The Relation Between Penetration and Decay in Creosoted Southern Pine Poles

By R. H. COLLEY and C. H. AMADON

Poor penetration of the non-durable sapwood is the most important factor in the decay of creosoted southern pine poles. Over 3000 such poles that had been treated with coal tar creosotes of varying types at thirteen creosoting plants in the South have been critically inspected to determine when and where decay started. The poles had been in line from five to twenty-six years under widely diverse climatic conditions in scattered localities east of the Mississippi River. Ninety-five per cent of the failures were poles in which the creosote had penetrated less than 1.8 inches and 60 percent of the sapwood thickness. No failures were found in poles that had been penetrated more than 2.1 inches and 75 per cent of the sapwood thickness. The current Bell System treating specifications require a penetration of 2.5 inches or 85 per cent of the sapwood thickness. The hazard of failure by decay during the ordinary service life of a line is reduced to a practical minimum in poles produced under these specifications.

Introduction

THE creosoted southern pine pole has been justly regarded as a long-lived unit of plant equipment. However, there have been enough instances of failure by internal decay during the first few years in line to focus attention on the poorer poles and to raise questions about the quality and probable length of service of creosoted poles in general. The data presented in this paper were obtained in the course of an investigation to determine how, when, and where decay starts in creosoted southern pine poles in line, and what proportion of the poles are decaying after different periods of service. The results of the study are of particular significance as a basis for engineering the treatment of poles in a satisfactory and economic manner.

General Conclusions About Decay in Poles in Line

In the sections of the lines that were inspected the incidence of decay was definitely correlated with the depth of penetration of the creosote and the per cent of sapwood penetrated.

When all of the 3102 inspected poles of all ages up to 26 years were taken together:

(*a*) There were 62 failures, all of which had penetration less than 2.1 inches and 75 per cent of the sapwood thickness; and the 62 failures were 2.00 per cent of the total poles inspected; and

(*b*) Of these failures 59, or 95.16 per cent, had penetration less than 1.8 inches and 60 per cent of the sapwood thickness.

All the field evidence indicates that the inspected poles, when the sapwood had been well penetrated with creosote, were practically immune to destruction by wood-destroying fungi for a long time. It is equally clear that if early failures in line and consequent replacement charges are to be reduced to a practical minimum it is essential to inspect the treated poles closely and to eliminate the poorly treated ones before they are shipped to the Telephone Companies.

The Inspected Lines

The selection of the lines to be inspected was based largely on geographical location without prior knowledge of the condition of the poles. An attempt was made to get as wide a distribution as possible. The lines were located in Florida; in the Piedmont section of North Carolina and South Carolina; in the Appalachian foothills and mountains of Tennessee, North Carolina and Virginia; in the Lake States region in Illinois, Wisconsin and Michigan; and in northern New Jersey. Sections of the chosen lines contained from 100 to 200 or more poles that had been set consecutively in one year. Old records, plus identifying marks placed on these poles when they were treated, made it possible to determine the supplier of the poles and the type of creosote used in treatment.

Method of Inspection

External decay is relatively rare in creosoted southern pine poles, so the inspection methods employed were directed particularly at finding internal decay. The latter occurs as a result of infection by water or air-borne spores that probably enter through checks or cracks

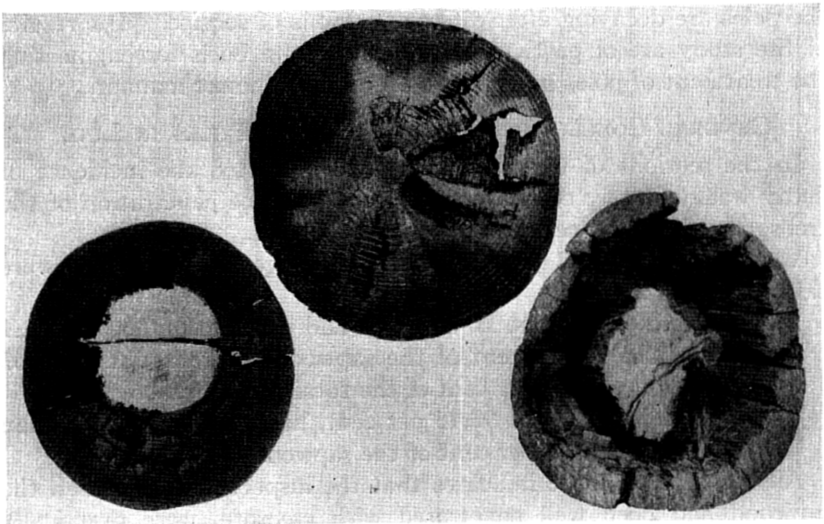

Fig. 1—Cross-sections of poles which failed because of decay that developed in the internal untreated sapwood.

