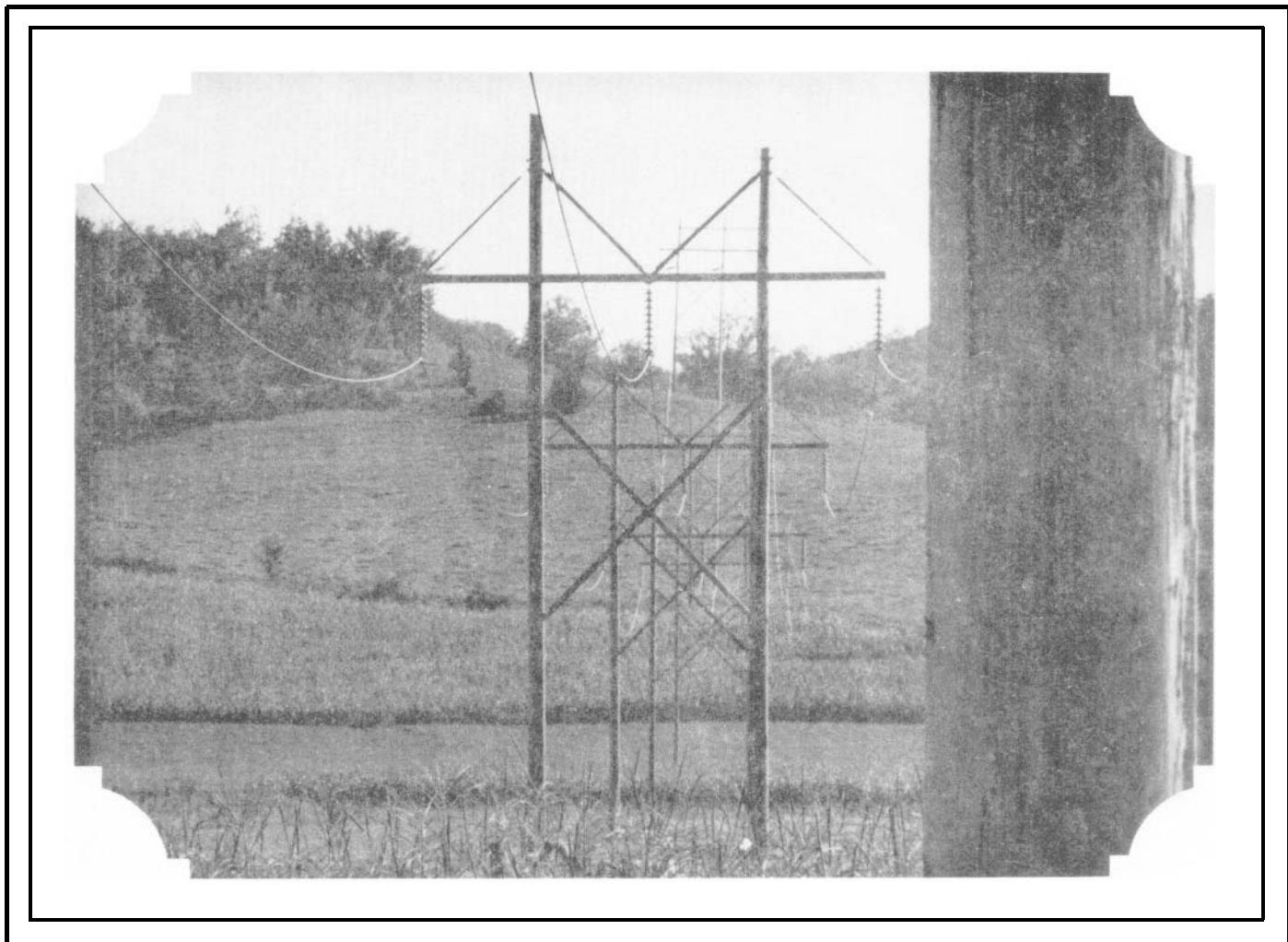


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U.S. DEPARTMENT OF AGRICULTURE ~ FOREST SERVICE ~ FOREST PRODUCTS LABORATORY ~ MADISON, WIS,

# DERIVATION OF FIBER STRESSES FROM STRENGTH VALUES OF WOOD POLES



## SUMMARY

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Factors of variability, round form, moisture content, and effect of preservative treatment that influence fiber stress values for wood poles are discussed. The report is based on the authors' studies of these factors for Sectional Committee 05 on Wood Poles of the American Standards Association. Tables of strength values from three sources of data are compared with the values adopted by the ASA.

