

U. S. FOREST SERVICE
RESEARCH PAPER

FPL 23

APRIL 1965

U. S. DEPARTMENT OF AGRICULTURE FOREST SERVICE
FOREST PRODUCTS LABORATORY MADISON, WIS.

Physical and Mechanical Properties of
SALIGNA EUCALYPTUS
Grown in Hawaii



ABSTRACT

Physical and mechanical properties were determined for saligna eucalyptus (Eucalyptus saligna, Smith) grown in Hawaii.

In comparison with wood of the same species grown in Australia, saligna eucalyptus grown in Hawaii was lower in density, shrinkage, and compressive strength parallel to grain; it was about equal in strength in bending and shear; and it was stiffer.

Compared to commercially important Mainland species, saligna eucalyptus grown in Hawaii is considered exceptionally stiff and the green wood is stronger than average for its density: however, strength of air-dry wood and hardness of green and air-dry wood are considered about average for the density.

Prepared in cooperation with the Pacific Southwest Forest and Range Experiment Station, U. S. Forest Service, The Division of Forestry, Hawaii Department of Land and Natural Resources provided substantial financial support, some material, and also aided in logging and preparing the material. R. G. Skolmen, Research Forester at the Station's Forestry Research Center, Hawaii, selected the material and provided information on the trees and forests sampled. Hawaiian Fern-Wood Ltd. logged part of the material and helped prepare material for shipment.

The Forest Products Laboratory is maintained at Madison, Wis., in cooperation with the University of Wisconsin.

PHYSICAL AND MECHANICAL PROPERTIES OF SALIGNA EUCALYPTUS GROWN IN HAWAII¹

By
C. C. GERHARDS, *Engineer*

FOREST PRODUCTS LABORATORY, FOREST SERVICE
U. S. DEPARTMENT OF AGRICULTURE

INTRODUCTION

Saligna eucalyptus (*Eucalyptus saligna*, Smith) is a diffuse-porous hardwood native to Australia where it is commonly known as Sydney blue gum. It has been described as rose red in color but may vary from pink to red, as having grain that is usually straight or slightly interlocked, and as being easy to work, nail, and finish (2).² A general-purpose hardwood, it has mainly been used for construction as plates, joists, and studs and for flooring and steps.

The species has been extensively planted in many other areas, including South Africa and Hawaii, where growth rate has been remarkable. In Hawaii the species, commonly known as saligna eucalyptus or floodedgum eucalyptus (4), is suspected of being hybridized to varying degrees with *E. grandis* and *E. botryoides*. Since saligna eucalyptus has grown so well, considerable interest

has developed in including it among species to broaden the Hawaii forest products industry, but knowledge of the properties of saligna wood grown in Hawaii has been practically nonexistent.

The U.S. Forest Products Laboratory, in collaboration with the Pacific Southwest Forest and Range Experiment Station and the Forestry Division of the Hawaii Department of Land and Natural Resources, undertook research to evaluate physical and mechanical properties of saligna wood that would be of most interest for its use in construction.

This report presents physical and mechanical properties of saligna based generally on standard methods of testing (1) and an evaluation of those properties in comparison to saligna grown in Australia and to commercially important Mainland species.

¹This Paper supersedes a preliminary report, "Some Strength and Related Properties of Green Wood of Hawaiian *Eucalyptus Saligna*," issued as U.S. Forest Service Research Note FPL-09 in 1963.

²Underlined numbers in parentheses refer to Literature Cited at the end of this paper.

DESCRIPTION OF MATERIALS

Material used in this study is considered representative of *saligna eucalyptus* grown in Hawaii. Trees from two sites, located about 60 miles apart on the island of Hawaii, were sampled. One of those sites is in Wood Valley about 5 miles from Pahala, and the other is about 3 miles from Honokaa in the Kalopa section of Hamakua Forest Reserve.

Both sites have somewhat similar growth conditions. Mean annual temperatures are about 70°F.,

with minimum winter temperatures of about 55°F.; high relative humidities persist all year. Annual precipitation averages about 60 inches at Wood Valley and 100 inches at Hamakua Forest Reserve. Both sites are located on gentle slopes at about 2,100 feet elevation where drainages are good and soils moist. Occasional floods have occurred at the Wood Valley site.

The material was obtained from planted trees introduced with other species in about 1911 at