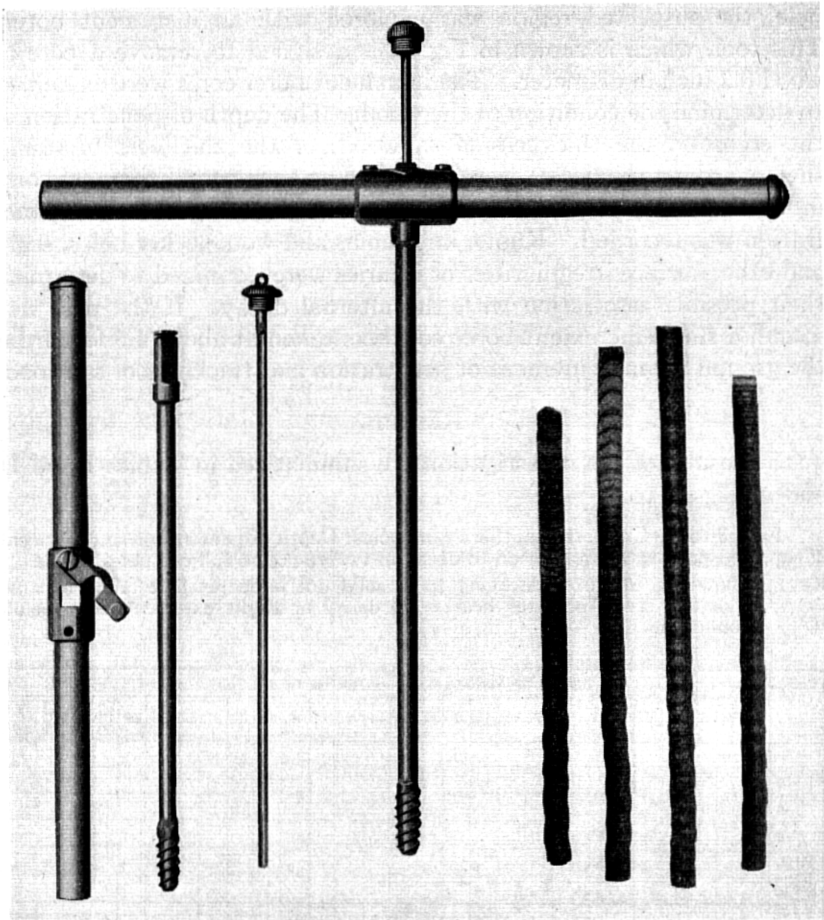

Fig. 2—The increment borer. The central figure shows the borer assembled. At the left are the extractor, the hollow boring tube, and the handle. Four increment borer cores are shown at the right.

and find favorable conditions for growth in untreated, non-durable sapwood lying beneath the treated outer layers of wood. Cross sections of poles showing internal decay of the untreated sapwood are shown in Fig 1.

A systematic inspection of 3102 poles in the selected lines was made by one of the authors, Mr. C. H. Amadon. The possible variances that might arise from different personal methods and interpretations were therefore minimized as far as practicable. Each pole was first tested by sounding with a hammer or a hatchet. When the hammer blows produced a dull lifeless tone, suggesting a hollow or decaying pole, the suspected region was explored with an increment borer. This tool, which is shown in Fig. 2, is designed to remove a core of wood 0.2 inch in diameter. The increment borer cores were examined to determine the condition of the wood. The depth of penetration of the creosote, the thickness of sapwood, or the thickness of sound shell overlying the decay, were measured on each core if there was any internal decay present. In each decaying pole the shallowest penetration was recorded. Knots, knot holes and woodpecker holes, scars and other surface irregularities or injuries were examined to determine their possible association with the internal decay. If the pole was sound, a single increment borer core was taken at about 4.5 feet from the ground for measurement of penetration and thickness of sapwood.

Results

The results of the investigation are summarized in Tables I and II and in Figs. 3 to 9.

Figs. 3 to 7—Creosoted southern pine poles: Depth of penetration and per cent of sapwood penetrated in relation to decay in twelve-pound full cell poles in line.

Key: Hollow dot indicates decaying pole; solid dot indicates pole failed because of decay; cross indicates heartwood decay or slight external decay below ground line.

