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Effect of Steaming and Kiln Drying On the Properties Of Southern Pine Poles

Part I: Mechanical Properties

Warren S. Thompson

Abstract

Data were obtained on the effect of method of conditioning on the bending and compression strength of southern pine utility poles and piling sections. Three conditioning methods were studied: Steam conditioning at 245° F. for 14 hours, kiln drying at a maximum dry bulb temperature of 152° F., and kiln drying at a maximum dry bulb temperature of 182° F. Kiln-dried poles had significantly higher strength values than the steamed poles for all strength properties except MOE. Differences in strength between kiln-dried and steam-conditioned poles ranged from 14 percent in the case of maximum crushing strength to 37 percent for fiber stress at the proportional limit. Poles kiln dried at 152° F. had higher strength values than those dried at 182° F. but the differences were not deemed to be of any practical significance. A supplemental study was run to determine the effect of conditioning method on the development of seasoning defects and preservative retention.

Investigations on the effect of processing temperatures on the mechanical properties of wooden members date back at least to 1906 and the work of Hatt (10). Since that time numerous reports have dealt with this subject (7, 8, 9, 11). They show conclusively that there is a range of temperature—short of that required to cause outright destruction—within which wood undergoes chemical degradation and sustains losses in strength to a degree dependent upon the duration and severity of exposure.

Reductions in the strength of wood associated with exposure to high temperatures assume practical importance in the processing of wood for preservative treatments. Current AWPA standards permit steam conditioning of southern pine poles and piling for up to 20 hours at a maximum temperature of 245° F. (4, 5). A conditioning temperature of 259° F. was allowed under these standards prior to 1960. The adoption of the lower value by industry was prompted by the publication in 1960 of the results of the ASTM Wood Pole Research Program (16). Work under this program showed that southern pine poles sustain strength reduction of up to 40 percent when steamed for a prolonged period of time at 259° F. Supplementary tests of limited scope indicated that poles steamed at temperatures of 240° to 245° F. for 15 hours had strength values closer to those for untreated poles.

Although it is unquestionably true that steam conditioning reduces the strength of southern pine poles and piling, the magnitude of the reductions caused by steaming practices permitted under

The author is Director, Forest Products Utilization Laboratory, Mississippi State University, State College, Mississippi.

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Table 1. — RECORD OF TREATMENT OF THE THREE GROUPS OF POLES INCLUDED IN THE STUDY.

Operation	Group I	Group II	Group III
Steaming temperature (°F.)	245	——	——
Duration (hr.)	14	——	——
Initial vacuum (in. Hg.)	25	——	——
Duration (hr.)	3.50	——	——
Air pressure (psi)	60	50	50
Duration (hr.)	0.75	0.50	0.50
Oil pressure (psi)	200	140	140
Duration (hr.)	5.75	1.50	1.50
Oil temperature (°F.)	194	150	150
Final vacuum (in. Hg.)	25	26	26
Duration (hr.)	0.50	0.50	0.50
Total treating time (hr.)	25.50	3.75	3.75
Net retention (lb./ft.^{3})	10.29	10.59	10.24

current standards has not been satisfactorily defined. This problem has been further complicated in recent years by wide-scale employment within the treating industry of artificial seasoning methods, principally kiln drying, for which there are no standards governing the maximum temperature that can be used. Accordingly, questions have been raised concerning the relative effect of kiln drying and steam conditioning on the strength of southern pine poles and piling.

The purpose of this study was to determine the effect of processing temperature on the chemical, mechanical, and treating properties of southern pine wood. The study was divided into two parts. Part one was an investigation of the influence of the type and severity of conditioning method on the strength in bending and compression of utility poles and piling sections, respectively. The results of this investigation are reported here. The results of part two of the study, which was concerned with the interrelationship between chemical and mechanical changes in wood following steam treatments, will be reported in a second paper.