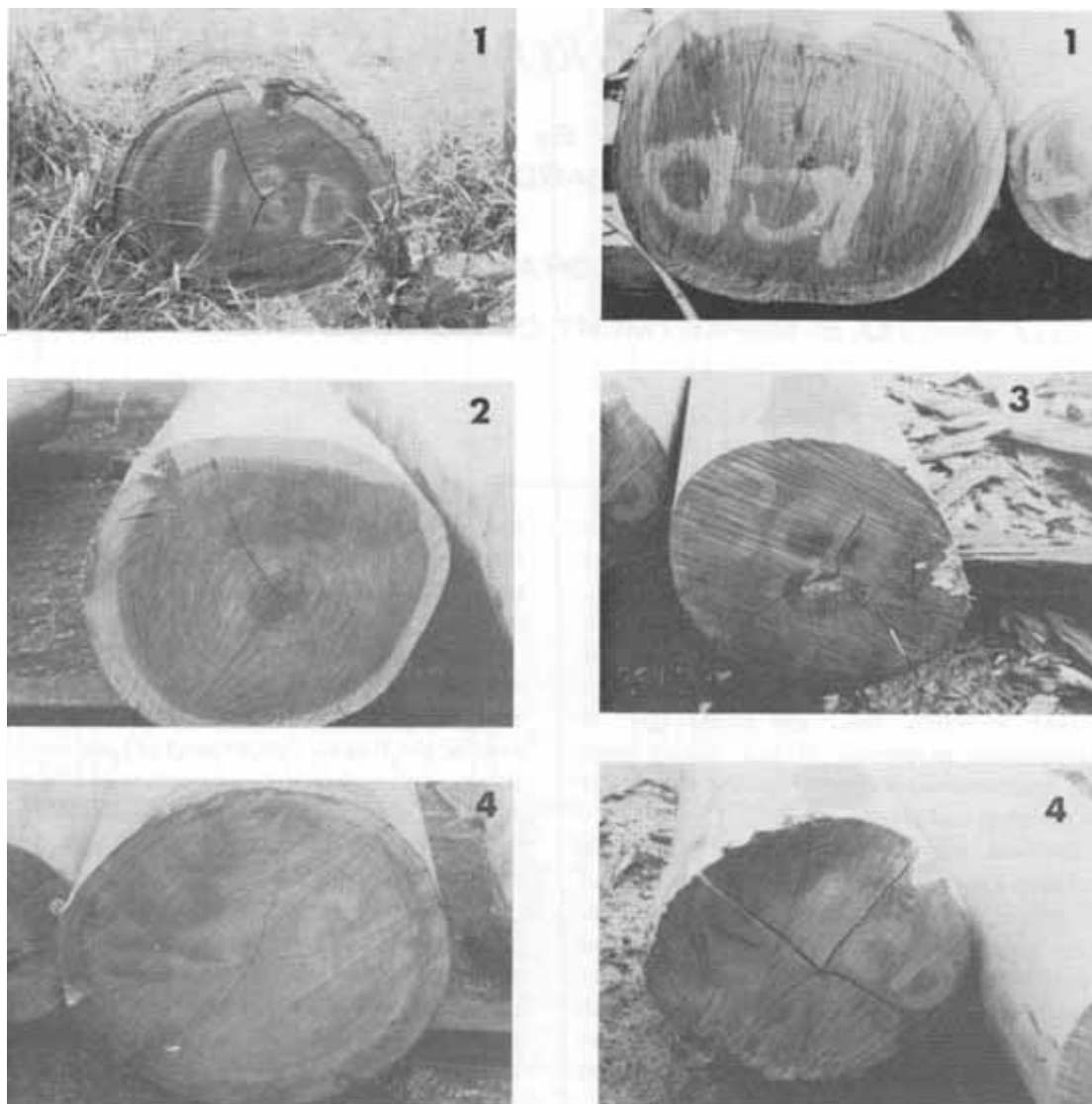


Figure 1.--Typical end splits in *saligna eucalyptus* bolts 1 day after felling or bucking. All are c-d bolts, those on the left from the Wood Valley site and those on the right from the Hamakua Forest Reserve. Number on each picture is the bolt number.

ZM 122 709

Wood Valley and in 1934 on Hamakua Forest Reserve. The planted forest in Wood Valley is composed of mixed eucalypts and silk-oak (*Grevillea robusta*) and is estimated to contain 150 trees per acre over 20 inches in diameter at breast height. *Saligna eucalyptus* trees, about 30 percent of the stand, are the largest in average size.

The forest on Hamakua Forest Reserve consists of 16 percent *saligna*, 55 percent *robusta* eucalyptus (*Eucalyptus robusta*), 23 percent silk-oak, and 6 percent ohia (*Metrosideros collina*).³ When the trees were sampled in 1961, the introduced species were 27 years old and the ohia was estimated to be 40 to 200 years old. Altogether there are about 80 trees per acre that exceed 12 inches in diameter at breast height in this forest. *Saligna* here was also slightly larger in average diameter than *robusta* eucalyptus or silk-oak.

Saligna trees sampled at Wood Valley in 1961 were about 50 years old. Those trees were either

dominant or codominant. They ranged between 22 and 37 inches in diameter at breast height and 150 and 200 feet high with 80 to 110 feet merchantable. The trees sampled from Hamakua Forest Reserve were all 27 years old, were dominant, ranged between 16 and 26 inches in diameter at breast height, and were 130 to 170 feet high with 60 to 90 feet merchantable.

Sample material consisted of the c-d bolt (8- to 16-foot height) of each tree and the a-b bolt (0- to 8-foot height), k-l bolt (40- to 48-foot height), and s-t bolt (72- to 80-foot height) of one of the trees from each site. All bark was removed from the bolts, and each bolt was brush-coated with pentachlorophenol and coated with a wax-type sealer.

End splits developed in all logs during either felling or bucking. Figure 1 shows photographs of some of the logs taken 1 day after felling. Enlargement and extension of those end splits and some checks that developed during shipping are



ZM 120 184

Figure 2.--End splits and checks in *saligna eucalyptus* bolts from Wood Valley site about 1-1/2 months after felling. Identified bolt-ends correspond to those shown on the left in figure 1.

³Also known as 'ohi' a-lehua, and formerly listed as *M. polymorpha*.

shown in figure 2 after the logs had arrived at this Laboratory--about 1-1/2 months after felling. Extensions of some of the end checks were evident

in disks cut from midbolt height at the time of specimen preparation. Representative midbolt cross sections are shown in figure 3.