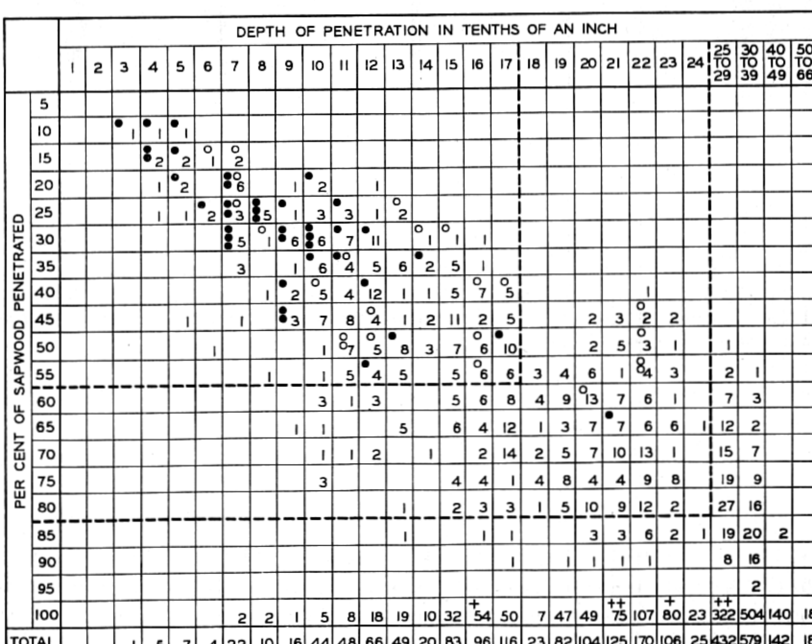

Fig. 3—2393 poles in miscellaneous lines less than ten years (average 7.7 years)

Per cent of sapwood penetrated	Depth of penetration in tenths of an inch																											
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25 TO 29	30 TO 39	40 TO 49	50 TO 66
5																												
10																												
15					1																							
20							1																					
25				●1	●1		●1	●1																				
30															○1													
35									1			1				1												
40												○2																
45													○○2				○1	○1										
50																	○1		○1	1			○1					
55																1									1			
60																	○2	1				1			1			
65																							1	3	1	1		
70																	○1				1				1			
75																			1				1					
80																1								1	1	2		
85																										2		
90																												
95																									1			
100										1	4		1	2		+5	4	+6	6	4	4	10	6	6	34	43	15	2
TOTAL				1	2		2	1	1	1	4	3	3	2	1	8	9	8	8	5	5	11	9	10	40	48	15	2

Fig. 4—199 poles in Lynchburg-Savannah line. Age 12 years.

Per cent of sapwood penetrated	Depth of penetration in tenths of an inch																											
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25 TO 29	30 TO 39	40 TO 49	50 TO 66
5																												
10				●1																								
15					●●3																							
20																												
25								1	●1	1	●1		1															
30					●1	1	1		2	○2	●●3	1			1													
35									1	1	●1	●●●4	1		1													
40											●○4	1	1		2													
45											1	1	2	2	4													
50										1	●1			1	1	1		2		1					1			
55											○1					1			1		1				1			
60											1						1	1				1	1					
65																	1	1	1			2	2			1		
70																	1		1	2					2			
75											1											1	1		1	1		
80																	1			1					1			
85																									1			
90																									1			
95																												
100									1	1	+3	3	1	3	1	2	5	2	2	2	3	4	3	3	14	10	3	
TOTAL				1	4	1	1	1	5	6	17	10	6	6	10	4	9	6	5	6	4	8	7	3	22	12	3	

Fig. 5—157 poles in Petersburg-Denmark line. Age 15 years.

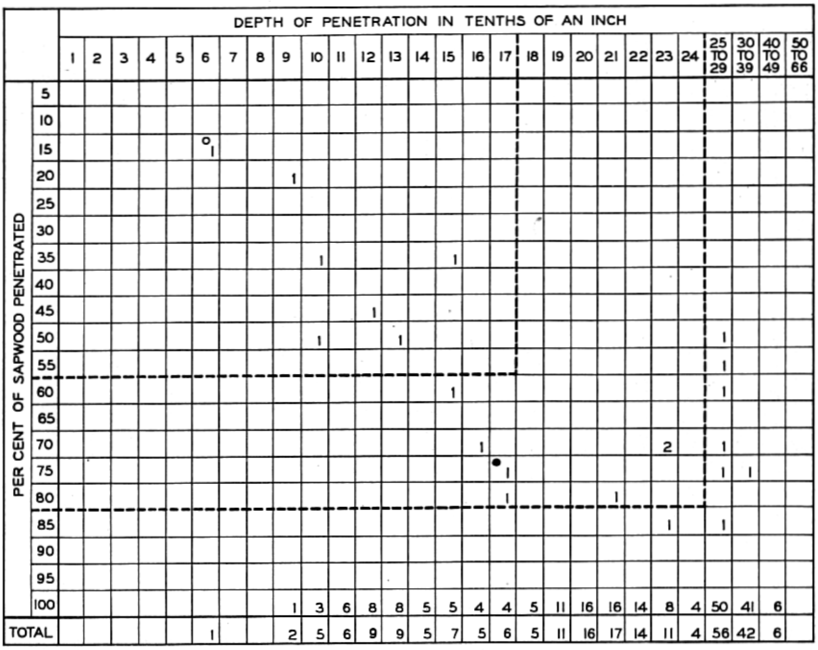

Fig. 6—237 poles in Jacksonville-Key West line. Age 19 years.

