Issued December 29, 1910.

U. S. DEPARTMENT OF AGRICULTURE,

FORESTRY SERVICE—Circular 179.

HENRY S. GRAVES, Forester.

UTILIZATION OF CALIFORNIA EUCALYPTS.

By

H. S. BETTS AND C. STOWELL SMITH,

ASSISTANT DISTRICT FORESTERS.

51755°—Cir. 179—10——1

WASHINGTON : GOVERNMENT PRINTING OFFICE : 1910

CONTENTS.

ILLUSTRATIONS.

UTILIZATION OF CALIFORNIA EUCALYPTS.

INTRODUCTION.

A great deal of attention has recently been focused on the planting and growing of eucalypts in California. Many companies have been organized, much capital has been invested, and the large acreage already planted is being rapidly increased. The Forest Service has sought to aid eucalyptus growers by publishing such information concerning the tree and its uses as it could secure after careful study.

Information presented for this purpose has at times been misused. Short passages have been quoted in such a way as to convey a misleading impression and sometimes even to falsify the original meaning. Extravagant estimates of the probable returns from planted eucalyptus have been widely circulated, and there is reason to fear that many persons have formed an altogether false idea of the merits of eucalyptus growing as a field for investment, and have supposed that this false idea was justified by statements and figures of the Forest Service.

The truth is that there are as yet too many elements of uncertainty involved to permit a close calculation of money returns to be made. There is, however, every reason to believe that under proper conditions eucalyptus growing will be profitable. In eucalyptus growing as in any other class of commercial operations the investor needs to know not only whether the enterprise into which he thinks of putting his money is financially sound, but also how large a return is probable. It is the aim of the Forest Service to aid those who wish to know as nearly as possible what can be counted on by finding out and making known both what the tree will yield in wood and what uses the product will be suitable for. One of the elements of uncertainty is the value of the wood for high-grade purposes.

The problem of utilizing eucalyptus wood readily and without undue waste is a difficult one because of its tendency to warp, shrink, and check in drying. In wood from trees as young as the California growers generally count on cutting, this tendency is much stronger than in the wood from mature forest-grown trees in Australia and

Tasmania. In the hope of finding means of controlling this tendency and for the further purpose of ascertaining the mechanical properties of eucalyptus wood, so that its industrial usefulness may be determined, the Forest Service has recently carried out, in cooperation with the University of California, a series of tests of several of the more common California species. It has also under way a number of seasoning and durability experiments. This circular gives in condensed form the results of the mechanical tests and the status of the other unfinished experiments, together with some information in regard to the uses of eucalyptus wood in California and Australia.

On the Pacific coast a natural hardwood supply is wanting. Oak and other hardwood lumber shipped in from the Eastern States command such high prices as to make their use impracticable for most purposes. There is need of some hardwood that will grow rapidly and produce good lumber. Of the woods so far tried the eucalypts appear most likely to fill this need. True, they will not endure extreme cold, but experience indicates that in considerable portions of California and more restricted sections of New Mexico and Arizona conditions are well adapted to growing them.

EUCALYPTUS IN CALIFORNIA.

The eucalyptus is a native of Australia and the adjacent islands, where some 150 varieties are found. It was introduced in California in 1856, when it was planted around San Francisco Bay for ornamental purposes. During the next few years it was planted in the Santa Clara Valley for wind-breaks. Since 1865 the eucalypts have been extensively planted in California, mainly for wind-break purposes around orchards and vineyards, and also for fuel. The extensive planting operations of the past four or five years have been taken up with the idea of furnishing not only fuel, but also telegraph poles, piling, and lumber large enough to make vehicle and carriage stock and furniture material.

About 75 species of eucalypts have been grown in California. The blue gum (*Eucalyptus globulus*) was the first species introduced into the State, and has been much more extensively planted than the others. Probably 90 per cent of the eucalyptus in California at the present time is blue gum. Of the many other species introduced, red gum (*E. rostrata*), sugar gum (*E. corynocalyx*), gray gum (*E. tereticornis*), and manna gum (*E. viminalis*) make up by far the greater part. These five give indications of being well adapted to California conditions, although, of course, others may be found which will give just as satisfactory results.

As a rule, blue gum grows erect; it branches low in isolated specimens, but in close plantings the crowns are small and the lower trunks fairly clean. It reaches its greatest development along the coast and in river bottoms where foggy days are common and the annual rainfall is at least 15 inches. This species when grown under favorable conditions ranks among the fastest growing trees of the world. The wood is yellowish white and easily polished.

Red gum is of slower growth than blue gum and liable to produce a crooked trunk, even in close plantings. The wood varies in color

FIG. 1.—Stand of blue gum (Eucalyptus globulus) about 36 years old. Newark, Cal.

from very light to dark blood red. It is capable of taking a very fine polish, and can be cut into the thinnest of lumber and veneers. Red gum trees withstand frost better than blue gum, and the species is one of the most drought-resistant of the eucalypts of commercial value, although it is outranked in this respect by sugar gum. Although red gum has a slow height growth as compared with blue gum, in diameter growth it is one of the most rapid of all the eucalypts.

Sugar gum in close planting grows erect with a very open crown. Isolated specimens generally have low scattering branches. The wood is of a yellowish-white color. The sugar gum is one of the most drought-resistant of the eucalypts, as has been said, but it is unable to withstand frost.

Gray gum has a very erect habit of growth, whether growing alone or in close plantations. The branches are usually few and scattered, and the crown open. The wood varies in color from white to light brownish red. The value of this species as a tree for planting in California has only come to light recently. It apparently makes a somewhat more rapid growth than red gum and withstands heat and frost fully as well.

Manna gum has an erect habit. In color the wood varies from light brown in the sapwood to a yellowish white in the heartwood. This species withstands low temperatures as well as the red gum. It can be grown on land and under conditions so unfavorable that many of the other species whose wood is more valuable would barely live and make only an inferior growth.

CHARACTERISTICS OF THE WOOD.

The wood of the eucalypts, unlike that of our northern-grown oaks and hickories, has no distinctive alternate bands of spring and summer wood. On this account the age of the trees can not be determined by counting the rings on a cross section of the stump. Bands of wood of different colors and densities can be distinguished on a cross section of eucalyptus, but they are often not continuous, and several may occur in a year's growth. The fibers of the wood are much interlaced, making it tough and more difficult to split for fuel than most woods. The grain is often irregular, which makes the wood liable to chip under the planer, but gives it a very pleasing effect when it is smoothly finished. When first felled, the eucalypts contain a large amount of water; often more than half the weight of the green wood is made up of water. Green eucalyptus logs sink immediately. This large amount of moisture and the irregular structure of the wood make eucalyptus lumber difficult to season properly. In color the wood of the eucalypts varies widely, as has been indicated, shades of yellow, brown, and red predominating. In hardness and dry weight there is also a wide range.

STRENGTH.