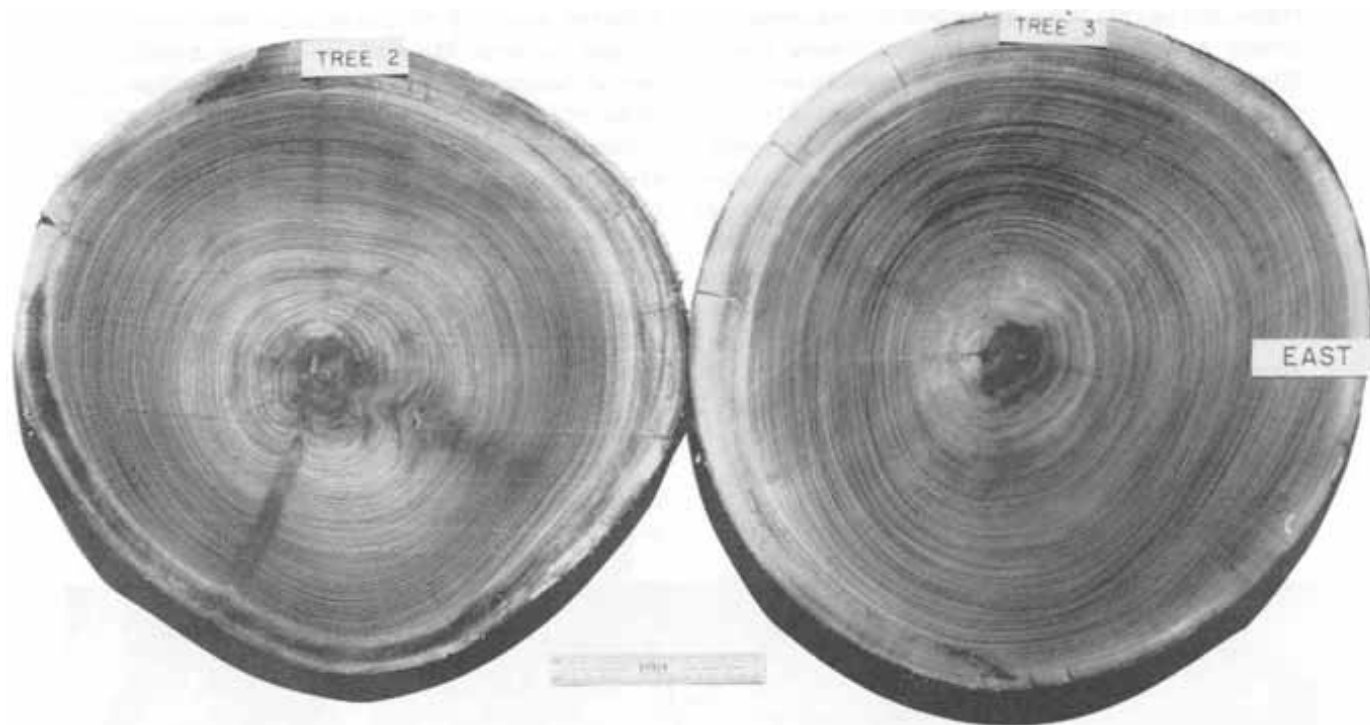


Figure 3.--Cross sections at midbolt height of two bolts of saligna eucalyptus from which specimen material was obtained, showing typical splits and checks (Wood Valley site). ZM 120 620

PROCEDURES

Standard methods (1) were used in determining properties, except for certain modifications in number of samples and their selection. These modifications consisted of limiting evaluation of mechanical properties to those of static bending, compression parallel to grain, hardness, shear, and toughness, and selecting specimens according to a random sampling method rather than the standard cruciform method.

The sampling method consisted of selecting standard-size sticks from random locations within each 4-foot-long bolt. Five sticks were selected for toughness, four for static bending, and two for each of the remaining properties. Stick selection was not limited to one type of test if sufficient material was available for another type. Special care was taken to cut sticks designated for hardness, shear, or toughness with a flat orientation

of annual rings,

Two end-matched specimens were cut from each stick designated for compression or hardness, and two end-matched pairs of radial and tangential specimens were cut from each stick designated for shear or toughness. A single specimen was cut from each stick assigned for static bending. One specimen or pair of specimens of each end-matched pair was tested in the green condition and the other air-dry. Two static bending specimens were tested green and the others air-dry.

In addition to the mechanical properties, the physical properties--radial, tangential, and longitudinal shrinkage and specific gravity related to position radially in the tree--were determined.

Radial and tangential shrinkage specimens were selected in the standard manner. Four longitudinal shrinkage specimens, 1 inch square by 10 inches

along the grain, were randomly selected from each 4-foot bolt. For evaluating specific gravity-radial position, specimens 2 inches square by 1 inch along the grain were serially cut along an average radius from log cross sections.

Shrinkages were measured from the green condition to equilibrium moisture contents at 75° F. and 64 percent relative humidity, 80° F. and 30 percent relative humidity, and oven-dry.

PRESENTATION OF RESULTS

Data on physical properties are presented in table 1 and data on mechanical properties in table 2. Data on variations of physical and mechanical properties of green wood are presented in table 3. For comparison, tables 1 and 2 contain published data for saligna eucalyptus grown in Australia (3, 5) and for a number of other

species (7, 8). Specific gravity-radial position relationships for some of the saligna logs are presented in figure 4. Data on physical and mechanical properties of saligna from various heights of two trees are presented and discussed in the Appendix.

