heavy load (10 tons when the truck is loaded). A great number of these "bolsters" (all of the same age) are in service, none having been removed except for test, and all are apparently fit for at least 30 years' more work.

The American Oak* bolsters represent the average condition of this timber after from five to eight years' service in the same class of wagons.

The Teak bolsters generally last from eight to ten years in the same service, by which time they are usually badly split and cracked, and have to be removed.

The uniformity of the results obtained with Tuart and Blackbutt under the various tests was very marked, there being considerably less range between the maximum and minimum values recorded with these than with any of the other timbers tested.

(g) Blackbutt "beams" 12in. x 4in. and 9in. x 5in., that had been in use for five years as "sole bars" in the heavy timber wagons used by the mill owners for conveying the logs to the mills, were cut and tested for

* The plates showing the actual condition of these bolsters appeared in the large edition (now out of print) and are not reproduced in this pocket-book edition.

cross bending, etc., and the results obtained were equal in every way to those given by unused seasoned timber.

This test is of particular interest, as although Blackbutt is not so strong as others of the Western Australian hardwoods, yet this timber is capable of successfully withstanding, without deterioration, many years of what is probably one of the most severe services to which timber can be put. Throughout the tests of this timber the general soundness of the specimens was very noticeable, and owing to the large size of the trees, it undoubtedly ranks with Karri in the production of large beams of uniform quality throughout. It is also the lightest of the Western Australian hardwoods, which should render it of special utility where minimum weight is of importance, such as in rolling-stock construction, etc.

(h) Two 12in. x 12in. Jarrah beams that had been in use as a slipway at Fremantle since the year 1873 were cut up and examined, and were found to be sound after having been 32 years under water.

(i) One log of Red Gum and two logs of Tuart, that had been lying in damp ground for periods of 12, 15, and 12 years respectively, were cut up and tested, and found to be thoroughly sound throughout, and in nowise deteriorated.

(j) Many examples of Karri beams that had been in service in wagon under-frames for 19 years were examined and were found to be sound, particularly in those cases in which the timber had been partly seasoned before use.

The foregoing examples are sufficient to demonstrate the "soundness" and "durability" of the Western Australian timbers under various conditions.

Dry Rot, White Ants, etc.

Dry Rot is a disease to which "cut" timber is subject, and which destroys the "fibre," reducing it ultimately to a powder.

The disease occurs generally in timber used in damp and unventilated conditions, particularly when the timber has been used in the "green" state, and hence railway "sleepers" are very prone to develop it. It appears to be infectious, and is probably due to, or at least assisted by the decomposition of the sap. As it is known that certain of our timbers are more prone to develop this disease than others, a chemical examination of the saps was made, the results of which are given in Table No. 3. Although this examination was of a comparatively elementary nature, yet certain facts were determined, which to a certain extent explained the different results that are obtained from the various timbers in practice.

Jarrah is well known to be practically free from all risks of dry rot, except under conditions extremely favourable to its development; and it is noticeable that 99½ per cent. of the sap of this timber is either moisture or volatile matter, and further, that the acidity is very small. It is to be expected, therefore, that decomposition will not take place, and hence its immunity to dry rot.

Wandoo, also, never develops this disease, and the examination of its sap, which is present in the timber to a comparatively small extent only, shows it to be of a thick viscous, gummy nature, of which only slightly over 50 per cent. is volatile. It attacked metals to a lesser extent than any of the others tested, including Jarrah, notwithstanding its relatively high "acidity," this apparently being due to a coating of gum which always formed over the immersed metals. When left standing and open to the air, no signs of decomposition were apparent, the sap being entirely unaffected. This timber might, therefore, be expected to be immune from dry rot, as is found to be the case in practice.

Karri, whilst in every other respect almost unequalled as a sleeper timber, is prone to develop dry rot if used when green in damp ground, and in the examination of its sap it was found to decompose when exposed to the air; and further that it exercised a greater effect upon the metals immersed in it than was the case with any of the other saps.

Blackbutt and Red Gum results are not so conclusive, although in neither case was there any noticeable fermentation after standing; sufficient data are not yet available as to their immunity from dry rot when used as sleepers, as they have been in use for a comparatively short time only. Of the sleepers examined, none as yet (after five years' service) show any sign of the disease.

Tuart has not been used to any great extent in situations where it would come in contact with the ground, and is, in fact, altogether too valuable a timber for such uses, but so far as is known it does not develop dry rot.

From the preceding remarks with regard to the development of dry rot it is seen that the presence of the sap is the chief source of trouble. This can be avoided in those timbers that are generally affected, either by using seasoned timber for sleepers, and preferably in some dry, well-ventilated ballast, such as blue metal, under which conditions Karri will give excellent results; or by artificially removing the sap from the timber when green, and replacing it by some suitable substitute. Such a process* is now being experimented upon, which promises not only to render the timber practically immune to dry rot, but also to attacks from white ants, and should this process, which is both simple and cheap, prove successful, as experiments to date promise, there can be no doubt that Karri will prove one of the most valuable "sleeper" timbers in the world.

Jarrah and Wandoo, when sound and free from sap wood, are not attacked by white ants except in certain districts in the North-Western portion of the State, in which no known "cut" timber of sufficient size to provide sleepers is immune to attack; Blackbutt, Red Gum, Tuart, and Karri rarely suffer beyond the sap wood.

Hardness and Toughness.

An examination of the results of the hardness and spalling tests as given in the Schedule affords sufficient proof that the Western Australian timbers possess the requisite degree of "hardness" to provide the best sleepers, and this is further demonstrated by the smallness of the indentation produced by the rail in the sleepers.

---

* Powellising process.

"Holding" power of Dog Spikes.

A considerable number of tests were made to determine the pull required to draw the spikes out of new and old sleepers, and the results of these tests are summarised in Table No. 4.

