DETECTION OF HEART ROT VOIDS IN TREES USING STRESS WAVE ANALYSIS

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DISCLAIMER

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Abstract

The ability to detect the presence of heart rot in living trees offers a significant improvement in the ability to manage a stand of timber. The objective of the research was to determine if heart rot voids in log sections could be detected using stress wave analysis techniques. Six aspen log sections, representing the species and size of trees of most concern to the Alberta Department of Forestry, were investigated which contained various degrees of degradation. Nondestructive parameters were obtained from the frequency spectra of induced stress waves and subsequently correlated to the degree of degradation in each log section. The stress wave analysis NDE technique was able to identify not only the presence of heart rot voids, but also the extent of the void within the log section, with a correlation coefficient of 0.98. Thus, the research verified the feasibility of using the stress wave analysis NDE technique for detecting heart rot in log sections. The availability of such a technique would enable the monitoring of the progress of decay within a stand. Decisions can then be made as to the optimal time in which to harvest the stand to maximize the commercial yield.

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Introduction

There is a good probability that heart rot in standing trees can be identified using stress wave analysis techniques. Such techniques have been used to successfully predict mechanical properties of a variety of wood products. Although these techniques have not been used to detect decay in wood, it is reasonable to expect that large defects such as heart rot voids can be detected. This report provides information on the feasibility study conducted for detecting heart rot voids in aspen trees. The objective of the research reported herein was to determine if heart rot voids in log sections could be detected using stress wave analysis techniques.

Data Collection

Six aspen (*Populus tremuloides, Michx.*) log sections, approximately five ft. in length were obtained by Engineering Data Management, Inc. (EDM) from live trees cut in the Roosevelt National Forest of Colorado, USA. Each of these sections was approximately nine inches in diameter and possessed similar growth rates. The species and the diameter of the log sections were chosen to represent those trees of most concern to the Alberta Department of Forestry for detecting heart rot.

Two of the test sections were visually observed to be sound and free of heart rot sections, decay or other voids. The other four sections contained heart rot of various sizes. After being cut in the forest, the log sections were wrapped in plastic to retard the loss of moisture from the log section and transported to the EDM laboratory for nondestructive evaluation (NDE). Figure 1 is a photograph depicting the six log sections with various degrees of degradation which was subsequently correlated with NDE parameters.

Figure 1. Cross Sections of the Aspen Logs used for the Nondestructive Evaluation.

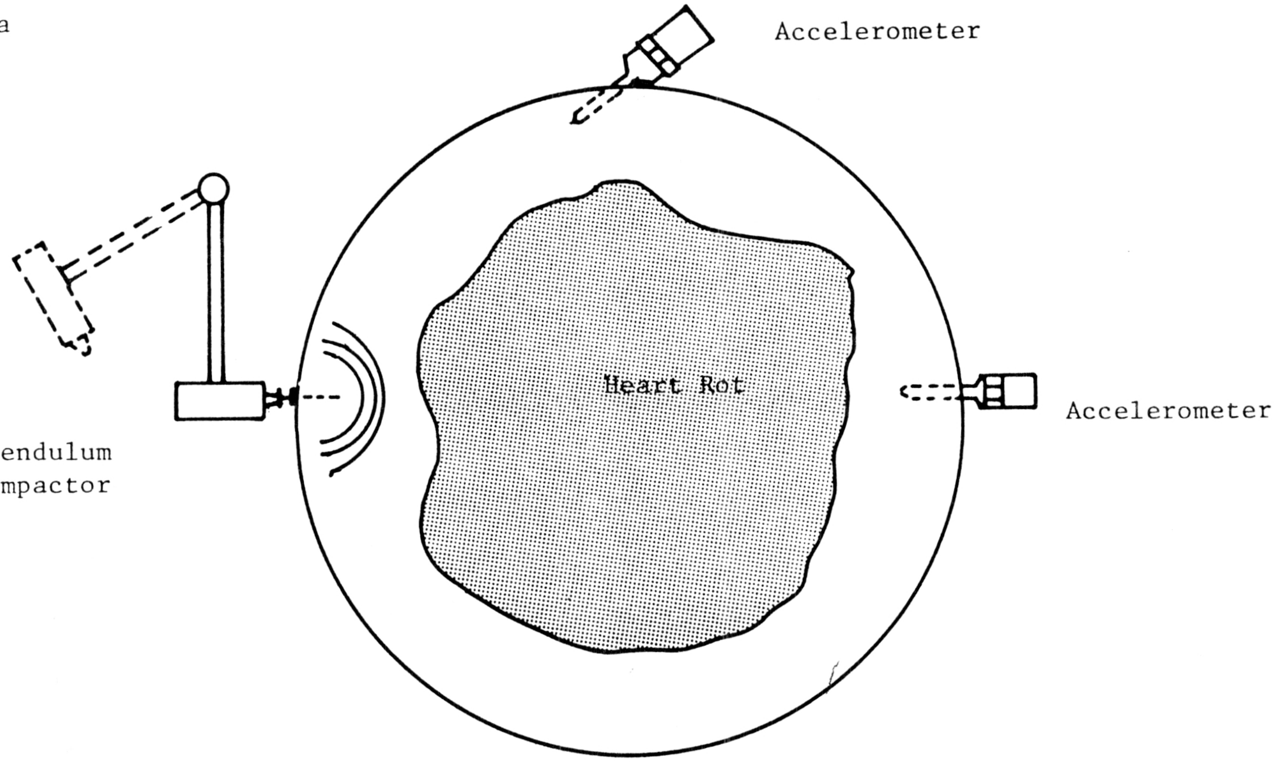
A stress wave was induced into each log section by impacting a 1" (25 mm) long double-headed nail using a pendulum impactor. The stress wave was sensed by two accelerometers located in the same cross sectional plane as the impact. Figure 2a illustrates the test setup used for data collection. A threaded pin was specially machined to attach the piezoelectric accelerometers to the log section. A mechanical stop on the pendulum lever arm ensured a constant energy level was delivered with each impact. This control provided a reproducible NDE signal. As shown in Figure 2b, three test planes were used on each log. The test setup shown in Figure 2a was repeated at each of the test planes shown in Figure 2b. Five impacts were delivered at each test location and the resulting signals were averaged to obtain representative NDE data for each log. The stress wave measurements from the accelerometers were collected on a digital oscilloscope and stored on a micro computer which enabled fast, accurate data acquisition.