The material used in the eucalyptus tests was in every case selected from growing trees, so that the determination of the species was certain. The trees were all about 15 years old, with the exception of the two cut at Berkeley, Cal. (shipment 17), which were about 30 years old. The timber, therefore, contained a large amount of sapwood, and it must be borne in mind that the results of the tests were only such as could be obtained with wood from immature trees. The tests were made at the testing laboratory of the Forest Service, at the University of California, Berkeley, Cal.

Clear, straight-grained specimens are needed in determining the strength of the wood itself apart from the influence of defects. The results of tests made on this class of material can also be used for comparison with similar tests on other kinds of woods. Pieces 2 by 2 inches in section have been found well suited to tests of this kind. For bending [a] they are cut about 30 inches long, and for compression parallel to the grain and compression perpendicular to the grain, from 6 to 10 inches long. The blocks for shear parallel to the grain are cut with a projecting lip, which is sheared off under test. In making a bending test the beam is supported at the ends and loaded at the middle. The supports for the beam are on the weighing platform of the testing machine, so that the load on the beam can be determined at any time during the test. This load is applied by a crosshead which can be forced down on the test specimen by means of heavy screws turned by a train of gears. The deflection or bending of the beam is measured by an apparatus consisting of a light steel frame on which is mounted a movable pointer. In making a test the frame is rested on two nails driven into the beam near the ends and the pointer attached to the center of the beam in such a way that it moves over a graduated arc when the beam bends, and thus shows the deflection.

The test is conducted by loading the beam with about one-twentieth of the probable breaking load and noting the deflection. The load is then increased by a certain increment which is recorded with the corresponding deflection and the process continued until the beam breaks. The results of tests on beams of various sizes are reduced to a unit basis, so that direct comparisons as to strength and stiffness can be made between pieces of different sizes of the same or different species of wood.

In computing the results, the breaking strength is represented by "modulus of rupture," the stiffness by "modulus of elasticity," the load the material will carry without taking a set by "fiber stress at the elastic limit," and the ability to withstand shock without taking a set by "elastic resilience."

Tests in compression parallel with the grain are made by crushing the specimens endwise as they stand upright on the platform of the

---

[a] For a detailed description of methods used in the tests, see Forest Service Circular 38 (revised), "Instructions to Engineers of Timber Tests."

testing machine. In the case of compression perpendicular to the grain the tests are made by placing a piece of metal 2 inches wide across the test specimen as it lies flat on the platform of the machine and pressing the piece of metal against the block of wood by means of the crosshead of the machine. This test is carried only slightly beyond the elastic limit of the wood under test, since loading beyond that point has at present no significance. The action is similar to that of a rail on a tie.

FIG. 2.—Eucalyptus poles. Newark, Cal.

In making a shearing test the block is clamped firmly in a frame with the lip projecting. The frame is placed on the platform of the machine and the lip sheared off by applying a sliding plate to the upper surface of the lip in a direction parallel to the grain.

The moisture condition of the tested pieces is determined by cutting an inch section from them and drying the section at 100° C. until it ceases to lose weight. The loss in weight expressed in per cent of the dry weight indicates the moisture content of the piece at the time of the test.

BLUE GUM.

Table 1 gives the results of the tests on blue gum arranged according to locality of growth. The material cut in any one locality is designated as a shipment. In the case of shipments 10 and 17, tests were made on both green and air-dry material. In the other three shipments green material only was tested. At the bottom of Table 1 all the shipments are combined. In analyzing Table 1 a considerable variation in the strength values of blue gum grown in different localities is noticeable, and also a variation in the strength of the wood of trees cut from the same locality (shipments 66 and 84). In comparing the results of the tests on the different shipments values for green material are used so as to avoid the influence of moisture. It has been found that, in the case of small sticks, after a condition of about 30 per cent of moisture has been reached a further addition of moisture has no influence on the strength.

TABLE 1.—*Blue gum (Eucalyptus globulus). Strength of small, clear pieces, 2 by 2 inches in section.*

[Arranged according to locality of growth.]

	Condition of seasoning.	Moisture.	Weight per cubic foot.		Bending.					Compression parallel to grain.		Compression perpendicular to grain.		Shearing.	
			As tested.	Oven dry.[a]	Number of tests.	Fiber stress at elastic limit.	Modulus of rupture.	Modulus of elasticity.	Elastic resilience.	Number of tests.	Crushing strength.	Number of tests.	Strength at elastic limit.	Number of tests.	Strength parallel to grain.
SHIPMENT 10.—FROM TREE CUT NEAR SANTA MONICA, CAL.															
		Per cent.	*Pounds.*	*Pounds.*		*Lbs. per sq. in.*	*Lbs. per sq. in.*	*1,000 lbs. per sq. in.*	*In. lbs. per cu. in.*		*Lbs. per sq. in.*		*Lbs. per sq. in.*		*Lbs. per sq. in.*
Average	Green	77.8	66.0	45.2	52	5,135	9,880	1,504	1.05	111	4,150	....	....	26	1,326
Maximum	...do	111.1	68.6	50.1	....	7,350	11,920	2,020	2.28	....	5,315	....	....	....	2,005
Minimum	...do	58.8	61.8	38.5	....	1,360	6,550	950	.27	....	2,120	....	....	....	810
Average	Air dry	19.2	47.9	45.6	17	7,560	12,400	1,712	1.91	19	6,205	19	1,056	205	1,738
Maximum	...do	29.0	51.5	....	....	9,320	16,510	2,200	2.84	....	7,610	....	1,433	....	3,100
Minimum	...do	11.4	41.4	....	....	5,590	10,470	1,180	.79	....	4,800	....	552	....	1,100
SHIPMENT 17.—FROM TWO TREES CUT AT BERKELEY, CAL.															
Average	Green	43.8	61.8	52.3	19	8,616	13,887	2,789	1.55	17	6,158	17	1,415	38	1,725
Maximum	...do	53.5	67.4	55.6	....	10,300	15,500	3,520	2.43	....	7,070	....	1,679	....	2,522
Minimum	...do	36.4	56.8	47.2	....	6,550	12,270	2,042	.80	....	5,310	....	1,247	....	1,291
Average	Air dry	23.4	59.8	56.6	22	9,960	15,560	2,187	2.57	22	8,092	24	1,505	36	2,030
Maximum	...do	24.4	79.6	....	....	12,230	18,160	2,750	4.18	....	9,950	....	2,050	....	2,500
Minimum	...do	18.6	50.1	....	....	7,420	12,720	1,566	1.45	....	6,020	....	975	....	1,447
SHIPMENT 18.—FROM TREES CUT AT COLEGROVE, NEAR LOS ANGELES, CAL.															
Average	Green	71.0	68.2	48.6	27	5,820	10,400	1,386	1.41	31	4,725	32	1,221	60	1,602
Maximum	...do	109.4	74.3	61.4	....	8,010	13,800	1,754	2.45	....	6,230	....	2,476	....	2,320
Minimum	...do	45.0	52.0	40.4	....	4,330	7,740	916	.78	....	3,400	....	522	....	882

SHIPMENT 66.—FROM TREES CUT NEAR ELWOOD STATION, CAL.