From this it is seen that, although there is a considerable falling off in the hold on the spike as the sleeper ages, yet after long periods in service, in some cases up to 20 years, the spikes were still sufficiently firm to hold the rail securely in place.

The results obtained from Wandoo were particularly striking in this respect, and are unequalled by any of the other well-known sleeper timbers of New South Wales and Queensland.

In Table No. 5 a summary is given of the results of the above tests, also of those conducted by the Railway Department in Queensland, published by the Queensland Government in 1905 (*see* "The Merchantable Timber of Queensland," page 32), and it is to be noticed that in each of the "averages" Western Australian sleepers, although of greater age, give considerably higher results than were obtained in the Queensland tests.

GENERAL.

Before closing this report one item remains deserving of special mention, namely the extraordinary strength of *Eucalyptus cornuta,* locally known as Yate.

This timber is as yet practically unknown, but is common to the South-West portion of the State, the trees usually attaining a diameter of from 2ft. 6in. to 3ft., and a maximum height of 100 feet. As a "sawn" timber it is probably the strongest in the world, being far ahead of the rest of the Australian hardwoods in every variety of tests, and in one tensile test with this timber a breaking load of 17½ tons per square inch was recorded, a value only 3½ tons below that usually specified for wrought iron of ordinary quality. The results given are fair averages only, the timber being obtained as logs, which were wholly cut up and tested.

Many specimens of the less important timbers were received and tested, the results being included in the Schedule. Amongst these are the Banksias, She-oaks, and Swamp Oak, which whilst being fairly strong, are, owing to the nature of the grain, particularly suitable for ornamental work of every kind and for the panelling of rail and tram coaches, for which purpose they are at present being used.

Table I.—*RESULT OF CROSS-BENDING TESTS FOR BEAMS OF VARIOUS SIZES.*

At 12 *per cent. Moisture.*

(All results are expressed in lbs. per square inch.)

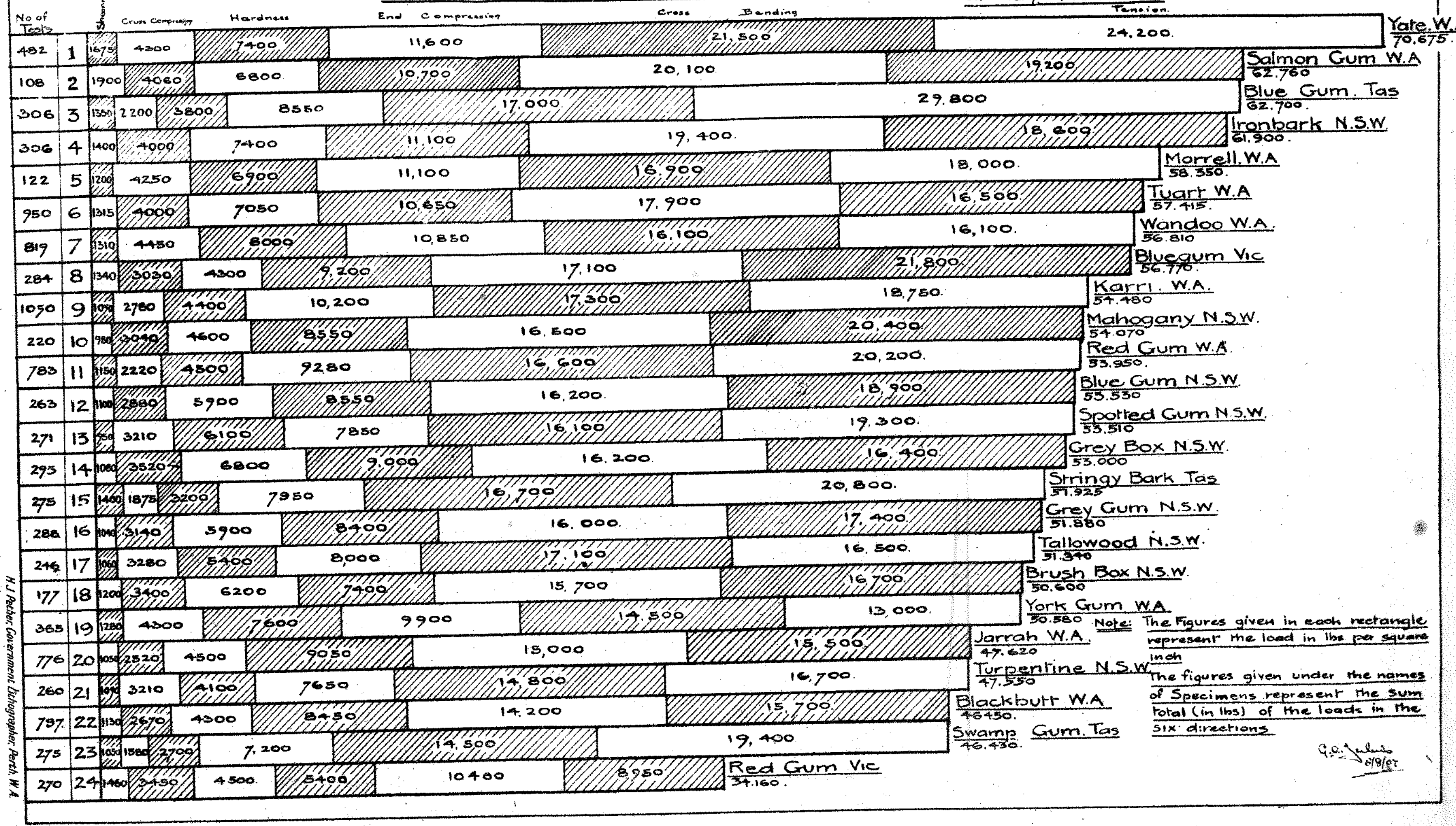
Class of Timber.	For Beams up to 10 square inches Sectional Area.			For Beams up to 25 square inches Sectional Area.			For Beams over 25 square inches Sectional Area.		
	Ultimate. extreme fibre stress.	Extreme fibre stress at apparent elastic limit.	Modulus of Elasticity.	Ultimate extreme fibre stress.	Extreme fibre stress at apparent elastic limit.	Modulus of Elasticity.	Ultimate extreme fibre stress.	Extreme fibre stress at apparent elastic limit.	Modulus of Elasticity.
Jarrah ...	16,700	11,300	2,360,000	15,000	10,300	2,080,000	13,100	8,900	1,660,000
Karri ...	19,100	15,200	3,020,000	17,300	13,550	2,680,000	16,000	12,400	2,425,000
Tuart... ...	20,300	17,550	2,800,000	17,900	15,900	2,560,000	16,250	14,400	2,380,000
Wandoo ...	18,250	15,150	2,450,000	16,100	13,650	2,190,000	14,000	11,700	1,910,000
Blackbutt ...	15,750	12,800	2,225,000	14,200	11,000	2,000,000	12,600	9,350	1,800,000
Red Gum ...	19,400	14,700	2,870,000	16,600	12,600	2,590,000	12,900	9,400	2,000,000
Yate	23,000	18,300	3,050,000	21,500	17,000	2,800,000	18,000	14,800	2,500,000
York Gum ...	15,800	12,500	2,000,000	14,000	10,800	1,700,000			
Salmon Gum	21,000	16,100	2,650,000	19,500	14,380	2,340,000			
Morrell ...	19,700	15,600	2,520,000	16,000	12,100	2,250,000			

