POLE INSPECTION: WHAT DO THE DEVICES TELL YOU?

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Abstract

The ability of various nondestructive inspection devices to estimate residual strengths of utility structures was compared to full scale bending tests of Douglas-fir poles removed after 19 to 45 years of service. NDE devices tended to over-estimate residual strength, although the differences were sometimes slight. The results suggest that none of the devices could completely replace conventional physical inspection for detecting internal decay and estimating residual strength of poles, although the supplemental information they provide can be useful for identifying future maintenance issues.

Introduction

While many utilities believe their poles provide average service lives between 30 and 40 years, a number of recent surveys suggest that the figures are actually between 70 and 100 years in many regions (Morrell, 1999; Stewart, 1996). The use of effective specifications, regular inspection and aggressive treatment all contribute to the extraordinary performance of wood poles (Morrell, 1996). During the second half of this century we have seen the emergence of a number of advances that have enhanced pole performance, including pentachlorophenol, waterborne preservatives, through-boring, and a number of highly effective methods for arresting decay in service (Graham, 1983). These advances have resulted in an improved ability to prevent decay from becoming established, and, when decay does occur, to rapidly arrest the infestation to minimize potential strength losses (Zabel and Morrell, 1992).

One area of wood pole performance that has lagged behind is inspection. The ability to detect and estimate the effects of fungal and insect attack is critical for several reasons. First, considerable losses in material properties can occur at very early stages of decay (Wilcox, 1978). Failure to detect decay in a routine inspection may mean that 10 or more years may pass before the pole is reinspected, permitting substantial additional damage. In addition, many remedial treatments are more effective when applied to sound wood. Finally, effective decay detection coupled with tools for accurately estimating residual pole strength allows the inspector to make better recommendations concerning remedial treatment and restoration strategies.

Pole inspection has traditionally consisted of sounding a pole with a hammer to detect large voids, then, depending on the species and geographic location, either drilling a series of steep sloping holes to detect internal voids or digging around the pole and scraping the surface to detect decayed wood (Goodell and Graham, 1983; Graham and Mothershead, 1967; Mothershead and Graham, 1962, REA, 1974, Wilson, 1992, 1996). The inspector then estimates the effective residual circumference and, using tables that are specific to each utility, determines if the pole is a reject, potentially reinforceable, treatable, or sound. In general, poles must retain at least 2/3 of their original ANSI value to remain serviceable or be capable of being reinforced to that level (IEEE, 1993)

Utility engineers have long expressed frustration with the imprecise nature of pole inspection. Rejection criteria are often extremely conservative to account for the imprecision of the inspection process coupled with the inherent variation in wood properties. The result is a tendency to reject sound poles to avoid the potential for accepting rejects that might pose a future liability.

A number of devices have been developed to meet the needs of utility engineers including recording drills, acoustic devices and various mechanical testers (Anonymous, 1987; Broughton et al., 1996; Dana and Stingle, 1947; Deuer, undated, Esyln, 1965, 1979; Friis-Hansen, 1980; Gardner et al., 1980; Habermahl, 1985; Lindgren, 1987; Loos, 1961; Miller, 1963; Mothershead and Stacey, 1965; Muenow, 1966; Murphy et al., 1987; Piirto and Wilcox, 1978; Ricard and Mothershead, 1966; Sandoz et al., 1991; Shigo, 1980; Shigo et al., 1977; Shortle, 1982; Shortle et al., 1978; Smith and Morrell, 1989; Tang et al., 1995; Wilcox, 1983; 1988). In most instances however, utilities are largely left on their own in terms of assessing the effectiveness of each system in terms of their existing inspection program. A number of new devices have emerged in the North American market, but there is little data comparing these tools with the existing methods. This report describes preliminary results from an evaluation of 4 inspection tools (Table 1).

