COMPARISON OF THE STRENGTH OF SECOND GROWTH VS. PLANTATION GROWN RED PINE POLES

Thesis for the Degree of M. S.

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ABSTRACT

There is, in the State of Michigan, a large reserve of red pine trees suitable for harvesting and processing for use as utility and building poles.

The objective of this study was to determine whether poles from plantation grown red pine trees are as strong and stiff as those from naturally regenerated trees. The American Standards Association Specifications [4] of dimension and defect limitations were assumed for acceptance of poles from both groups.

The objective was approached by the following three methods: (1) By comparing strength values of both groups in full scale bending tests (major tests), (2) by comparing strength values of both groups tested as small clear specimens (minor tests), and (3) by comparison of the values obtained in this study with the values of other published studies and reports.

Full scale tests were conducted on 32 poles from a plantation and 32 from a second growth stand. Ten small clear specimens were cut from the butt of each of these poles, of which five were tested in static bending and five in compression parallel to the grain.

The moisture content of all poles tested was above 30 percent. Plantation grown and second growth poles combined had an average modulus of rupture (maximum fiber stress in bending) of 4860 pounds per square inch, with a standard deviation of 475 pounds per square inch. There appeared to be no difference in the modulus of rupture, specific gravity, or in the sum of knot diameters between plantation and second growth poles.

COMPARISON OF THE STRENGTH

OF

SECOND GROWTH VS. PLANTATION GROWN

RED PINE POLES

by

Kim O. Wilkins

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INTRODUCTION

Acceptance criteria for poles are based upon the estimated loading to be resisted in service. Bending is the principal load system on poles in use. This bending load is caused by horizontal wind forces on wires, which are most critical when the wires are ice covered. Column loads are of little consequence except when poles support loads such as extremely heavy transformers and other objects. [10] Thus, the maximum fiber stress in bending (modulus of rupture in bending) is the strength property on which the poles can be judged.

The class designation of the American Standards Association [4] for poles depends on the circumference and the length of each pole under consideration. Because each class must carry a specific load, the modulus of rupture in bending for a species is used to determine the minimum circumferences for each length and class of pole.

American Bell Telephone Company conducted pole tests as early as 1891. The first pole tests by the United States Forest Service were made at the University of Colorado in 1911. [11] The American Standards Association established a committee for dealing with poles in 1924. In 1931 the ASA Sectional Committee 05.0 published the first specifications for allowable fiber stress values of utility poles. [10] These specifications underwent several revisions until the 1948 edition was published. The maximum fiber stress value for red pine was listed as 6600 psi. Due to much criticism of the entire 1948 specifications, the ASTM Wood Pole Research Program was established in 1953, under the direction of ASTM

Committee D-7. In 1954 extensive testing of wood poles began at the Forest Products Laboratory. Some 620 poles were tested by the completion date of 1960. During this time the Ontario Hydro Research Division tested western red cedar, jack pine and red pine poles. Their report of 1958 [8] indicated that the maximum fiber stress of red pine was 5749 psi.

The ASTM Wood Pole Research Program did not include testing of red pine, however, the recommendation was made that the maximum fiber stress of red pine remain at 6600 psi, the value which was listed in the ASA Specifications 05.0-1948. The final report listed the following conclusions: "There is significant correlation of the strength of untreated poles with that of untreated small clear specimens, and of treated poles with treated small clear specimens." [11]

Most of the prior testing of full scale poles has been conducted on poles which had been butt soaked. In the ASTM report,[11] poles were completely submerged and soaked long enough to bring their moisture content to, or above, the fiber saturation point before testing. No work has been done on the comparison of results to indicate the influence of moisture content on the strength of utility poles. No recent testing has been done on red pine, comparable to that conducted in the ASTM Wood Pole Research Program.

METHOD OF TESTING

All tests were conducted in accordance with ASTM Standards. The testing was divided into major and minor classifications. Major tests were conducted on the full size poles. Data was obtained to determine the moisture content, rate of growth, specific gravity, strength in static bending, and modulus of elasticity. Minor tests, modifications of ASTM Alternate Specifications D 1036-58 [2], were conducted on small clear specimens taken from the butt end of the poles. Data for strength in compression parallel to the grain was obtained in addition to data for the same properties on the full size poles listed above.

Major Tests

Source of Material. - Sixty four red pine poles, 32 grown in a plantation in Roscommon County, and 32 from natural regeneration (second growth) in Bloomfield Township, Missaukee County, were selected in accordance with ASA Standard 05.1-1963. [4] The poles were cut, shaved by machine and transported, by truck, to the Department of Forest Products Department, Michigan State University. Within 36 hours after cutting, the poles were placed in storage and covered with black six mill polyethylene sheeting. The moisture content was maintained above 30 percent by periodic spraying of water where poles had become exposed. Anti-stain solution was applied to all poles prior to storage under the sheeting to control staining and decay.

Description of Poles. - Both groups of poles were cut from trees with an average height of 56 feet. Pole lengths varied between 33 and 35 feet. Testing personnel cut the poles to 30 feet, removing the excess from the tip or butt, in order to vary the class of the pole and in order to allow for a better fit in the testing jig. Table 1. shows the classes of resulting poles, which are in accordance with the ASA Specifications 05.1-1963. [4]

TABLE 1.--Pole classes

Class of Pole		Plantation	Second Growth
5		12	11
6		15	17
7		5	3
9		--	1
	Total	32	32

Prior to testing, a comprehensive inspection was conducted on each pole and a record kept of the size and location of all knots larger than 0.5 inches and any other strength reducing defects. Records were also kept on the amount and location of crooks, sweeps, and stains. Figure 1. is a picture of the inspection of a pole and Figure 2. shows the method by which information was obtained. After each pole was broken, borings were taken at 2, 15, and 28 feet from the butt for moisture content determination.

Apparatus. - Each pole was tested in accordance with the cantilever method described in ASTM Standard D 1036-58. [1] The poles were individually placed on the test floor (see Figures 3 and 4) and the butts were clamped into a rigid position (see Figure 5). The load was applied at a continuous rate of four inches per minute with a hand winch. At each 100 pound interval of load, deflection readings were taken at the three locations shown in

Figure 1.--Bole inspection for defects, measurement of circumferences, and size and location of knots.

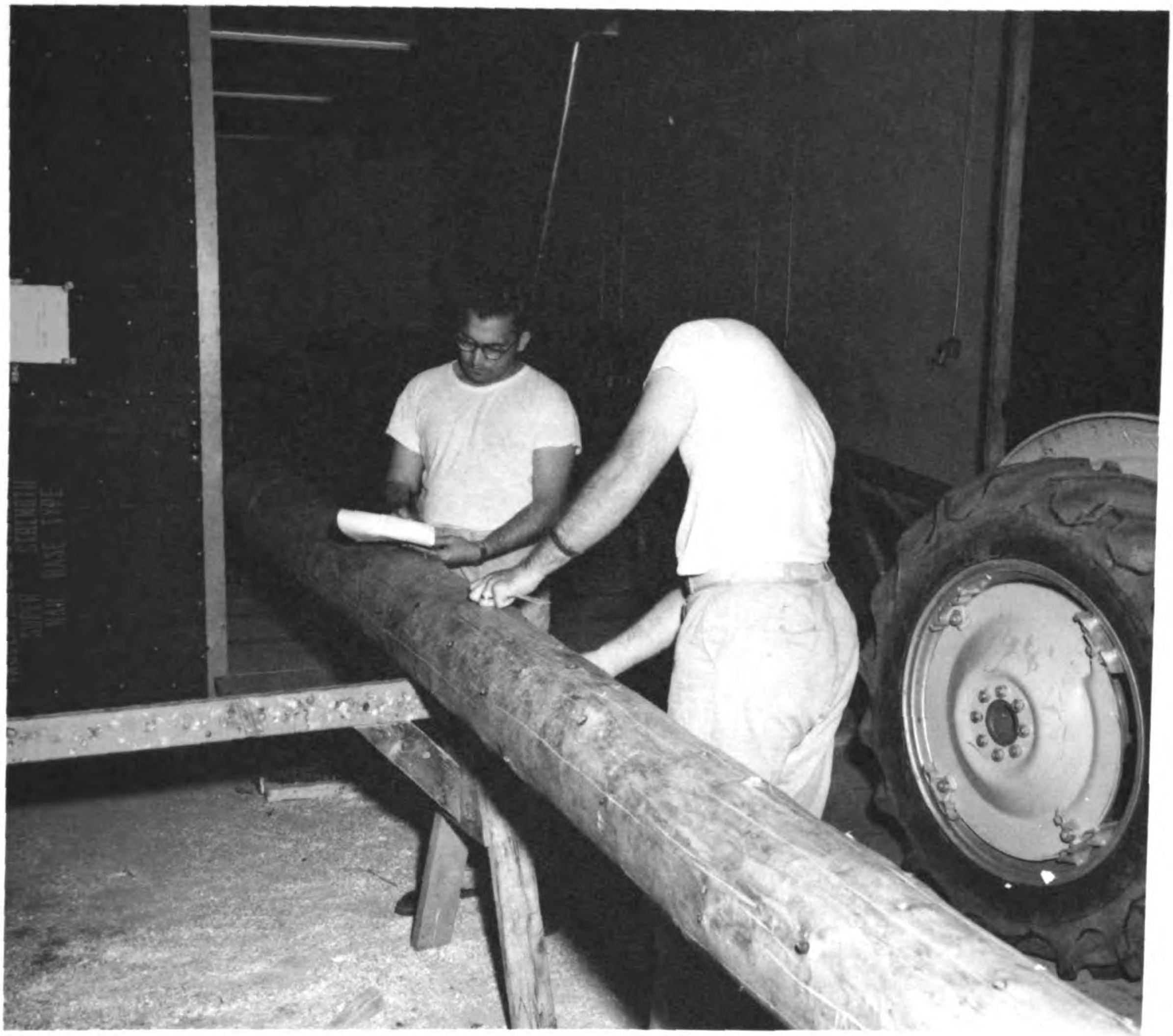


Figure 2.--Form used in recording the moisture content and defects other than knots.

POLE TEST

POLE DATA I.

DATE 6 - 23 - 64 RECORDER C BEHR TEST POLE NO. P-1

POLE SPECIES RED PINE POLE CLASS 6

POLE LENGTH 30' 6" POLE WEIGHT NOT WEIGHED

MOISTURE CONTENT

2' FROM BUTT 100.6 15' FROM BUTT 110.9 28' FROM BUTT 134.4

GROWTH RINGS 11 /INCH AT BUTT. AVERAGE MC = 115.3

DEFECTS

MAX. CROOK	NONE	INCHES	LOCATION FROM BUTT	
SWEEP SINGLE	"	INCHES	LOCATION FROM BUTT	
SWEEP DOUBLE	"	INCHES	LOCATION FROM BUTT	
SWEEP DOUBLE	"	INCHES	LOCATION FROM BUTT	
INSECT DAMAGE	"		LOCATION FROM BUTT	
CHECKS	"		LOCATION FROM BUTT	
SHAKES	"		LOCATION FROM BUTT	
OTHERS			LOCATION FROM BUTT	
			LOCATION FROM BUTT	
			LOCATION FROM BUTT	

COMMENTS SUMMER WOOD % AT BUTT & BREAK

1ST INCH	35	33
2ND INCH	30	20

Figure 2a.--Form for mapping locations and recording [illegible] sizes.