Table II.—*APPROXIMATE VALUES OF THE "MOISTURE PERCENTAGE" AFTER VARIOUS PERIODS OF NATURAL SEASONING FOR TIMBER SAWN AND STACKED IN THE OPEN AND WELL VENTILATED.*

Name of Timber.	"Moisture" per cent. of Dry Weight.											
	For all sizes "Green."	For sizes up to 30 square inches sectional area.				For sizes from 60 to 80 square inches sectional area.				For sizes over 100 square inches sectional area.		
		After 6 months.	1 year.	2 years.	3 years.	After 1 year.	2 years.	3 years.	5 years.	After 1 year.	3 years.	6 years.
Jarrah	50	34	26	17	13	33	25	19	14	39	28	21
Karri	54	38	29	21	14	37	28	21	15	43	31	22
Tuart	43	34	27	18	14	33	26	22	16	37	27	22
Wandoo ...	28	24	21	17	15	23	20	17	15	25	20	17
Blackbutt ...	61	45	37	26	18	43	33	25	18	49	35	24
Red Gum ...	75	57	45	31	21	51	39	30	20	60	40	27
Yate	32	28	25	20	17	27	23	20	16	29	23	19

Graphic Representation of the Strength of Australian Hardwoods at 12% Moisture.

W.A. Timber Tests — 1907 —



H.J. Pether, Government Lithographer, Perth, W.A.

TABLE V.—*SUMMARY OF TESTS TO DETERMINE THE HOLDING POWER OF DOG SPIKES IN SLEEPERS.*

Compared with the results of tests on "Sleepers" cut from other Hardwoods.

Name of Timber.	State.	Sleepers taken from Track with Spikes undisturbed.						Sleepers taken from Track re-driven Spikes in fresh holes.						New Sleepers and New Spikes.	
		Actual.			Average.			Actual.			Average.				
		No.	Age. Years.	Load.	No.	Age. Years.	Load.	No.	Age. Years.	Load.	No.	Age. Years.	Load.	No.	Load (Average).
Wandoo	Western Australia	30	18	3,403	...	...	...	30	18	5,170	...	...	...	...	...
Do.	do.	29	8	4,462	59	13	3,923	30	8	7,836	60	13	6,503	...	...
Karri	do.	21	19	3,309	21	19	3,309	20	19	3,690	20	19	3,690	16	6,731
Jarrah	do.	40	13	1,641	59	16	1,695	75	13	2,991	...	...	...	24	5,676
Do.	do.	19	20	1,809	...	...	...	8	11	2,696	83	12	2,962	...	...
Red Gum	do.	42	4	5,359	42	4	5,359	48	4	4,951	48	4	4,951	...	...
Blackbutt	do.	59	4	2,659	59	4	2,659	60	4	4,801	60	4	4,801	...	...
Average of 5 Western Australian Timbers	... ...	...	...	...	240	11·2	3,389	...	...	...	271	10·4	4,581	40	6,203
Ironbark	Queensland and New South Wales	14	14·3	4,032	14	14·3	4,032	10	22·8	3,393	10	22	3,393	12	5,386
Spotted Gum	do. do. do.	4	4	2,325	4	4	2,325	8	8	4,472	8	8	4,472	4	4,466
Red Gum	Queensland	12	8	2,001	12	8	2,001	8	8	4,242	8	8	4,242	...	...
Blue Gum	do.	8	11	2,933	8	11	2,933	8	8	4,307	8	8	4,307	...	...
Gum Top Box	do.	8	8	4,066	8	8	4,066	8	8	2,860	8	8	2,860	...	...
Red Stringy Bark	do.	8	6	3,082	8	6	3,082	4	13	2,975	4	13	2,975	8	4,039
White Stringy Bark	do.	4	7	1,335	4	7	1,335	...	...	...	...	...	...	...	...
Tallow Wood	Queensland and New South Wales	4	9	2,775	4	9	2,775	4	13	2,491	4	13	2,491	8	3,223
Black Wood	Queensland	4	24	2,375	4	24	2,375	...	...	...	...	...	...	...	...
Messmate	do.	4	7	1,982	4	7	1,982	...	...	...	...	...	...	...	...
Average of 10 Queensland Timbers ...	... ...	...	...	...	70	9·8	2,690	...	...	...	50	11·4	3,534	32	4,278

The results of tests of Queensland sleepers are quoted from "The Merchantable Timber of Queensland," published in 1905 by the Queensland Government.