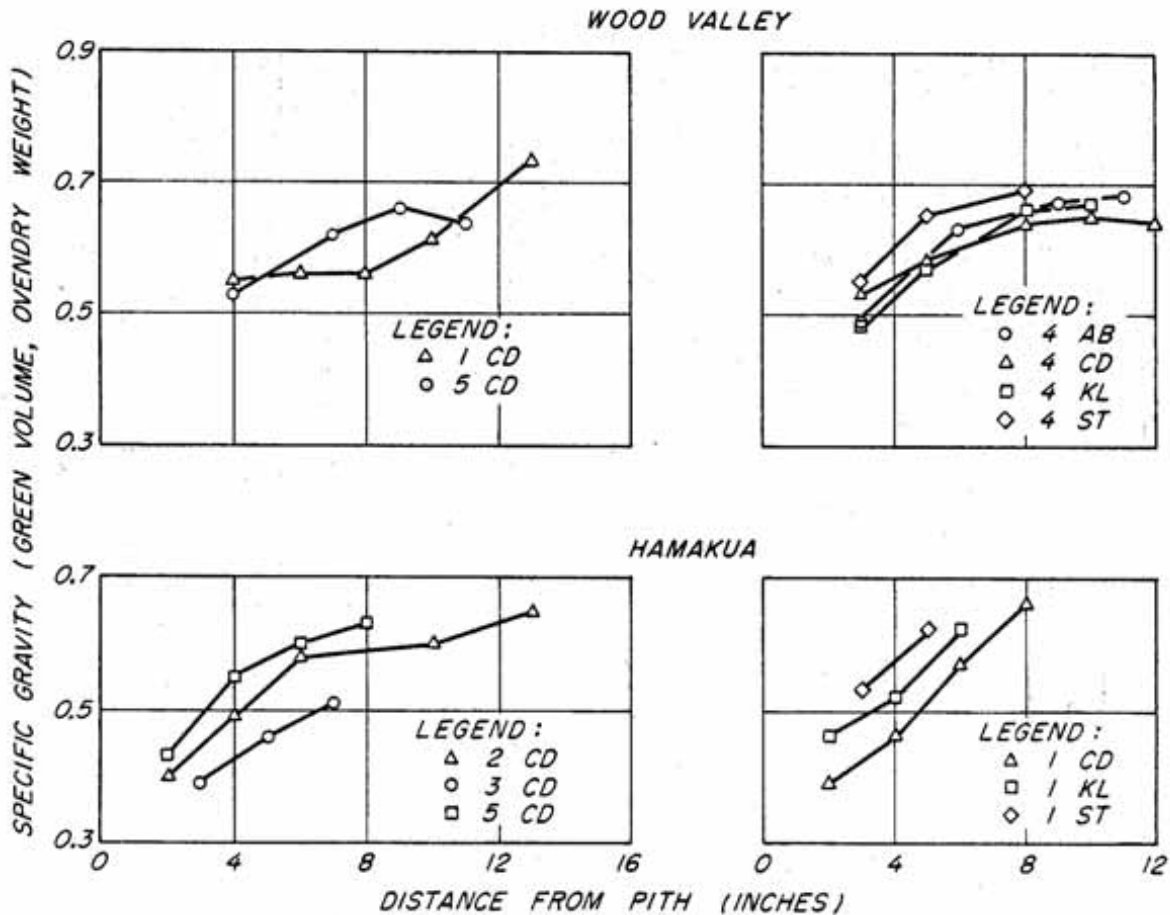


Figure 4.--Variation of specific gravity with radial position in the saligna eucalyptus trees from two sources.

Table 1.--Shrinkages and specific gravities of saligna eucalyptus grown in Hawaii and Australia and of other species¹

Species	Number: Specific gravity ² of trees			Shrinkage, green to --															
	Green	Air-dry	Volume	75° F., 64 percent relative humidity	80° F., 30 percent relative humidity	85° F., 20 percent relative humidity	90° F., 10 percent relative humidity	95° F., 5 percent relative humidity	100° F., 0 percent relative humidity	Longitudinal	Tangential	Radial	Longitudinal	Tangential	Radial	Longitudinal	Tangential	Radial	
<i>Saligna eucalyptus</i> from:																			
Wood Valley	5	0.63	0.70	13.4	4.0	9.0	0.03	4.2	12.7	6.6	5.7	11.1	0.11	4.1	16.3	7.3	12.7	0.22	4.1
Hanalei Forest Reserve	5	.55	.62	13.0	3.0	8.0	.01	10.8	6.4	4.5	10.0	.10	14.1	5.7	11.6	.22	16.8		
Average.....	10	.59	.66	13.2	3.5	8.5	.02	11.8	6.5	5.1	10.6	.10	15.2	6.5	12.1	.22	18.0		
Adjusted.....				12.0	3.8	8.8													
Other species from Hawaii ²																			
<i>Robusta eucalyptus</i> (<i>Eucalyptus robusta</i>)	8	.60	.66																
<i>Ohia</i> (<i>Metrosideros collina</i>)	11	.70	.81																
Species from the Mainland ³																			
White oak (<i>Quercus alba</i>)	20	.60	.68																
Shagbark hickory (<i>Carya ovata</i>)	24	.64	.72																
Yellow birch (<i>Betula alleghaniensis</i>)	17	.55	.62																
White ash (<i>Fraxinus americana</i>)	23	.55	.60																
Species from Australia ⁴																			
<i>Eucalyptus saligna</i>	19	.66	.75	12.0	5.4	9.5													
<i>Eucalyptus grandis</i>	33	.60	.67	12.0	4.1	7.5													
<i>Eucalyptus botryoides</i>	13	.71	.82	12.0	5.1	9.8													

¹Based on specimens from c-d bolts (8- to 16-foot height).

²Based on sticks selected for mechanical tests.

³12 percent moisture content.

⁴Based on radial, tangential, and longitudinal shrinkages.

⁵Forest Products Lab. Rpt. 2191, "Physical, Mechanical and other Properties of Five Hawaiian Woods," 1960.

⁶U.S. Dept. Agr. Tech. Bull. 479, "Strength and Related Properties of Woods Grown in the United States," 1935.

⁷CSIRO Div. of Forest Products Tech. Paper 13, "Shrinkage and Density of Australian and Other Southwest Pacific Woods," 1961.

Table 2.--Mechanical properties of saligna eucalyptus grown in Hawaii and Australia and of other species¹