# DERIVATION OF FIBER STRESSES FROM STRENGTH VALUES OF WOOD POLES

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Forest Products Laboratory<sup>1</sup>  
Forest Service  
U.S. Department of Agriculture

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By  
L. W. WOOD, Engineer  
and  
L. J. MARKWARDT, Assistant Director (Retired)

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## INTRODUCTION

Much information on the strength and related properties of wood poles has been obtained from the Wood Pole Research Program at the Forest Products Laboratory. The program was sponsored by the American Society for Testing and Materials in cooperation with some 75 agencies and organizations. The information was published by ASTM.<sup>2</sup>

Sectional Committee 05 on Wood Poles of the American Standards Association reviewed the data, leading to committee action<sup>3</sup> and adoption of a revised American Standard.<sup>3</sup> During the review, the authors of this paper, members of Committee 05, were asked to analyze the data from the ASTM program and other relevant sources and to report to the Committee on their

recommendations for the derivation of fiber stresses for pole design. The recommendations were discussed and modified in Committee and adopted.

Interest in the factors for conversion of strength test data to fiber stress for design was high at the time and has continued high as specification 05.1<sup>3</sup> is being discussed for adoption in national and state safety codes. This report, therefore, presents and discusses the authors' recommendations and modifications on fiber stresses made in Committee 05. The Laboratory representatives concurred in the action of the Sectional Committee.

The introduction to the report made to Committee 05 is pertinent and is repeated here as follows:

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<sup>1</sup>Maintained at Madison, Wis. in cooperation with the University of Wisconsin.

<sup>2</sup>Wood, L. W., Erickson, E. C. O., and Dohr, A.W. Strength and related properties of wood poles. American Society for Testing and Materials Special Technical Publication 295, 1960.

<sup>3</sup>American Standards Association. American standard specifications and dimensions of wood poles. American Standards Association Specification 05.1-1963. 1963.

"The extensive data from the ASTM Wood Pole Research Program, providing a comparison of the strength of treated and untreated poles, together with results of tests of small clear specimens and previous data affords the most comprehensive basis for establishment of stresses for wood poles that has ever been available. Earlier studies had shown that preservatives themselves, such as creosote, did not affect the strength of wood but the current study afforded for the first time an appraisal of the effect of different treating processes on strength that must be considered.

In the meantime, additional important information has been obtained on two fronts--the service performance of the different pole species

under current treating procedures and the moisture content of poles in service. An analysis and integration of all these factors is essential in reconciling some apparent inconsistencies in present data and translating the data into recommended design stresses. A careful study of the data along this line results in a system of rationalizations that afford the technical basis, supplemented by engineering judgment, for such design stresses. In this analysis it is not surprising that some discrepancies still exist, but speaking broadly, it is remarkable that nearly identical results are obtained between the analysis based on small clear specimens and that based on pole tests."

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## FACTORS CONSIDERED IN FIBER STRESSES

Factors considered in the analysis and interpretation of strength data to derive fiber stress include variability, form factor, moisture content, and treatment effect. Duration of load is an important factor in working stresses for many

wood products, but is omitted here because service loadings from wind gusts on ice-covered conductors are of short duration, comparable to the duration of the pole tests (about 15 minutes).

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## VARIABILITY

Variability has been traditionally recognized in developing design stresses for poles. When it was considered in the 1948 edition of the American Standard, it was thought that a value obtained by subtracting one-half the standard deviation from the average of individual pole strength values would be suitable for design.<sup>4</sup> That value was estimated to beat about the 5 percent exclusion level in the frequency distribution of actual bending moment resistances of groups of three poles in service.