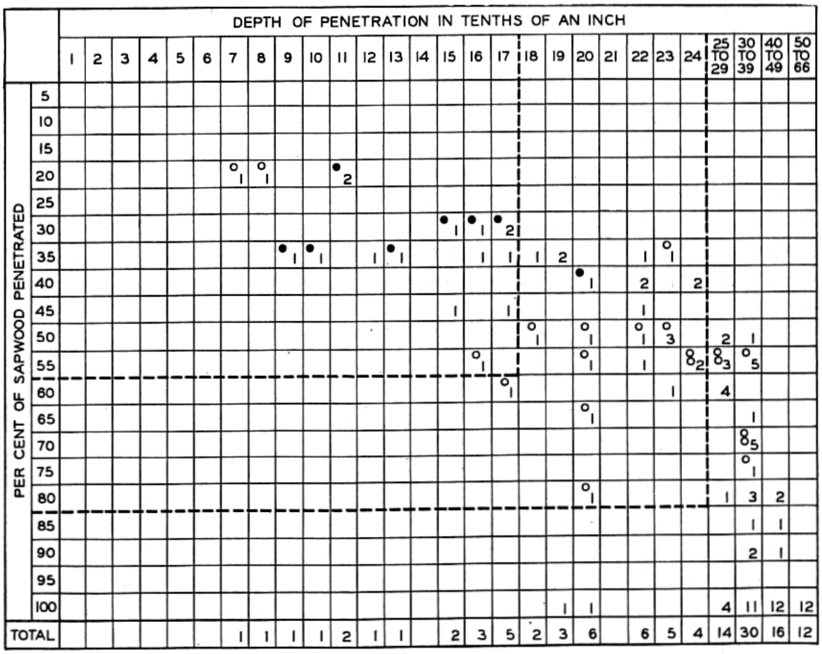

Fig. 7—116 poles in New York-Scranton line. Age 26 years.

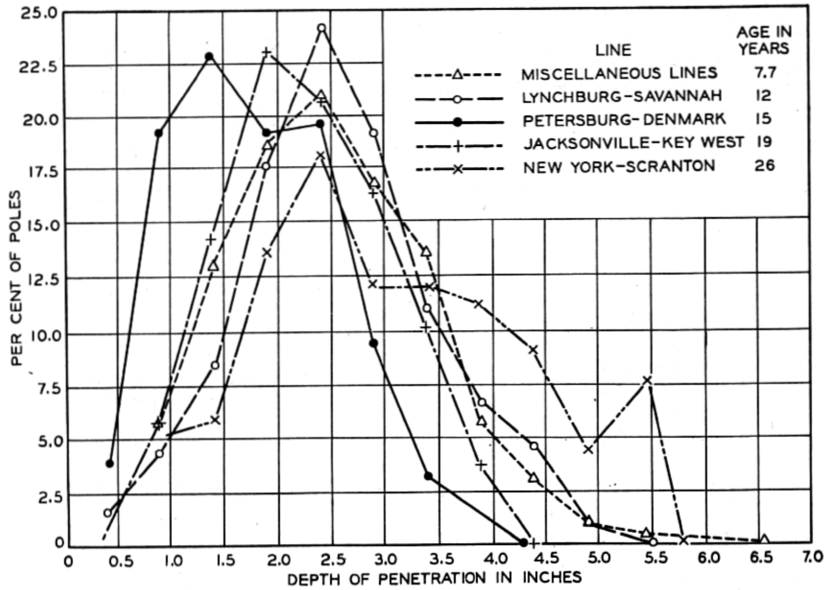

Fig. 8—Frequency curves for depth of penetration in twelve-pound full cell creosoted southern pine poles in line.