Average......	Green.....	87.2	67.6	44.2	22	6,217	10,996	1,523	1.45	20	5,102	19	1,286	19	1,636
Maximum....	...do.......	115.3	71.4	48.6	....	8,030	12,400	1,817	2.25	....	5,920	....	1,597	....	2,000
Minimum....	...do.......	74.0	65.2	36.9	....	3,150	8,040	1,025	.38	....	4,090	....	920	....	1,230

SHIPMENT 84.—FROM TREE CUT NEAR ELWOOD STATION, CAL.

Average......	Green.....	61.5	69.3	52.6	38	9,650	14,850	2,115	2.53	36	6,770	33	1,415	30	1,796
Maximum....	...do.......	97.8	71.8	58.8	....	12,800	17,900	3,194	4.59	....	8,090	....	2,130	....	2,070
Minimum....	...do.......	47.3	63.3	40.1	....	6,330	11,000	1,215	1.33	....	4,150	....	1,060	....	1,470

ALL SHIPMENTS COMBINED.

Average......	Green.....	69.9	66.9	48.2	158	6,907	11,800	1,788	1.58	215	4,919	101	1,329	173	1,625
Maximum....	...do.......	115.3	74.3	61.4	....	12,800	17,900	3,520	4.59	....	8,090	....	2,476	....	2,522
Minimum....	...do.......	36.4	52.0	36.9	....	1,360	6,550	916	.27	....	2,120	....	522	....	810
Average......	Air dry....	21.6	54.6	51.8	39	8,914	14,183	1,980	2.28	41	7,218	43	1,307	241	1,782
Maximum....	...do.......	29.0	79.6	....	....	12,230	18,160	2,750	4.18	....	9,950	....	2,050	....	3,100
Minimum....	...do.......	11.4	41.4	....	....	5,590	10,470	1,180	.79	....	4,800	....	552	....	1,100

[a] The values in this column are based on a swelling of 21.8 per cent volume when the moisture is increased from 0 to the fiber saturation point or above. The fiber saturation point is taken as 30 per cent moisture.

In shipment 84, taken from a tree cut near Elwood Station, Cal., the average strength values for green material are greater than in the other shipments in bending (except modulus of elasticity in shipment 17), in both kinds of compression,[a] and in shear. In shipment 66, however, which was cut from the same locality as shipment 84, the strength values are lower than in the Berkeley material (shipment 17). The trees showing the lowest strength values were those cut near Santa Monica, Cal. (shipment 10). This, of course, must not be taken to mean that all blue gum grown near Santa Monica is comparatively weak. The material from Colegrove (shipment 18) is slightly higher in strength values than that cut near Santa Monica.

A combination of the results of the tests on green blue gum gives, in the bending tests, an average fiber stress at the elastic limit of 6,907 pounds per square inch; an average modulus of rupture of 11,800 pounds per square inch; an average modulus of elasticity of 1,788,000 pounds per square inch; and an average elastic resilience (shock-resisting ability) of 1.58 inch-pounds per cubic inch. The average crushing strength parallel to grain is 4,919 pounds per square inch; the average strength perpendicular to the grain at the elastic limit is 1,329 pounds per square inch; and the average shearing strength, 1,625 pounds per square inch.

In the air-dry material the strength is increased except in compression perpendicular to the grain. Several air-dry strength values for blue gum and similar values for white oak are given in Table 2 for purposes of comparison. The average moisture of the blue gum (21.6 per cent) is considerably higher than the average of the oak (12 per cent). To make the comparison perfectly fair, both woods should be at the same moisture content or both in a green condition. Such results for oak are not available. In considering Table 2, therefore, it should be kept in mind that the results from blue gum would be higher had the moisture been further reduced.

TABLE 2.—*Strength of air-dry blue gum and white oak.*

	Blue gum (21.6 per cent moisture).	White oak[b] (12 per cent moisture).
	Pounds per square inch.	*Pounds per square inch.*
Bending—modulus of rupture	14,183	13,100
Compression with grain—crushing strength	7,218	8,500
Shearing with grain	1,782	1,000

[a] The strength values for compression perpendicular to grain are the same in shipments 84 and 17.

[b] Taken from Forest Service Circular 15, "Summary of Mechanical Tests on Thirty-two Species of American Woods."

In a series of tests on hickory, now under way by the Forest Service, the average modulus of rupture of several kinds in a green condition, including pignut, shagbark, mockernut, big shellbark, nutmeg, and water hickory, runs from 9,200 pounds per square inch for nutmeg hickory, which is considered an inferior variety, to 11,450 pounds per square inch for pignut. For comparison with these figures, blue gum has an average modulus of rupture for green material of 11,800 pounds per square inch, or slightly larger than for pignut hickory. The dry weight per cubic foot of blue gum is about 49 pounds. The average weight of oven-dry pignut hickory is about 51 pounds per cubic foot.

OTHER SPECIES.

Table 3, arranged in the same way as Table 1, gives the results of tests on the four eucalypts, red gum, sugar gum, gray gum, and manna gum. Green sugar gum is seen to have strength values considerably above the other species. It has an average bending strength of 16,480 pounds per square inch and an average crushing strength of 7,215 pounds per square inch. Red gum (shipment 73) comes next in strength, with an average modulus of rupture of 12,570 pounds per square inch and an average crushing strength of 6,047 pounds per square inch. Shipment 14, also red gum from a different locality, is considerably lower in strength than shipment 73. Manna gum (shipment 9) shows the lowest strength values of the four species, although shipments 80 and 83, also manna gum, have strength values slightly above the weakest of the two red gum trees. Gray gum (shipments 68 and 77) occupies an intermediate position in regard to strength.

TABLE 3.—*Red gum (E. rostrata), sugar gum (E. corynocalyx), gray gum (E. tereticornis), and manna gum (E. viminalis). Strength of small, clear pieces 2 by 2 inches in section.*

[Arranged according to locality of growth.]