POLE DATA II

DATE 6-23-64 RECORDER C. BEHR TEST POLE NO. P-1

CIRCUMFERENCE	DISTANCE FROM BUTT	BUTT SWEEP OR CROOK DOWN (24 20 16 12 8 4 0 4 8 12 16 20 24)	SUM OF KNOT DIAM.	REMARKS
32.75	1			
31.00	2			
	3	.8	.8	
29.25	4	.7 .8	1.5	
	5	.6 .6	1.2	
28.50	6	.6 .9	1.5	
	7	.6 .6 .9	2.1	
28.00	8	.7 .6 1.	2.3	
	9	.8 .6 1. .7	3.1	
27.25	10	.6 .8 .9	2.3	
	11			
26.50	12	1.1 .7 .9 1.3 1.4	5.4	
	13			
26.50	14	1 1.0 1.3 1.2 1.2	5.7	
	15	1.2 .6 .8 .6	3.2	
25.00	16	1.4	1.4	
	17	.9 .7 .9 1.6 .6	4.7	
25.00	18	.9 1.1 1.0	3.1	
	19	1.2 .8 1 1.3 1.4	5.7	
24.25	20			
	21	1 1.3 1.5	3.8	
23.25	22	1.2 1 .6 1.6 1.4	5.7	
	23			
22.75	24	1.5 1 .7 1.3 1.6	6.0	
	25	1.2 1 1.5	3.7	
22.00	26			

Figure 2b.--Form for mapping locations and recording knot sizes, and sketch of failure.

POLE TEST

POLE DATA II

DATE 6-23-64 RECORDER C. BEHR TEST POLE NO. P-1

CIRCUMFERENCE	DISTANCE FROM BUTT	BUTT SWEEP OR CROOK DOWN (24 20 16 12 8 4 0 4 8 12 16 20 24)	SUM OF KNOT DIAM.	REMARKS
	27	1.6 1.6	3.2	
21.00	28	1.1 .9 .7 1.5 1.4	5.6	
	29			
20.25	30	1.4 1.1 1.6	4.1	
	31			
	32			
	33			
	34			
	35		76.10	TOTAL

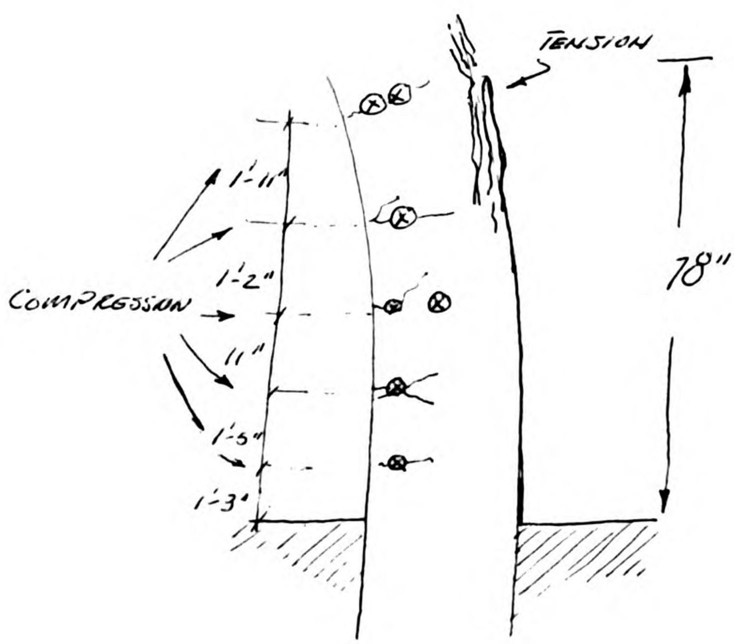
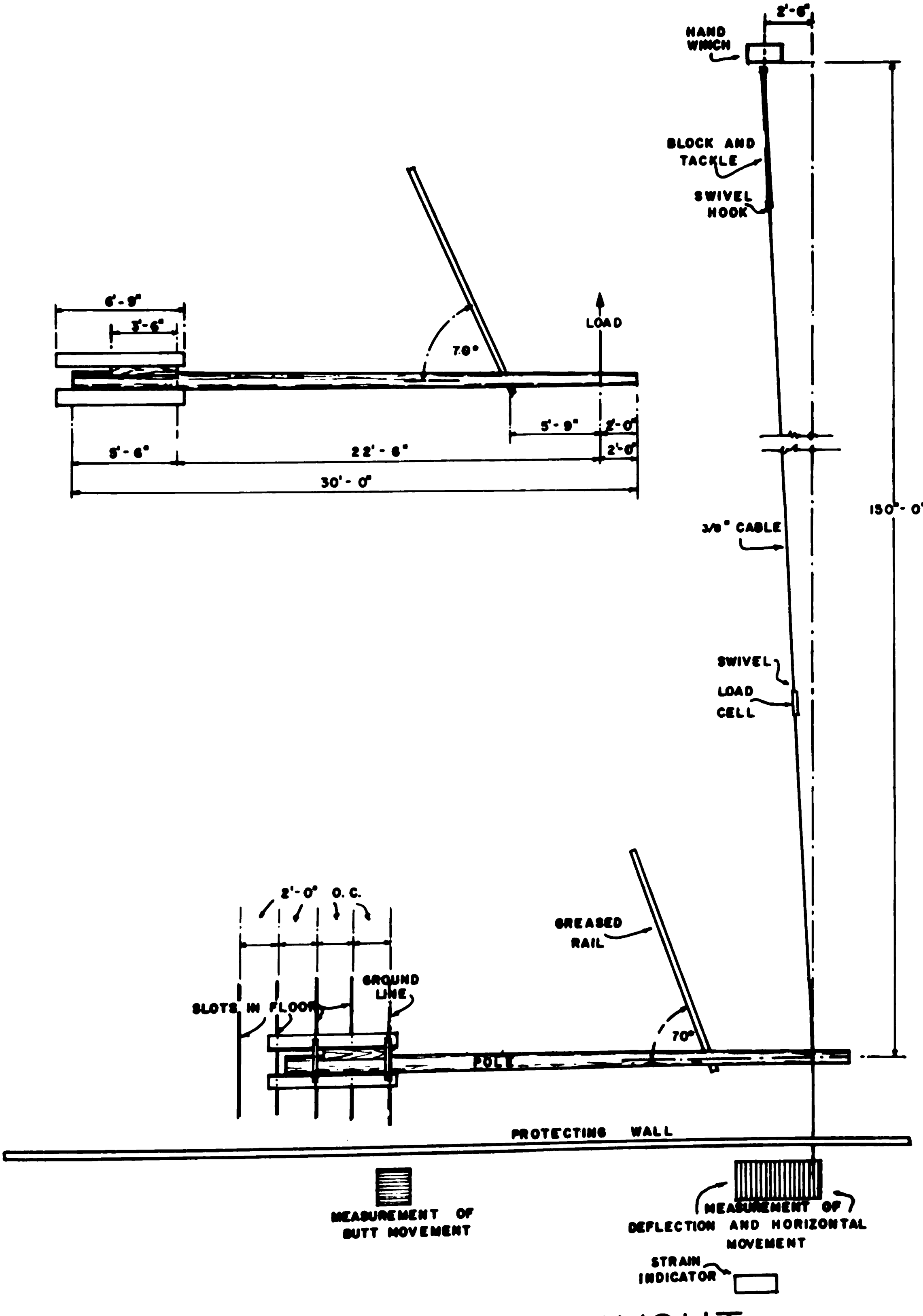


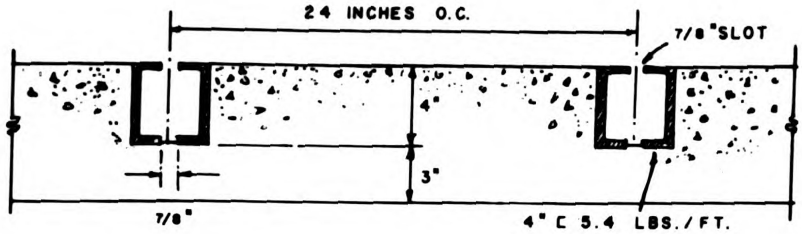
Figure 3.--Testing floor layout.



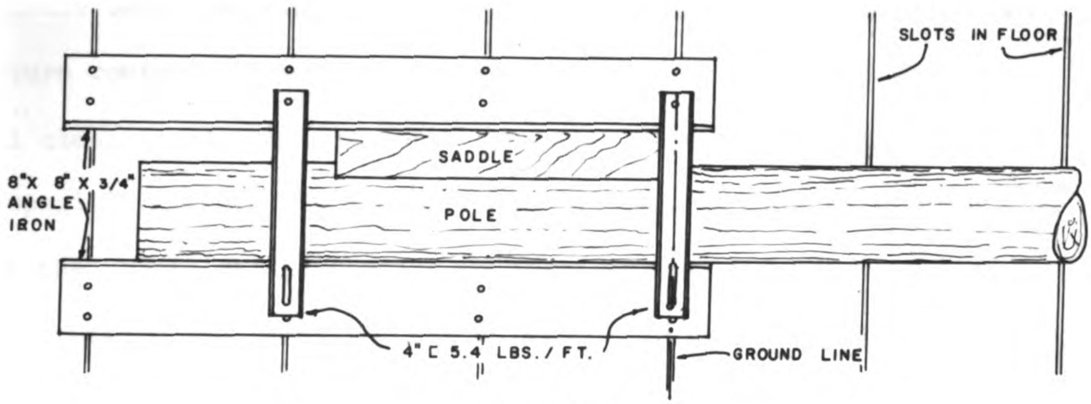
TESTING FLOOR LAYOUT

Figure 4.--Deflection of poles during major testing.

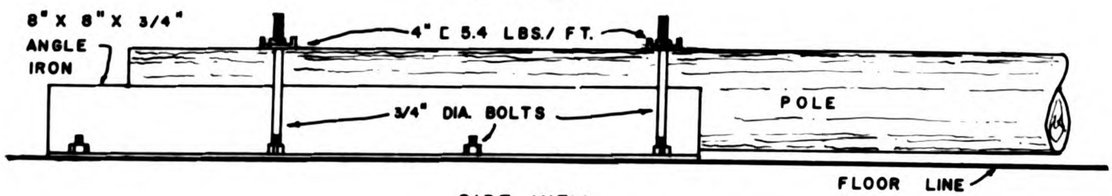
Figure 5.--Testing floor details and method of anchoring butt of poles.



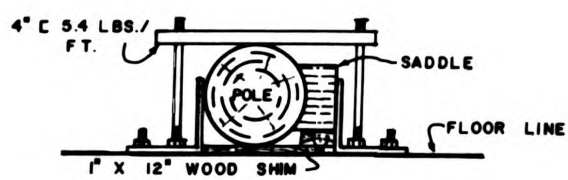
FLOOR SECTION



PLAN VIEW

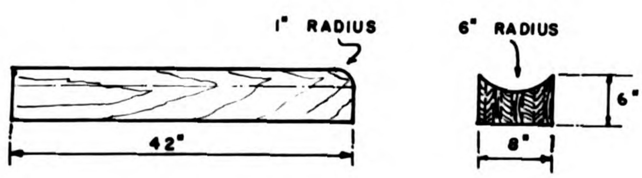


SIDE VIEW



END VIEW

ANGLE IRON BUTT CLAMPS



SADDLE

TESTING FLOOR DETAILS

Figure 6. The load readings were made through the use of an SR-4 strain indicator, connected to the load cell shown in Figures 7, 8 and 9. The loading rate and deflection readings were in accordance with the above standards.