Experimental Procedure

Tests of Poles

One hundred and fifty Class 6, 30-foot southern pine poles were selected for use in this phase of the study. All poles had a minimum rate of growth of 6 rings per inch, or 30 percent or more summerwood, in the outer 2 inches of radius at the butt end, and were straight and free of knots larger than 1 inch in diameter in the lower 10 feet of length. Only those poles that had a circumference within the range of 24.5 to 27.0 inches at a point 6 feet from the butt, and which had a moisture content of 40 percent or higher in the outer 1/2-inch of radius, were selected for use in the study. The poles were selected without regard to species, usually as they came from the pole machine. All poles were machine peeled.

The poles were assigned to three treatment groups of 50 poles each and seasoned according to the following schedules:

- Group I — Steam conditioned 14 hours at 245° F.
- Group II — Kiln dried for 158 hours. Initial conditions: 140° F., 20° wet-bulb depression; final conditions: 152° F., 35° wet-bulb depression. Final average moisture content: 31.5 percent.
- Group III — Kiln dried for 160 hours at dry-bulb temperatures of 170° to 182° F. and wet bulb depressions of 50° to 65° F. Final average moisture content: 13.0 percent.

The conditioning schedules to which poles in Groups I and II were subjected are representative of the steaming and kiln-drying practices, respectively, that are currently employed with southern pine poles. The kiln schedule used with poles in Group III represents the most severe drying conditions that have been used commercially; it was selected to provide a basis for judging the effect on strength of prolonged exposure of poles to severe drying conditions. Results of a cursory survey indicate that kiln schedules this severe are no longer being used.

Immediately following conditioning, all poles were treated with creosote to a nominal retention of 10 pounds per cubic foot, using commercial treating facilities. Group I poles were treated in with a charge of partially-seasoned poles, following a steam-conditioning period of 14 hours at 245° F., as previously described. Poles in Groups II and III were treated with two charges of kiln-dried poles for which identical treating cycles were used. No initial steaming was used, but the two charges were given a 30-minute final steaming before being pulled. Details of the treating schedules employed with the three groups are given in Table 1.

Because of the widely varying moisture content of the poles in the three groups, all poles were stored in water for a period of 6 to 12 weeks prior to testing. This procedure served to insure that the moisture content of all poles was above the fiber saturation point at the time of testing, thus eliminating moisture content as a variable in the study.

The poles were removed from water storage in groups of 12 to 15 for testing. Prior to testing, five increment cores were extracted from the central 10 feet of each pole for moisture content and specific gravity determinations and creosote assay. The cores were trimmed so that only the outer 2 inches were retained for analysis. Moisture content and creosote retentions were determined according to AWPA Standard A6-67 (6). Specific gravity was determined by the maximum moisture method described by Smith (13).

The circumference of each pole was measured at [illegible]-foot intervals along its length, at the "groundline" (5.5 feet from the butt), and at the load point (2 feet from the tip). All defects such as knots, resin pockets, and mechanical injuries were measured and plotted in terms of their circumferential and longitudinal position on the poles.

Bending tests were conducted using the cantilever method described by ASTM Standard D1036-[illegible]. Load was applied by a winch, powered by a hydraulic motor which was turned by a 10 hp electric motor. While this system provided the desirable feature of an infinitely variable feed rate, the rate of loading was so variable at slow winch speeds that a double block and tackle laced with Manila rope was placed in series with the cable connecting the winch to the pole to insure that a constant rate of loading could be maintained.

All tests were conducted at a feed rate of 5.0 inches per minute. A load cell of 10,000 pounds capacity was connected between the pole and the pull cable to measure load. A time-load plot for each pole was made using a single-point recorder. Both the load cell and the recorder were calibrated periodically during the study.

Deflection at the load point, shortening of the lever arm caused by deflection of the pole, and movement of the pole at the groundline were recorded at load increments of 200 pounds. Loading was continued until failure occurred. Type of failure, the distance of the point of failure from the load point, and the location of failure with respect to knots and other defects were recorded for each pole prior to removal from the test crib.

Maximum load for each pole was corrected for a constant error of 40 pounds in the zero calibration of the recorder. The corrected data were used to calculate modulus of rupture at the groundline and load point, fiber stress at the proportional limit, and modulus of elasticity.