Species	Number of trees	Moisture content	Specific gravity	Static bending			Toughness			Compression parallel to grain			Hardness	Shear parallel to grain	
				Modulus of rupture	Modulus of elasticity	Work to failure	Radial	Tangential	Proportional limit	Modulus of elasticity	Proportional limit	Modulus of elasticity			End	Side
				P.s.i.	P.s.i.	in.-lb. per cu. in.	in.-lb.	in.-lb.	in.-lb.	P.s.i.	P.s.i.	lb.	lb.	P.s.i.	
Saligna eucalyptus from:															
Wood Valley	5	64	0.63	8,000	2,000	12,300	1.86	13.0	370	390	4,030	2,260	5,850	1,250	1,550
	12	12	0.70	10,300	2,400	17,300	2.52	18.0	390	370	5,040	2,750	9,160	1,850	2,060
Manakua Forest Reserve	5	91	0.55	6,200	1,950	10,700	1.15	12.0	370	360	3,880	2,250	5,270	1,000	1,400
	12	12	0.62	9,400	2,370	15,600	2.13	16.7	400	360	5,320	2,740	8,670	1,340	1,660
Average.....	10	77	0.59	7,100	1,980	11,500	1.50	12.5	370	380	3,960	2,250	5,560	1,130	1,470
	12	12	0.66	9,900	2,390	16,400	2.33	17.4	390	370	5,180	2,740	8,920	1,600	1,860
Other species from Hawaii⁴															
Robusta eucalyptus (<i>Eucalyptus robusta</i>)	8	88	0.60	6,500	1,780	10,400	1.38	9.2	260	260	3,560	.....	5,260	1,100	970
	12	66	0.66	8,200	2,200	15,600	1.77	14.5	270	280	4,150	.....	8,200	1,670	1,330
Ohia (<i>Metrosideros collina</i>)	11	67	0.70	6,000	1,800	10,100	1.18	10.6	410	410	3,090	.....	4,720	1,340	1,680
	12	12	0.81	10,700	2,370	18,300	2.75	16.7	380	390	5,270	.....	8,900	2,390	2,090
Species from the Mainland⁵															
White oak (<i>Quercus alba</i>)	20	68	0.60	4,700	1,250	8,300	1.08	11.6	.....	.....	3,090	.....	3,560	1,120	1,060
	12	68	0.68	8,200	1,780	15,200	2.77	14.8	.....	.....	4,760	.....	7,440	1,520	1,360
Shagbark hickory (<i>Carya ovata</i>)	24	60	0.64	5,900	1,570	11,000	1.28	23.7	4720	4730	3,430	.....	4,580	.....	1,520
	12	72	0.72	10,700	2,160	20,200	3.01	25.8	4610	4660	.....	.....	9,210	.....	2,430
Yellow birch (<i>Betula alleghaniensis</i>)	17	67	0.55	4,200	1,500	8,300	0.70	16.1	2420	2410	2,620	.....	3,380	810	780
	12	62	0.62	10,100	2,010	16,600	2.89	20.8	2370	2370	6,130	.....	8,170	1,480	1,880
White ash (<i>Fraxinus americana</i>)	23	42	0.55	5,100	1,460	9,600	1.04	16.6	.....	.....	3,190	.....	3,990	1,010	960
	12	60	0.60	8,900	1,770	15,400	2.60	17.6	.....	.....	5,790	.....	7,410	1,720	1,950
Species from Australia⁶															
<i>Eucalyptus saligna</i>	7	64	0.64	7,200	1,770	11,000	.....	.....	.....	.....	4,540	2,000	5,930	1,390	1,310
	12	75	0.75	10,900	2,210	17,700	.....	.....	.....	.....	6,820	2,550	9,570	2,040	1,820
<i>Eucalyptus grandis</i>	18	64	0.64	7,400	1,940	11,700	.....	.....	.....	.....	4,930	2,340	5,970	1,300	1,240
	12	72	0.72	10,800	2,280	17,300	.....	.....	.....	.....	6,650	2,720	9,690	1,910	1,650
<i>Eucalyptus botryoides</i>	12	72	0.72	7,800	2,120	12,200	.....	.....	.....	.....	5,380	2,340	6,680	1,520	1,380
	12	82	0.82	12,200	2,540	18,900	.....	.....	.....	.....	8,030	3,050	11,100	2,370	2,140

¹Based on specimens from c-d bolts (8- to 16-foot height).

²Based on weight when oven-dry and volume at indicated moisture content.

³Based on sticks selected for mechanical tests.

⁴Forest Products Lab. Rpt. 2191. "Physical, Mechanical and Other Properties of Five Hawaiian Woods," 1960.

⁵U.S. Dept. Agr. Tech. Bull. 479. "Strength and Related Properties of Woods Grown in the United States," 1935.

⁶CSIRO Div. of Forest Products Tech. Paper 25. "The Mechanical Properties of 174 Australian Timbers," 1963.

Table 3.--Variation of strength and related properties of green wood of saligna eucalyptus grown in Hawaii^{1, 2}

Item	Number of specimens	Mean	Standard deviation	Coefficient of variation	Standard error of mean	Coefficient of variation of 50 species ³	Units for columns 3, 4, and 6
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
				Pct.		Pct.	
Specific gravity	204	0.59	0.084	14.3	0.006	10	.....
Shrinkage							
Radial--green to oven-dry	38	6.6	1.26	19.2	.20	15	Pct.
Tangential--green to oven-dry	40	12.1	2.20	18.1	.35	14	Pct.
Longitudinal--green to oven-dry	80	.22	.072	33.2	.008		Pct.
Static bending							
Fiber stress at proportional limit	39	7,120	1,892	26.6	303	22	P.s.i.
Modulus of rupture	39	11,510	1,807	15.7	289	16	P.s.i.
Modulus of elasticity	39	1,960	279	14.2	48	22	1,000 p.s.i.
Work to proportional limit	39	1.5	.70	46.7	.11	38	In.-lb. per cu. in.
Work to maximum load	39	12.5	2.76	22.1	.44	34	In.-lb. per cu. in.
Toughness:							
Load on radial surface	97	370	95.1	25.7	9.7		In.-lb.
Load on tangential surface	95	375	73.6	19.7	7.6		In.-lb.
Combined radial and tangential	192	372	85.0	22.8	6.1		In.-lb.
Compression parallel to grain:							
Crushing strength at proportional limit	34	4,000	1,025	25.6	176	24	P.s.i.
Maximum crushing strength	39	5,550	1,200	21.6	192	18	P.s.i.
Modulus of elasticity	38	2,250	426	19.0	69	29	1,000 p.s.i.
Hardness:							
End	40	1,127	262	23.3	41	17	Lb.
Side	40	1,120	251	22.4	40	20	Lb.
Shear parallel to grain:							
Maximum shearing strength	76	1,470	267	18.2	31	14	P.s.i.

¹Each specimen given equal weight, except for specific gravity, each stick given equal weight.

²Based on specimens from c-d bolts (8- to 16-foot height).

³From U.S.D.A. Agr. Handb. 72, "Wood Handbook," 1955.