Purl 1 is a acoustic device that tests the pole by inserting a receiver at one point in the pole, then testing at numerous locations around the pole at the same elevation. The results at each point consist of either a positive or negative response. The responses around the pole at a given height are tabulated and can be used to construct an internal image of the remaining shell, which can, in turn, be used to calculated residual strength based upon the American National Standards Institute (ANSI) 05.1 assumed fiber stress values for a given species (ANSI, 1992).

Pole Test is another acoustic device which places a transponder on one side of the pole, and a receiver on the opposite side, at the same elevation. A pendulum on the transponder is dropped, sending a sound wave through the pole. The time of flight for the wave as well as certain wave characteristics are collected by the receiver. This information is compared to previous tests of a population of poles of the same species. This population was destructively sampled after being evaluated with the Pole Test to provide an actual bending strength that could be compared with the acoustic data. Thus, this tool compares the existing pole with the previously sampled population to provide an estimated bending strength. The manufacturer, however, recommends that this device be used in conjunction with other internal inspection tools such as a drill to develop better estimates of the residual shell.

The Resistograph uses a small diameter bit to drill into the wood. The revolutions of the drill bit are recorded as the bit enters the wood. Wood that is harder will require more turns of the bit to penetrate a given distance and this information can be used to detect voids or weakened wood. This information can then be used to estimate residual shell thickness much in the same way as a conventional sound bore inspection. The advantage of the Resistograph is that the small hole made by the drill bit produces less effect on material properties of the pole. This could become a significant factor when poles are repeatedly subjected to sound and bore inspections.

PoleCalc is a calculation program that uses residual shell thickness measurements made using either a Resistograph, increment borer hole or conventional drill hole to calculate the residual bending strength based upon the assumed ANSI value for that species. It is similar to several other programs including Dcalc, a program from Engineering Data Management.

Materials and Methods

Thirty Douglas-fir poles in the PacifiCorp system located in the Willamette Valley in Western Oregon were selected. Some of the poles had been identified for replacement by the utility's regular inspection program, while the others were slated for removal due to line upgrades.

The poles were inspected within the groundline zone by first sounding with a hammer, then each pole was inspected using a Purl I, an EDM Pole Tester, and a Resistograph (Table 1). The poles were then removed from service and returned to OSU for testing. Many of these poles were classified as joint use poles and we are still awaiting removal of the telecommunication component from 12 poles. In addition, we were unable to further evaluate two other poles because they were too short after removal. The remaining 16 poles were tested to failure in cantilever loading. Total load and deflection were recorded and, with pole circumference were used to calculate Modulus of Rupture at groundline (MOR-GL). The height at which the pole failed was also noted.

Following mechanical testing, increment cores were removed from each pole at three equidistant sites around the pole at 300 mm increments along the length. The residual shell thickness at each location was assessed using a shell depth indicator, then the increment core was cultured for the presence of decay and nondecay fungi on malt extract agar. The shell thickness data was used in the PoleCalc system to develop an estimated residual strength. To ensure that the devices were used as specified, the proponents of the various devices performed the inspections on the poles and provided their data to OSU.

Poles tested ranged from 19 to 45 years old and were primarily penta chlorophenol in P-9 Type A oil or creosote treated. One pole had been treated with penta using the Cellon process (Table 1). The poles were primarily class 3 and 4 and were between 30 and 45 feet long. Seven of the poles tested to failure had been removed from service due to decay, while the remainder had been removed as part of a line upgrade.

Results and Discussion

Most of the test poles failed in bending at groundline (Table 2). MOR at groundline ranged from 3220 to 10,827 psi, and 14 of 15 poles failed below the ANSI specified value. The finding was not surprising, given the fact that these poles had been in service for many years and a number had evidence of internal decay. The most recently installed pole tested well above the ANSI value.