Tests of Small, Clear Specimens

One-half of the poles in each treatment group were selected by a systematic sampling scheme after they had been tested in bending and a 7-foot section removed from the butt end of each. Two [illegible] specimens 2-1/2 by 2-1/2 by 48 inches were sawn from each section. Taper sawing was used to reduce the incidence of diagonal grain. The two specimens were cut from opposite sides of the section and from points as close to the pole surface as practical.

The specimens were returned to water storage for 2 weeks to increase their moisture content above the fiber saturation point. At the end of this period, each was surfaced to a cross sectional dimension of 2 by 2 inches and cross cut to yield a [illegible]-inch-long static bending specimen and an 8-inch-long compression specimen. These specimens were stored at high humidity until tested. Upon removal from storage, their moisture contents were checked with a resistance-type moisture meter and the specimens tested following the procedure outlined in ASTM Standard D143-52 (2).

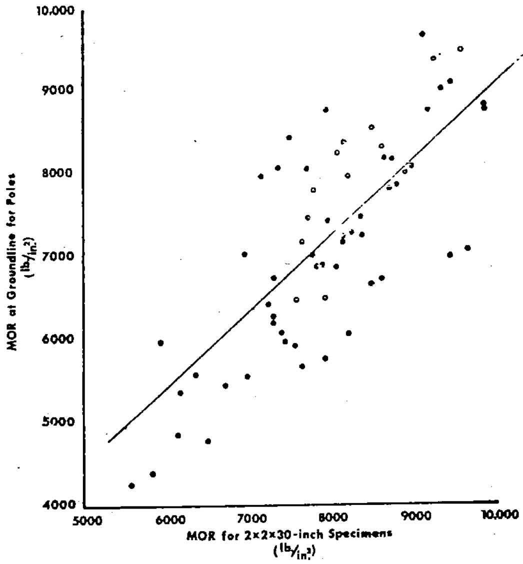

Figure 1. — Relationship between modulus of rupture of class 6, 30-foot poles and clear specimens: Y = 6.19 + 0.90X; r = 0.81

Data from the static bending tests were used to calculate modulus of rupture, fiber stress at the elastic limit, and modulus of elasticity. Maximum crushing strength, fiber stress at the elastic limit, and modulus of elasticity were calculated from the compression test data.

Tests of Piling Sections

A single piling section was cut from the same poles from which the 7-foot sections were cut. These sections, initially 49-inches long, were located along the length of the pole so that the diameter at the small end of the test specimen would be 7.5 ± 0.5 inches when the sections were trimmed to a final length of 36 inches.

As in the case of the other specimens, the piling sections were stored in water until tested. Prior to testing, they were trimmed to a length of 36 inches, the circumference at both ends measured, and the size and location of all knots recorded. Increment cores were removed from each section for moisture and specific gravity determinations.

The specimens were tested to failure in compression in a 200,000-pound-capacity testing machine, following the procedure outlined in ASTM Standard D198-27 (3). The type of compression failure and its location with respect to defects were recorded for each section. The test data were used to calculate maximum crushing strength.

Discussion of Results

Static Bending and Compression Tests

The average strength values for poles and for piling sections and small, clear specimens cut from

Table 2. — RESULTS OF MECHANICAL TESTS ON CLASS 6, 30-FOOT SOUTHERN PINE POLES AND SPECIMENS CUT THEREFROM FOR THREE SEASONING SCHEDULES.

Test	Steam Conditioned	Kiln dried at 152° F.	Kiln dried at 182° F.	Average
	(Psi)			
Static Bending — 30′ Poles[a]				
Max. fiber stress at groundline	5747	7902	7282	6977
Max. fiber stress at breakpoint	5450	7540	7174	6722
Modulus of elasticity	1173×10^3	1272×10^3	1160×10^3	1202x10
Fiber stress at EL at groundline	3578	5021	4524	4374
Static Bending — 2″x2″x30″ Pieces[a]				
Max. fiber stress	7080	8914	7996	7922
Fiber stress at elastic limit	4139	4540	3811	4163
Modulus of elasticity	1457×10^3	1477×10^3	1453×10^3	1462x10
Compression — 3′ Piling Section[b]				
Max. crushing strength	2706	3292	3090	3029
Compression — 2″x2″x8″ Pieces[a]				
Max. crushing strength	3386	4259	3939	3861
Fiber stress at elastic limit	2163	2772	2541	2492
Modulus of elasticity	1667×10^3	1762×10^3	1655×10^3	1695x10
Specific Gravity	.541	.534	.522	.532
Moisture Content (%)	36.3	36.7	40.9	38.0

[a]Each value is the average of 50 tests.