	Condition of seasoning.	Moisture.	Weight per cubic foot, as tested.	Bending.					Compression parallel to grain.		Compression perpendicular to grain.		Shearing.	
				Number of tests.	Fiber stress at elastic limit.	Modulus of rupture.	Modulus of elasticity.	Elastic resilience.	Number of tests.	Crushing strength.	Number of tests.	Strength at elastic limit.	Number of tests.	Strength parallel to grain.
		Per cent.	*Pounds.*		*Lbs. per sq. in.*	*Lbs. per sq. in.*	*1,000 lbs. per sq. in.*	*In. lbs. per cu. in.*		*Lbs. per sq. in.*		*Lbs. per sq. in.*		*Lbs. per sq. in.*
SHIPMENT 14.—RED GUM (E. ROSTRATA) FROM TREE CUT NEAR SANTA MONICA, CAL.														
Average	Green	61.9	67.1	9	5,048	9,496	1,137	1.27	17	4,255				
Maximum	do	75.5	69.3		6,650	12,100	1,628	1.94		5,230				
Minimum	do	28.1	64.3		3,260	8,070	749	.79		3,590				
Average	Air dry	17.4	55.6	9	6,042	12,369	1,201	1.84	8	6,508	12	1,848	17	2,587
Maximum	do	21.9	58.4		8,110	15,200	1,515	2.90		6,890		2,620		3,520
Minimum	do	13.3	49.9		3,280	9,630	990	.53		5,890		994		1,830
SHIPMENT 73.—RED GUM (E. ROSTRATA) FROM TREE CUT NEAR ELWOOD STATION, CAL.														
Average	Green	58.9	69.0	29	8,430	12,570	1,724	2.36	26	6,047	24	1,620	21	1,739
Maximum	do	87.2	75.6		11,000	15,100	2,246	3.87		7,270		2,680		2,220
Minimum	do	46.0	55.3		5,730	9,220	1,105	.96		4,160		1,060		1,280
SHIPMENT 11.—SUGAR GUM (E. CORYNOCALYX) FROM TREE CUT NEAR SANTA MONICA, CAL.														
Average	Green	43.1	70.9	11	9,770	16,480	2,215	2.42	30	7,215			4	2,139
Maximum	do	53.5	73.6		11,700	18,800	2,590	3.36		8,310				2,415
Minimum	do	35.1	67.5		6,860	14,800	1,890	1.39		5,790				1,960
Average	Air dry	18.0	63.4	9	10,519	19,046	2,207	2.90	17	8,370	17	2,304	20	2,829
Maximum	do	21.9	72.1		12,720	21,650	2,615	4.85		9,450		3,190		3,660
Minimum	do	13.8	57.0		8,580	17,020	1,855	2.03		6,000		1,333		2,000

SHIPMENTS 68 AND 77.—GRAY GUM (E. TERETICORNIS) FROM TWO TREES CUT NEAR ELWOOD STATION, CAL.

Average	Green	62.8	67.8	26	6,947	11,248	1,653	1.68	24	5,402	22	1,323	21	1,528
Maximum	do	98.5	74.4		9,740	13,400	4,460	3.09		6,420		1,875		1,850
Minimum	do	47.6	50.3		4,520	9,360	1,087	.52		3,870		766		925
Average	Air dry	18.1	64.7	13	10,820	16,327	2,300	2.88	13	8,898	13	2,441	12	2,106
Maximum	do	20.5	72.3		14,650	18,450	2,770	4.80		10,190		3,500		2,450
Minimum	do	15.6	50.6		7,630	13,200	1,810	1.63		7,100		1,500		1,843

SHIPMENT 9.—MANNA GUM (E. VIMINALIS) FROM TREE CUT NEAR CHICO, CAL.

Average	Green	85.6	66.5	33	5,121	8,740	1,222	1.35	48	4,220			20	1,606
Maximum	do	113.3	69.7		7,010	10,420	1,980	1.87		5,440				2,015
Minimum	do	57.6	57.6		3,400	7,260	762	.44		3,330				1,288
Average	Air dry	20.0	50.5	22	6,385	10,874	1,381	1.73	19	5,728	22	1,203	38	1,787
Maximum	do	41.1	56.9		9,120	13,750	1,760	3.22		6,390		2,150		2,540
Minimum	do	12.0	44.6		4,150	9,200	1,095	.36		5,040		650		1,056

SHIPMENTS 80 AND 83.—MANNA GUM (E. VIMINALIS) FROM TREES CUT NEAR ELWOOD STATION, CAL.

Average	Green	71.9	64.8	48	6,761	10,660	1,452	1.84	46	4,783	44	1,173	34	1,475
Maximum	do	101.5	79.4		8,530	13,100	2,287	3.13		5,780		1,640		1,760
Minimum	do	36.2	61.0		5,010	7,730	732	.90		3,900		806		1,010
Average	Air dry	17.2	49.9	19	9,067	15,096	2,167	2.14	18	7,269	14	1,283	13	1,619
Maximum	do	19.8	53.2		12,480	17,980	2,745	3.16		8,720		1,625		1,969
Minimum	do	15.3	44.0		5,620	11,430	1,582	1.02		5,720		1,092		1,323

Of the five species of eucalyptus tested, the highest strength values are possessed by sugar gum. It appears from a general résumé of the mechanical tests on the five species of eucalyptus that there may be a considerable variation in the strength of the same species grown in different localities or of different trees cut in the same locality. The strength of some species, such as sugar gum, blue gum, and red gum, compares favorably with that of white oak, pignut, and shagbark hickory, while the other species rank with what are considered the weaker varieties of hickory. The number of tests made on the eucalypts are too few to warrant final conclusions, but they indicate strongly that at least several species are equal to the better grades of hickory in bending and crushing strength.

Of course the quality that makes hickory superior to other woods for certain uses, particularly for vehicle construction and handles, is its toughness. Even though eucalyptus equaled or exceeded hickory in strength and stiffness, it could not compete with hickory for these uses unless it combined with its strength and stiffness a degree of toughness approaching that of the hickory. The experiments on eucalyptus have not yet been carried far enough to afford data for a comparison of its toughness with that of hickory.

Table 4[a] gives the partial results of tests on Australian eucalypts. In the case of blue gum the results are slightly higher than those on California-grown material, while red gum grown in Australia shows a lower strength than the average of the two California shipments. Of the other species in Table 4, yate, wandoo, and ironbark average about the same as California sugar gum, and the others about the same as California blue gum.

---

[a] Taken from the Supplement to the Western Australia Timber Tests. No statement was included as to whether the oven-dry weights were computed with the aid of a shrinkage factor. It is possible, therefore, that these tests were not made by exactly the same method as that followed in the case of the California woods.

TABLE 4.—*Strength of some of the eucalypts of Australasia.*

[Taken from the "Supplement to the Western Australian Timber Tests," 1906, by G. A. Julius, B. Sc. M. E.]

[Green material. Average values.]