All of the nondestructive inspection devices tended to over estimate residual pole strength in comparison with actual bending tests when used alone (Table 2). PoleTest over-estimated strength in 10 of 15 tests, Purl 1 over-estimated strength in 12 of 15 tests, and PoleCalc over-estimated strength in 13 of 17 cases. Pole inspection is a delicate balance between identifying and removing unsafe poles without removing an excessive amount of sound poles. In most instances, utilities take fairly conservative approaches to pole inspection since the cost of an unplanned outage can easily exceed the costs of saving a marginal pole. Conversely, utilities entering their first maintenance cycle are often surprised by the number of reject poles identified and seek to "save" these poles within their systems.

The primary benefit of the nondestructive inspection devices is the ability to rapidly assess a pole without causing any further negative material effects; however, the devices must reliably predict when a pole should be further inspected. In a number of cases, the devices failed to detect poles that were far weaker than the ANSI values for Douglas-fir poles (ANSI, 1992). The over-estimate of bending strength with the Purl1 and PoleCalc stem, in part, from a reliance on the ANSI fiber stress values as the baseline for calculating remaining pole strength. The ANSI values are means with a fairly wide standard deviation reflecting the natural variability of a given wood species. Thus, some of the poles in our test sample may have naturally been low strength poles. Using ANSI values as the base for calculating residual strength of these poles would inherently over-estimate strength.

One approach to enhancing the value of the non-destructive test devices is to combine the results obtained with two or more devices. One such effort to incorporate multiple assessments to estimate residual strength was undertaken by the supplier of Pole Test. In this exercise, they used the output from the Resistograph to estimate the cross sectional area at groundline. This strength value was then used by the Pole Test device as the basis for calculating residual pole strength. Using this value, Pole test predictions tended to be closer to the actual bending strength, although the devices still over-predicted strength in 6 out of 13 poles. The EDM prediction was within 500 psi of the actual bending strength for 4 of 13 poles and under-predicted strength for 2 poles. While under predicting strength can increase the likelihood that sound poles will be removed as a part of routine maintenance, the predicted values in both cases were well above the NESC minimums. As a result, the poles would not have been slated for rejection based upon the NDE outputs.

Combining Pole Test and Resistograph data clearly illustrates the benefits of using several tools that provide different information on pole condition. Utilities, however, must carefully assess the relative merits of this approach within their systems. Both the Resistograph and Pole Test are sophisticated instruments that are best used by trained personnel capable of interpreting the resulting data. In addition, detailed assessments of this nature must also include information on attachments and loadings. In most cases, pole inspection is contracted and the process is production-oriented. As a result, the additional time required may not be suitable for inspecting every structure. This approach may be best used on poles that traditional inspection methods have slated for removal or reinforcement. This would reduce the number of structures requiring more detailed inspection, allowing for more time per structure.

The results suggest that NDE devices are supplemental tools for assessing material properties, rather than stand-alone systems that eliminate the need to perform more physical assessments (Figures I-3).

Previous attempts to compare inspection devices have produced similar variations in performance (Inwards and Graham, 1980; Zabel et al., 1982). Inwards and Graham (1980) compared conventional inspection with increment borers and culturing, the Shigometer, the D-K-Tecktor and a resistance type moisture meter. While each was useful, none was uniformly effective at estimating residual strength or detecting decay. More recently, an International Research Group on Wood Preservation report described a series of trials that include many of the above devices along with a mechanical tester that applied a bending load to the standing pole, a Pilodyn, and most adorably, a sniffer dog that detected odors produced by decay fungi (Morris and Friis-Hansen, 1984). Once again, none of the methods was entirely satisfactory, although the dog doubled as an excellent companion and watch dog.

Conclusions

None of the NDE devices proved entirely satisfactory for predicting residual bending strength, although some of the devices did accurately detect internal voids.

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Table 1. Nondestructive inspection devices evaluated.

Trade Name	Source	Operating Principle
Purl 1	Intraline Inc., Burlingame, CA	Sonic with program to calculate shell
Pole Test	EDM, Fort Collins, CO	Sonic compares output to previously tested population of similar poles
Resistograph	EDM, Fort Collins, CO IML, Marietta, Georgia	Drill device
Pole Calc	New York State Electric and Gas Corp., Binghamton, NY	Uses shell thickness to estimate strength

Table 2. Characteristics and conditions of Douglas-fir poles used to compare inspection devices.