The value recognizes that there is load-sharing among three adjacent poles and that pole sizes in any class vary from the required minimum to the minimum of the next larger class, design

being based on the minimum size. Later calculations confirmed this as a reasonable approach.

Table 11 of the ASTM pole report<sup>2</sup> summarizes the variability of modulus of rupture in six species of treated poles. The standard deviation (expressed in percentage) ranged from 10.8 to 16.0 percent, averaging 13.9 percent. This average value of the standard deviation was regarded as the most desirable estimate of variability to represent all species. The authors therefore recommended and the Committee approved that a factor of  $(100 - \frac{14}{2}) = 93$  percent be applied to average strength values to derive pole fiber stresses.

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## FORM FACTOR

Studies of small clear specimens at the Forest Products Laboratory have shown that the form factor for a beam of circular cross section,

compared with a square beam, is 1.18. Although there is a depth factor for poles, there is no direct evidence that it is the same as for sawn

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<sup>4</sup>Colley, R. H. Ultimate fiber stresses for wood poles. Bell Telephone System Technical Publications, Monograph B-615, about 1932.

beams. Evaluation of either factor is difficult, since they may be masked by other effects--such as the presence of the natural defects that are permitted with suitable limitations in poles.

Factors for round shape, depth, and defects were considered together by comparing the strength of small, clear specimens in standard strength tests with the strength of untreated poles in the ASTM program. The comparison is given in Table 1.

All but one of the ratios (table 1) exceeded unity, and the average of the seven values was 1.06. A value of 1.05 was recommended to the Committee as a reasonable evaluation of the combined form, depth, and defect factors applicable to the derivation of stresses for poles from standard strength data on small clear specimens. It

was later agreed in Committee that the low value of the ratio in lodgepole pine was due to an abnormal occurrence of defects, and that 1.08 was a better estimate of the combined factor,

Table 1. Comparison of strength of small, clear specimens with strength of untreated poles

Species	Average strength value		Ratio, poles to small clear specimens
	Small clear specimens	Poles--all sizes	
	P. S. I.	P. S. I.	
Western redcedar	5,120	5,370	1.05
Douglas-fir	7,590	8,180	1.08
Western larch	8,180	8,500	1.04
Lodgepole pine	5,490	4,810	.88
Longleaf and slash pines	8,620	9,260	1.07
Shortleaf and loblolly pines	7,320	8,720	1.19
All southern pines	7,970	8,990	1.13

### MOISTURE CONTENT

The indeterminate effect of moisture content on the strength of wood poles has been one of the factors involved in the inconsistencies of early test data on wood poles. To eliminate this factor completely, the ASTM Wood Pole Research Program was confined to unseasoned poles. Extensive studies have been made on moisture-strength relations of wood in small clear specimens, and reliable formulas have been developed for moisture-strength adjustment applicable to such material. The adjustments, even for small clear specimens, are valid only with uniform moisture distribution throughout the piece, with little or no moisture gradient between the interior and exterior. This condition cannot be attained in large single-piece members, such as structural timbers and poles. Available data on the increase in strength of wood poles with seasoning are rather meager.

A moisture-strength study by Wilson, Carlson, and Luxford<sup>5</sup> included a small amount of tamarack and shortleaf pine pole material. Their findings are illustrated in figure 1, A and B. The figures show strength increases of 17 and 10 percent over the green condition, respectively, at 20 percent moisture content.

Figure 1, C, shows average strength values in groups of lodgepole pine poles tested at various

moisture contents, adjusted to a basis of equal specific gravity. The data were presented in an interim report in the ASTM Pole Program. An increase in strength of 14 percent over the green condition at 20 percent moisture content is shown.

Although the data are not extensive, they suggest that a factor of 1.10 is a conservative estimate of strength increase in poles from seasoning to 20 percent moisture content.

Much information on moisture content of poles in service has been collected in recent years in a cooperative project of the Forest Products Laboratory and the Rural Electrification Administration. Poles surveyed generally had been in service for several years and were observed under a variety of conditions with respect to weather and previous rainfall. Results are summarized in table 2 (moisture contents below ground) and table 3 (moisture contents at two heights above ground).