SUMMARY OF THE RESULTS OF TESTS OF THE HARDWOOD TIMBERS OF AUSTRALIA AND SIX REPRESENTATIVE FOREIGN HARDWOODS.

W.A. Timber Tests, 1906-7.

	Name of Timber. — Local Name.	Name of Timber. — Botanical Name.	Specific Gravity, etc. — Weight in lbs. per cub. foot. — Average when first cut.	Weight in lbs. per cub. foot. — Average at 12 per cent. Moisture, per cent. Dry Weight.	Weight in lbs. per cub. foot. — Average Dry Weight.	Moisture when Green. — Per cent. of Total Weight.	Moisture when Green. — Per cent. of Dry Weight.	Whether Green or at 12 per cent. Moisture.	Transverse Strength for Specimens of approximate 20 sq. inches Sectional Area. — No. of Tests	Transverse Strength — Ultimate Extreme Fibre Stress in lbs. per sq. inch.	Transverse Strength — Extreme Fibre Stress at apparent elastic limit in lbs. per sq. inch.	Transverse Strength — Modulus of Elasticity in lbs. per sq. inch.	Shearing Strength along the Grain (Prof. Johnston's Method). — No. of Tests.	Shearing Strength — Ultimate Strength in lbs. per sq. inch.	Strength in Cross Compression. — Load applied over whole Surface of Specimen. — No. of Tests.	Load applied over whole Surface of Specimen. — Load in lbs. per sq. inch to produce a deformation of 3 per cent.	Load confined to a width of 4in. approximately equal to half length of Specimen. — No. of Tests.	Load confined to a width of 4in. — Load in lbs. per sq. inch to produce a deformation of 3 per cent.	Tensile Strength. — No. of Tests.	Tensile Strength. — Ultimate Strength in lbs. per sq. inch.	Strength in End Compression. — No. of Tests.	Ultimate Load per sq. inch for Columns with various Ratios of Length to Minimum Lateral Dimension. — 12/1 and under.	18/1.	24/1.	30/1.	36/1.	Modulus of Elasticity for Ratios of 12/1 and under.	Hardness. — No. of Tests.	Hardness. — Static Load in lbs. per sq. inch required to produce an indentation of $\frac{1}{20}$ of an inch.	Spalling Test. 40lbs. dropped 5ft. on 3in. cylindrical head. — No. of Tests.	No. of Blows sustained — Before Failure Commenced.	No. of Blows sustained — Before Complete Failure.
W.A. TIMBERS.	JARRAH	*Eu. marginata*	68	55	48	33	50	*Green* Dry	203	10,600 15,000	8,300 10,300	1,450,000 2,080,000	102	940 1,050	49	1,630 2,150	59	2,030 2,520	71	13,400 15,500	290	6,250 9,050	5,920 8,580	5,320 7,710	4,530 6,560	3,550 5,140	1,336,000 1,493,000	51	3,700 4,500	51	5	6
	KARRI	*Eu. diversicolor* ...	72	58	50	35	54	*Green* Dry	312	11,500 17,300	8,600 13,550	1,750,000 2,680,000	108	900 1,050	58	1,625 2,060	100	2,350 2,780	102	13,150 18,750	385	5,500 10,200	5,340 9,900	5,040 9,350	4,450 8,250	3,370 6,250	1,317,000 2,027,000	43	3,800 4,400	40	5	6
	TUART	*Eu. gomphocephala* ...	78	68	60	30	43	*Green* Dry	318	11,800 17,900	9,300 15,900	1,630,000 2,560,000	93	970 1,315	30	2,100 3,700	60	2,750 4,000	88	13,300 16,500	331	6,975 10,650	6,550 10,000	5,840 8,920	4,970 7,590	3,920 5,980	1,793,000 1,895,000	59	5,800 7,050	41	8	10
	WANDOO	*Eu. redunca*	79	71	63	22	28	*Green* Dry	287	14,000 16,100	11,750 13,650	1,850,000 2,190,000	61	1,150 1,310	36	2,745 3,900	43	3,375 4,450	50	14,350 16,100	324	8,320 10,850	7,840 10,220	6,990 9,120	5,860 7,640	4,410 5,750	1,690,000 1,751,000	54	6,500 8,000	31	16	16
	BLACKBUTT	*Eu. patens*	69	54	46	38	61	*Green* Dry	255	10,500 14,200	8,000 11,000	1,650,000 2,000,000	64	890 1,130	36	1,340 2,080	44	1,820 2,670	63	13,250 15,700	331	5,100 8,450	4,940 8,190	4,560 7,560	3,990 6,610	3,020 5,000	1,246,000 1,319,000	40	2,900 4,300	39	3	5
	RED GUM	*Eu. calophylla*	72	56	47	43	75	*Green* Dry	252	11,350 16,600	9,000 12,600	1,800,000 2,590,000	51	720 1,150	36	1,250 1,750	85	1,625 2,220	45	13,600 20,200	301	6,620 9,280	6,280 8,800	5,740 8,050	5,065 7,100	3,995 5,600	1,242,000 1,776,000	49	2,850 4,500	63	4	6
	YATE	*Eu. cornuta*	79	71	64	24	32	*Green* Dry	122	16,700 21,500	12,700 17,000	2,300,000 2,800,000	28	1,250 1,675	27	2,535 3,400	49	2,980 4,300	31	19,700 24,200	233	6,660 11,600	6,400 11,150	5,840 10,180	5,060 8,820	4,080 7,100	1,421,000 1,900,000	19	5,400 7,400	11	9	12
	YORK GUM	*Eu. loxophleba*	77	67	59	23	30	*Green* Dry	135	12,200 14,500	10,000 11,000	1,500,000 1,800,000	30	1,140 1,280	17	1,800 3,700	24	2,550 4,300	25	11,400 13,000	134	7,650 9,900	7,260 9,400	6,530 8,450	5,440 7,040	4,170 5,400	1,225,000 1,185,000	17	5,800 7,600	37	12	15
	SALMON GUM ...	*Eu salmonophloia* ...	70	66	60	20	25	*Green* Dry	24	16,500 20,100	12,600 15,000	2,100,000 2,500,000	10	1,210 1,900	24	2,875 3,380	11	3,375 4,060	19	16,900 19,200	26	8,100 10,700	7,650 10,100	6,810 9,000	5,500 7,270	3,900 5,150	1,295,000 1,500,000	18	6,300 6,800	4	20	24
	MORRELL	*Eu. longicornis*	73	64	56	23	30	*Green* Dry	24	15,600 16,900	11,600 12,250	2,150,000 2,400,000	10	1,220 1,200	17	2,825 3,500	15	3,575 4,250	13	16,200 18,000	40	7,850 11,100	7,460 10,550	6,680 9,450	5,410 7,650	3,890 5,500	1,831,000 2,010,000	20	5,700 6,900	19	17	22
	SHEA OAK	*Casuarina Fraseriana* ...	60	52	45	25	33	,,	30	12,000	11,100	1,356,000	4	1,480	...	...	...	...	4	9,000												
	BANKSIA	*Banksia verticillata* ...	59	35	29	50	100	,,	15	10,300	7,290	1,148,000	3	1,100	...	...	...	...	3	8,000												