[b]Each value is the average of 25 tests.

these poles are given in Table 2. A summary of the results of data analyses for each of the series of mechanical tests is presented in Table 3.

Kiln-dried poles had significantly higher test values than steam-conditioned poles for all strength properties except modulus of elasticity. The average modulus of rupture at the groundline for poles dried at a maximum temperature of 152° F. was 7902 psi, while the comparable value for steamed poles was 5747 psi. The greater part of the difference between the two (37 percent) probably represents the reduction in strength attributable to steaming. However, the treating conditions to which Group I poles were subjected were likewise more severe than those used with the two groups of kiln-dried poles (Table 1). Comparable differences for modulus of rupture at the point of failure, fiber stress at the proportional limit, and maximum crushing strength were, respectively, 32 percent, 26 percent, and 14 percent.

Poles kiln dried at 152° F. had higher strength values than those dried at 182° F. The differences between the two, while statistically significant, were quite small and probably have little if any importance from a practical standpoint. They ranged from 5 percent in the case of modulus of rupture at the point of failure to 11 percent for fiber stress at the proportional limit.

Previous work has shown a close relationship between the bending strength of wood and the 3/2 power of specific gravity.[1] The average specific gravity of the steamed poles included in this study was slightly larger than that for kiln-dried poles, although not significantly so (Table 3). Since this variable was not significant, comparisons of bending strength values adjusted for differences in specific gravity have little meaning here. However, attention is called to the fact that such adjustments would serve to increase the difference in bending strength between steamed and kiln-dried poles by approximately 3 percentage points and decrease the difference between the two kiln-dried groups by a similar amount.

Bending strength values for poles tested in this study, after making appropriate adjustments for differences in specific gravity, generally compare favorably with results obtained with southern pine poles in the ASTM Wood Pole Research Program (16). The average modulus of rupture of steam conditioned poles treated with creosote in the ASTM study was 5490 psi, compared to a value of 5747 psi obtained at this laboratory. A direct comparison between the two studies in the bending strength values for treated, kiln-dried poles was not possible. The only group of kiln-dried poles

[1]This relationship is directly applicable only to specimens of uniform cross section. Its use here is intended to provide a first approximation of changes in strength of poles associated with changes in specific gravity.

included in the ASTM study was dried at about the same temperature, 150° F., as that used for Group II poles in this study; but the poles were only 20-feet long and were machine tested. The average modulus of rupture for these poles, adjusted for differences in specific gravity, was 8250 psi. This value is in line with the value of 7902 psi obtained with poles kiln-dried at 152° F. (Table 2).

Unlike strength in bending and compression, the stiffness of the test poles was not affected to a significant degree by conditioning method. The average modulus of elasticity of kiln-dried poles exceeded that for steamed poles by less than 4 percent. Similar results were obtained in tests on small, clear bending and compression specimens cut from the treated poles. Values for modulus of elasticity were 1457 x 10^3, 1427 x 10^3, and 1453 x 10^3 psi for 2 by 2 by 30-inch bending specimens cut from steamed poles and poles kiln dried at 152° and 182° F., respectively. The difference between steamed and kiln-dried poles was less than 1 percent. Similarly, the difference in average modulus of elasticity for 2 by 2 by 8-inch compression specimens representing the two conditioning methods was only about 2 percent.

Values of modulus of elasticity in bending were consistently lower, both in the case of poles and small, clear specimens, than published values (16). This disparity remained after adjusting the data for differences in specific gravity. For example, the average values for modulus of elasticity for all poles and bending specimens cut therefrom were 1202 x 10^3 and 1462 x 10^3 psi, respectively. Comparable values provided by the ASTM Study (16) for poles of similar specific gravity were on the order of 1600 x 10^3 to 1800 x 10^3 psi. No explanation could be found for these differences.