Pole #	Initial Treatment	Class Length (Ft.)	Year Installed	GL Circ. (in.)	Failure Ht. (ft.)[a]	Breaking Circum. (in.)[b]	MOR-GL (psi)	Estimated Strength (psi)[c]				Reason for Removal
								EDM Alone	EDM/ Shell	Purl 1	PoleCalc	
355	Penta	4-40	1965	36.5	2.0	36.6	3926	6700	5963	5144	7280	Decay
356	Penta	3-40	1962	41.0	GL	41.0	3220	6950	4745	6624	6288	Decay
358	Creo	3-35	–	34.0	GL	34.0	3435	8000	4198	8000	6440	Decay
361	Penta	4-35	1963	35.0	GL	35.0	3731	7850	5731	8000	6400	Decay
362	Penta	3-30	1962	36.5	1.6	35.0	4084	7390	6429	8000	5952	Decay
365	Penta	5-35	?	30.6	GL	30.6	4248	7460	5390	7176	6392	Decay
366	Penta	3-35	?	34.0	GL	34.0	4951	8100	5317	7968	6832	Decay
371	Creo	3-40	1980	36.0	GL	36.0	10827	9050	8598	8000	8000	Upgrade
374	Cellon	4-45	1962	37.0	GL	37.0	6765	7530	6702	8000	3792	Upgrade
375	Creo	3-55	1966	42.0	GL	42.0	6530	5830	5247	8000	7960	Upgrade
376	Creo	4-40	?	34.0	GL	34.0	5336	6990	UTT	7776	8000	Upgrade
382	Penta	5-30	1954	38.0	GL	38.0	7974	7610	7610	8000	7992	Upgrade
383	Creo	3-55	1962	44.0	GL	44.0	6925	8450	7352	8000	8000	Upgrade
384	Penta	4-40	1960	36.0	GL	36.0	4882	–	-	–	6560	Upgrade
385	Cellon	4-40	1962	35.5	GL	35.5	3706	–	-	–	4584	Upgrade