The poles were loaded until complete failure occurred. After each pole was broken, the 5' 6" butt section and a 12" section at the break were removed, labelled, and placed in storage to keep the moisture content above thirty percent. From the butt section, the small clear specimens were cut. From the 12" section at the break, the specific gravity was taken in accordance with ASTM procedures [2], using the volume at the testing moisture content and the weight oven dried. Figure 10. shows the way in which the specific gravity samples were taken.

<u>Calculations</u>. - For each full size pole tested, the maximum fiber stress, in bending (modulus of rupture), was calculated at the ground line and at the position of failure. Fiber stress at the proportional limit was also calculated at the ground line and at the position of failure. The fiber stresses were calculated in accordance with ASTM D 143-52 [2] by the following formula:

$$F = \frac{32\pi^2 Pa}{C^3} \qquad (1)$$

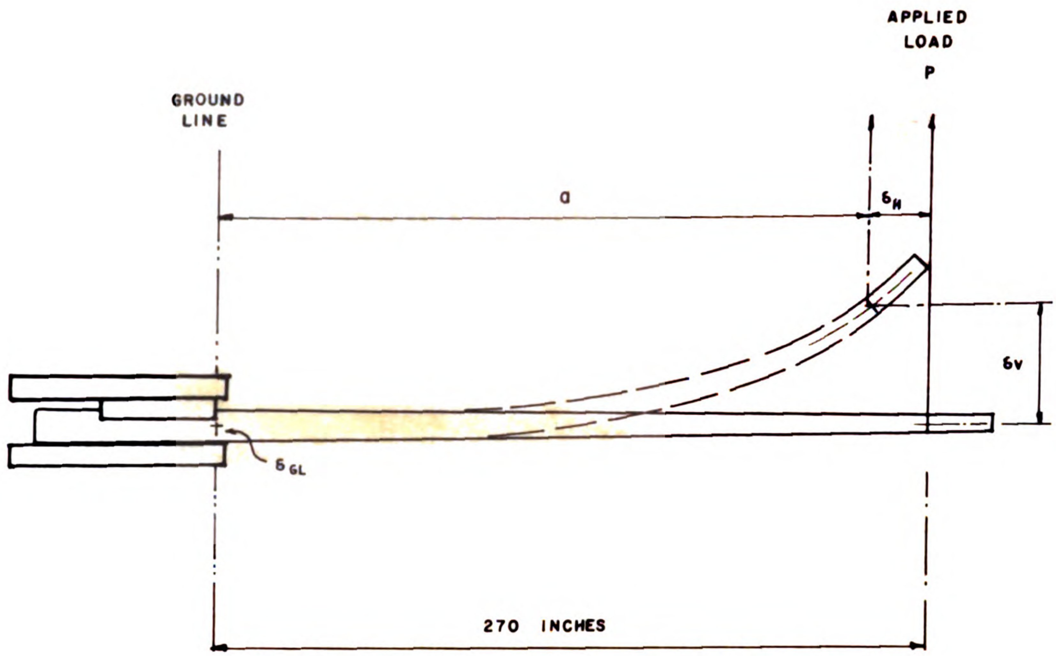
where: F = maximum fiber stress at ground line or at break, in pounds per square inch,

P = load at failure or at proportional limit, in pounds,

a = distance from ground line or break to point of load, in inches,

C = circumference of pole at the ground line or at the break, in inches.

Figure 6.--Deflection locations.



where: $\delta = \delta_V - \delta_{GL}$, actual deflection, in inches,

δ_V = deflection at loading point, in inches,

δ_{GL} = movement of pole at ground line, in inches,

δ_H = movement of tip towards butt, in inches,

P = load, in pounds,

a = length of lever arm, in inches.

Figure 7.--Stations for reading load and deflections, located outside of testing area.


DELICATE INSTRUMENTS

Figure 8.--Major testing load cell, where strain gages are cemented to 3/8 inch steel rod and wire leads can be seen at left end of load cell.

Figure 9.--Major testing load cell with protective covering against damage.

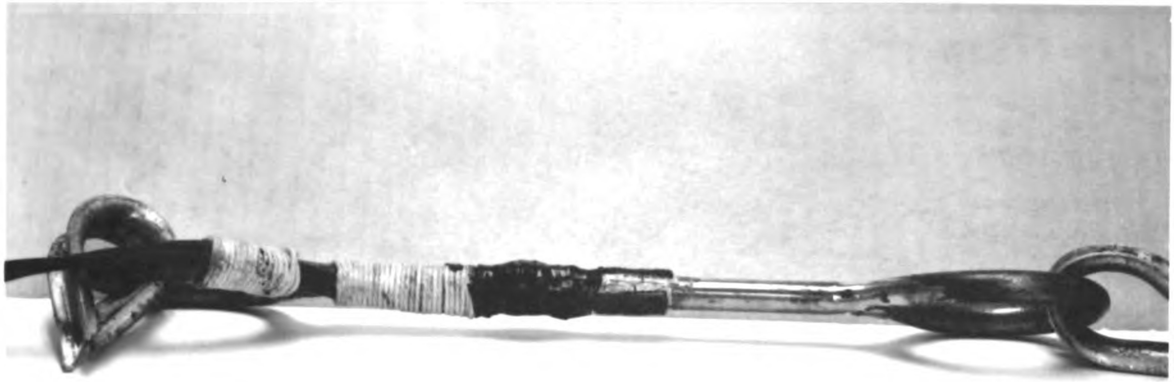
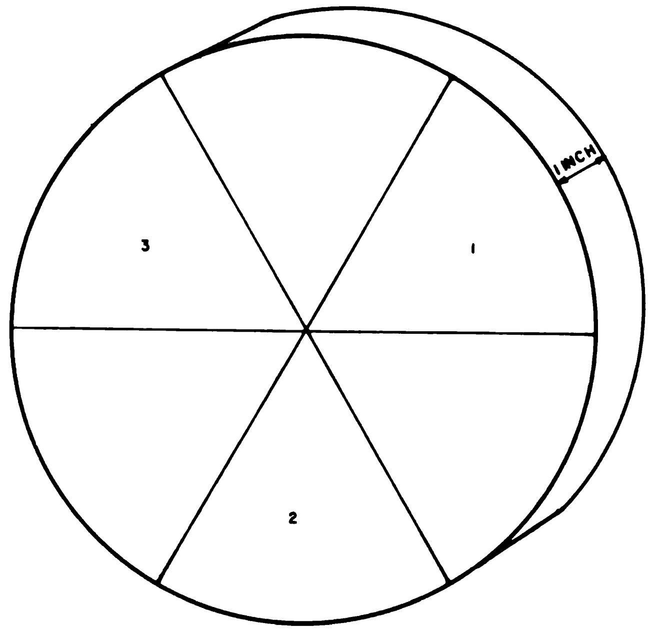
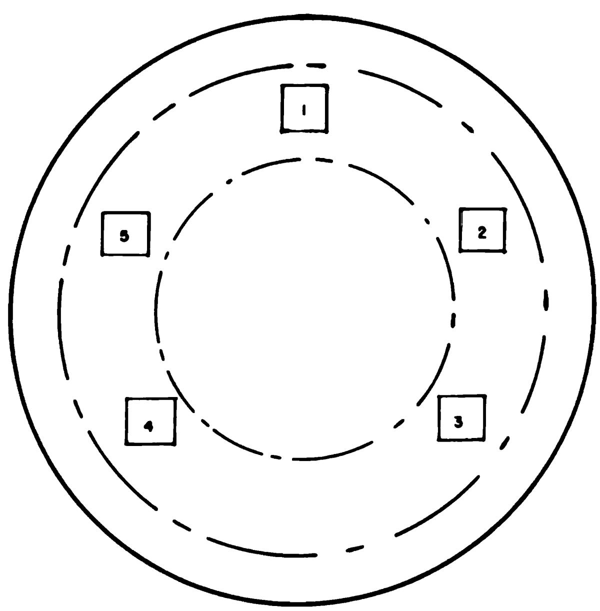


Figure 10.--Top: view showing location of three specific gravity specimens from butt and break.
Bottom: end view showing location of the five small clear specimens.



SPECIFIC GRAVITY SPECIMENS



SMALL CLEAR SPECIMENS

RELATIVE LOCATIONS OF SPECIMENS

For each pole the modulus of elasticity was calculated according to the following formula: (see Figure 6.)

$$E = \frac{64\pi^3 a^3 P}{3C_A{}^3 C_B \alpha} \qquad (2)$$

where: E = modulus of elasticity, in pounds per square inch,

a = actual length of lever arm, in inches,

P = applied load 2 feet from tip end, in pounds,

C_A = circumference of pole at ground line, in inches,

C_B = circumference of pole at point of loading, in inches,

α = actual deflection at point of loading, in inches.

This formula was derived from the following ASTM Standard: D 1036-58 [1] formula:

$$E = \frac{4a^3 b}{3\pi L} \quad \frac{P}{\Delta A^3 B} \qquad (3)$$

where: E = modulus of elasticity, in pounds per square inch,

a = length from ground line to loading point, in inches,

b = length from ground line to butt end, in inches,

L = length between butt end and loading point ($a+b=L$), in inches,

P = applied load 2 feet from tip end, in pounds,

Δ = observed deflection of a line drawn from loading point to butt end, in inches,

A = radius of pole at ground line, in inches,

B = radius of pole at loading point, in inches.

Figure 11. shows a load-deflection curve which was drawn in order to calculate the applied load (P) and the actual deflection (α) of the loading point.