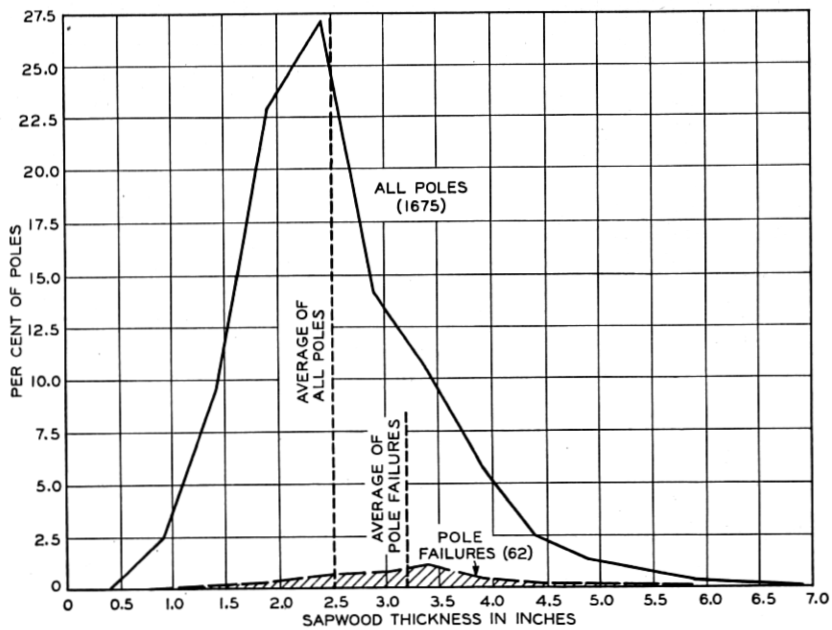

Fig. 9—Frequency curves for sapwood thickness in relation to failure from decay in twelve-pound full cell creosoted southern pine poles penetrated less than 2.5 inches.

TABLE I

CREOSOTED SOUTHERN PINE POLES: SUMMARY OF DATA ON LOCALITY, AGE, CREOSOTE, AND PENETRATION, IN RELATION TO INCIDENCE OF DECAY IN 12 POUND FULL CELL POLES IN LINE

	Years in Line	Type of Creosote (Average Residue Above 360° C.)	Number of Poles Inspected	Sound Poles				Poles with Internal Sapwood Decay			
				No.	Per Cent	Average Penetration		No.	Per Cent	Average Penetration	
						Inches	Per Cent of Sapwood			Inches	Per Cent of Sapwood
IN LINE 10 YEARS OR LESS (AVERAGE 7.7)											
FLORIDA											
West Palm Beach-Miami Line											
Group 1	8.5	11.14	85	85	100.0	2.4	84.7	—	—	—	—
" 2	8.5	12.79	27	27	100.0	2.2	83.5	—	—	—	—
" 3	8.5	16.57	137	127	92.8	2.1	84.3	10	7.2	1.1	44.5
" 4	8.5	31.12	20	19	95.0	2.4	90.5	1	5.0	0.7	33.0
	8.5		269	258	95.9	2.2	84.8	11	4.1	1.0	43.4
TENNESSEE											
Nashville-Montgomery Line											
Group 1	5.0	12.00	198	190	96.0	2.3	89.2	8	4.0	1.0	31.0
Nashville-Chattanooga Line											
Group 1	7.0	12.68	24	21	87.5	2.7	77.6	3	12.5	0.8	27.0
" 2	8.0	12.00	151	143	94.7	2.6	88.8	8	5.3	1.3	51.3
" 3	9.0	19.23	25	23	92.0	2.8	88.4	2	8.0	1.7	47.0
" 4	8.0	24.81	112	103	92.0	2.3	86.2	9	8.0	1.3	42.4
" 5	7.0	16.53	57	57	100.0	3.0	97.0	—	—	—	—
" 6	10.0	10.66	106	105	99.0	2.5	95.0	1	1.0	2.2	60.0
	8.3		475	452	95.2	2.7	90.1	23	4.8	1.3	44.6

TABLE I—*Continued*

	Years in Line	Type of Creosote (Average Residue Above 360° C.)	Number of Poles Inspected	Sound Poles				Poles with Internal Sapwood Decay			
				No.	Per Cent	Average Penetration		No.	Per Cent	Average Penetration	
						Inches	Per Cent of Sapwood			Inches	Per Cent of Sapwood
NORTH CAROLINA											
Greensboro-Selma Line											
Group 1	8.0	31.12	144	143	99.3	3.3	92.7	1	0.7	1.6	43.0
Asheville-Kings Mountain Line											
Group 1	9.0	31.12	51	51	100.0	2.1	73.9	—	—	—	—
" 2	7.0	34.07	23	22	95.7	2.9	94.3	1	4.3	0.7	20.0
	8.0		74	73	98.7	2.3	80.0	1	1.3	0.7	20.0
Asheville-Greenville Line											
Group 1	5.0	34.07	106	106	100.0	2.5	90.2	—	—	—	—
VIRGINIA											
Washington-Lynchburg Line											
Group 1	7.0	24.81	130	130	100.0	2.8	92.8	—	—	—	—
" 2	7.0	19.23	66	62	93.9	2.7	85.4	4	6.1	1.8	41.2
	7.0		196	192	98.0	2.7	90.5	4	2.0	1.8	41.2
ILLINOIS											
Crete-Watseka Line											
Group 1	9.0	12.56	199	188	94.5	2.4	79.1	11	5.5	0.9	33.2
Joliet-Ottawa Line											
Group 1	9.0	11.14	124	122	98.4	2.7	90.4	2	1.6	0.9	27.5
Wyanet-Peoria Line											
Group 1	8.0	11.14	101	101	100.0	2.5	89.5	—	—	—	—