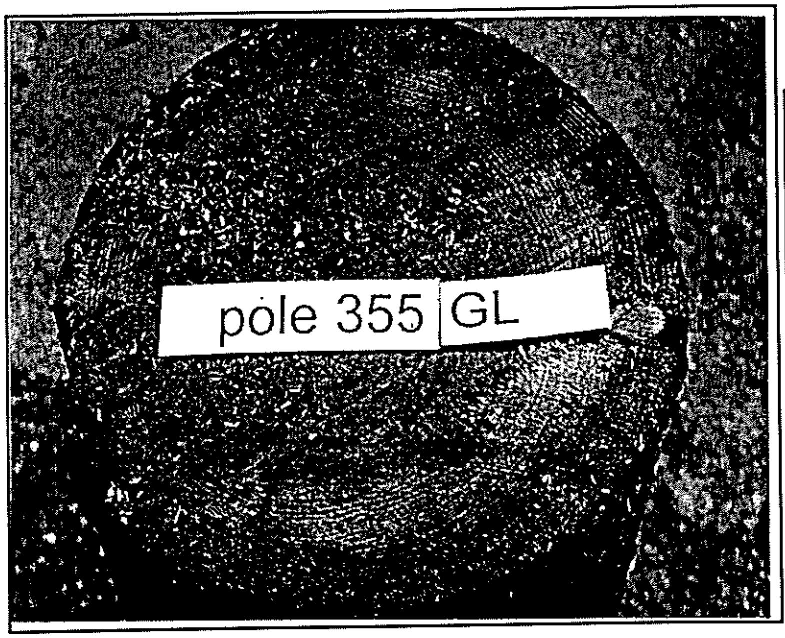
a. Distance above groundline

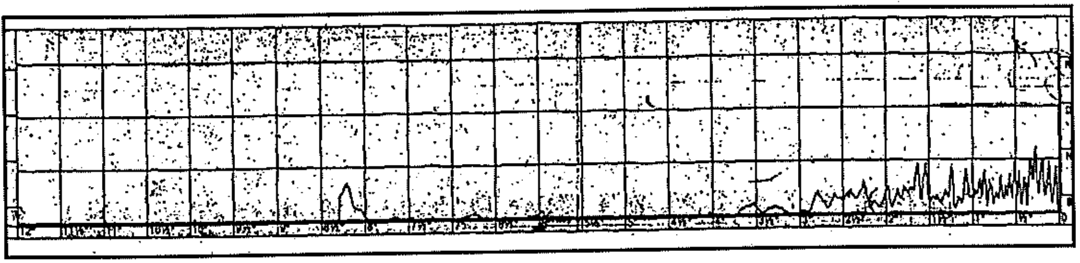
b Circumference at failure site

c. Uses a combination of PoleTest and shell thickness as estimated using Resistograph

Tag No. 355

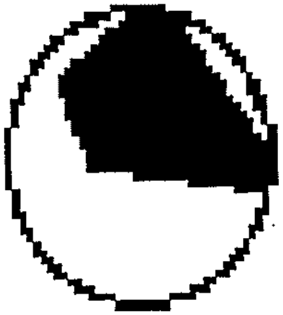
Pole #	Treatment	Class	Length	Year	GL Cir in	Break Ht ft	Tested MOR lbs	Est. EDM lbs.	Est. Purl1 lbs	Est. Polecalc lbs	Reason Removed
295622	penta	4	40	1965	36.5	2	3926	6700	5144	7280	decay

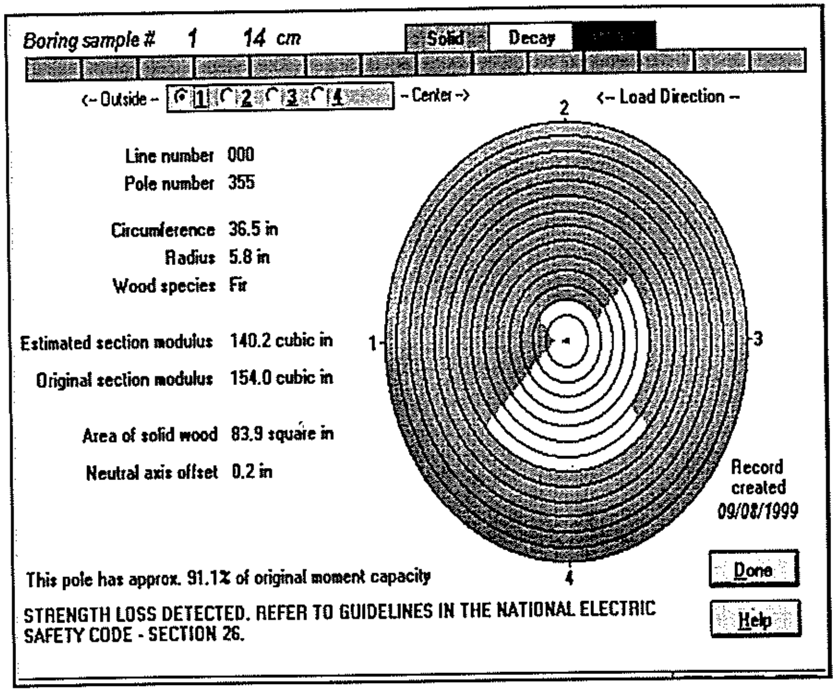




Position 1
Height Above Butt : 1 inch

Co-ordinates of Centroid : X	-2.08039
Y	15.95621
Strength about Vertical Axis :	64.29874 %
Strength about Horizontal Axis :	51.17142 %
Minimum Strength of Section :	64.29874 %
Angle of Axis to the horizontal neutral axis about which the pole is bent to give the minimum strength :	14.5 °