	JAM WOOD	*Acacia acuminata* ...	73	62	54	20	25	,,	7	15,300	14,200	2,355,000	2	1,180	...	...	...	...	2	12,000	*...	...	...	...	...	...	...	...	...	...	...	...
	SWAMP OAK	*Casuarina sp.*	76	65	56	30	43	,,	17	20,650	16,300	2,373,000	3	1,160	...	...	...	...	3	17,000												
	NATIVE PEAR ...	*Xylomelum occidentale* ...	56	46	40	30	43	,,	17	7,669	6,500	845,000	4	920	...	...	...	...	3	7,000												
EASTERN STATES TIMBERS.	Blue Gum	*Eu. globulus*	70	55	49	30	44	*Green* Dry	142	12,100 17,000	8,700 15,000	2,450,000 3,500,000	31	1,160 1,350	28	1,125 1,650	31	1,475 2,200	43	25,180 29,800	41	5,500 8,550	... ...	... ...	... ...	... ...	1,800,000 2,480,000	18	2,600 3,800	... ...	... ...	... ...
	Swamp Gum	*Eu. regnans*	63	41	37	41	70	*Green* Dry	128	8,750 14,500	6,100 12,800	1,800,000 3,300,000	30	700 1,050	30	650 1,080	30	825 1,580	29	15,000 19,400	38	4,200 7,200	... ...	... ...	... ...	... ...	... ...	20	1,400 2,700	... ...	... ...	... ...
	Stringy Bark	*Eu. obliqua*	65	42	38	42	72	*Green* Dry	131	9,400 16,700	7,000 15,600	1,700,000 3,625,000	32	820 1,400	28	745 1,310	30	1,215 1,875	26	13,400 20,800	36	4,650 7,950	... ...	... ...	... ...	... ...	1,550,000 2,380,000	20	1,900 3,200	... ...	... ...	... ...
	Blue Gum	*Eu. globulus*	69	55	49	28	40	*Green* Dry	139	12,000 17,100	9,000 15,000	2,250,000 3,200,000	29	910 1,340	40	1,425 1,970	30	1,860 3,030	29	17,650 21,800	37	5,850 9,200	... ...	... ...	... ...	... ...	1,700,000 2,620,000	20	3,100 4,300	... ...	... ...	... ...
	Red Gum	*Eu. rostrata*	64	49	44	30	44	*Green* Dry	112	6,800 10,400	5,100 9,600	740,000 1,409,000	31	1,010 1,460	30	1,570 2,160	30	2,400 3,450	34	7,080 8 950	43	3,750 5,400	... ...	... ...	... ...	... ...	... ...	20	3,250 4,500	... ...	... ...	... ...
	Ironbark	*Eu. paniculata* and *crebra*	80	64	57	29	40	*Green* Dry	160	14,600 19,400	12,450 18,500	2,175,000 3,400,000	29	1,120 1,400	29	2,425 3,470	29	2,870 4,000	35	15,000 18,600	35	7,750 11,100	... ...	... ...	... ...	... ...	... ...	18	5,800 7,400	... ...	... ...	... ...
	Grey or White Box ...	*Eu. hemiphloia*	80	52	47	41	70	*Green* Dry	147	12,500 16,200	10,180 15,200	2,000,000 2,700,000	29	840 1,080	28	2,010 3,020	31	2,500 3,520	30	13,900 16,400	38	6,400 9,000	... ...	... ...	... ...	... ...	1,850,000 2,380,000	20	4,900 6,800	... ...	... ...	... ...
	Tallowwood	*Eu. microcorys*	77	58	52	32	48	*Green* Dry	104	13,000 17,100	10,800 15,200	1,955,000 2,550,000	24	900 1,060	29	1,950 2,520	30	2,450 3,280	29	14,000 16,500	39	6,000 8,000	... ...	... ...	... ...	... ...	... ...	20	5,300 5,400	... ...	... ...	... ...
	Grey Gum	*Eu. propinqua*	76	50	46	39	64	*Green* Dry	137	11,400 16,000	9,300 14,900	1,760,000 2,800,000	29	880 1,040	30	2,040 2,870	30	2,750 3,140	30	12,300 17,400	41	7,050 8,400	... ...	... ...	... ...	... ...	1,500,000 1,950,000	21	5,600 5,900	... ...	... ...	... ...
	Turpentine	*Syncarpia laurifolia* ...	73	47	42	42	74	*Green* Dry	117	10,425 14,800	8,300 13,800	1,700,000 2,350,000	26	780 1,090	29	1,575 2,250	30	2,075 3,210	30	12,000 16,700	36	5,660 7,650	... ...	... ...	... ...	... ...	1,400,000 1,940,000	21	3,600 4,100	... ...	... ...	... ...
	Spotted Gum	*Eu maculata*	73	50	45	38	61	*Green* Dry	124	12,380 16,100	9,700 15,000	2,050,000 2,800,000	30	920 950	30	1,825 2,310	31	2,300 3,210	30	15,580 19,300	36	5,800 7,850	... ...	... ...	... ...	... ...	1,660,000 2,650,000	20	4,100 6,100	... ...	... ...	... ...
	Blue Flooded Gum ...	*Eu. saligna*	71	47	42	40	67	*Green* Dry	119	11,700 16,200	9,800 15,500	1,850,000 2,670,000	30	880 1,100	30	1,700 2,330	30	2,050 2,880	27	15,450 18,900	37	6,250 8,550	... ...	... ...	... ...	... ...	1,550,000 2,630,000	20	4,300 5,900	... ...	... ...	... ...
	Brush Box	*Tristania conferta* ...	76	51	46	39	65	*Green* Dry	44	11,250 15,700	9,200 14,700	1,625,000 2,480,000	32	900 1,200	29	1,860 2,700	31	2,140 3,400	26	12,850 16,700	29	4,950 7,400	... ...	... ...	... ...	... ...	... ...	15	4,300 6,200	... ...	... ...	... ...
	Mahogany	*Eu. resinifera*	77	56	50	34	52	*Green* Dry	62	13,200 16,500	11,180 14,500	1,950,000 2,700,000	32	920 980	31	1,675 2,130	32	2,275 3,040	26	15,500 20,400	53	6,125 8,550	... ...	... ...	... ...	... ...	... ...	15	3,700 4,600	... ...	... ...	... ...
TIMBERS.	*Lignum vitae*	*Guaiacum officinale* ...	...	73	...	...	...	...	...	12,000	...	...	...	...	...	...	...	...	...	11,000	...	10,000	...	...	...	...	...	...	6,600	...	...	...
	Djatti	... ...	...	41	37	...	...	...	6	15,200	13,000	1,957,000	2	880	3	1,270	5	1,800	3	9,600	5	8,000	...	...	...	...	1,395,000	...	...	...	...	...
	Teak	*Tectona grandis* ...	...	47	...	...	...	...	...	15,500	...	...	...	...	20	1,180	20	1,380	...	15,000	...	9,000	...	...	...	...	...	20	2,350	26	2	4
	English Oak	*Q. pedunculata*	...	52	...	...	...	...	...	11,800	...	...	...	...	...	...	...	...	...	10,500	...	8,600	...	...	...	...	...	...	3,600	...	...	...
	Hicory	*H. ovata*	...	51	...	...	...	...	...	14,500	10,800	2,100,000	...	1,100	...	...	...	2,700	...	11,000	...	9,500	...	...	...	...	...	...	3,500	...	...	...
	American Oak	*Q. alba et sp.*	...	48	...	...	...	...	...	11,500	8,500	1,800,000	...	1,000	25	1,650	21	1,980	...	10,000	...	8,000	...	...	...	...	...	20	3,240	24	10	13