Table 2 indicates that only Douglas-fir and western redcedar had moisture contents six inches below groundline that were lower than 20 percent in an appreciable percentage of the poles. Table 3 shows moisture contents at 6 inches and at 4 feet above groundline that were lower than 20 percent in a high percentage of poles in all of surveyed species. At 4 feet above ground, a zone

<sup>5</sup>Wilson, T. R. C., Carlson, T. A., and Luxford, R.F. The effect of partial seasoning on the strength of wood. Proceedings, American Wood-Preservers' Association, 1930.

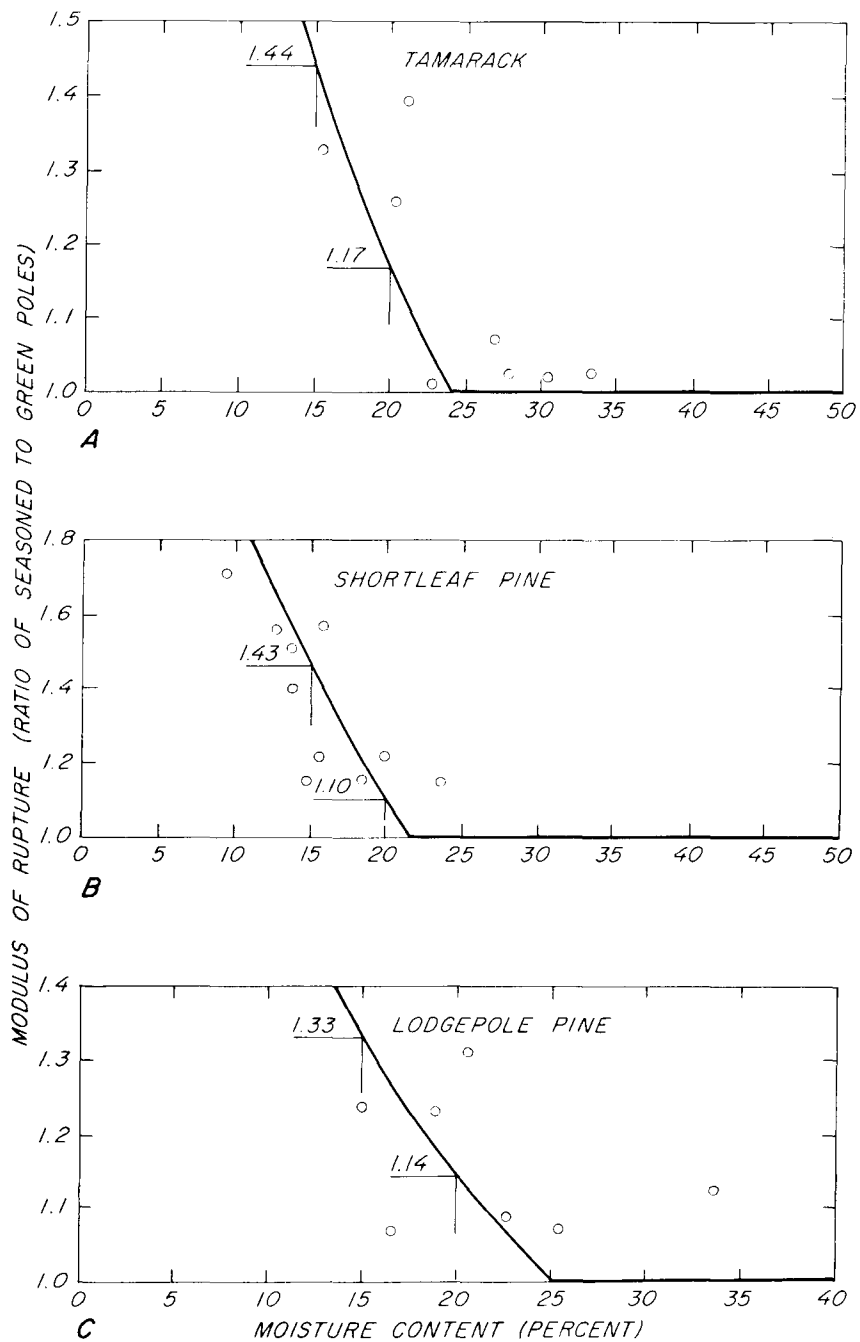


Figure 1.--Effect of moisture content on strength of poles of three species. A, Tamarack poles; B, shortleaf pine poles; and C, lodgepole pine poles.