Line number 000
Pole number 355

Circumference 36.5 in
Radius 5.8 in
Wood species Fir

Estimated section modulus 140.2 cubic in
Original section modulus 154.0 cubic in

Area of solid wood 83.9 square in
Neutral axis offset 0.2 in

Record created 09/08/1999

This pole has approx. 91.1% of original moment capacity

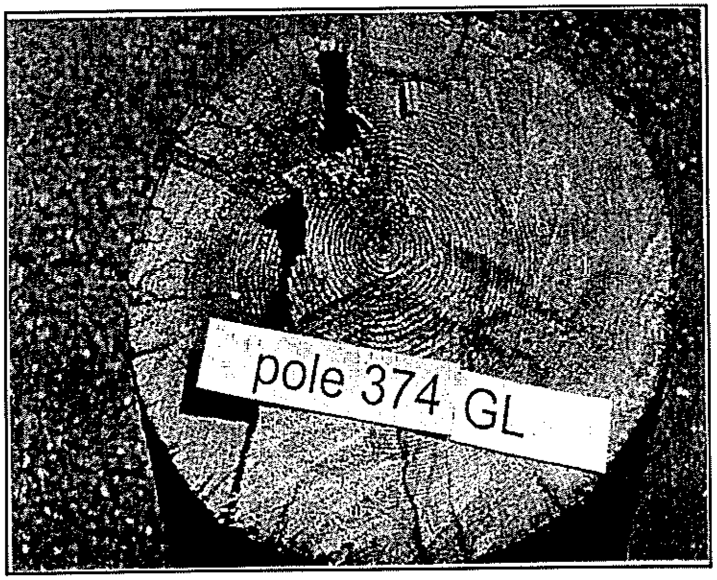
STRENGTH LOSS DETECTED. REFER TO GUIDELINES IN THE NATIONAL ELECTRIC SAFETY CODE - SECTION 26.

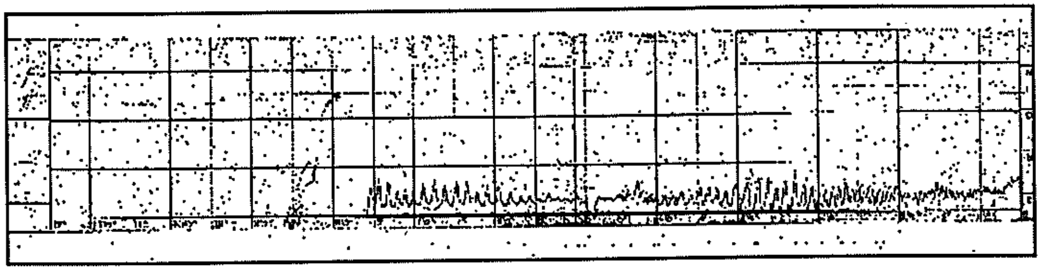
Figure 1. Test evaluation data for pole number 355.

3.24

Tag No. 374

Pole #	Treatment	Class	Length	Year	GL Cir in	Break Ht ft	Tested MOR lbs	Est. EDM lbs.	Est. Purl1 lbs	Est. Polecalc lbs	Reason Removed
31105	cellon	4	45	1962	37	GL	6765	7530	8000	4792	upgrade