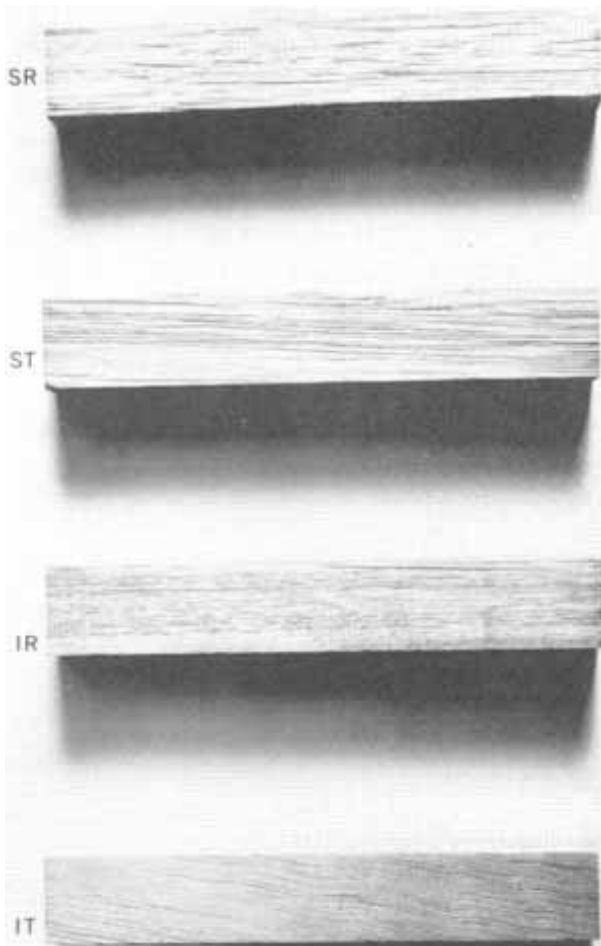
DISCUSSION OF RESULTS

Large trees of some species introduced into Hawaii contain a central core of brash wood termed "brittleheart." Brittleheart is suspected of being caused by long-term growth stresses that subject the interior of the tree to excessive longitudinal compression (6) Brittleheart may be suspected when logs split after falling or bucking,

as happened to the saligna eucalyptus of this study. Such wood was observed in specimens from the interior of saligna bolts. Test data from those specimens were generally excluded from the results in static bending, compression-parallel, and toughness,

Test specimens with grain slopes in excess of

1 in 20 are usually excluded from standard strength studies. The grain of saligna specimens was not always straight; in some cases it was highly interlocked, giving the appearance of severe cross grain on tangential surfaces. This may be observed in figure 5. Few specimens were actually culled



ZM 124 855

Figure 5.--Straight grain (S) and interlocked grain (I) in saligna eucalyptus grown in Hawaii. Radial surfaces are marked as R, and tangential surfaces as T.

because of this type of cross grain. When they were, it was generally because the resulting cross grain was severe and extended to an appreciable depth into the specimens. Thus, results of this study are not based on all straight-grained wood but reflect to a certain extent some interlocked grain.

Specific gravity of the wood generally appeared to increase with increasing distance from the pith (fig. 4) but had attained a maximum value in most of the 50-year-old trees from Wood Valley.

Average specific gravity of the wood from Wood Valley was higher than that from Hamakua Forest Reserve, but this was probably a reflection of the difference in ages of trees from both sites. Average specific gravity of saligna from both sites, 0.59 for green wood and 0.66 for air-dry wood, was lower than saligna or the suspected hybridizer species--*E. grandis* and *E. botryoides*--grown in Australia, practically the same as *robusta* grown in Hawaii, and slightly lower than white oak (*Quercus alba*) of the Mainland.

Shrinkage averaged higher in wood from Wood Valley than from Hamakua Forest Reserve. Average shrinkage to 12 percent moisture content was lower in saligna grown in Hawaii than in Australia. In both comparisons the results are normal because shrinkage within a species usually increases with increasing specific gravity (7).

Total shrinkage for Hawaii-grown saligna averaged somewhat higher than for *robusta* and slightly lower than for *ohia*. Compared to Mainland species, total shrinkage was higher than that for most commercially important species but similar to that for the true hickories (7).

As would be expected on the basis of its higher specific gravity, saligna from Wood Valley averaged higher in strength in static bending and in compression and shear parallel to grain than wood from Hamakua Forest Reserve. However, there was no appreciable difference in either modulus of elasticity or toughness.

Based on its modulus of elasticity, saligna can be considered to be an exceptionally stiff wood, especially in comparison to the commercially important species grown on the Mainland, as none had as high an average modulus of elasticity (7). Modulus of elasticity averaged somewhat higher in saligna grown in Hawaii than in Australia. On the average, strength of green wood of saligna in static bending and compression parallel to grain can be considered high for the density. Only a very few commercially important Mainland species exceed those strength values of saligna (7). The same strength properties of air-dry saligna, however, are exceeded by a number of species--mostly hickories but a few of the oaks and black locust as well. Compared to saligna grown in Australia, green wood from Hawaii averaged about the same in bending strength but less in compressive strength, and air-dry wood less in both bending and compressive strength.

Hardness of saligna can be considered about average for its specific gravity. Hardness values

for both green and air-dry saligna are generally comparable to those for many of the Mainland oaks and robusta grown in Hawaii but lower than those for saligna of Australia.

Shear strength of the green wood was slightly higher than might be expected for saligna's specific gravity, as it averaged slightly higher than many commercially important Mainland species of comparable specific gravity. Air-dry shear strength, however, was exceeded by many Mainland species, some of which were lower in specific gravity.

Toughness of both green and air-dry wood averaged essentially the same, but this has been

the usual result obtained for many species. Many species have not been evaluated for toughness according to the existing standard method; however, on the basis of available data, saligna may be considered of average toughness for its specific gravity. Its toughness was comparable to that of yellow birch or ohia but not to shagbark hickory, an exceptionally tough species.

With the exception of moduli of elasticity in static bending and compression parallel to grain, variations of data on the physical and mechanical properties as measured by the coefficient of variation were generally higher than average values reported for 50 species (7).