The specific strength and index of deflection for major and minor tests in both plantation and second growth poles were calculated according to the following formulae: [7]

$$S \text{ (in compression)} = \frac{C_{max}}{[SG]} \qquad (4)$$

$$S \text{ (in bending)} = \frac{R}{[SG]^{1.5}} \qquad (5)$$

$$\text{Index of deflection} = \frac{E}{[SG]^{2.0}} \qquad (6)$$

where: C_{max} = maximum fiber stress in compression parallel to the grain, in pounds per square inch,

SG = specific gravity,

R = maximum fiber stress in bending (modulus of rupture), in pounds per square inch,

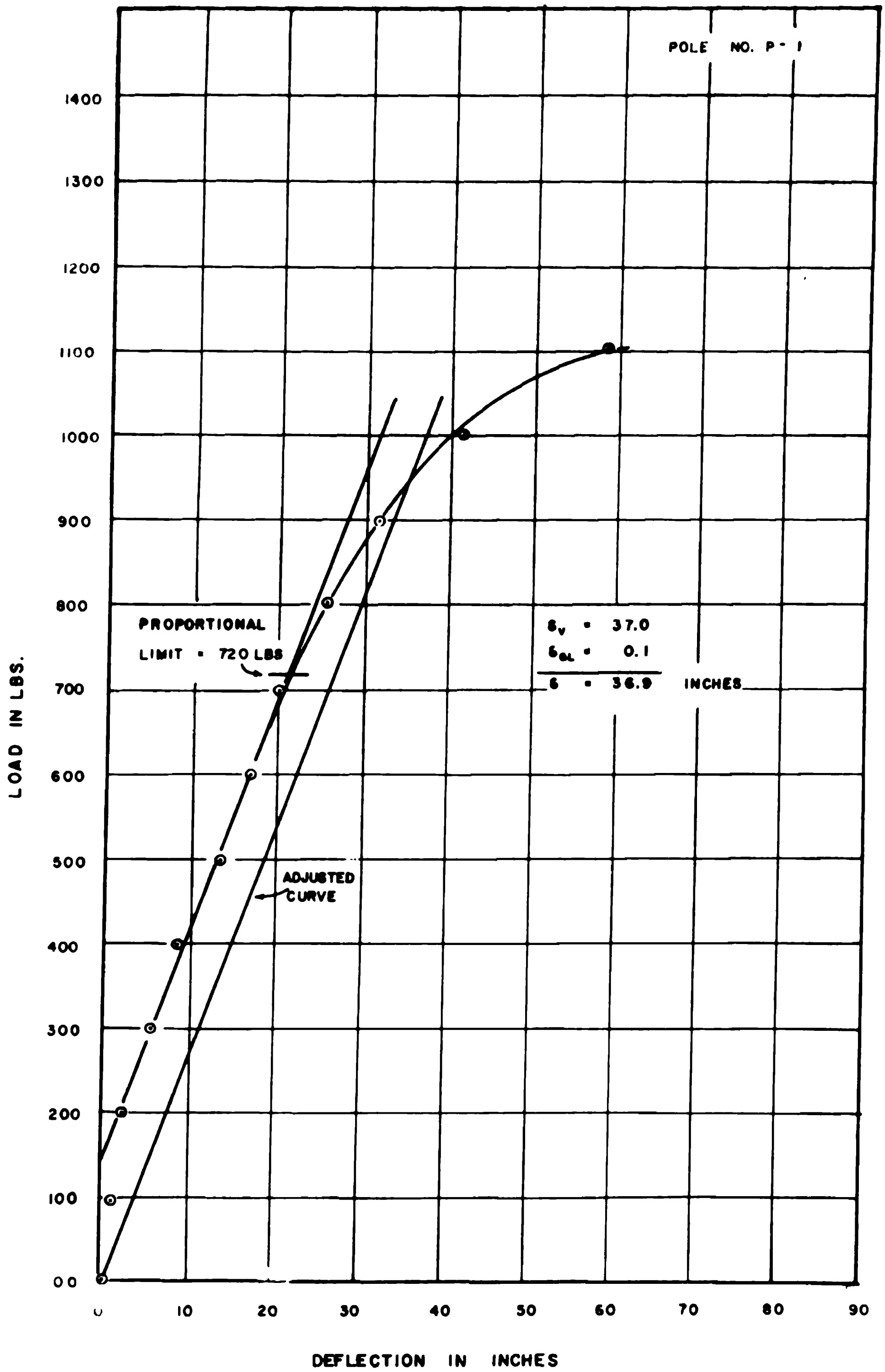
E = modulus of elasticity, in pounds per square inch.

The above values were calculated from the strength values of the wood with the moisture content above 30 percent (green).

Minor Tests

Source of Materials. - Five static bending and five compression specimens were cut from the 5'6" butt section of each pole. The moisture content of the butt was maintained above 30 percent. After cutting all specimens were stored, completely submerged, in a solution of water and

Figure 11.--Major load deflection curve.



MAJOR LOAD DEFLECTION CURVE

anti-stain chemical.

Description of Samples. - The static bending specimens were 1 inch x 0.5 inches x 16 inches. The compression specimens were 1 inch x 1 inch x 4 inches in accordance with the ASTM Standard: D 143-52 alternate method. [2] All specimens, as free from defects as possible, were cut parallel to the grain and generally within three inches of the surface (see Figure 10.). The measurements of each specimen were taken before testing, along with the weight and the rate of growth. After testing, each specimen was oven dried and reweighed for the determination of specific gravity and moisture content. The test procedure used for both static bending and compression tests followed that which is detailed in the ASTM Standard: D 143-52 [2], with the exception that in the static bending tests, the depth of the specimens and the speed of loading were changed. The depth was shortened from 1.0 inches to 0.5 inches to avoid crushing the fibers on the surface of the specimen, where it came in contact with the loading head. Due to this change in depth, the loading speed was increased from 0.05 inches per minute to 0.10 inches per minute, in accordance with the following ASTM Standard: D 198-27.[3]

$$N = \frac{zL^2}{6d} \tag{7}$$

where: N = rate of motion of the moving loading head, in inches per minute,

z = unit rate of fiber strain (.0015 in./in./min.), in inches per inch of outer fiber length per minute,

L = span between supports, in inches,

d = depth (thickness) of specimen, in inches.

Loads for the bending specimens were determined by an SR-4 type load cell and were graphed by an electronic recorder. The deflection was recorded on the same graph by a signal impulse every 0.02 inches, which produced the necessary load-deflection curve used in the calculation of modulus of elasticity in bending (see Figure 12.). Pictures of the equipment used in the bending test are displayed in Figures 13. and 14.

For the compression specimens, only the maximum fiber stress (modulus of rupture) was calculated. Compression tests made use of the same load recorder as was used in the bending tests. Figure 15. shows the testing set-up for the compression samples.

Calculations. - For each static bending specimen, the fiber stress at the proportional limit, the maximum fiber stress (modulus of rupture), and the modulus of elasticity were determined in accordance with the following formulae:

$$F_{PL} = \frac{3P_{PL}L}{2bh^2} \tag{8}$$

$$F_{MAX} = \frac{3P_{MAX}L}{2bh^2} \tag{9}$$

$$E = \frac{PL^3}{48bh^3\alpha} \tag{10}$$

where: F_{PL} = fiber stress at proportional limit, in pounds per square inch,

P_{PL} = load at proportional limit, in pounds,

P_{MAX} = maximum load, in pounds,

P = applied load, in pounds,

F_{MAX} = maximum fiber stress, in pounds per square inch,

E = modulus of elasticity, in pounds per square inch,

L = length of span, in inches,

b = width, in inches,

h = height, in inches,

α = deflection, in inches.

For each compression specimen, the maximum fiber stress (modulus of rupture) was calculated according to the following formula:

$$F_{MAX} = \frac{P}{bh} \qquad (11)$$

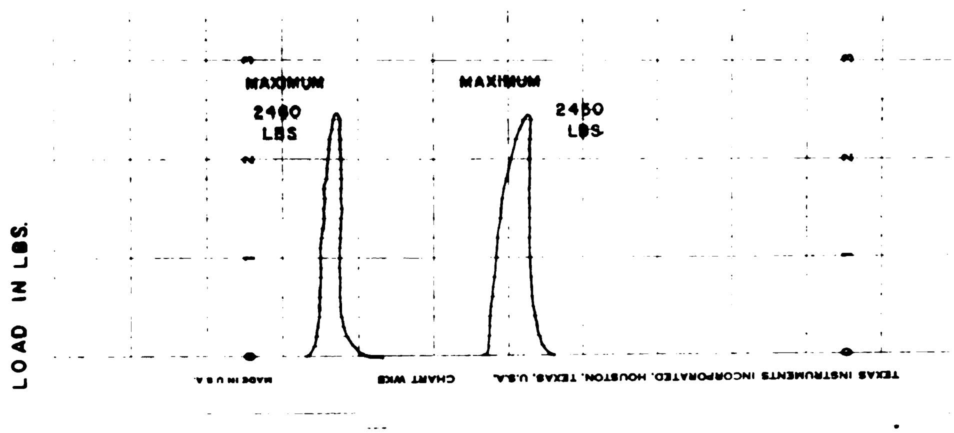
where: F_{MAX} = maximum fiber stress in compression, in pounds per square inch,

P = maximum load, in pounds,

b = width, in inches,

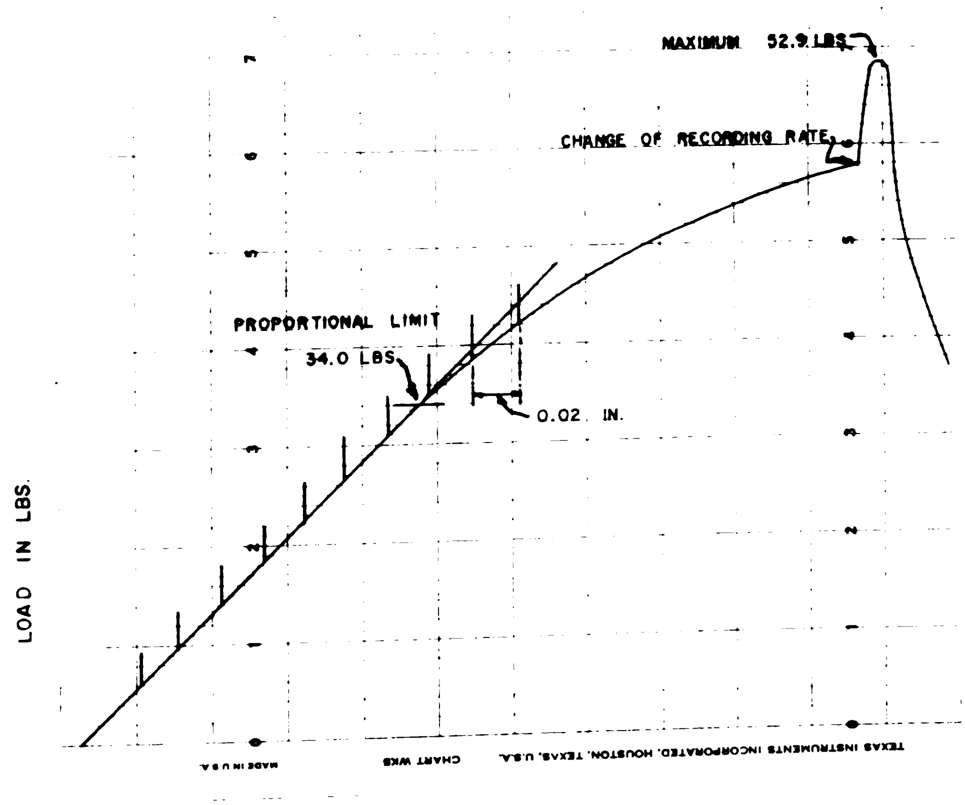
h = height, in inches.

Figure 12.--Charts from electronic recorder which was attached to load cells in minor tests.



NO DEFLECTION READINGS WERE TAKEN

COMPRESSION



DEFLECTION UNITS = 0.02 INCHES

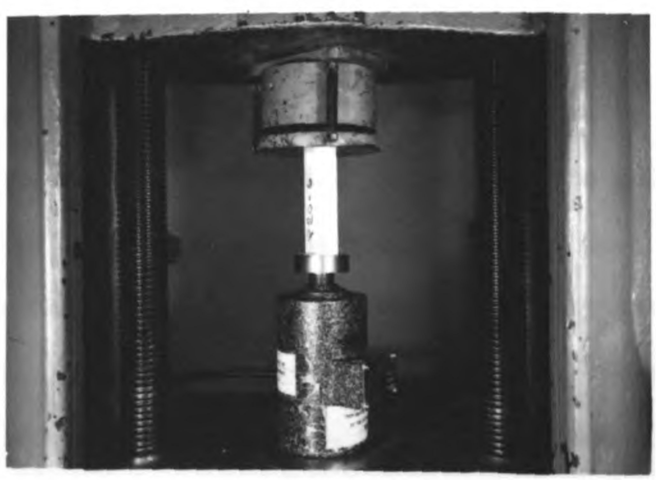
STATIC BENDING

MINOR LOAD DEFLECTION CURVES

Figure 13.--Minor static bending loading equipment.