Local name.	Botanical name.	Where grown.	Weight per cubic foot. When first cut (pounds).	Weight per cubic foot. Oven dry (pounds).	Moisture (per cent).	Bending. Number of tests.	Bending. Fiber stress at elastic limit (pounds per square inch).	Bending. Modulus of rupture (pounds per square inch).	Bending. Modulus of elasticity (1,000 pounds per square inch).	Compression parallel to grain. Number of tests.	Compression parallel to grain. Crushing strength (pounds per square inch).
Blue gum	E. globulus	Tasmania	70	49	44	142	8,700	12,100	2,450	41	5,500
Do	do	Victoria	69	49	40	139	9,000	12,000	2,250	37	5,850
Red gum	E. rostrata	do	64	44	44	112	5,100	6,800	740	43	3,750
Ironbark	E. paniculata and crebra.	New South Wales	80	57	40	160	12,450	14,600	2,175	35	7,750
Jarrah	E. marginata	Western Australia	68	48	50	203	8,300	10,600	1,450	290	6,250
Karri	E. diversicolor	do	72	50	54	312	8,600	11,500	1,750	385	5,500
Tuart	E. gomphocephala	do	78	60	43	318	9,300	11,800	1,630	331	6,975
Wandoo	E. redunca	do	79	62	28	287	11,750	14,000	1,850	324	8,320
Yate	E. cornuta	do	79	64	32	122	12,700	16,700	2,300	233	6,660

SHRINKAGE.

In order to determine the amount of shrinkage in blue gum, 28 pieces, $2\frac{1}{2}$ by $2\frac{1}{2}$ by 12 inches, were dried out slowly from a green to a bone-dry condition. Sixteen of the pieces were selected so that two sides were tangential to the annual rings of growth, while in the other twelve the rings ran diagonally. The drying was carried on first in a warm room and finally in an oven. The pieces were weighed and measured at intervals for a period of about one year.

When a piece of green or wet wood is dried, no change in dimensions takes place until a point called the "fiber-saturation point" [a] (generally in the neighborhood of 30 per cent moisture) is passed. The wood then begins to shrink in cross-sectional area and continues to do so uniformly with the removal of moisture until it is bone dry. Longitudinal shrinkage is so small as to be negligible. As a rule the heaviest wood shrinks the most, and sapwood shrinks more than heartwood of the same specific gravity. Shrinkage is greater also in the direction of the circumference of a log than in a radial direction.

The shrinkage tests on blue gum showed an average shrinkage in volume of 21.8 per cent [b] when pieces were dried from a green to an oven-dry condition. Of this amount about 7 per cent is radial

[a] For a full discussion of the fiber-saturation point, see Forest Service Circular 108, "The Strength of Wood as Influenced by Moisture," by H. D. Tiemann.

[b] All shrinkage percentages are given on a basis of oven-dry volume.

shrinkage and about 15 per cent tangential. Consider that air-dry wood contains about 10 per cent moisture; since the shrinkage varies uniformly with the removal of moisture after the fiber-saturation point is passed, the change in volume when the amount of moisture is reduced from 30 or above to 10 per cent will be only two-thirds as much as when the moisture is reduced from 30 to 0 per cent. That is, with a total shrinkage of 21.8 per cent, the reduction in volume when blue gum is dried from a green to an air-dry condition would be about 14 per cent. The maximum shrinkage in volume in the 28 blue-gum tests was 34.6 per cent and the minimum 13.5 per cent.

By way of comparison, eastern red oak, when dried from a green to an absolutely dry state, has an average shrinkage in volume of about 18 per cent—very little less than in the case of blue gum. For hickory, the data on shrinkage are very limited. Such tests as have been made indicate a shrinkage of from 20 to 30 per cent when the wood is dried from a green to an oven-dry condition.

SEASONING.

The seasoning of eucalyptus offers the most difficult and pressing problem in connection with extending the use of California-grown timber. In strength, hardness, and durability several species of California-grown eucalypts have shown themselves practically equal to certain of our native woods that are particularly useful on account of those very properties, but no satisfactory method of seasoning eucalyptus lumber grown in California has yet been worked out on a commercial basis. The warping of veneer material does not necessarily destroy its value, since it can be flattened by heavy pressure and held in position by glue.

In Australia, as stated in "Notes Regarding Timbers of Western Australia," [a] the practice is to strip and stack at the mills for at least twelve months all timber intended for such uses as joinery work, house building, and flooring. The custom of putting into almost immediate use freshly cut sleepers and bridge timbers and letting them season in the work is practiced to some extent, but is considered by Australian engineers as detrimental to the life of the timber. They recommend stacking structural material and allowing it to season before use.

In "Notes on the Commercial Timbers of New South Wales," by Mr. J. H. Maiden, it is stated that very few of the eucalypts will stand the severe test of being cut into flitches while fresh and full of moisture without warping and checking. Mr. Maiden states that good results may be obtained either by barking the tree and allowing it to die gradually before felling it, or by gradually drying the timber in the

[a] Issued in 1906 under authority of Hon. Newton J. Moore.

log before cutting it up. Emphasis is given to the fact that for the best results in seasoning the eucalypts should not be cut when the trees are bringing forth new leaves.

Successful methods of drying Australian eucalypts do not necessarily apply to California-grown wood, since not only are the conditions of growth different, but the trees cut in Australia for lumber are very much older than those in California.

The seasoning of the test specimens in the Forest Service experiments was accomplished by piling under cover. After two months'

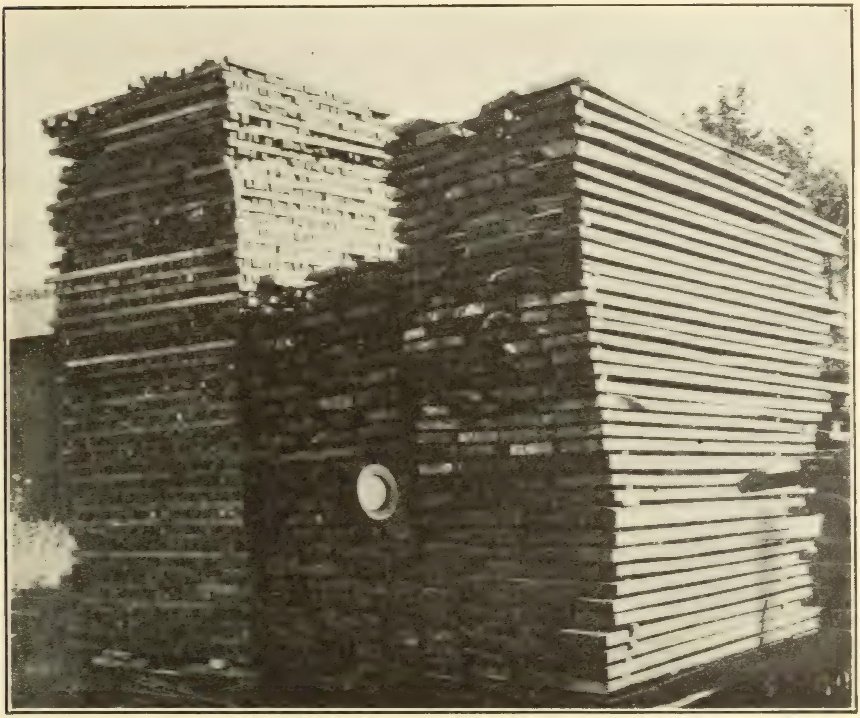

FIG. 3.—Blue-gum lumber seasoning in the yard. San Jose, Cal.