Results on Small, Clear Specimens

The pattern of differences in average strength values among small, clear specimens representing steam conditioning and kiln drying was similar to that for the poles and piling sections. Reductions in strength attributable to steaming, however, were much smaller in clear specimens than in the poles. For example, the modulus of rupture for static bending specimens cut from poles kiln dried at [illegible] F. exceeded that for specimens cut from steamed poles by 26 percent. The difference between the two groups in fiber stress at the elastic limit was only 10 percent. Apparently, the strength reductions in clear wood were due to the effect of steaming on the wood substance, while the greater reduction in poles was caused by the additional effect of defects which developed during conditioning and treatment.

Poles were usually lower in both strength and stiffness than clear specimens. The difference ranged from 10 to 20 percent. Again, the difference probably represents the effect of defects in the poles that were not present in the small specimens.

Results of tests on poles and 3-foot piling sections were well correlated with results of corresponding tests conducted on the clear specimens. The relationships are shown in Figures 1, 2, and 3 for modulus of rupture, modulus of elasticity, and maximum crushing strength, respectively.

Character and Location of Failure

Most of the poles failed by a combination of compression and associated tension. Pure tension and compression failures were rare. Horizontal shear was associated with compression failures in three instances.

The first evidence of failure usually occurred on the tension side of the poles and was characterized by the failure of a few fibers. This was normally followed by a buckling of fibers on the compression side and the development of the characteristic "wrinkle" associated with compression failures. The actual failure of the poles, as judged by a decrease in load, varied from pole to pole, but followed a definite pattern among treatment groups. The predominate type of failure was assumed to be compression if a gradual reduction in load occurred and tension if the reduction were sudden. Based on this premise, tension failures predominated among kiln-dried poles and compression failures among steam-conditioned poles.

More than 90 percent of the poles failed within 6 feet of the groundline, and all except three failed within 8 feet of that point. Approximately 25 percent failed within 1 foot of the groundline, but only 10 percent failed at the groundline proper. Failure would normally be expected to occur at or near the groundline for southern pine poles of the size included in this study. According to Wood and coworkers (16), the maximum stress in a cantilever with the shape of a frustum of a cone occurs where its diameter is 1.5 times the diameter at the point of load application. However, since none of the

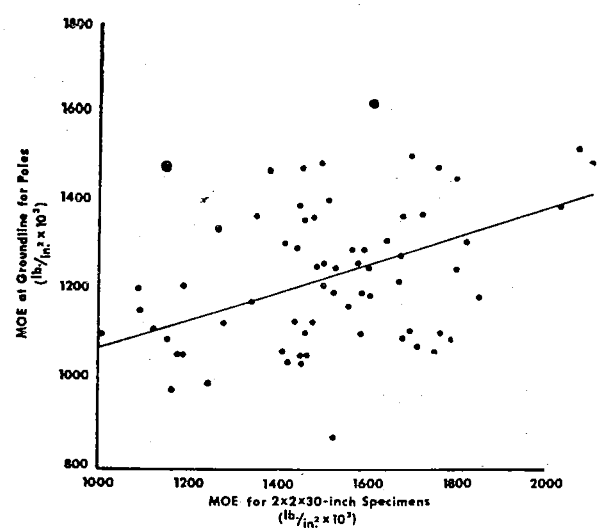

Figure 2. — Relationship between modulus of elasticity of class 6, 30-foot poles and clear specimens: $Y = 761.66x10^3 + 0.31X$; $r = 0.48$

poles included in this study approached that diameter ratio at or above the groundline, maximum stress occurred at the groundline.

Failure of the poles was clearly associated with knots or other defects in less than 10 percent of the tests. In all instances the point of failure was so far removed from the largest knot and the 1-foot section containing the largest sum of knot diameters that it can be assumed that they had no effect on the strength of the poles. Only 22 percent of the poles had knots within 1 foot of the point of failure; and where failure occurred at or near those knots, the strength of the poles was not significantly reduced. The average modulus of rupture at the groundline for poles that had knots within 1 foot of the point of failure was only 6 percent smaller than the average value for all poles.