Figure 14.--Minor static bending and compression load and deflection recording equipment.

Figure 15.--Minor compression loading equipment.



TEST RESULTS

The results of major and minor tests are presented in detail in Tables 3 through 12.

Major Tests

In the major tests, the first visible sign of failure was the appearance of localized compression failures across the fibers of the compression face at the knot whorls. This failure was generally followed by splintering of fibers on the tension face. Even though wrinkles on the compression face occurred early, at about one-third of maximum load, the appearance of tension failure occurred just before total failure of the pole. Of the 32 plantation poles tested, 13 failed at, or very near, knot whorls, which included all nine of the brash failures. The second growth poles showed only eight failures that appeared to be affected by knot whorls, which included all four of the brash failures. Figures 16, 17, 18 and 19 show typical failures.

Only 30.5 percent of the poles tested appeared to be affected by the presence of knots and other defects. These were the poles which failed at knot whorls. Thirteen of the poles tested showed a brash failure. These 13 were among the same poles that were affected by knots. Brash failures constituted 20.3 percent of all the failures. Most failures occurred in the middle half of the pole. The average sum of knot diameters larger than 0.5 inches, for this area, was 36.6 inches for plantation poles and 33.8 inches for second growth poles.

Figure 16.--Major tests, compression failure.

Figure 17.--Major tests, tension failure.

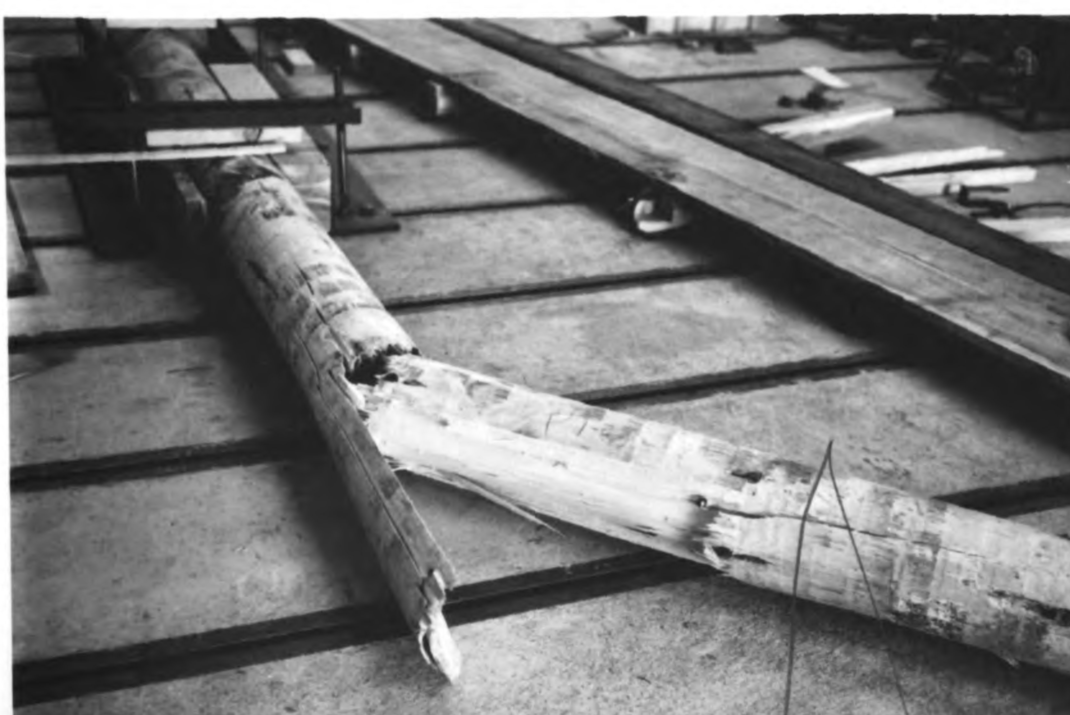


Figure 18.--Major tests, brash failures.

Figure 19.--Major tests, typical failure.

The average maximum fiber stress for plantation grown poles was 4800 psi and for second growth was 4920 psi. The average maximum fiber stress for plantation and second growth poles combined was 4860 psi, which is 1740 below the fiber stress given by the American Standards Associations' Specification and Dimensions for Wood Poles, ASA Designation: 05.1-1963 [4] for red pine poles. The average modulus of elasticity for plantation poles was found to be 842,000 psi and for second growth poles 873,000 psi.

Minor Tests

The average maximum fiber stress for the bending specimens from the plantation poles was 4730 psi, compared to 5410 psi for the second growth poles. The average modulus of elasticity for the bending specimens from the plantation poles was 916,000 psi, while for the second growth bending specimens it was 1,113,000 psi. The specific gravity of these specimens for plantation and second growth poles was .356 and .370 respectively.

The results of the compression test gave an average maximum fiber stress in compression for the plantation specimens of 1980 psi and 2105 psi for the second growth specimens.

The bending specimens failed most often on the compression face. Less than 10 percent of the specimens showed any failure on the tension face. The compression specimens often failed in a manner described in the ASTM [2] as brooming. This was due, in part, to the high moisture content under which the tests were run.

The specific strength and index of deflection values for major and minor tests are given in Table 2.

TABLE 2.--Specific strength and index of deflection

Test	Plantation (psi)		Second Growth (psi)		Average (psi)	
	Major	Minor	Major	Minor	Major	Minor
Specific strength (bend.)	20,300	22,000	20,600	24,000	20,430	23,000
Specific Strength (comp.)	--	5,440	--	5,610	--	5,520
Index of deflection x 1000	6,150	7,106	6,109	8,130	6,130	7,618

TABLE 3.-- Summary of test results

Tests	Units	Plantation		Second Growth		Significant at	Combined	
		Average	SD	Average	SD	.05 Level	Average	SD
MAJOR:								
Maximum fiber stress at ground line	psi	4800	501	4920	414	No sign. diff.	4860	457
Maximum fiber stress at break	psi	4610	538	4780	475	No sign. diff.	4690	508
Modulus of elasticity	1000 psi	842	98.5	873	120.5	No sign. diff.	857.5	109.5
Moisture content	%	127	--	118	--	No stat. test run	123	--
Specific gravity (Vol. test, wt. OD)		.370	.018	.378	.020	No sign. diff.	.374	.019
Ultimate load	psi	1404	--	1440	--	No stat. test run	1422	--
Knots in entire pole	No.	66.28	13.32	63.03	15.03	No sign. diff.	64.66	14.18
Knots in center half	No.	36.56	8.44	33.84	7.93	No sign. diff.	33.25	8.18
Pole age	Yrs.	52	--	61.3	--	No stat. test run	56.6	--
MINOR:								
Maximum fiber stress	psi	4730	616	5410	627	Average different	--	621
Modulus of elasticity	1000 psi	916	198	1113	240	Average different	--	222
Moisture content	%	187	--	150	--	No stat. test run	168	--
Specific gravity (Vol. test, wt. OD)		.359	.025	.370	.017	SD different	--	--
COMPRESSION:								
Maximum fiber stress	psi	1990	182	2105	508	SD different	--	--
Moisture content	%	185	--	177	--	No stat. test run	181	--
Specific gravity (Vol. test, wt. OD)		.365	.018	.375	.020	No sign. diff.	.370	.019

TABLE 4.--Plantation grown, size and number of knots

Pole No.	Sum of Diameter of Knots in				Number of Knots in			
	Lower 1/4	Middle 1/2	Upper 1/4	Total	Lower 1/4	Middle 1/2	Upper 1/4	Total
P-1	7.1	46.4	22.6	76.1	10	47	18	75
P-2	9.2	38.5	22.0	69.7	12	36	18	66
P-3	7.9	41.7	16.4	66.0	10	39	12	61
P-4	8.8	33.0	18.0	59.8	14	42	20	76
P-5	10.3	26.1	22.1	58.5	14	27	21	62
P-6	8.3	35.0	19.2	62.5	11	33	15	59
P-7	15.9	41.5	25.7	83.1	20	34	20	74
P-8	0.0	19.4	22.7	42.1	0	26	18	44
P-9	1.8	27.2	22.9	51.9	3	29	18	50
P-10	7.0	41.9	28.4	77.3	10	40	22	72
P-11	6.9	37.4	23.1	67.4	9	37	18	64
P-12	2.0	32.8	22.8	57.6	3	33	18	54
P-13	5.7	30.8	23.5	60.0	9	37	20	66
P-14	6.0	40.9	22.2	69.1	9	43	18	70
P-15	15.3	41.2	23.3	79.8	24	39	19	82
P-16	15.0	42.8	29.1	86.9	19	37	22	78
P-17	9.1	42.0	20.0	71.1	13	41	15	69
P-18	7.0	35.6	25.3	67.9	10	38	20	68
P-19	3.1	23.2	21.0	47.3	5	39	17	61
P-20	2.5	39.0	16.8	58.3	4	43	14	61

TABLE 4.--Continued

Pole No.	Sum of Diameter of Knots in				Number of Knots in			
	Lower 1/4	Middle 1/2	Upper 1/4	Total	Lower 1/4	Middle 1/2	Upper 1/4	Total
P-21	2.4	23.6	24.3	50.3	4	29	18	51
P-22	4.8	34.0	21.7	60.5	7	39	18	64
P-23	6.3	31.9	24.3	62.5	9	34	19	62
P-24	14.2	53.9	25.7	93.8	18	47	19	84
P-25	7.6	41.1	19.0	67.7	10	41	18	69
P-26	11.6	32.9	21.5	66.0	19	34	19	72
P-27	4.7	35.4	23.7	63.8	7	37	19	63
P-28	9.3	47.3	22.5	79.1	14	48	19	81
P-29	14.8	48.1	26.5	89.4	19	48	24	91
P-30	2.4	19.3	12.2	33.9	4	25	15	44
P-31	8.0	40.2	16.6	64.8	14	46	20	80
P-32	7.8	45.9	23.2	76.9	9	44	17	70
Average*	7.6	36.6	22.1	66.3	10.7	37.9	18.4	67.0

*Average knot size of knots over 0.5 is 0.989 inches.