exposure in this way a portion of the sticks were kiln-dried. The process of seasoning was accompanied by much shrinkage and twisting in the sapwood of the young trees. The shrinkage occurred only in the sapwood, and was not uniform throughout the stick, so that the cross section of a square stick was distorted. It was not usually accompanied by checking and splitting in sticks 2 by 2 inches in section, although the drying was continued until not more than 8 or 9 per cent of moisture remained, a condition of dryness which corresponds to thoroughly seasoned stock. Sticks 4 by 4 inches in cross section which contained the heart or pith of the tree checked longitudinally during the drying, whether dried in the open air or in the kiln, but sticks of the same size which were cut at a distance of several inches from the heart showed no more inclination to split and check than did the sticks 2 inches square. Wood from the more mature trees gave better results in seasoning than that from the younger trees. Judging from the results of seasoning the test specimens, the same general rules should be followed in seasoning the eucalypts as in the case of the oaks and hickories. The early seasoning of green-sawed lumber especially should proceed slowly and evenly.

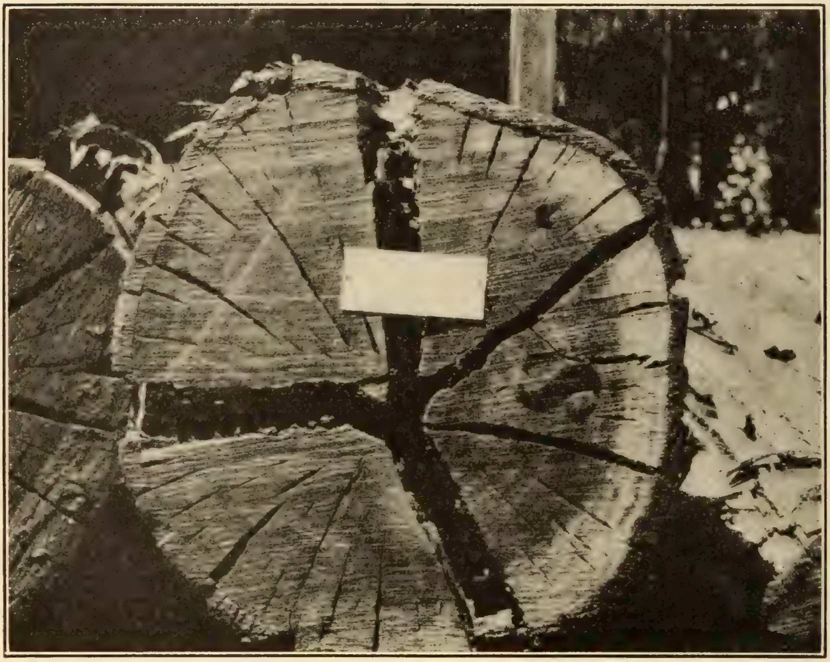

FIG. 4.—Unpeeled blue-gum pole cut March 26, after four months air seasoning. Sutro Forest, San Francisco, Cal.

In the most satisfactory seasoning of eucalyptus lumber so far accomplished, open piling under cover with uniform and close sticking has been practiced, together with high piling to produce weight. In some cases weights are placed on top of the piles to prevent warping and twisting during seasoning. When air seasoning alone is employed, three years' time is considered necessary for the most satisfactory results, although material seasoned for two years is used for less particular purposes.

Based partly upon Australian practice, a series of seasoning experiments has been started by the Forest Service to determine the best methods of handling California-grown eucalypts, particularly the blue gum. These experiments have not yet proceeded far enough to furnish data to answer the various questions to be determined. So far they have been confined to poles and logs, but they will be extended to include lumber, and possibly veneer. Only young, immature timber is included, since it is claimed that this class of material will be most widely utilized in California for lumber. The main points to be determined in the seasoning of logs and poles are:

(1) The effect of season of felling trees upon subsequent loss of moisture, checking, and shrinking.

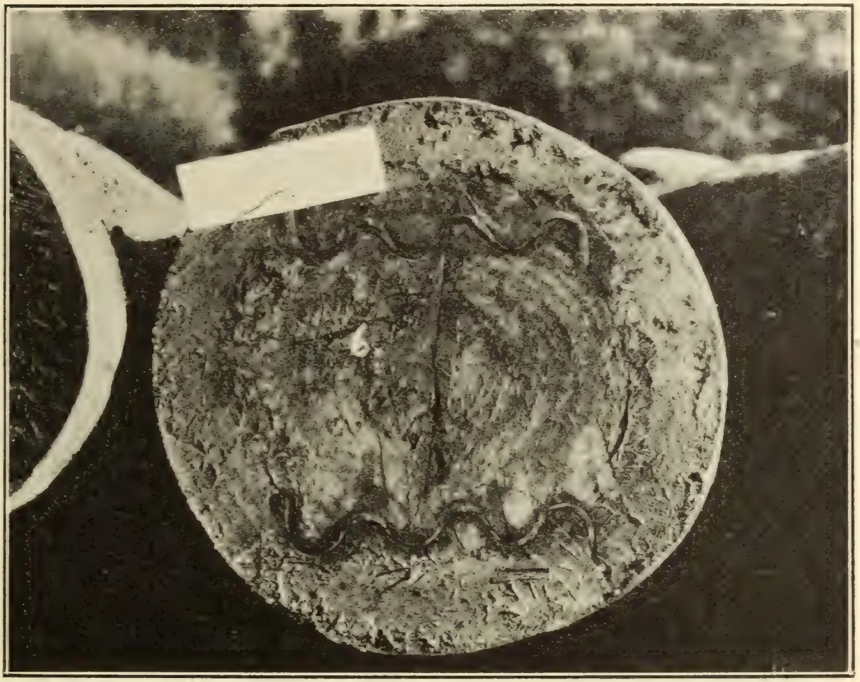

FIG. 5.—Blue-gum log protected with S irons to minimize checking during seasoning.

(2) The effect of the depth and the season of girdling upon loss of moisture, checking, and shrinking.

(3) The effect of peeling poles cut at different seasons upon the loss of moisture and the amount of checking and shrinking, as against leaving the poles unpeeled.

(4) The effect of various means of preventing checking, such as the use of S irons and painting the butts.

(5) The effect of soaking green peeled logs in fresh and in salt water for varying periods.

(6) The effect of climatic conditions on the coast and in the interior valleys upon rate of moisture loss, checking, and shrinking.

(7) The effect of methods of piling while seasoning on loss of moisture, checking, and shrinking.

For the pole-seasoning experiments 72 blue-gum trees from 10 to 13 inches in diameter, breast-high, with a clear length of 34 feet were obtained. Part of these trees were cut in the spring of 1909, and part in the fall. They were chosen from three different localities typical of coast fog-belt conditions, interior valley conditions practically free from fog, and inland conditions on the edge of the fog belt.