TABLE I—*Continued*

	Years in Line	Type of Creosote (Average Residue Above 360° C.)	Number of Poles Inspected	Sound Poles				Poles with Internal Sapwood Decay			
				No.	Per Cent	Average Penetration: Inches	Average Penetration: Per Cent of Sapwood	No.	Per Cent	Average Penetration: Inches	Average Penetration: Per Cent of Sapwood
WISCONSIN											
Chicago-Minneapolis Line											
Group 1	7.0	12.91	67	66	98.5	2.6	86.1	1	1.5	0.9	42.7
" 2	7.0	12.56	32	32	100.0	2.6	84.4	—	—	—	—
" 3	9.0	31.12	65	59	90.8	2.1	79.9	6	9.2	1.0	29.4
" 4	9.0	10.66	110	109	99.1	2.3	90.6	1	0.9	1.1	34.4
" 5	9.0	16.58	23	23	100.0	2.2	95.5	—	—	—	—
	8.0		297	289	97.3	2.3	87.0	8	2.7	1.0	31.6
MICHIGAN											
Detroit-Ann Arbor Line											
Group 1	9.0	10.66	153	153	100.0	2.4	94.6	—	—	—	—
" 2	7.0	12.91	57	57	100.0	2.2	88.6	—	—	—	—
	8.4		210	210	100.0	2.3	92.9	—	—	—	—
	7.7		2393	2324	97.1	2.4	88.1	69	2.9	1.1	38.4
IN LINE 12 YEARS											
NORTH CAROLINA											
Lynchburg-Savannah Line											
Group 1	12.0	39.76	81	78	96.2	2.8	97.1	3	3.8	1.8	45.5
" 2	12.0	33.68	118	106	89.8	2.6	91.5	12	10.2	1.3	44.9
	12.0		199	184	92.5	2.7	93.8	15	7.5	1.4	45.0

TABLE I—*Continued*

	Years in Line	Type of Creosote (Average Residue Above 360° C.)	Number of Poles Inspected	Sound Poles				Poles with Internal Sapwood Decay			
				No.	Per Cent	Average Penetration		No.	Per Cent	Average Penetration	
						Inches	Per Cent of Sapwood			Inches	Per Cent of Sapwood
In Line 15 Years											
South Carolina Petersburg-Denmark Line Group 1	15.0	39.76	157	139	88.5	2.0	77.0	18	11.5	1.0	33.0
In Line 19 Years											
Florida Jacksonville-Key West Line Group 1	19.0	31.59*	237	235	99.1	2.3	96.7	2	0.9	1.1	45.0
In Line 26 Years											
New Jersey New York-Scranton Line Group 1	26.0	3.30†	116	88	75.8	3.5	77.8	28	24.2	2.0	59.8

* Residue above 315° C.
† Residue above 350° C.

TABLE II

SUMMARY OF PENETRATION AND FAILURE DATA FOR 12 POUND CREOSOTED SOUTHERN PINE POLES IN LINE

Age of Line (Years)	Number of Poles Inspected	Number and Per Cent of Poles Having Penetration Less Than								Per Cent of Poles Having 100% Sapwood Penetration	Failures * Because of Decay in Poles Having Penetration Less Than			
		1.8″ and 60%		2.5″ and 85%		3.0″ and 90%		3.5″ and 90%			1.8″ and 60%		2.5″ and 85%	
		No.	%	No.	%	No.	%	No.	%		No.	% of total poles	No.	% of total poles
7.7	2393	286	11.95	610	24.49	730	30.50	780	32.60	65.73	35	1.46	36	1.50
12.0	199	17	8.54	35	17.59	40	20.10	43	21.61	76.88	4	2.01	4	2.01
15.0	157	55	35.03	81	51.59	88	56.05	90	57.32	42.61	14	8.92	14	8.92
19.0	237	7	2.95	14	5.90	21	8.86	22	9.28	90.71	0	0.00	1	0.42
26.0	116	17	14.66	41	35.95	51	43.95	64	55.19	35.34	6	5.17	7	6.03
Total Poles	3102										59	1.90	62	2.00

* There were no failures in poles having penetration in excess of 2.1 inches and 75% of the sapwood.