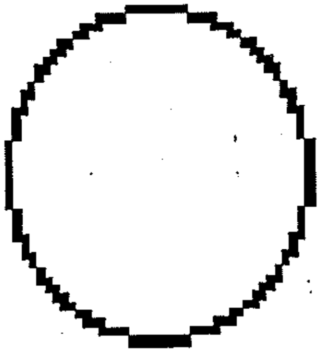


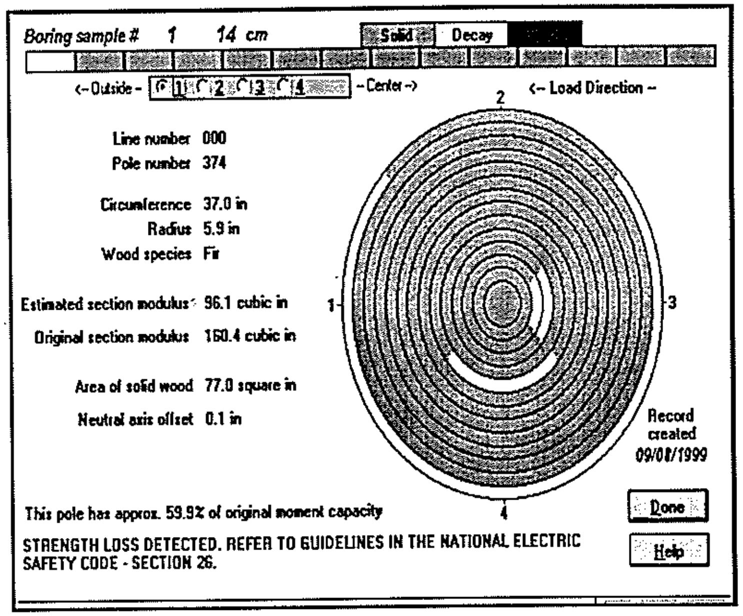
Position 1

Height Above Butt : 1 inch

Co-ordinates of Centroid :

X	0.00000	
Y	20.00000	
Strength about Vertical Axis :	100.00000	%
Strength about Horizontal Axis :	100.00000	%
Minimum Strength of Section :	100.00000	%
Angle of Axis to the horizontal neutral axis about which the pole is bent to give the minimum strength :	90.0	°





Boring sample # 1 *14 cm*

Line number 000
Pole number 374

Circumference 37.0 in
Radius 5.9 in
Wood species Fir

Estimated section modulus 96.1 cubic in
Original section modulus 160.4 cubic in

Area of solid wood 77.0 square in

Neutral axis offset 0.1 in

Record created 09/08/1999

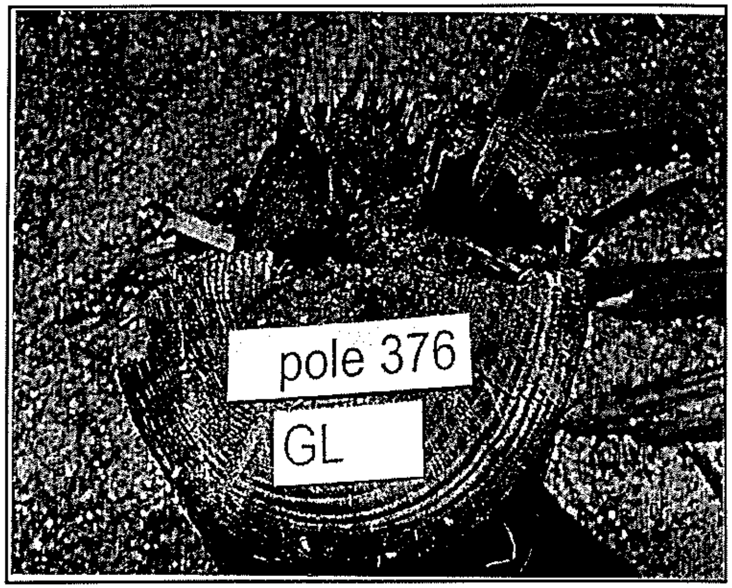
This pole has approx. 59.9% of original moment capacity