To determine the effect of soaking in fresh and salt water upon subsequent seasoning, forty 8-foot blue-gum logs, 10 to 12 inches in diameter, cut in the spring of 1909, were used. Some of the logs were peeled and some left unpeeled, and part of both lots were placed in fresh water and part in salt. At the beginning of the rainy season the same amount of material was obtained and subjected to the same treatment.

UTILIZATION.

Up to the present time knowledge based on actual utilization of California-grown eucalypts is meager. Not only has no large amount of timber of merchantable size ever been available, but manufacturers and consumers are naturally reluctant to use a new and little-known wood in place of those which have proved entirely satisfactory for certain purposes. However, enough has been done to indicate that some species of eucalypts grown in California may prove excellent substitutes for woods in use at present for cordwood, piling, posts, poles, cross-ties, mine timbers, paving blocks, insulator pins, furniture, finish, veneer, cooperage, vehicle stock, and tool handles.

Thoroughly seasoned eucalyptus makes a very satisfactory fuel. It gives a quick, hot fire, burns with a bright blaze, and emits a pleasant aromatic odor. Its heating qualities, as compared with other California fuel woods, have not yet been determined. At present eucalyptus for fuel purposes can be obtained at a somewhat lower price than California oak. The best fuel is obtained from the slower-growing, more mature trees. It is probable, however, that a large share of the eucalyptus cordwood placed on the market within the next few years will be cut from young, rapid-growing trees. It is necessary to split eucalyptus cordwood as soon as cut, as it will become very hard and tough as it dries. This is particularly true of blue gum. In some cases the fibers are so interlocked that it becomes impossible to split the blocks at all. In seasoning cordwood, the piles should be raised from the ground, or decay may take place in the lower layers.

The blue gum in its natural state does not make a satisfactory post or pole, because it decays rapidly in contact with the soil. This is particularly true of young, rapid-grown trees. Sawed posts or poles or split posts, consisting largely of heartwood, would undoubtedly give better results. However, trees large enough to make sawed poles will probably be of more value for other purposes, and it would be very difficult to split posts. Red and sugar gum are more durable than blue gum. It is probable that blue-gum posts with a creosote preservative treatment can be made equal or superior to redwood in durability. At the present price of redwood posts, however, it is a question whether such treatment would save money. For poles a preservative treatment costing from $1.50 to $3 will

FIG. 6.—A ferry slip, San Francisco, Cal., constructed of blue-gum piles.

probably make eucalyptus more durable than the untreated cedar and redwood now employed. Eucalyptus is so heavy, however, that the extra expense in handling would, in all likelihood, render the cost of the treated pole in the line too great to justify its use under present conditions. As the supply of cedar and redwood fails this condition may be changed.

The eucalypts are well fitted in form and strength for use as marine piles. An investigation of the condition of piling in Pacific coast waters demonstrated that blue gum is more durable than other untreated woods that are commonly used. Eucalyptus piles suffer less from abrasion, also, than piles of other species. The life of blue-gum piling has shown great variation at the several ports where it has been used, due probably to the difference of infestation by the marine borers at the different places, and to the difference in season of cutting. The resistance of the piles to the marine borers is believed by some pile users to be entirely due to hardness; by others, to the oils contained in the wood; and by still others to the combination of the two. Those who hold to the first view advocate cutting the trees when they are most nearly dormant; those who hold to the second, when growth is vigorous. The first generally advocate thorough seasoning; while the second insist that the piles should be driven green. The practice of driving the piles green is probably the best, for it prevents not only the loss of the oils by seasoning but also excessive checking. Old, slow-grown trees are to be preferred in all cases. Owing to their weight, eucalyptus piles are of course more expensive to handle than other timbers.

Very little eucalyptus has been used for cross-ties in the United States. A few hundred blue-gum ties were laid by the Southern Pacific Company in central Nevada some years ago. They exhibited good wearing qualities and had the requisite strength, but in some cases failed to hold the spikes, probably because the ties were laid while the wood was green, and consequently split badly in a short time. The ties lasted for four years without signs of decay, but at the end of eleven years few were still intact. If they had been thoroughly and carefully air seasoned before laying, better results might have been obtained.

At present eucalyptus for ship work and general construction purposes is obtained largely from foreign countries. As soon as the California material has had time to reach the necessary size, and the proper methods of seasoning have been worked out, it will probably be used to a considerable extent for structural purposes, since it possesses the necessary strength and is durable when not brought into contact with the soil. Eucalyptus has been used only to a very limited extent as a mine timber.

Thoroughly dry eucalyptus possesses every requisite of a first-class furniture wood. There has never been any attempt on a large scale to manufacture furniture from eucalyptus, but several sample pieces have been made with excellent success. The wood has a beautiful grain and takes a high polish. If thoroughly seasoned material is used there is little danger that furniture or finish made from it will not hold its shape.

The value of eucalyptus, particularly blue gum, for insulator pins, has been thoroughly demonstrated. Eucalyptus pins have been used extensively in California and have been shipped to Canada and the Eastern States. After fifteen years' service, sound pins are still in use.

Eucalyptus is sometimes used by farmers in California for wagon poles, shafts, axles, doubletrees, bolsters, spokes, hubs, felloes, and for the wooden parts of plows, harrows, and other agricultural implements, and, so far as known, it has given satisfaction. The results of the laboratory tests show that its strength is sufficient for vehicle construction.

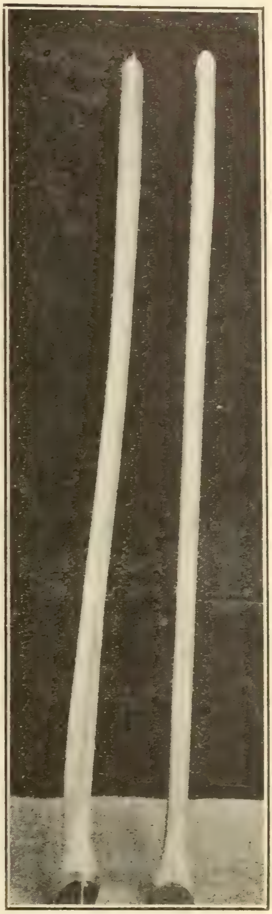

FIG. 7.—Blue-gum (crooked) and hickory (straight) ax helves. Blue-gum helve cut from plank air-seasoned for two years.

As yet the value of eucalyptus for cooperage stock is unknown. A barrel company in California made some 5-gallon and 10-gallon kegs from blue gum, which presented a satisfactory appearance. These kegs have been filled with wine to determine the effect of the wood upon it.

Ax and pick handles have been made from blue-gum planks cut from young trees. The planks had been air seasoned for about two years, but the handles, particularly those for axes, warped excessively.