* The specimens tested "transversely" for these five timbers averaged 10 sq. inches sectional area.

G. A. JULIUS,
5th August, 1907.

TABLE III.—*RESULTS OF CHEMICAL EXAMINATION OF "SAPS."*

Name of Timber.	Colour of Sap.	Nature of Sap.	Specific. Gravity.	Percentage of Moisture and Volatile Matter.	Nature of Residue.	"Acidity" in terms of $H_2C_2O_4$.	Weight of Muntz Metal dissolved by 20 grammes of "Sap."	Weight of Wrought Iron dissolved by 20 grammes of "Sap."	Percentage of Tannin.	Volatile Acid expressed as Acetic Acid.
				per cent.		per cent.	grammes.	grammes.	per cent.	
Jarrah	Light reddish brown ...	Very thick fluid ...	1·001	99·5	Red brown film only	0·216	·0165	·1445	·07	Trace
Karri	Dark red	do.	1·020	96·5	Brittle gum of bright red colour ...	1·458	·1080	·2240	·851	"
Tuart	Dark brown	"Thin" fluid	1·1085	77·7	Brown and friable	9·018	·0528	·1716	11·68	"
Wandoo	Red brown	Thick viscous fluid ...	1·1932	53·0	Hard dark gum, very dark brown in colour	7·614	·0160	·0770	17·00	"
Blackbutt	Very dark brown ...	Very fluid	1·0483	89·4	Brittle deposit, almost black ...	2·862	·0790	·1450	4·86	"
Red Gum	Red brown	do.	1·045	90·7	Gummy deposit, dark red colour ...	2·214	·0660	·1420	3·85	"
Yate	Very dark brown ...	do.	1·083	81·7	Dark brown deposit	7·587	·0500	·2330	12·03	0·5 per cent.

TABLE IV.—*HOLDING POWER OF DOG SPIKES IN SLEEPERS.*

⅝in. Dog Spikes used in all cases. Diameter of hole bored, ⅝in.