Table I is a summary of the data on locality, age, creosote penetration, and incidence of decay for 3102 telephone poles in line in the eastern part of the United States. The pole groups are based on years in service and geographic settings.

Figures 3 to 7 are records of the penetration and the condition of each of the 3102 poles at the time they were inspected. Five age groups are represented, from 7.7 years to 26 years, respectively. These records are graphic illustrations of the fact that the failed poles and the decaying poles had poor penetration. Each solid dot represents a single pole failure, and each hollow dot represents a single infected pole. For example, in Fig. 3 for poles in line ten years or less, the figures and symbols in the 0.8 inch and 25 per cent block mean that there were five poles having penetration 0.8 inch and 25 per cent of the sapwood thickness; and of these five poles two were sound and three were so badly deteriorated that they had to be removed. Similarly in the 0.7 inch and 25 per cent block, two of the three poles were failures and one was infected.

The crosses in the 100 per cent line indicate poles with a little heartwood decay or with slight external decay at the ground line.

The broken lines in Figs. 3 to 7 delimit the individual data for poles having penetration less than 1.8 inches and 60 per cent of the sapwood thickness, and less than 2.5 inches and 85 per cent of the sapwood thickness, respectively. The latter is the minimum penetration called for in current American Telephone and Telegraph Company's specifications for creosoted southern pine poles.

The abscissa in each of the five figures has been warped beyond 2.4 inches in order to condense the charts to reasonable proportions for reproduction. Complete data on the range in penetration for the five age groups are shown in the form of frequency curves in Fig. 8. The 15-year sample from the Petersburg, Virginia–Denmark, South Carolina, line obviously has the poorest penetration of the five groups. It also had the highest per cent of pole failures, as shown by Table II.

Table II is a summary of the number and per cent of the 3102 poles in which the sapwood had been penetrated less than (*a*) 1.8 inches and 60 per cent, (*b*) 2.5 inches and 85 per cent, (*c*) 3 inches and 90 per cent, and (*d*) 3.5 inches and 90 per cent; and it also shows the per cent of poles with 100 per cent sapwood penetration, as well as the penetration in the poles that failed.

Table III contains typical analyses of creosote used in treating the poles.

TABLE III

Typical Analyses of Creosotes

Used during the years indicated in treatments of poles represented in Tables 1 to 3

Distillation	1906	1916	1918	1920	1925	1925	1927	1927	1929	1929
0° to 205° C.	12.0	1.86	2.41	3.88	2.98	3.39	2.53	3.47	3.24	1.55
0° to 235° C.	58.0	24.18	4.24	14.33	12.96	24.50	11.75	21.09	14.18	8.14
0° to 315° C.	91.6	68.41	31.86	44.09	43.64	72.08	46.93	66.50	45.95	55.30
0° to 360° C.	96.7*	Not recorded	44.60	59.80	64.77	88.62	67.40	86.85	64.52	82.15
Residue above 360° C.	3.3†	Not recorded	55.10	39.76	34.81	11.14	32.28	12.75	35.10	17.56
Water	Not recorded	Not recorded	1.10	2.7	1.0	1.7	1.9	1.1	1.0	0.7
Tar acids	" "	7.57	1.77	3.0	3.3	7.6	3.1	6.6	2.9	4.3
Sulphonation residue	" "	1.00	2.40	0.5	1.5	2.8	1.8	2.8	1.7	1.0
Benzol insoluble	" "	0.14	1.40	1.9	0.24	0.51	0.42	0.31	0.48	0.29
Specific gravity	1.034	1.052	1.105	1.108	1.079	1.046	1.079	1.045	1.085	1.068

* Distilling to 350° C.
† Residue above 350° C.

Discussion and Interpretation of Results

In reading the following discussion and interpretation of results it should be remembered:

(1) That the poles came from representative areas of the pine forest and from representative treating plants of the South;
(2) That all of the poles inspected were treated in accordance with the process specifications covering a full-cell treatment and calling for a net retention of at least 12 pounds of creosote per cubic foot of wood in the charge; but related studies indicate that the retention in individual poles probably varied from less than 2 to more than 20 pounds per cubic foot;
(3) That the poles were accepted if the treating process and the quantity of oil used conformed to the specifications;
(4) That there was no required inspection at the time the poles were creosoted to determine the results of treatment in terms of penetration and distribution of the creosote in the poles; and
(5) That every pole inspected in the line was the original pole placed in the respective year designated.