CONCLUSIONS

Based on the data obtained from samples grown at two sites in Hawaii, wood of saligna eucalyptus is exceptionally stiff and, when green, is stronger in static bending, compression parallel to grain, and shear than its average specific gravity of 0.59 would indicate. Strength of air-dry wood and hardness of green and air-dry wood are about average for the specific gravity of 0.66. Shrinkage of the wood is considered high for its specific gravity,

LITERATURE CITED

- (1) American Society for Testing and Materials. 1952. Standard methods of testing small clear specimens of timber. ASTM D 143-52.
- (2) Boas, I. H. 1947. The commercial timbers of Australia, their properties and uses. Commonwealth Sci. Indus. Res. Organ. 344 pp., illus. Melbourne.
- (3) Bolza, E., and Kloot, N. H. 1963. The mechanical properties of 174 Australian timbers. Commonwealth Sci. Indus. Res. Organ., Div. Forest Products Tech. Paper No. 25. Melbourne.
- (4) Bryan, L. W., and Walker, C. M. 1962. A provisional check list of some common native and introduced forest plants in Hawaii. Pacific Southwest. Forest and Range Expt. Sta. Misc. Paper 69.
- (5) Kingston, R. S. T., and Risbon, C. J. E. 1961. Shrinkage and density of Australian and other Southwest Pacific woods. Commonwealth Sci. Indus. Res. Organ., Div. Forest Products. Tech., Paper No. 13. Melbourne.
- (6) Skolmen, R. G., and Gerhards, C. C. 1964. Brittleheart in eucalyptus robusta grown in Hawaii, Forest Products Jour, 14(12): 549-554.
- (7) U.S. Forest Products Laboratory, 1955. Wood handbook. U.S. Dept. Agr., Agr. Handls. 72. 528 pp., illus.
- (8) Youngs, R. L. 1960. Physical, mechanical, and other properties of five Hawaiian woods. U.S. Forest Products Lab. Rpt. 2191.

APPENDIX A

Reported values of strength and related properties of wood have traditionally been based on wood obtained from c-d bolts or bolts near the c-d bolts. Usually, material from other heights in a single tree from each sample site have been evaluated to provide some idea of variation with height. Additional material from one tree at each site sampled for saligna eucalyptus was evaluated and results are presented in tables 4 and 5.

There does not appear to be any consistent pattern in the variation of specific gravity or mechanical properties with height in the two trees. However, there seems to be an indication in the amount that the wood shrank. In both trees, shrinkage of wood tended to increase with increasing heights up to at least 48 feet but then to decrease at some height above that point.

Table 4.--Shrinkages and other physical characteristics of saligna eucalyptus from various heights in two trees

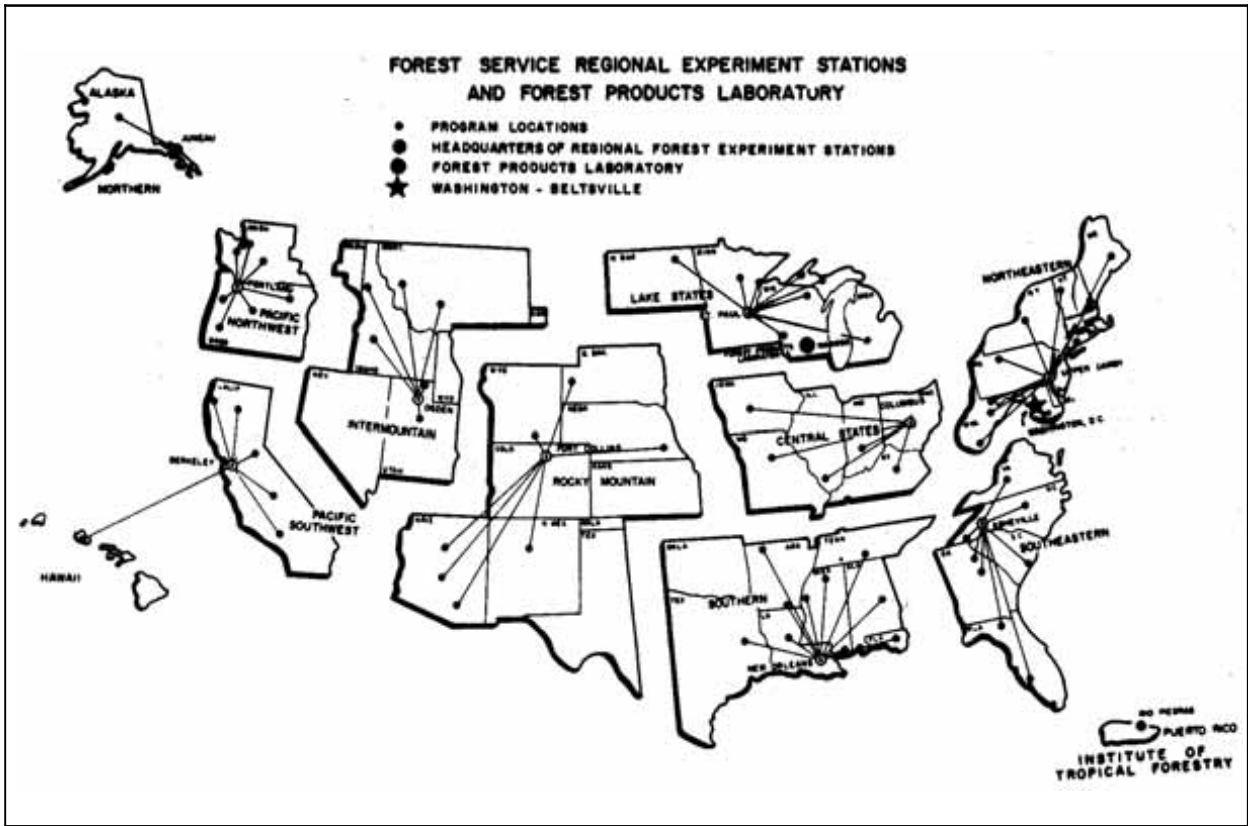
Source	Moisture content	Boil: No.	Moisture content	Shrinkage, green to --													
				Specific gravity	75° F., 64 percent relative humidity	80° F., 30 percent relative humidity	Owendry	Longitudinal: metric	Longitudinal: volume	Longitudinal: weight	Radial: metric	Radial: volume	Radial: weight				
Wood Valley	.66	a-b	.71	13.5	3.4	6.8	-0.01	10.0	6.6	5.0	9.0	0.10	13.6	6.4	10.5	0.21	16.4
		c-d	.73	13.5	3.4	7.4	-0.1	10.5	6.5	5.2	9.8	.08	14.6	6.6	11.3	.20	17.3
		k-1	.74	13.6	3.5	7.9	-0.1	11.1	6.7	5.7	10.2	.08	15.4	7.3	11.8	.19	18.4
		s-t	.60	13.7	3.7	7.4	-0.2	10.8	6.6	5.6	9.6	.06	14.7	7.2	11.3	.15	17.8
Hamabua Forest Reserve	.65	a-b	.70	13.4	2.3	6.6	.02	8.8	6.6	3.8	8.8	.11	12.4	4.9	10.3	.20	14.9
		c-d	.63	13.2	2.9	7.9	-0.1	10.6	6.5	4.4	10.0	.07	14.0	5.5	11.6	.16	16.6
		k-1	.64	13.0	3.5	8.4	.00	11.6	6.4	5.0	10.6	.10	15.2	6.4	12.2	.20	18.0
		s-t	.64	13.4	3.6	7.6	.02	10.9	6.5	4.8	9.9	.11	14.3	6.0	11.5	.20	17.0