It is generally agreed that knots and knot whorls of maximum size permitted under current standards and specifications have little effect on pole strength, occurring as they do in the upper half of the pole. Some question remains, however, regarding the effect of strength of small knots that occur in the lower half of poles. The data provided by this study indicate that such knots are of minor importance.

Other Effects of Conditioning

Defects — Conditioning and preservative treatment of the poles were accompanied by the development of seasoning checks, pith checks, and, in some instances, ring shakes. The extent of defect development associated with steam conditioning and various kiln schedules was investigated in a supplementary study involving 120 poles 10-feet long and 6 to 9 inches in diameter. The poles were inspected for defect development after conditioning and treating with creosote to a retention of 10 pounds per cubic foot. An index consisting of the product of the number of checks 6 inches or more in length and the length and depth of the largest single check or split was the criterion used to judge the severity of checking.

Poles kiln-dried within the temperature range of 150° to 155° F. at a wet-bulb depression of 20° to 25° F. showed significantly less checking than either steamed poles or poles dried under more severe kiln conditions. Checking was most severe in poles dried for 140 hours at temperatures of 180° to 185° F. and a wet-bulb depression of 40° F. However, checking in this group was only slightly more severe than, and did not differ significantly from, poles steam conditioned at 245° F. for 14 hours. It appears, therefore, that steaming poles at temperatures and for durations permitted under current standards causes checking approximately equal in severity to kiln drying for 6 days at a dry-bulb temperature of 180° to 185° F. and a wet-bulb depression of 40° F.

Kiln drying at temperatures of 160° to 165° F. and wet-bulb depressions of 20° to 35° F. caused

Table 3. — RESULTS OF ANALYSIS OF VARIANCE OF THE EFFECT OF CONDITIONING METHOD ON THE STRENGTH OF CLASS 6, 30-FOOT SOUTHERN PINE POLES AND SPECIMENS CUT THEREFROM.

Test	Analysis of Variance F Values[a]		
	Seasoning Methods	Group I vs. II and III[b]	Group II vs. III
Static Bending — 30′ Poles			
Max. fiber stress at groundline	64.21(2, 147)**	118.40(1, 147)**	10.03(1, 147)**
Max. fiber stress at breakpoint	58.07(2, 147)**	113.02(1, 147)**	3.30(1, 147)
Modulus of elasticity	.38(2, 147)	.13(1, 147)	.64(1, 147)
Fiber stress at EL at groundline	39.36(2, 147)**	69.66(1, 147)**	9.05(1, 147)**
Static Bending — 2″x2″x30″ Pieces			
Max. fiber stress	937.80(2, 66)**	1724.30(1, 66)**	151.20(1, 66)**
Fiber stress at elastic limit	41.38(2, 66)**	57.79(1, 66)**	24.98(1, 66)**
Modulus of elasticity	.02(2, 66)	.01(1, 66)	.01(1, 66)
Compression — 3′ Piling Sections			
Max. crushing strength	17.46(2, 69)**	30.90(1, 69)	4.03(1, 69)*
Compression — 2″x2″x8″ Pieces			
Max. crushing strength	15.70(2, 66)**	27.20(1, 66)**	4.12(1, 66)*
Fiber stress at elastic limit	5.11(2, 66)*	8.40(1, 66)**	1.83(1, 66)
Modulus of elasticity	.31(2, 66)	.10(1, 66)	.52(1, 66)
Specific Gravity	.63(2, 147)	.20(1, 147)	1.07(1, 147)

[a]Numbers in parentheses refer to degrees of freedom associated with the larger and smaller mean squares, respectively. Values marked with a double asterisk (**) and a single asterisk (*) are significant at the 0.01 and 0.05 levels of probability, respectively.

[b]Groups I, II, and III refer to poles steam conditioned, kiln dried at 152° F. and kiln dried at 182° F., respectively.