TABLE 5.--Second growth, size and number of knots

Pole No.	Sum of Diameter of Knots in				Number of Knots in			
	Lower 1/4	Middle 1/2	Upper 1/4	Total	Lower 1/4	Middle 1/2	Upper 1/4	Total
S-1	20.6	45.6	21.9	88.1	27	48	23	98
S-2	12.7	49.5	23.4	85.6	17	52	19	88
S-3	3.5	40.3	23.3	67.1	5	41	21	67
S-4	2.0	35.3	13.0	50.3	3	41	17	61
S-5	7.6	30.6	18.5	56.7	11	34	17	62
S-6	4.2	38.4	27.4	70.0	6	40	23	69
S-7	.6	21.5	18.8	40.9	1	28	21	50
S-8	9.3	41.9	24.2	75.4	14	38	21	73
S-9	9.0	28.1	23.8	60.9	13	33	22	68
S-10	5.3	32.3	25.3	62.9	7	36	22	65
S-11	6.5	41.1	22.0	69.6	7	40	22	69
S-12	4.1	36.0	18.8	58.9	6	44	18	68
S-13	8.0	39.2	27.8	75.0	11	43	22	76
S-14	5.4	24.6	17.2	47.2	8	30	19	57
S-15	5.4	27.6	18.9	51.9	8	37	21	66
S-16	4.6	21.9	19.0	45.5	10	25	18	53
S-17	1.2	20.2	14.4	35.8	2	28	16	46
S-18	9.5	32.6	20.9	63.0	14	39	20	73
S-19	3.1	20.7	19.1	42.9	5	26	20	51
S-20	--	--	--	--	--	--	--	--

TABLE 5.--Continued

	Sum of Diameter of Knots in				Number of Knots in			
Pole No.	Lower 1/4	Middle 1/2	Upper 1/4	Total	Lower 1/4	Middle 1/2	Upper 1/4	Total
S-21	10.7	44.2	27.0	81.9	15	45	23	83
S-22	11.8	35.0	26.3	73.1	16	35	21	72
S-23	7.7	34.8	24.1	66.6	11	40	23	74
S-24	1.2	24.3	20.1	45.6	2	31	17	50
S-25	7.1	32.7	18.6	58.4	11	38	18	67
S-26	17.7	45.3	22.9	85.9	25	50	22	97
S-27	17.1	37.6	33.1	87.8	22	38	25	85
S-28	13.4	42.3	27.8	83.5	18	41	24	83
S-29	1.5	30.3	16.2	48.0	2	31	15	48
S-30	4.0	25.2	26.6	55.8	6	30	28	64
S-31	2.8	33.7	24.9	61.4	4	44	22	70
S-32	6.0	37.6	22.5	66.1	9	39	22	70
S-33	5.9	32.6	16.6	55.1	8	38	15	61
Average*	7.17	33.8	22.1	63.02	10.1	37.6	20.5	68.25

*Average size of knots over 0.5 is 0.923 inches.

TABLE

Pole No.
P-1
P-2
P-3
P-4
P-[illegible]
P-[illegible]
P-[illegible]
P[illegible]
P[illegible]
P[illegible]

TABLE 6.--Plantation grown pole information

Pole No.	Pole Class	Age of Pole	Rings Outer 2 in.	Specific Gravity Sap & Heartwood* Butt	Break	Moisture Content Distance From Butt 2'	15'	28'	Ave.
P-1	6	52	21	.398	.339	100.6	110.9	134.4	115.3
P-2	6	52	21	.344	.317	83.7	71.4	136.4	97.1
P-3	6	52	21	.342	.338	None	was	taken	
P-4	6	52	19	.394	.357	127.5	141.6	162.3	143.8
P-5	7	52	19	.428	.350	91.7	133.6	103.8	109.7
P-6	5	52	19	.384	.354	106.0	116.2	179.4	133.8
P-7	6	52	19	.394	.350	156.3	133.8	64.3	118.1
P-8	5	52	19	.397*	.368	93.7	150.1	136.2	126.2
P-9	5	52	19	.416	.349	84.0	135.8	98.4	106.0
P-10	5	52	19	.386	.349	145.2	108.1	110.7	121.3
P-11	6	52	21	.378	.357	133.5	149.3	119.0	133.9
P-12	6	52	21	.388	.337	127.6	129.1	162.0	139.5
P-13	5	52	21	.416	.374	108.6	114.8	132.2	118.5
P-14	6	--	--	.423	.356	131.9	134.0	161.9	142.6
P-15	5	52	21	.378	.344	113.3	163.3	158.2	144.9
P-16	6	52	18	.375	.335	135.2	133.2	106.5	124.9
P-17	6	52	18	.391	.332	120.7	92.4	92.5	101.8
P-18	5	52	18	.366	.350	100.9	116.8	118.5	112.0
P-19	6	52	20	.395	.413	106.2	105.9	92.0	101.3
P-20	6	52	20	.382	.339	132.1	137.0	125.5	131.5
P-21	5	52	20	.388	.365	111.4	112.7	150.0	124.7
P-22	6	52	20	.410	.361	135.0	117.5	156.2	136.2
P-23	5	52	20	.418	.384	113.6	123.5	134.7	123.9
P-24	7	52	20	.351	.332	160.2	133.3	125.3	139.6
P-25	5	52	20	.399	.356	98.4	112.5	117.4	109.4
P-26	5	52	20	.408	.360	133.0	146.1	142.6	140.5
P-27	6	52	20	--	.327	113.9	117.8	129.4	120.3
P-28	5	52	20	.400	.355	90.4	108.8	102.4	100.5
P-29	7	52	20	.382	.332	--	--	--	--
P-30	7	52	20	.427	.370	85.9	107.1	125.4	106.1
P-31	6	52	18	.411	.344	85.3	77.5	130.7	97.8
P-32	7	52	18	.368	.325	84.3	161.3	170.6	138.7
Average		52	19.7	.392	.359	111.6	123.1	129.2	121.9

*Volume at test, weight at oven dry.

TABLE 6.--Continued

Circumference (inches)				Sapwood		Summer Wood	
Butt	G.Line	Break	Top	Depth In.	Area %	Butt	Break
32.75	28.8	26.8	20.25	3	84	32%	26%
29.50	27.6	23.75	18.0	3	86.4	37%	22%
30.25	29.5	28.8	19.25	2.75	84.9	36%	30%
29.67	28.0	27.2	19.75	2.75	89.9	35%	27%
29.75	26.6	27.0	18.00	3.62	85.9	35%	25%
34.0	30.5	29.5	20.5	3	83.9	35%	30%
29.5	28.1	27.25	18.0	3.5	93.0	32%	32%
33.5	30.2	29.0	21.00	4.25	94.8	Miss.	30%
31.5	29.6	28.4	20.25	3.5	93.0	35%	26%
31.0	29.6	27.8	19.5	3.1	88.2	37%	37%
30.5	28.9	28.5	20.0	3.5	91.0	31%	27%
32.75	28.8	28.5	20.75	3.0	91.3	34%	27%
33.75	29.2	28.8	21.25	3.25	87.7	35%	34%
29.25	28.7	26.4	20.0	3	88.8	40%	27%
29.75	29.2	28.4	19.0	3.4	90.6	32%	30%
31.0	29	28	19.50	3.25	88.8	31%	22%
29.0	27.1	25.8	18.25	3.125	90.7	31%	30%
33.0	29.5	29.0	21.5	3.250	89.9	31%	22%
30.5	27.8	27.5	19.00	3.250	92.2	42%	34%
29.5	28.3	27.5	20.25	3.250	89.9	31%	27%
34	30.4	29.4	22.08	4.000	92.5	32%	27%
32.5	28.6	27.6	20.75	3.250	89.9	30%	34%
34.5	29.0	28.1	21.50	3.250	93.1	36%	32%
30.5	29.0	28.6	15.00	3.250	87.7	27%	26%
34.3	30.8	30.5	21.75	3.750	91.8	47%	17%
30.2	29.0	27.7	19.50	3.250	87.7	34%	29%
33.5	29.8	28.9	18.25	4.000	96.0	--	20%
32.5	29.4	28.8	21.25	3.500	88.9	35%	31%
28.50	27.3	26.8	16.00	3.000	88.9	29%	27%
30.5	28.6	26.6	20.50	3.250	92.2	--	34%
29.5	28.1	27.6	19.50	3.500	93.0	32%	45%
29.0	27.0	26.5	16.75	3.125	90.7	34%	25%
34.2	28.8	27.8	19.6	3.308	89.9	34%	28.5%

TABLE 7.--Second growth pole information

Pole No.	Pole Class	Age of Pole	Rings Outer 2 in.	Specific Gravity Sap & Heartwood* Butt	Break	Moisture Content Distance From Butt 2'	15'	28'	Ave.
S-1	9	57	23	.359	.332	126.9	154.7	150.0	143.8
S-2	5	57	23	.398	.373	92.0	75.6	140.0	102.5
S-3	5	57	23	.419	.367	100.0	138.8	156.6	131.8
S-4	6	57	23	.392	.351	111.2	121.7	140.7	124.5
S-5	6	57	23	.401	.376	112.4	140.9	135.9	129.7
S-6	6	61	22	.396	.363	120.1	138.7	175.9	144.9
S-7	5	61	23	.431	.396	84.4	80.8	90.4	85.2
S-8	5	61	22	.378	.341	110.5	108.4	152.4	123.7
S-9	5	61	22	.389	.402	76.1	91.1	131.4	99.5
S-10	6	61	22	.385	.344	109.1	126.1	125.6	120.2
S-11	5	62	24	.388*	.379	88.4	113.0	154.6	118.6
S-12	6	62	24	.403	.381	74.6	89.9	91.2	85.2
S-13	5	62	24	.414	.362	106.1	124.5	136.8	122.4
S-14	6	62	24	.377	.360	82.4	92.5	100.7	91.8
S-15	6	62	24	.382	.351	112.5	142.6	129.2	128.1
S-16	7	59	24	.392	.376	86.4	120.3	121.5	109.4
S-17	6	59	24	.369	.365	113.7	120.6	143.8	126.0
S-18	7	59	24	.393	.370	94.1	125.3	147.1	122.1
S-19	6	59	24	.375	.376	112.2	146.7	160.0	139.6
S-20	Pole broke during unloading								
S-21	6	69	18	.366	.337	77.8	146.8	155.1	126.5
S-22	6	69	19	.407	Missing				
S-23	6	69	19	.394	.370	82.8	40.0	111.2	78.0
S-24	5	69	19	.435	.404	107.4	113.7	140.2	120.4
S-25	6	69	19	.361	.357	101.5	110.8	103.5	105.2
S-26	7	60	18	.367	.323	132.4	110.9	155.2	132.8
S-27	6	60	18	.384	.337	122.0	131.2	105.6	119.6
S-28	6	60	18	.396	.330	106.2	100.0	134.6	113.6
S-29	5	60	18	.411	.351	125.2	129.2	162.4	138.9
S-30	6	60	18	.424	.373	124.4	137.2	167.0	142.8
S-31	5	60	21	.410	.361	107.4	109.5	93.6	103.5
S-32	6	60	21	.404	.364	113.7	117.9	129.5	120.3
S-33	5	60	21	.410	.363	Missing			
Average		61.3	21.5	.3944	.3624	103.7	116.6	134.7	118.3