Eucalyptus wood from immature trees may be regarded as having many prospective uses. The methods by which the wood is to be handled for the various uses are, however, not yet worked out, and many difficulties will doubtless be encountered on account of the tendency of the wood to shrink, warp, and check. Until these tendencies can be controlled the waste in utilization must necessarily be very great, and returns from commercial plantations consequently will be lower than they otherwise would be.

The value of eucalyptus for fuel is of course not influenced by its peculiarities of seasoning.

Another possible source of revenue is the distillation of the leaves and twigs for the production of eucalyptus oil. The higher grades of eucalyptus oil are at present manufactured largely in Australia, and there seems to be no good reason why the same methods applied in this country should not produce equally valuable oil.

EUCALYPTS IN AUSTRALIA.

Some time ago the Forest Service asked the American consul at Melbourne, Australia, a number of questions concerning the utilization of the native eucalypts in his district. The following quotations are from his replies, dated December 18, 1909, and June 30, 1910:

In reply to your letter of August 10, 1909, submitting certain questions relative to eucalyptus trees and lumber in this consular district (State of Victoria), I would inform you that as the result of interviews with the conservator of forests of the State and other inquiries upon the subject it is now possible to furnish the desired information, which will be found below. Your letter to the American consular agent at Fremantle, Western Australia, of same date and containing similar questions, has been replied to through this consulate, and the information, which was procured through the department of agriculture, which controls forestry matters in that State, will also be found herein:

STATE OF VICTORIA.

Question No. 1. What species are being manufactured and for what purpose? (Both common and botanical names.)

Answer. The following extracts from the evidence given before a Royal Commission on State Forests and Timber Reserves which investigated the subject in Melbourne in 1901 show the principal species and uses to which they are put, viz:

River red gum (*E. rostrata*).—The most important tree in the State on account of its durability and many uses to which it is put; the timber is of a very deep red, very heavy, hard, and dense, with inlocked grain; greatly valued for use in contact with the ground, hence preferred for piles, railway sleepers, fencing posts, house foundations, etc.; also largely employed for bridges and pier decking, short beams, cross-ties, and street-paving blocks, and makes excellent fuel and charcoal; a valued medicinal kino, which is a useful astringent, is extracted from the older trees.

Blue gum (*E. globulus*).—This valuable tree is of a straight symmetrical bole; timber strong and durable, and weighs about 60 pounds per cubic foot; makes good railway sleepers and is used for upper timbers and decking in jetty and bridge work, bridge piles, shafts, felloes, spokes, and framework of vehicles, and in general building and construction.

Question No. 2. In general what is the size and age of the trees being cut? Is young timber utilized, that is, trees under 30 years of age?

Answer. The indigenous virgin crop of lumber is still being cut in Victoria for the purposes of building and construction, i. e., sawmill lumber. No lumber goes through the mills cut from trees under 30 years of age or under 2 feet diameter, as such would warp badly; and in the case of framing for buildings, outside weatherboards or flooring would hollow in the "flat" and curl at the edges. As a general rule, red gum (*E. rostrata*) is cut with a saw at, say, 60 years and upward. In the case of the best lumber of this species, the ages of the trees are estimated to be from 100 to 150 years old. Red gum is largely used for piles for inland bridges, as well as jetties in navigable and tidal waters. The age of young pile trees used for such purposes, and ranging from 16 to 24 inches in diameter at the butt end, is estimated at 25 to 50 years, according to the soil in which the tree grows. Most eucalypts grow quickly up to about the twentieth to the twenty-fifth year, but, whether they are under artificial treatment or grow as a thick crop in a natural forest, they gradually slow off after some growth or increase of girth, as they begin to produce the best quality of lumber between the hardwood and sapwood. Trees under 30 years of age are only used for props in gold and coal mines. Young trees, such as red iron bark

(*E. leucoxylon*) and gray box (*E. hemiphloia*), are largely employed for telegraph and telephone poles, the length being 20, 25, and 30 feet; these range from 9 to 12 inches in diameter, and grow in the rotation of about 20 to 30 years. Trees such as blue gum (*E. globulus*) and white ash (*E. amygdalina*) are not, as a rule, durable when used in contact with the ground, and hence such trees, whether of pile or pole size, are not favored for telegraph, bridge, or jetty work. Iron bark and gray box poles or piles last on an average thirty years in the ground, but in some cases last even longer.

Question No. 3. What methods of seasoning are employed in bringing lumber into a thoroughly dry condition and what per cent is destroyed during the process of seasoning?

Answer. As a rule natural methods of seasoning only are employed; the lumber when cut being stacked horizontally with a slight dip at one end, and filleted or slotted between each row of pieces to secure even circulation of air; such lumber is usually kept for nine to twelve months before it is considered to be fit for use. In cheap construction, however, hardwood is often employed in an unseasoned condition, and, of course, shrinks and warps badly. Recently, owing to the difficulty of getting well-seasoned hardwood at short notice, the forest department of the State has undertaken to put in for experiment several drying kilns, one or two of which will be on the American "moist air" system, with or without fans or blowers. The loss of hardwood in drying is estimated at 8 to 12 per cent. Trees are felled at an age of 60 to 90 years for the production of sawn lumber.

WESTERN AUSTRALIA.

Answer to question No. 2. All sizes over 6 feet in girth measured at 3 feet from the ground. Small quantities of young timber under this girth are also used for piles and telegraph poles. The age is not known.

Answer to question No. 3. The only method of seasoning is that of drying in stacks in the open. No data are available as to the percentage that is lost in seasoning.

SOUTH AUSTRALIA.

Answer to question No. 1. To a certain extent for wheelwright's work, telegraph poles, posts and rails—some posts from trees 20 years old have lasted fifteen years and are still good—but older timber is often preferred if obtainable.

Answer to question No. 2. Most of the timber cut is the natural growth of the natural forests; computation of age is usually a difficult matter owing to the indefinite appearance of annual rings; but the age may be estimated in general (due regard being had to the species and location of the trees) at 50 to 200 years and sometimes over. Exceptional cases might occur of trees being 300 or 400 years old.

Answer to question No. 3. So far as can be ascertained, no artificial methods of seasoning are in use at the present time in this State, beyond the ordinary process of seasoning in the shade.

One of the pertinent facts brought out in these letters is the age of the eucalyptus trees required to produce satisfactory lumber. Another is the lack of definite information in Australia covering methods for rapidly drying eucalyptus lumber. Although it is by no means certain that conditions in Australia are directly comparable to conditions in California, yet the facts stated in the letters are certainly significant and should be borne in mind in developing the eucalyptus industry in the Pacific Coast States. If, for instance, it becomes necessary to wait sixty years or more before felling eucalyptus trees in California in order that the lumber may be suitable for finer uses, such as finish and furniture, it will have a decided bearing upon the profits to be obtained. For this reason a thorough investigation of the utilization of locally grown eucalyptus is well worth while.

Approved.

W. M. Hays,

Acting Secretary of Agriculture.

Washington, D. C., *July 22, 1910.*

[Cir. 179]