Class of Sleepers.	Length of time in use.	Locality used.	Original Driving.					Re-driven.		Remarks.
			Pull required in lbs.	No. of Tests.	Class of Spike.			(Spikes—all Class B.)		
					A.	B.	C.	Pull required in lbs.	No. of Tests.	
Jarrah	13 years	Mundijong, S.W.R.	1,641	40	32	8	...	2,991	75	Very wet district; sandy soil in cutting; rainfall between 30in. and 35in.; ironstone gravel ballast.
Do.	11 years	Great Southern Railway ...	...	...	...	...	...	2,696	8	Medium rainfall, between 14in. and 20in.; red loamy soil.
Do.	New unused sleepers ...	... ...	...	...	...	...	...	5,676	24	
Do.	20 years	Newcastle Railway	1,809	19	1	4	14	...	...	Medium rainfall; mostly red loam and gravel country.
Karri	19 years	1m. 26c., Great Southern Railway	3,309	21	10	...	11	3,690	20	Very wet district; rainfall, 35in. or over; sandy soil.
Do.	New unused sleepers ...	... ...	...	...	...	...	...	6,731	16	
Wandoo	18 years	Newcastle Railway	3,403	30	29	1	...	5,170	30	Medium rainfall; mostly red loam and gravel country.
Do.	8 years	Cue Railway	4,462	29	...	29	...	7,836	30	Very dry district; varying rainfall.
Red Gum	4 years	Northam-Goomalling Railway ...	2,174	20	...	20	...	3,334	18	Medium rainfall; red loamy soil.
Do.	4 years	Nannine Railway	6,787	29	...	29	...	5,922	30	Very dry district; varying rainfall.
Blackbutt	4 years	Northam-Goomalling Railway ...	3,046	30	...	30	...	5,001	30	Medium rainfall; red loamy soil.
Do.	4 years	Nannine Railway	2,259	29	15	14	...	4,602	30	Very dry district; varying rainfall.

APPENDICES.

Further tests carried out by Mr. E. S. Hume, Chief Mechanical Engineer, Western Australia, viz.:—

NOTES ON THE TABLES.

CROSS-BENDING TESTS OF HEAVY JARRAH BEAMS.

These tests were carried out with beams measuring 16in. by 12in. over a span of 28ft. The timber contained an average of 36 per cent. of moisture and was, therefore, green. These tests show only a small divergence from those carried out by Mr. Julius with smaller sections.

GENERAL TESTS OF CERTAIN WESTERN AUSTRALIAN WOODS.

Red Tingle Tingle (*Eucalyptus Jacksonii*).—This tree, which grows to a great height and large diameter, is confined to a relatively small area of country along the Frankland River, near Nornalup Inlet. It yields a dense heavy wood of great strength. It is slightly stronger than Karri in transverse, end and cross compression, while its tensile strength is 15,700lbs. per square inch, as compared with 18,750lbs. per square inch. It is also somewhat harder than Karri. This is clearly a valuable timber, and it will be necessary to make a further investigation of the district where it grows with a view to reserving as much of it as possible.

Karri Sheaoak (*Casuarina decussata*).—This tree grows only in the Karri country, and is easily recognisable by the extreme corky nature of its bark. The timber is not so strong transversely as *Casuarina Fraseriana*, but its tensile strength is higher. It lacks, however, the figured grain which makes the Sheaoak of the Jarrah belt so prized for cabinet work. Experiments with the corky bark show it to be a very efficient insulator.

Coolibah (*Eucalyptus microtheca*).—This species grows in the extreme North-West of Western Australia and is also to be found in Queensland and the Northern

Territory. It yields a dense, heavy timber of great strength. There would seem to be a future for this wood for uses to which *lignum vitae* is generally put. It has already come into use for tail bearings for steam boats and bushes for sewerage pumps; also for bowls, and is giving satisfaction. A static load of 12,544lbs. is required to produce an indentation of 1/20in. in Coolibah, while *lignum vitae* is indented to the same extent by 6,600lbs. It will be seen from this that Coolibah is almost twice as hard as *lignum vitae.*

POWDER BARK (*Eucalyptus accedens*).—This tree has been frequently confused with Wandoo (*Eucalyptus redunca, var. elata*). They are both to be found growing in the same locality along the Eastern Railway in the neighbourhood of Baker's Hill and Clackline. Powder Bark, however, may be distinguished by its very pale powder blue bark. The timber has a reputation for durability in the ground. A fence post was obtained near Baker's Hill which had been in the ground for forty years, and showed very little sign of decay. As a timber it is not as strong as Wandoo.

TRANSVERSE STRENGTH OF BEAMS COMPARED WEIGHT FOR WEIGHT.

A question that is frequently asked is, "What is the relative strength, weight for weight, of our native timbers?" The table on page 56 has been compiled in order to make a comparison easy. With the exception of Oregon, the weights and strengths have been taken from Mr. Julius's and Mr. Hume's tests, which were both carried out in this State. The figures for Oregon have been taken from Bulletin No. 88 of the Forest Service of the United States. Yate has been taken as the strongest and heaviest timber, or 100 per cent., and the others are shown in order of strength, weight for weight, while Padouk, Teak, and Oregon have been added as they are commonly-used imported woods.

CROSS BENDING TESTS OF JARRAH BEAMS.

Size.	Moisture per cent. of total weight.	Span in Feet.	Actual Load registered to fracture beam. Tons.			Load at apparent elastic limit. Tons.			Ultimate extreme fibre stress in lbs. per square inch.			Extreme fibre stress at apparent elastic limit in lbs. per square inch.			Modulus of elasticity in lbs. per square inch.		
			Max.	Min.	Av'age	Max.	Min.	Av'age	Max.	Min.	Av'age	Max.	Min.	Av'age	Max.	Min.	Average.
16" x 12"	35·86	28	24·89	21·92	24·04	23·5	18·8	20·4	10,280	8,050	8,830	8,640	6,910	7,490	1,800,700	1,398,200	1,621,600
...	33	...	Tests made by Mr. Julius on smaller specimens. See table p. 49.							*	10,600	...	...	8,300	...	...	1,450,000
...	11	...								†	15,000	...	...	10,300	...	...	2,080,000

* Green. † Seasoned.