*Volume at test and weight at oven dry

TABLE 7.--Continued

Circumference (inches)				Sapwood		Summer Wood	
Butt	G.Line	Break	Top	Depth In.	Area %	Butt	Break
27.25	25.8	25.2	14.75	3	88.8	37%	32%
31.25	29.2	28.0	19.00	3.5	90.9	37%	31%
33.5	31.3	30.1	21.75	4	92.2	40%	27%
36.0	29.3	27.7	18.25	5.4	95.2	31%	27%
30.75	28.7	28.3	20.25	4.25	88.4	37%	35%
34.0	29.8	29.6	20.75	3.9	92.2	37%	34%
35.0	31.6	30.0	22.0	4.1	92.8	35%	31%
32.25	30.3	30.0	19.5	3.5	86.7	29%	30%
33.25	30.4	28.8	22.75	3.25	87.7	42%	35%
30.0	28.8	28.8	19.5	3.25	87.7	31%	30%
32.5	29.5	28.3	21.25	3.25	89.9	32%	45%
31.75	28.3	27.6	20.50	2.25	84.9	32%	27%
31.75	29.6	29.1	20.25	4.0	92.5	42%	32%
29.5	27.4	26.5	19.50	3.75	91.8	42%	32%
31.25	27.8	27.3	20.50	3.75	93.7	34%	22%
27.0	25.5	25.1	18.0	2.8	88.1	32%	25%
32.0	27.1	26.1	21.25	3.5	93.0	37%	37%
28.0	26.6	26.2	18.5	3.4	91.6	32%	30%
29.5	27.8	27.1	19.75	3.75	93.7	32%	31%
31.5	29.6	27.8	20.00	3.12	85.9	33%	22%
30.25	28.3	27.9	18.25	3.50	87.9	27%	--
29.00	28.9	28.2	20.25	3.25	91.8	32%	--
33.25	29.3	28.7	22.00	3.25	85.4	35%	42%
31.50	28.5	28.20	19.50	3.00	88.8	34%	33%
29.00	27.3	24.0	16.50	3.50	90.9	31%	22%
30.75	28.8	28.5	18.5	3.25	85.4	32%	36%
29.75	28.2	26.0	17.50	3.12	89.4	37%	35%
34.25	31.0	30.8	21.00	3.50	90.9	30%	33%
31.50	27.6	26.8	17.25	4.00	96.0	31%	32%
33.00	29.7	28.0	21.00	3.50	90.0	31%	29%
29.25	27.1	27.1	17.50	3.25	89.9	55%	32%
33.00	30.5	30.3	22.00	3.50	90.9	37%	31%
31.33	28.7	27.0	19.7	3.51	90.4	35%	31%

TABLE 8.--Plantation growth major test results

Pole No.	Pole Class	Ultimate Load Lbs.	Maximum Fiber Stress Ground Line Psi	Maximum Fiber Stress Break Psi
P-1	6	1120	3820	3420
P-2	6	1090	4380	5380
P-3	5	1510	4550	4310
P-4	6	1500	5650	5150
P-5	7	1075	4800	4150
P-6	5	1510	4270	4402
P-7	6	1100	4040	4130
P-8	5	1620	4840	4280
P-9	5	1450	4640	4580
P-10	5	1550	4900	4860
P-11	6	1600	5530	5330
P-12	6	1350	4680	4340
P-13	5	1610	5210	5080
P-14	6	1550	5200	4740
P-15	5	1700	5210	5120
P-16	6	1390	4670	4850
P-17	6	1190	4960	4080
P-18	5	1350	4410	4280
P-19	6	1180	4570	4590
P-20	6	1380	4980	4700
P-21	5	1780	5220	4860
P-22	6	1380	4870	5420
P-23	5	1590	5360	4950
P-24	7	1380	4570	4350
P-25	5	1600	4500	4190
P-26	5	1450	4800	4590
P-27	6	1300	3950	3730
P-28	5	1600	4830	4690
P-29	7	1130	4440	4210
P-30	7	1350	5770	5000
P-31	6	1500	5540	5310
P-32	7	1080	4550	4270
Average		1404	4800	4610
Standard Deviation		--	501	538

TABLE 8.--Continued

Fiber Stress at Pro. Limit (psi)		Mod. of Elast., 1000 psi	Position of Break From Ground Line, Inches	Type of Break
Ground Line	Break			
2500	2260	660	70	C & T*
3090	3840	785	134	T at whorl (brash)
2900	2780	660	29	C
3870	3940	787	45	C & T
3580	3090	899	25	C & T at whorl
3032	3150	664	16	C & T at whorl
2600	2660	830	18	T at whorl (brash)
2980	2990	884	24	C & T
3380	3340	856	34	C
3480	3480	860	46	C & T at whorl
3270	3160	918	20	C & T at whorl (brash)
3200	2910	766	35	C & T
3460	3380	708	17	C & T
3290	3070	963	73	C & T
2920	2910	954	23	C & T
2950	2940	898	27	T at whorl (brash)
3560	2940	880	76	T at whorl (brash)
2830	2750	831	18	C & T
2950	2990	847	15	C & T
3240	3080	854	35	C & T at whorl (brash)
2930	2690	1000	45	C & T
2770	2760	719	29	C & T
3020	2370	945	77	C & T
3130	2990	778	24	C & T at whorl (brash)
2770	2530	798	30	C & T
2860	2760	845	44	C & T at whorl (brash)
2340	2220	780	36	C & T
2610	2560	754	21	C & T
2760	2630	824	26	C & T at whorl (brash)
3760	3330	1012	36	C & T
3650	3510	963	24	C & T
2862	2690	916	30	C & T at whorl
3080	2960	842	37.6	
--	--	98.5	--	

*C = Compression failure; T = Tension failure

TABLE 9.--Second growth major test results

Pole No.	Pole Class	Ultimate Load Lbs.	Maximum Fiber Stress: Ground Line Psi	Maximum Fiber Stress: Break Psi
S-1	9	900	4240	4200
S-2	5	1420	4470	4700
S-3	5	1760	4800	4280
S-4	6	1680	5140	4823
S-5	6	1550	5510	5480
S-6	6	1680	5200	5020
S-7	5	2130	5440	5900
S-8	5	1600	4740	4530
S-9	5	1750	4990	4690
S-10	6	1500	4960	4956
S-11	5	1700	5280	5130
S-12	6	1400	5110	4960
S-13	5	1600	5020	4960
S-14	6	1300	5130	5000
S-15	6	1150	4460	4352
S-16	7	1000	5040	5000
S-17	6	1350	5680	5210
S-18	7	1200	5104	4580
S-19	6	1360	5200	5160
S-20	Pole broken during unloading			
S-21	6	1250	4010	4070
S-22	6	1250	4330	4500
S-23	6	1460	5050	5000
S-24	5	1600	5090	5090
S-25	6	1400	4880	4720
S-26	7	980	4020	3360
S-27	6	1475	5040	4800
S-28	6	1220	4480	4010
S-29	5	1770	4860	4720
S-30	6	1450	5490	5450
S-31	5	1520	4790	4560
S-32	6	1200	4958	4960
S-33	5	1650	4840	4710
Average		1440	4920	4780
Standard Deviation		--	414	475

TABLE 9.--Continued

Fiber Stress at Pro. Limit (psi)		Mod. of Elast., 1000 psi	Position of Break From Ground Line, Inches	Type of Break
Ground Line	Break			
2060	2050	871	11	C & T*
2510	2320	714	49	C & T
2620	2340	773	48	C & T at whorl
3200	2540	769	88	C & T
3560	3400	1099	12	C & T at whorl
3890	3730	698	14	C & T
3710	4180	913	9	C & T
2950	2820	1056	20	C & T
2530	2680	870	26	C & T
2620	2620	1160	0	T at whorl (brash)
2710	2660	918	36	C & T
4290	4370	700	14	C & T
3450	3680	916	9	C at whorl
2710	2650	911	24	C & T
2570	2510	846	20	C & T
3110	3120	958	20	C & T at whorl
4130	3790	912	48	C & T
2930	2800	1049	24	C & T
3190	3220	996	18	C & T
from truck				
2320	2370	872	42	T at whorl (brash)
2430	2490	873	12	C & T
2840	2820	1048	6	C & T
3670	2670	787	24	C
2740	2670	823	16	C & T (brash)
2943	2480	747	114	T (brash)
3080	2940	910	20	C & T
3400	3080	920	78	C & T at whorl
2840	2760	721	12	C & T
3450	3440	869	23	C & T
2810	2680	766	39	C & T
3100	3100	743	1	C & T
2920	2840	826	12	C & T at whorl
3040	2960	873	27.8	
--	--	120	--	

*C = Compression failure; T = Tension failure

TABLE 10.--Plantation grown - minor tests, average results of static bending

Pole No.	Specific Gravity (Vol. at test, Weight Oven Dry)	Moisture Content at Test (%)	Rings Per Inch	Summer Wood (%)	Static Bending		
					Stress at Pro. Limit (psi)	Maximum Fiber Stress (Mod. of R) (psi)	Mod. of Elast., 1000 psi
P-1	.344	179	10	22	1820	3580	482
P-2	--	--	10	21	2240	4690	937
P-3	.319	173	9	21	2750	4190	720
P-4	.359	181	9	22	2770	5220	981
P-5	.337	171	7	19	2310	4670	1028
P-6	--	--	9	25	2570	4810	851
P-7	.329	185	7	23	2120	4120	816
P-8	.369	171	9	19	2450	4600	827
P-9	.338	161	8	21	2730	5270	1152
P-10	--	--	9	25	2400	4830	1065
P-11	.358	191	9	25	2340	4710	986
P-12	.358	187	8	26	2410	3760	721
P-13	.409	154	11	25	2720	5540	1145
P-14	.378	134	12	26	2660	5380	1076
P-15	.386	174	10	25	2530*	5310*	1232*
P-16	.338	108	11	21	2380	4700	847
P-17	--	--	10	27	2810	5150	1133
P-18	.324	127	9	20	1940*	4320*	813*
P-19	.402	97	8	26	2110	4290	647
P-20	.356	170	9	26	2360	4820	1045

TABLE 10.--Continued

Pole No.	Specific Gravity (Vol. at test, Weight Oven Dry)	Moisture Content at Test (%)	Rings Per Inch	Summer Wood (%)	Static Bending: Stress at Pro. Limit (psi)	Static Bending: Maximum Fiber Stress (Mod. of R) (psi)	Static Bending: Mod. of Elast., 1000 psi
P-21	.357	153	10	25	2120	4500	822
P-22	.367	155	10	22	1880	3830	678
P-23	--	--	9	28	1880	5410	1080
P-24	.324	201	8	20	2210	4640	864
P-25	.388	152	8	26	1890	4020	565
P-26	.329	157	8	21	2160	4690	952
P-27	.374	149	12	29	2780	5350	1197
P-28	.382	154	9	30	2190	3960	714
P-29	.369	143	9	26	2370	4470	793
P-30	.391	128	10	26	2550	6010	1306
P-31	--	--	9	27	2370	5520	1004
P-32	.354	187	8	16	2540	5160	1037
Average	.359	159	8.9	24	2360	4730	916
Standard Dev.	.025	--	--	--	290	616	198
N =	26	26	32	32	30	30	30

* Not used in averages because of missing samples

TABLE 11.--Second growth - minor tests, average results of static bending

Pole No.	Specific Gravity (Vol. at test, Weight Oven Dry)	Moisture Content at Test (%)	Rings Per Inch	Summer Wood (%)	Static Bending: Stress at Pro. Limit (psi)	Static Bending: Maximum Fiber Stress (Mod. of R) (psi)	Static Bending: Mod. of Elast., 1000 psi
S-1	.333	202	9	21	2170	4250	671
S-2	.385	124	11	27	2380*	5100*	855*
S-3	.390	143	8	18	2420	4710	637
S-4	.363	121	9	27	2430	5080	955
S-5	.365	139	14	30	2530	6060	1481
S-6	.384	136	9	25	2390*	4990*	974*
S-7	--	--	10	28	2770	5090	957
S-8	--	--	9	17	2470	4860	926
S-9	.409	132	10	22	2650	6090	1326
S-10	.353	145	10	26	2730	5660	1079
S-11	.390	146	10	27	2740	5660	1281
S-12	--	--	10	32	2390	5750	1145
S-13	.386	127	10	29	3020	5930	1550
S-14	--	--	10	25	2610	5820	1322
S-15	.369	163	9	27	2600	4870	974
S-16	--	--	10	29	2640	6220	1437
S-17	.360	160	9	24	3030	5030	1067
S-18	.395	144	11	25	2960	6050	1347
S-19	.360	175	10	29	4050	6310	1258
S-20	Pole broken during unloading						
S-21	.348	160	10	24	2560	4890	1082