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where poles commonly break from wind loads, southern pine was the only species with moisture contents lower than 20 percent in less than 96 percent of the poles. The higher moisture contents observed in southern pine reflect the common circumstance that steam-conditioned southern pine poles come from the treating cylinder with

moisture contents above the fiber saturation point,

An earlier report by the authors to Committee 05, based on the portion of the preceding data then available, indicated that moisture contents at 4 feet above the groundline would be lower than 20 percent in 83 percent of the southern pine poles in six Southeastern States. Table 3

Table 2.--Summary of moisture content survey 6 inches below ground in REA poles

Species	Region I <sup>1</sup>		Region II <sup>2</sup>		Region III <sup>3</sup>	
	Number of observations	Poles with moisture content below 20 percent	Number of observations	Poles with moisture content below 20 percent	Number of observations	Poles with moisture content below 20 percent
		Percent		Percent		Percent
Northern white-cedar	31	0	.....	.....	.....	.....
Western redcedar	127	7	.....	.....	47	13
Douglas-fir	166	17	57	39	144	12
Western larch	25	0	.....	.....	50	2
Jack pine	43	0	.....	.....	.....	.....
Lodgepole pine	181	4	29	0	184	9
Ponderosa pine	6	0	.....	.....	12	0
Red pine	2	0	.....	.....	.....	.....
Southern pine	363	1	223	0	46	2

<sup>1</sup>Region I, east of 100th meridian, north of 40th parallel.

<sup>2</sup>Region II, east of 100th meridian, south of 40th parallel.

<sup>3</sup>Region III, between 100th and 120th meridians.

Table 3.--Summary of moisture content survey above ground in REA poles

Species	Region I <sup>1</sup>			Region II <sup>2</sup>			Region III <sup>3</sup>			Region IV <sup>4</sup>		
	Number of observations	Poles with moisture content below 20 percent		Number of observations	Poles with moisture content below 20 percent		Number of observations	Poles with moisture content below 20 percent		Number of observations	Poles with moisture content below 20 percent	
		At 6 inches above ground-line	At 4 feet above ground-line		At 6 inches above ground-line	At 4 feet above ground-line		At 6 inches above ground-line	At 4 feet above ground-line		At 6 inches above ground-line	At 4 feet above ground-line
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
		Percent	Percent		Percent	Percent		Percent	Percent		Percent	Percent
Northern white-cedar	61	62	98	.....	.....	.....	.....	.....	.....	.....	.....	.....
Western redcedar	162	91	96	.....	.....	.....	201	98	99	.....	.....	.....
Douglas-fir	276	99	100	82	100	100	351	100	100	33	100	100
Western larch	25	100	100	.....	.....	.....	145	100	100	.....	.....	.....
Jack pine	88	85	100	.....	.....	.....	.....	.....	.....	.....	.....	.....
Lodgepole pine	280	93	98	29	100	100	481	99	99	.....	.....	.....
Ponderosa pine	23	100	100	.....	.....	.....	12	100	100	.....	.....	.....
Red pine	4	75	100	.....	.....	.....	.....	.....	.....	.....	.....	.....
Southern pine	490	72	90	633	66	85	94	100	100	.....	.....	.....

<sup>1</sup>Region I, east of 100th meridian, north of 40th parallel.

<sup>3</sup>Region III, between 100th and 120th meridians.

<sup>2</sup>Region II, east of 100th meridian, south of 40th parallel.