¹Based on sticks selected for mechanical tests.
²12 percent moisture content.

Table 5.--Mechanical Properties of saligna eucalyptus from various heights in two trees

Source	Moisture content	No.	Moisture content	Static bending										Toughness				Compression parallel to grain				Hardness									
				Specific gravity	Propor: Modulus	Work to rupture	Modulus of rupture	Modulus of elasticity	Limit of proportionality	Modulus of rupture	Modulus of elasticity	Limit of proportionality	Modulus of rupture	Modulus of elasticity	Limit of proportionality	Modulus of rupture	Modulus of elasticity	Limit of proportionality	Modulus of rupture	Modulus of elasticity	Limit of proportionality	Modulus of rupture	Modulus of elasticity	Limit of proportionality	Modulus of rupture	Modulus of elasticity	Limit of proportionality	Modulus of rupture	Modulus of elasticity	Limit of proportionality	
Wood Valley	.66	a-b	.67	8,600	1,940	12,800	2,14	11.9	0.49	360	350	0.63	4,080	2,280	3,730	0.64	1,260	1,200	1,630	63	1,230	1,200	1,820	66	1,340	1,290	1,800	62	1,300	1,150	1,750
		c-d	.68	8,700	2,100	12,700	2.04	9.8	.51	350	390	.65	4,960	2,400	6,300	.53	1,250	1,200	1,820	.73	1,910	1,680	2,190	.69	1,730	1,520	2,030	.59	1,510	1,190	1,630
		k-1	.70	9,500	2,300	13,600	2.20	12.5	.52	380	370	.61	3,620	2,260	5,450	.66	1,340	1,290	1,800	.74	4,850	2,380	8,790	.73	1,880	1,720	2,160	.64	1,500	1,140	1,600
		s-t	.69	8,700	2,050	13,400	2.08	13.3	.53	380	410	.65	4,300	2,390	6,200	.62	1,300	1,150	1,750	.69	1,660	1,470	2,170	.59	1,500	1,150	1,630	.69	1,730	1,520	2,030
Hamabua Forest Reserve	.65	a-b	.68	8,600	2,080	14,600	2.05	12.8	.71	370	340	.69	5,050	2,390	8,300	.69	1,660	1,470	2,170	.72	10,200	2,380	8,200	.72	4,000	2,760	8,840	.69	1,730	1,520	2,030
		c-d	.72	10,200	2,380	16,000	2.45	14.2	.72	410	370	.72	4,100	2,420	8,290	.70	1,660	1,470	2,170	.73	1,910	1,680	2,190	.69	1,730	1,520	2,030	.59	1,510	1,190	1,630
		k-1	.75	11,100	2,610	17,300	2.75	16.6	.72	400	380	.70	4,350	2,820	8,290	.66	1,340	1,290	1,800	.74	4,850	2,380	8,790	.73	1,880	1,720	2,160	.64	1,500	1,140	1,600
		s-t	.74	11,500	2,510	17,800	2.90	18.6	.72	430	390	.74	4,850	2,380	8,790	.66	1,340	1,290	1,800	.69	1,660	1,470	2,170	.59	1,500	1,140	1,600	.69	1,730	1,520	2,030
Hamabua Forest Reserve	.65	a-b	.73	9,200	2,090	16,300	2.45	14.4	.70	310	340	.63	4,090	2,110	7,440	.63	1,260	1,200	1,630	.69	1,660	1,470	2,170	.59	1,500	1,140	1,600	.69	1,730	1,520	2,030
		c-d	.63	9,400	2,080	15,200	2.39	14.4	.63	310	330	.66	5,320	2,140	8,730	.66	1,340	1,290	1,800	.73	1,910	1,680	2,190	.64	1,500	1,140	1,600	.69	1,730	1,520	2,030
		k-1	.65	11,300	2,480	17,000	2.88	16.4	.66	400	380	.60	5,360	2,810	8,030	.60	1,340	1,290	1,800	.69	1,660	1,470	2,170	.59	1,500	1,140	1,600	.69	1,730	1,520	2,030
		s-t	.64	9,900	2,220	15,500	2.48	16.0	.65	360	340	.60	4,990	2,440	8,530	.60	1,340	1,290	1,800	.64	1,500	1,140	1,600	.69	1,730	1,520	2,030	.59	1,500	1,140	1,600

¹Based on weight when owendry and volume at indicated moisture content.



Forest Service regional experiment stations and Forest Products Laboratory



FOREST PRODUCTS LABORATORY
U.S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE - - - MADISON, WIS.



In Cooperation with the University of Wisconsin