TABLE 11.--Continued

Pole No.	Specific Gravity (Vol. at test, Weight Oven Dry)	Moisture Content at Test (%)	Rings Per Inch	Summer Wood (%)	Static Bending: Stress at Pro. Limit (psi)	Static Bending: Maximum Fiber Stress (Mod. of R) (psi)	Static Bending: Mod. of Elast., 1000 psi
S-22	--	--	12	25	2640	5500	1113
S-23	.366	157	10	24	2930	5820	1298
S-24	--	--	9	29	2480	5900	1248
S-25	--	--	10	24	2560	5160	980
S-26	--	--	10	23	2780	4900	945
S-27	.364	180	7	19	1630	3850	539
S-28	--	--	10	25	2400	5500	1131
S-29	.382	153	9	30	2700	5270	1135
S-30	.378	158	8	28	2200	5380	1041
S-31	.357	156	7	25	2230*	5040*	1100*
S-32	.351	170	9	29	2700	5750	1295
S-33	.361	110	11	23	2660	5610	1046
Average	.370	150	9.7	26	2640	5410	1113
Standard Dev.	.017	--	--	--	387	627	240
N =	22	22	32	32	29	29	29

* Not used in averages because missing samples

TABLE 12.--Plantation grown - minor tests, average results of compression

Pole No.	Specific Gravity (Vol. at test, Weight Oven Dry)	Moisture Content, (%)	Rings Per Inch	Summer Wood (%)	Maximum Fiber Stress (Mod. of R) (psi)
P-1	.362	209	6	23	1710*
P-2	.333	221	11	24	1950
P-3	.349	197	8	25	1840
P-4	.345	200	9	29	1780
P-5	.371	192	9	32	1810
P-6	.364	194	9	32	1800
P-7	.324	208	6	22	1550
P-8	.365	191	8	21	1880
P-9	.352	203	8	31	1940
P-10	.376	186	10	27	2060
P-11	.381	191	11	26	2190
P-12	.353	206	8	28	1770
P-13	.402	178	11	32	2040
P-14	.357	168	11	26	2130
P-15	.380	181	10	24	2100
P-16	.356	183	10	28	1910
P-17	.361	175	8	20	2120
P-18	.344	212	9	21	1780
P-19	.395	166	6	32	1710
P-20	.357	191	9	35	1910
P-21	.367	192	8	22	1850
P-22	.358	200	9	23	1740
P-23	.372	167	10	23	2070
P-24	.347	216	7	20	1700
P-25	.381	189	7	33	1690
P-26	.358	179	9	25	2010
P-27	.378	183	10	35	2090
P-28	.387	189	9	31	2180
P-29	.369	183	7	32	1660
P-30	.396	153	11	30	2230
P-31	.396	178	9	34	2180
P-32	.355	210	10	32	1900
Average	.365	185	8.8	27	1990
Standard Dev.	.018	--	--	--	182
N =	32	32	32	32	31

* Not used in averages because of missing samples

TABLE 13.--Second growth - minor tests, average results of compression

Pole No.	Specific Gravity (Vol. at test, Weight Oven Dry)	Moisture Content, (%)	Rings Per Inch	Summer Wood (%)	Maximum Fiber Stress (Mod. of R) (psi)
S-1	.338	217	9	30	1730
S-2	.380	175	9	25	1990
S-3	.395	168	8	35	1900
S-4	.386	178	9	24	2340
S-5	.402	165	10	27	2450
S-6	.386	172	10	31	2000
S-7	.409	147	11	39	2220
S-8	.351	200	9	30	1840
S-9	.409	153	10	26	2440
S-10	.364	185	10	32	2020
S-11	.396	168	10	34	2270
S-12	.388	163	10	41	2010
S-13	.391	170	11	33	2380
S-14	.375	157	11	28	2350
S-15	.368	182	9	27	2220
S-16	.386	157	13	36	2270
S-17	.368	187	10	26	2170
S-18	.385	181	11	27	2200
S-19	.384	193	10	22	2510
S-20	.345	208	11	22	2050
S-21	Pole broke during unloading				
S-22	.349	163	7	18	1370
S-23	.366	178	9	27	2130
S-24	.374	180	10	33	2340
S-25	.360	174	9	25	1830
S-26	.350	190	10	33	1830
S-27	.389	175	10	28	2230
S-28	.367	175	9	28	1760
S-29	.385	184	9	28	2340
S-30	.386	182	8	28	2060
S-31	.354	198	9	22	2100
S-32	.367	180	10	36	2110
S-33	.369	174	9	32	1910
Average	.375	177	9.8	29	2100
Standard Dev.	.020	--	--	--	508
N =	32	32	32	32	32

DISCUSSION OF RESULTS

Major Tests

The average strength values of maximum fiber stress and modulus of elasticity for the plantation and second growth major tests showed no significant difference at the 0.05 level. Analysis of the size and location of knots of these two groups showed no significant difference at the 0.05 level in either the sum of knot diameters in the entire pole or in the middle half.

Wood, Erickson and Dohr in Strength and Related Properties of Wood Poles [11], stated that "It is difficult and probably impractical to make an adjustment of the strength values for moisture content in the air dry range." [11] The reasons for this were first, as the poles dry more strength reducing defects would occur and secondly, shrinkage during drying would reduce the bending strength because of a smaller radius. However, L. J. Jacobi in referring to wet test poles reports that "Poles used are drier and hence stronger than were the poles tested. Therefore, the stresses ultimately assigned may logically be higher than those shown for treated poles tested by the ASTM test." [6] The drying factor which Jacobi gives is 1.16 times the stress value of the poles tested above 30 percent moisture content.

Strength and Related Properties of Wood Poles [11] refers to an REA report on the moisture content of 351 poles in use in Illinois, Indiana, Minnesota, eastern North Dakota, and Wisconsin. This report shows that the ois

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moisture content, six inches above ground line, was below 15 percent for about 85 percent of the poles tested. The Wood Handbook [10] states that the strength of clear red pine increases by 4 percent for every 1 percent drop in moisture content below the "moisture-intersection point" of 24 percent. All poles used in this study had a moisture content in excess of 30 percent during testing. As shown above, the moisture content of the poles in use is generally below 15 percent. This would allow for the maximum fiber strength in bending to be increased by (24% - 15%) x 4 = 36 percent. If the above adjustments were made, the values for fiber stress in this study would be as shown in Table 14. The fiber stresses for red pine, as reported in other studies, are listed in Table 15.

In the past, most of the testing done has been on poles which have been butt soaked. This gave the butt section a moisture content of above 30 percent; however, the moisture content at the point of break was probably a much lower value as indicated by the REA study reported by the ASTM Wood Pole Research Program. [10]

Minor Tests

Tests of small clear specimens produced average values of 4730 psi and 5410 psi for fiber stress in bending for plantation and second growth respectively. The average value for modulus of elasticity of plantation specimens was 916,000 psi and for the second growth specimens was 1,113,000 psi. The average values of fiber stress and modulus of elasticity for these tests showed a significant difference at the 0.05 level. The combined average for fiber stress of the minor test in this study was 5070 psi as compared with that of 5800 psi for green conditions stated in the Wood Handbook. [10] Because of the significant difference indicated in the minor test, a ratio between major and minor was not made.

The presence of knots appears to reduce the strength of poles. However, only 30.5 percent of the failures occurred at, or close to, knots. Although the clear wood of second growth was stronger than that of plantation growth, the poles did not differ significantly. This was probably due to the effect of knots on the poles. This would indicate that the influence of knots throughout the pole is more important than the strength of wood itself for strength evaluations.

TABLE 14.--Strengths of red pine poles adjusted for moisture content

Method	Actual Fiber Stress, Maximum,psi	Adjustment Factor	Adjusted Strength
Jacobi [6]	4860	1.16	5640
Wood Handbook [10] (for clear wood)	4860	1.36	6610

TABLE 15.--Maximum fiber stress for red pine as reported by other studies

Study Reporting	No. Tested	Fiber Stress (psi)
Ontario Hydro [8]	125	5749
Canada Forest Service No. 31 [9]	27	7040
	25	6770
	25	6810
Bell Telephone Systems Monograph No. 1965 (as reported in [8])	166	6400
	Weighted Average	6280

CONCLUSIONS

On the basis of the observations made and the results obtained by this study, the following conclusions are made:

1. The clear wood of the second growth poles, as determined by tests performed on the small clear specimens, appeared to be stronger than that of the plantation grown poles.
2. There is a slight, but significant difference between the strength values of the poles (major test) and those of the small clear specimens (minor test) tested in this study.
3. There is no significant difference in the strength values, sum of knot diameters, or in the specific gravity between red pine plantation grown poles and second growth (natural regeneration) poles on the basis of tests conducted on the full-size poles.

RECOMMENDATIONS

Further study should be undertaken as follows:

1. The effect of moisture content on the strength of poles in service.
2. A comparison of butt soaked poles and completely submerged soaked poles with respect to fiber stress, determining a drying factor to be used.
3. A larger sample of red pine poles to more accurately estimate actual fiber stress.
4. The effect of knots on the overall strength of poles.

LITERATURE CITED

1. American Society for Testing and Materials. Part 6, 1961. "Static Tests of Wood Poles", ASTM Designation: D 1036-58. Philadelphia, 1961.

2. American Society for Testing and Materials. Part 6, 1961. "Testing Small Clear Specimens of Timber," ASTM Designation: D 143-52. Philadelphia, 1961.

3. American Society for Testing and Materials. Part 6, 1961. "Static Test of Timbers," ASTM Designation: D 198-27. Philadelphia, 1961.

4. American Standard Association. 1963. "Specifications and Dimensions for Wood Poles," ASA Designation: 05.1-1963. New York, 1963.

5. DECPMBT. "Specification for Treatment of Red Pine Poles," Revision A, October 21, 1963.

6. Jacobi, L. J. "ASTM Wood Pole Tests and the Development of New ASA Pole Specifications," Proceedings, Wood Pole Institute, pp. 7-12.

7. Panshin, A. J., DeZeeuw, Carl and Brown, H. P. "Textbook of Wood Technology," McGraw-Hill Book Company, Inc., New York, 1964, p. 186.

8. Platt, J. C. "The Strength of Wood Poles, Western Red Cedar and Red Pine," Hydro-Electric Power Commission of Ontario Research Division Report, No. 58-206, June, 1958.

9. Rochester, G. H., "The Strength of Telephone Poles; Eastern Cedar, Red Pine, and Jack Pine," Canada Forest Service, Circular No. 31, 1931.

10. "Wood Handbook," Prepared by the Forest Products Laboratory, United States Department of Agriculture, Handbook No. 72, Government Printing Office, Washington 25, D. C. 1955.

11. Wood, Lyman, E. C. O. Erickson and A. W. Dohr, "Strength and Related Properties of Wood Poles," Final Report of ASTM Wood Pole Research Program. American Society of Testing Materials, Philadelphia, September, 1960.