<sup>4</sup>Region IV, west of 120th meridian.

confirms that earlier report, or indicates slightly more drying in the humid Eastern States (Regions I and II). The authors' recommendation for a 10 percent increase in fiber stress for drying was modified in Committee 05 to 16 percent, based on the expectation that service moisture contents 4 feet above groundline would not exceed 20 per-

cent. Obviously, poles coming from treatment with higher moisture contents, as from steam-conditioning, will take time to dry to the lower value; how much drying may take place in transportation and storage, or what moisture content remains when the pole is placed in service, is not certain.

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## EFFECT OF PRESERVATIVE TREATMENT

The ASTM Wood Pole Research Program provided additional data on the effect of treating methods on strength of wood poles. These data, together with other available information on preservative treatment penetration and retentions, suggested effect of treatment factors that were applicable to the different methods employed for different species.

With the modifications of the steaming treat-

ment, three factors were recommended, as follows: Group A species, air dried and treated, 1.00; Group B species, Boultonized or equivalent, 0.90; and Group S species, steamed at 245° F. maximum and treated, 0.85. The application of these factors affords a basis for translating data on modulus of rupture of the untreated wood in terms of design stresses for treated poles with respect to treating method.

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## SPECIES FIBER-STRESS VALUES

The foregoing considerations yielded factors that were used to convert laboratory test values to values representing pole strength and pole use. Values were computed from three sources: standard strength tests of small, clear, green specimens, tests of full-size untreated poles, and tests of full-size treated poles. The original and converted values from each of the three sources are given in table 4. The table shows values of small, clear, green specimens from ASTM test poles for comparison with those from standard strength tests. It also shows the effect of the converted values from modifying the drying increase from 10 to 16 percent and the form factor from 1.05 to 1.08. Fiber-stress values adopted in Committee 05 are found in the last column of table 4.

With some exceptions, table 4 shows general agreement among the pole values computed from the three sources of data. This may be seen by comparing values in columns 7, 8, and 9 and values in columns 10, 11, and 12. Such a comparison gives validity to fiber stresses from standard strength tests of small clear specimens in those species where full-size poles were not tested.

The most important exception to close comparisons of values from the three sources occurs

in treated southern pine. These poles were steam-conditioned under older specifications permitting 259° F. maximum temperature, while the steaming records showed that this maximum was exceeded in some instances. A supplementary study in the ASTM Program<sup>2</sup> showed that steaming with a maximum temperature of 245° F. resulted in about 15 percent reduction of strength. That reduction was used in adjusting the strength of full-size untreated southern pine poles to give the converted values in columns 8 and 11 of table 4. A small gain in strength was also realized by applying the requirement of six rings per inch, as indicated in columns 7 and 10 of table 4.

In the full-size poles, treated western larch was appreciably lower in strength than the untreated larch, due to differences in specific gravity. The untreated larch appeared to be more nearly representative of the species, as indicated by values converted from the small clear specimens.

In lodgepole pine, both untreated and treated full-size poles were lower than the values from small clear specimens. After thorough discussion in Committee 05, it was agreed to maintain the fiber stress of 6,600 pounds per square inch previously assigned to that species, in view of

the good service record of poles used at that stress level. There is some indication from several sources that lodgepole pine may gain

more strength drying in service than do other common pole species.

Table 4.--Strength values and fiber stresses for wood poles.