A variety of nondestructive parameters were obtained from the frequency spectra of the stress waves. These variables were examined for trends relating to the presence of heart rot. Data analysis provided a high quality correlation between the nondestructive information and the extent of heart rot in the log sections.

Results

In order to establish a correlation between the NDE information and the extent of heart rot in a log section, it was necessary to quantify the extent of the heart rot. This was accomplished by determining the heart rot area ratio. The heart rot area ratio is computed as the cross sectional area of the heart rot divided by the gross cross sectional area of the log section. This ratio was computed at the test location by cutting the log sections in half and determining the extent of decay.

2a



2b

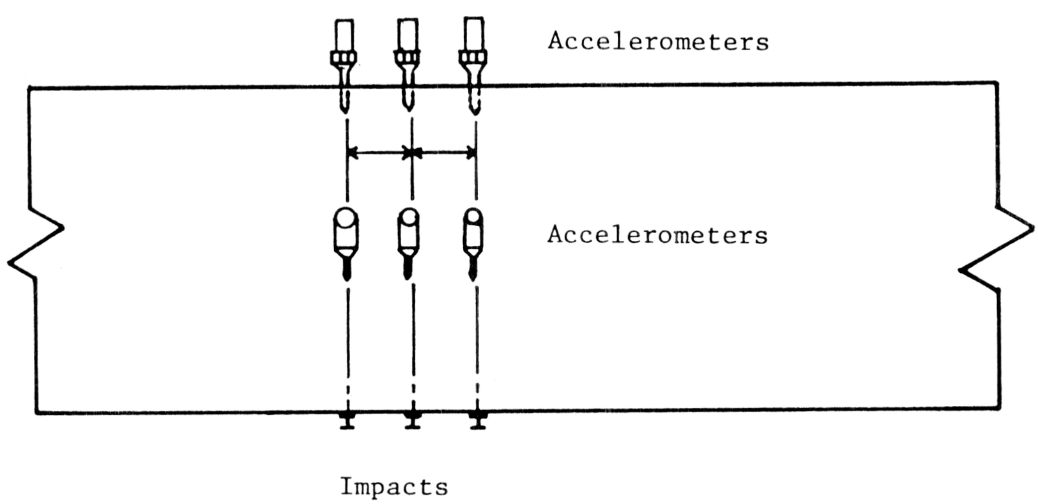


Figure 2. Schematics of the Nondestructive Test Setup.

By using linear regression techniques, it was possible to identify NDE parameters which provided statistically significant correlations with the heart rot area ratio. Figure 3 illustrates the quality of the correlation for the six test specimens. Although the limited sample size precluded a detailed statistical analysis, it is obvious from the trend exhibited, with a correlation coefficient of 0.98, that the NDE technique does enable the assessment of the extent of heart rot voids in the log sections.

Conclusions

The feasibility study clearly indicated that the stress wave NDE promises to be a highly reliable method which can quantify the degree of degradation in aspen log sections under laboratory conditions.

The objective of the research was to determine if heart rot voids in log sections could be detected using stress wave analysis techniques. This goal has been accomplished. Further, the stress wave analysis NDE technique appears to be able to identify not only the presence of heart rot voids, but also the extent of the void within the log section. The ability to detect the presence of heart rot in living trees offers a significant improvement in the ability to manage a stand of timber. The availability of such a technique will enable the monitoring of the progress of the decay within a given stand of timber. Decisions can then be made as to the optimal time in which to harvest a stand to maximize the commercial yield from that stand.