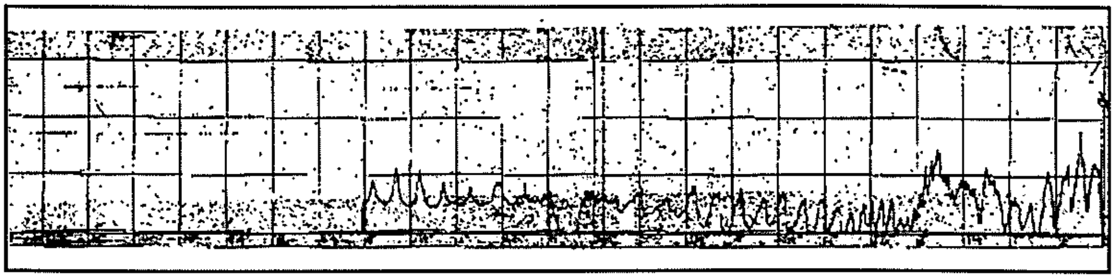
STRENGTH LOSS DETECTED. REFER TO GUIDELINES IN THE NATIONAL ELECTRIC SAFETY CODE - SECTION 26.

Figure 1. Test evaluation data for pole number 374.

**Tag No.
376**

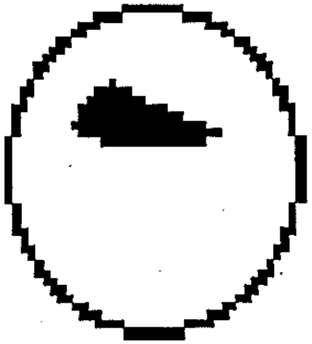
Pole #	Treatment	Class	Length	Year	GL Cir in	Break Ht ft	Tested MOR lbs	Est. EDM lbs:	Est. Purl1 lbs	Est. Polecalc lbs	Reason Removed
31701	creosote	4	40	?	34	GL	5336	6990	7776	8000	upgrade

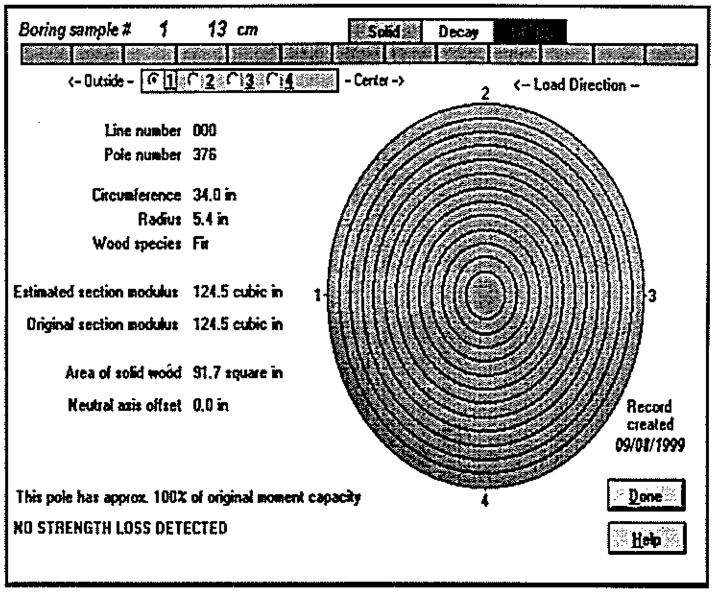




Position 1
Height Above Butt : 1 inch

Co-ordinates of Centroid :
X 0.17775
Y 19.53922
Strength about Vertical Axis : 97.15178 %
Strength about Horizontal Axis : 94.85680 %
Minimum Strength of Section : 97.15178 %
Angle of Axis to the horizontal neutral axis about which the pole is bent to give the minimum strength : 162.0 °





Boring sample # 1 13 cm

Line number 000
Pole number 376

Circumference 34.0 in
Radius 5.4 in
Wood species Fir

Estimated section modulus 124.5 cubic in
Original section modulus 124.5 cubic in

Area of solid wood 91.7 square in
Neutral axis offset 0.0 in

Record created 09/08/1999

This pole has approx. 100% of original moment capacity
NO STRENGTH LOSS DETECTED

Figure 1. Test evaluation data for pole number 376.