SUPPLEMENTARY TESTS OF WESTERN AUSTRALIAN HARDWOODS AND TWO REPRESENTATIVE FOREIGN HARDWOODS,

By Mr. E. S. Hume, Chief Mechanical Engineer, W. A. Government Railways.

Local Name.	Botanical Name.	Where Grown.	Weight.		Moisture when Green.		Percentage of Moisture.	Transverse Strength.									Ultimate shearing strength along the grain in lbs. per square inch.			Cross Compression.						End Compression.			Tension.			Hardness.
								Ultimate Extreme Fibre Stress.			Extreme Fibre Stress at apparent Elastic limit.			Modulus of Elasticity.						Load required to produce a deformation of 3 per cent.						Ultimate Load in lbs. per square inch.			Ultimate Strength in lbs. per square inch.			Static Load required to produce an Indentation of $\frac{1}{20}$ in.
			Green.	Dry.	Per cent. of Total Weight.	Per cent. of Dry Weight.		Lbs. per square inch.												Over whole surface.			Over Plate 4in. wide									
			Lbs. per Cub. feet.																	Lbs. per square inch.												
								Max.	Min.	Average.	Max.	Min.	Average.	Max.	Min.	Average.	Max.	Min.	Av'age	Max.	Min.	Av'age	Max.	Min.	Av'age	Max.	Min.	Av'age	Max.	Min.	Av'age	
Karri Shea-Oak (Corky Bark)	*Casuarina decussata* ...	Karri Country, W.A.	64	44	31	46	12	10,380	7,960	9,020	5,830	4,160	5,030	1,237,100	671,600	939,800	1,100	1,050	1,070	1,530	1,010	1,170	1,940	1,600	1,810	4,460	3,600	4,000	14,830	9,290	12,260	2,800
Red Tingle Tingle ...	*Euc. Jacksonii*	S.W. of W.A.	73	62	...	...	Green	13,290	11,140	12,100	10,830	7,680	8,940	2,234,600	1,568,500	1,863,900	1,170	770	940	1,560	1,380	1,430	1,650	1,460	1,530	6,410	6,000	6,190	14,350	8,980	11,665	4,550
							12	20,030	15,780	18,180	15,850	14,120	14,780	3,294,600	2,578,400	2,933,800	1,490	1,120	1,300	...	...	...	3,770	3,090	3,460	10,270	10,240	10,250	...	...	15,680	...
Coolabah	*Euc. microtheca*	Tropical, W.A.	...	82 *a*	...	...	16	18,720	14,670	17,360	15,370	13,550	14,460	2,255,300	1,994,200	2,095,100	2,150	1,670	1,910	4,900	4,550	4,730	6,520	5,510	6,110	10,870	9,800	10,510	13,930	13,010	13,470	12,540
Powder Bark ...	*Euc. accedens*	S.W. of W.A....	...	...	25	33	12	16,790	12,450	14,510	13,940	10,700	12,050	2,450,600	1,872,000	2,159,400	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Teak	*Tectona grandis*	Foreign ...	...	49	...	...	21	14,030	12,920	13,480	10,730	10,440	10,580	2,508,900	2,275,100	2,392,000	1,280	1,250	1,260	1,290	1,220	1,260	1,530	1,450	1,490	6,960	6,500	6,730	...	...	12,450	2,490
Padouk	*Pterocarpus dalbergioides*	Foreign ...	...	50 *c*	...	...	17	13,190	12,320	12,750	11,870	11,210	11,540	2,414,100	1,957,800	2,185,900	1,480	1,250	1,360	1,760	1,630	1,690	2,040	2,020	2,030	...	...	7,410	...	...	14,460	3,860

a 16 per cent. of moisture. *b* 21 per cent. of moisture. *c* 17 per cent. of moisture.

TRANSVERSE STRENGTH OF BEAMS OF W.A. TIMBERS COMPARED WEIGHT FOR WEIGHT.

Name of Timber.	Weight in lbs. per cubic foot at 12 per cent. moisture.	Extreme fibre stress in lbs. per square inch at apparent elastic limit.	Comparison with Yate.		
			Strength	Weight.	Strength. / Weight for weight.
W.A. TIMBERS.					
			%	%	%
Yate	71	17,000	100	100	100
Red Tingle Tingle ...	62	14,776	86·9	87·3	99·6
Karri	58	13,550	79·7	81 7	97 6
Tuart	68	15,900	93·5	95·8	97·6
Raspberry Jam ...	62	14,200	83·5	87·3	95·6
Salmon Gum	66	15,000	88·2	92·9	94·9
Red Gum	56	12,600	74·1	78·9	93·9
Sheaoak	52	11,100	65·3	73·2	89·2
Banksia	35	7,290	42·9	49·3	87
Blackbutt	54	11,000	64·7	76	85·1
Wandoo	71	13,650	80	100	80
Morrell	64	12,250	72	90·1	79·9
Jarrah	55	10,300	60·6	77·4	78·3
Coolabah (*a*)	82	14,461	85·1	115·2	73·8
York Gum	67	11,000	64·7	94·3	68·6
Native Pear	46	6,500	38·2	64·8	58·9
Karri-Sheaoak* (*Casuarina decussata*)	44	5,000	29·6	62	47·7
FOREIGN TIMBERS.					
Padouk (*c*)	50	11,539	67·9	70·4	96·4
Teak (*b*)	49	10,583	62	69·6	89·2
Oregon, select	34·4	4,690	27·6	48·4	57
Oregon, merchantable	32·4	4,625	27·2	45·6	59·6
Oregon, 2nd quality ...	33·9	3,740	22	47·7	46 1

* The corky-barked Casuarina from the Karri country.
(*a*) At 16 per cent. of moisture. (*b*) At 21 per cent. of moisture.
(*c*) At 17 per cent. of moisture.

By Authority: FRED. WM. SIMPSON, Government Printer, Perth.