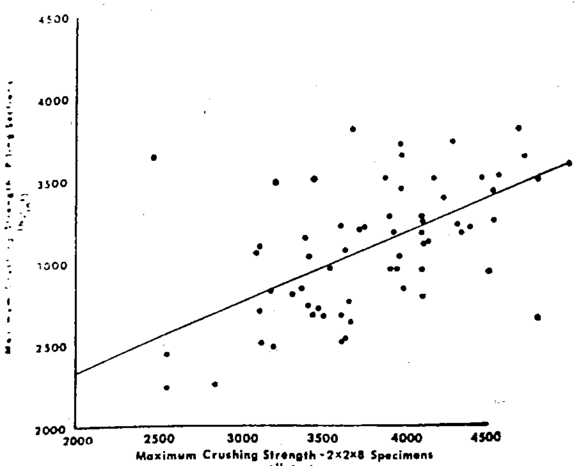

Figure 3. — Relationship between maximum crushing strength of 3-foot piling sections and clear specimens: $Y = 1500.41 + 0.41X$; $r. = 0.60$

significantly less checking and splitting than either kiln drying at higher temperatures or steaming. Checking was of only minor importance in poles dried at temperatures of less than 160° F. and wet-bulb depressions of 20° to 25° F.

Preservative Retention — Method of conditioning had an effect on retention of creosote by the test poles. All three groups of poles were treated with commercial charges, the retention for each of which exceeded 10 pounds per cubic foot (Table 1). Assays conducted on each of the poles at the time of testing, however, revealed that poles kiln dried at 182° F. contained significantly less preservative than those dried at a maximum temperature of 152° F. Only 14 percent of the poles in the former group had a retention of 7 pounds per cubic foot or larger, compared to 90 percent of those in the latter group. Fifty-seven percent of the steamed poles had retentions of 7 pounds per cubic foot or larger. The low retention values for poles dried at 182° F. are of particular interest in view of the fact that the assays on cores taken from the poles were conducted on the outer 2 inches. Had the outer half inch of each core been discarded before assaying—a practice required in most specifications—the retention values undoubtedly would have been smaller.

Among the possible explanations that could account for the differences in preservative retention between conditioning methods, the most plausible one is that the conditioning methods used induced different degrees of pit aspiration among the three groups of poles. Certainly, this explanation is supported by recent reports dealing with the effect of pit aspiration on the permeability of wood (12, 15). Results of a supplementary study, however, revealed no difference in either the retention or penetration of creosote in 120 poles that were dried at maximum temperatures ranging from 150° to 180° F. Air-permeability measurements made on samples removed from these poles both before and after kiln drying did not differ significantly either among kiln schedules or between times of sample removal. All permeability samples were processed through an alcohol series and conditioned at 70° F. and 50 percent relative humidity before testing. Measurements of air permeability were used because it was not practical to determine the permeability of wood to creosote in this study. According to Tesoro et al. (14), however, the permeability of wood to air bears a close relationship to its permeability to creosote.

The permeability data provided by this study are not in agreement with results published by Thomas (15) and others (12), which indicate that the permeability of southern pine wood is greatly reduced by drying. Clearly, additional work in this area is needed.

Summary

The effect of steam conditioning and kiln drying on the strength properties of southern pine poles was investigated. The principal results of the study are summarized below:

1) Kiln-dried poles had significantly higher strength values than poles steamed at temperatures and for durations permitted under current standards. The difference in strength among poles conditioned by the two methods ranged from 14 percent in the case of maximum crushing strength to 37 percent for fiber stress at the proportional limit.
2) Poles kiln-dried at a maximum temperature of 152° F. had significantly higher strength values than poles dried at 182° F. The difference between the two groups, which ranged from 5 to 11 percent, was judged to be of little practical importance.
3) Knots and other natural defects had only a minor effect on the bending strength of poles.
4) Poles kiln dried at maximum temperatures of 150° to 155° F. and wet-bulb depression of 20° to 25° F. contained less checking than either steamed-conditioned poles or poles dried at maximum temperatures of 180° to 185° F. Checking and splitting of poles dried at these latter temperatures was only slightly more severe than, and did not differ significantly from, poles steamed at 245° F. for 14 hours.
5) Poles dried for 7 days at 182° F. had significantly smaller retentions of creosote than poles either kiln dried at lower temperatures or steam conditioned. This result was not duplicated in supplementary tests of the effect of kiln schedule on creosote retention and penetration; and air-permeability measurements made on samples removed from poles both before and after seasoning by various kiln schedules did not differ either among schedules or between times of sample removal.

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