Species	Average of small clear specimens		Average test values from full-size ASTM poles, all sizes		Treatment group	Converted values based on a 10 percent increase for drying			Converted values based on a 10 percent increase for drying			Values adopted in American Standard 05.1-1963
	Untreated poles <sup>1</sup>	Standard strength tests	Untreated	Treated		Small clear specimens in standard strength tests <sup>2</sup>	Untreated poles <sup>3</sup>	Treated poles <sup>4</sup>	Small clear specimens in standard strength tests <sup>2</sup>	Untreated poles <sup>5</sup>	Treated poles <sup>4</sup>	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
	P.s.i.	P.s.i.	P.s.i.	P.s.i.		P.s.i.	P.s.i.	P.s.i.	P.s.i.	P.s.i.	P.s.i.	P.s.i.
Cedar												
Alaska-	.....	6,450	.....	.....	A	6,930	.....	.....	7,510	.....	.....	7,400
Northern white-	.....	4,250	.....	.....	A	4,560	.....	.....	4,950	.....	.....	4,000
Western red-												
United States	6,060	5,120	5,370	5,240	A	5,500	5,490	5,360	5,960	5,790	5,650	6,000
Canada	5,360	4,980	4,910	.....	A	5,350	5,020	.....	5,800	5,300	.....	6,000
Douglas-fir												
Coast	7,780	7,590	8,180	7,630	B	7,340	7,530	7,810	7,960	7,940	8,230	8,000
Inland north	.....	6,600	.....	.....	A	7,090	.....	.....	7,690	.....	.....	8,000
Fir												
California red	.....	5,950	.....	.....	A	6,390	.....	.....	6,930	.....	.....	6,600
Grand	.....	6,060	.....	.....	A	6,510	.....	.....	7,060	.....	.....	6,600
Noble	.....	5,790	.....	.....	A	6,220	.....	.....	6,750	.....	.....	6,600
Pacific silver	.....	5,890	.....	.....	A	6,300	.....	.....	6,860	.....	.....	6,600
White	.....	5,700	.....	.....	A	6,120	.....	.....	6,640	.....	.....	6,600
Hemlock, western		6,140			A	6,590			7,150			7,400
Larch, western	8,420	8,180	8,500	7,120	B	7,900	7,830	7,280	8,580	8,250	7,680	8,400
Pine												
Jack	.....	6,030	.....	.....	A	6,480	.....	.....	7,020	.....	.....	6,600
Lodgepole	5,100	5,490	4,810	5,030	A	5,900	4,920	5,150	6,400	5,190	5,430	6,600
Ponderosa	.....	5,130	.....	.....	A	5,510	.....	.....	5,980	.....	.....	6,000
Red	.....	5,820	.....	.....	A	6,250	.....	.....	6,780	.....	.....	6,600
Pine, southern												
Loblolly	7,480	7,340	8,990	5,540	S	6,700	7,810	5,670	7,270	8,240	5,980	.....
Longleaf	8,940	8,670	8,920	6,610	S	7,920	7,750	6,760	8,580	8,180	7,130	.....
Shortleaf	7,710	7,300	8,450	5,700	S	6,660	7,340	5,830	7,220	7,750	6,150	.....
Slash	8,010	8,570	9,600	7,850	S	7,820	8,340	8,030	8,480	8,800	8,470	.....
Average of 4 species												
6 rings per inch and over, all species	8,040	7,970	8,990	6,420	S	7,280	7,810	6,570	7,900	8,240	6,930	.....
Redwood	.....	6,060	.....	.....	A	6,510	.....	.....	7,060	.....	.....	6,600
Spruce												
Engelmann	.....	4,540	.....	.....	A	4,880	.....	.....	5,290	.....	.....	5,600
Sitka	.....	5,660	.....	.....	A	6,080	.....	.....	6,590	.....	.....	6,600
White	.....	5,580	.....	.....	A	5,990	.....	.....	6,500	.....	.....	6,600

<sup>1</sup>Values adjusted to groundline height of pole.

<sup>2</sup>Converted by applying the indicated increase for drying and factors of 1.05 for round form, 0.93 for variability, 1.00 for Treatment Group A, air dried and treated; 0.90 for Treatment Group B, Boultonized or equivalent and treated, and 0.85 for Treatment Group S, steamed at 245° F. maximum and treated.

<sup>3</sup>Converted by applying the indicated increase for drying, a factor of 0.93 for variability; and treatment factors as shown in footnote 2.

<sup>4</sup>Converted by applying the indicated increase for drying and a factor of 0.93 for variability.

<sup>5</sup>Conversion factors as shown in footnote 2, except for a factor of 1.08 for round form.



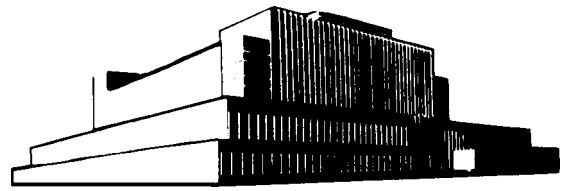
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