The evidence from the field data showed poor penetration to be by far the most important cause of fungous infection and failure by decay. As a matter of fact, the effect, if any, of geographical location or of the type of creosote used was completely masked by the penetration factor.

On account of the wide geographical distribution of lines it was expected that the effect of any definite climatic and meteorological influences on the occurrence of decay would be apparent. It might be expected, for example, that poles set along the warm, moist Florida east coast would be more vulnerable than poles located in the drier north temperate regions. However, the data in Table I for poles in line 10 years or less are not conclusive as to the effect that geographical location may have on the incidence of decay.

The creosotes used conformed as a whole, or in their most important characteristics, to the specifications in effect at the time the poles were treated; but there was a fairly wide divergence in gross chemical characteristics of the oils because of differences in the raw coal tar and in the methods of distilling the tar. Table I includes data on the kinds of creosote used, indicated by the fraction not distilling above 350° C. or 360° C. The data are taken to mean that as far as internal sapwood decay is concerned, the type of coal tar creosote, provided it is a true distillate of coal tar and that it conforms to the specifications, is less important than the thoroughness with which it is distributed throughout the non-durable sapwood of the poles.

The overall summary in Table I for the 2393 poles in line 10 years or less shows average values for penetration in sound poles and in poles with internal sapwood decay. The summary suggests the existence of the very important relationship between penetration and decay that is definitely shown in detail in Fig. 3. All of the internally decaying poles shown in this figure had penetration less than 2.3 inches and 70 per cent of the sapwood thickness. Furthermore, all except six of these decaying poles and all except one of the poles that failed had penetration less than 1.8 inches and 60 per cent of the sapwood thickness. The group defined by the latter figures may be considered as the "risk group," i.e., poles which by reason of poor penetration may become infected with wood-destroying fungi within 10 years. The 286 poles in this group in Fig. 3 were 11.9 per cent of the 2393 inspected poles that had been in line 10 years or less. The poles making up this 11.9 per cent were possible early failures, but the inspection revealed that only 63 of them, or 22.2 per cent, had actually begun to decay. Of these 63 poles with internal sapwood decay only 35, or 55.5 per cent, failed in service. The distinction between infection and failure is important. In terms of the whole 2393 poles 2.6 per cent were infected with internal decay and only 1.4 per cent failed.

The external decay at the ground line indicated in Figs. 3, 4, and 5 apparently did not exceed one half inch in depth. It was typical of the superficial rot usually found after the ground line of a pole has been raised following a few years of service. During these years the creosote in the exposed outer layers of the wood is depleted, and the favorable moisture conditions at the new ground line facilitate fungous infection of the poorly protected wood.

Another group of poles somewhat above the risk poles in quality may be defined as having penetration more than 1.8 inches and 60 per cent but less than 2.5 inches and 85 per cent of the sapwood thickness. Some of these poles are subject to infection prior to the fifteenth year. The data in Figs. 3, 4, and 5 show that decay developed in 11, or 2.98 per cent, of the poles in this group, and that only 1, or 0.27 per cent, failed in service.

The data in Figs. 6 and 7 and in Table II, show in a striking way the stability of the line when the per cent of poles having penetration greater than 2.5 inches or 85 per cent of the sapwood thickness is relatively large. Not a single pole in this group in the sample from the 19-year old line (Fig. 6) showed any indication of internal sapwood decay; and in this group in the sample from the 26-year old line (Fig. 7) decay developed in only 6, or 8.1 per cent, of the poles. Moreover, none of these decaying poles at the 26-year age had deteriorated far enough to require removal.

There is no evidence in the data warranting discrimination against thin sapwood poles because of possible extra decay hazard. The average sapwood thickness for all the inspected poles with penetration less than 2.5 inches was 2.52 inches, and the average sapwood thickness for the poles that failed was 3.19 inches. Only 34 per cent, on the average, of the sapwood thickness was penetrated in the poles that failed. When the distribution of the sapwood thicknesses of all the poles with penetration less than 2.5 inches, and the distribution of the sapwood thicknesses of the poles that failed, are plotted as in Fig. 9 there is a clear indication that serious interior decay is more likely to occur in the poorly treated thicker sapwood poles than in the thinner sapwood poles.

The results of the study of actual conditions in line provide a means for evaluating the practical effect of the current specifications for creosoting southern pine poles. The purpose of the specifications is to keep the number of well penetrated poles as high as commercial production will permit, and to eliminate practically all of the poorly penetrated poles at the source of supply. The hazard of failure by decay in poles produced under the specifications appears to be reduced to an economic minimum.