Recommendations

The research conducted verified the feasibility of using the stress wave analysis NDE technique for detecting heart rot in log sections in the laboratory. Before such a technique can be made available for field use, it

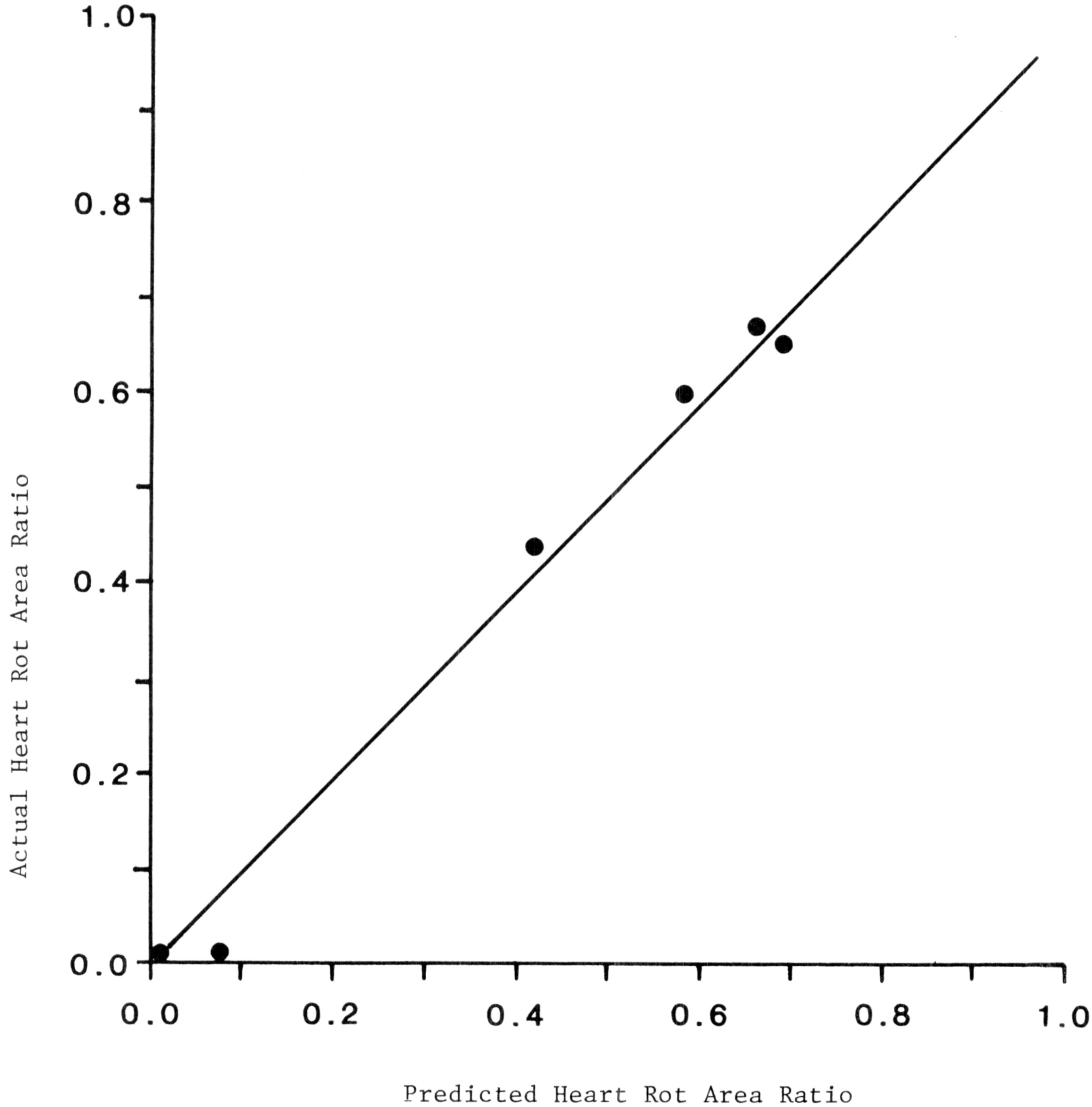


Figure 3. Heart Rot Area Ratios Predicted by a Stress Wave NDE Model as Compared to Actual Ratios.

is necessary to conduct additional research on living trees in the field. It is necessary to increase the sample size to enable verification of the accuracy of the technique in assessing the extent of heart rot within a given tree. Further, multiple measurements would be required to determine the limitations associated with NDE measurements taken at only one cross section.

Once a satisfactory data base has been established to provide representative data of the timber of concern to the Alberta Department of Forestry and the limitations of the technique are established, it will then be possible to assess the commercial viability of the technique. It is envisioned that a simple, portable device could be constructed which would enable a fast, accurate evaluation of the extent of heart rot in Aspen trees. The feasibility of constructing such a device has been demonstrated not only by the successful completion of this research, but also by EDM's success in developing portable field NDE devices for other applications such as the PoleTest™ (see attached).

New! Version 1.20
Expanded Data Base
Improved Repeatability

PoleTest™
"The Pole Strength Analyzer"

NONDESTRUCTIVE EVALUATION OF WOOD POLES

PoleTest™ is a simple-to-use instrument for predicting the bending strength of wood poles. The strength value is important data required in engineering design, management and maintenance of wood poles.

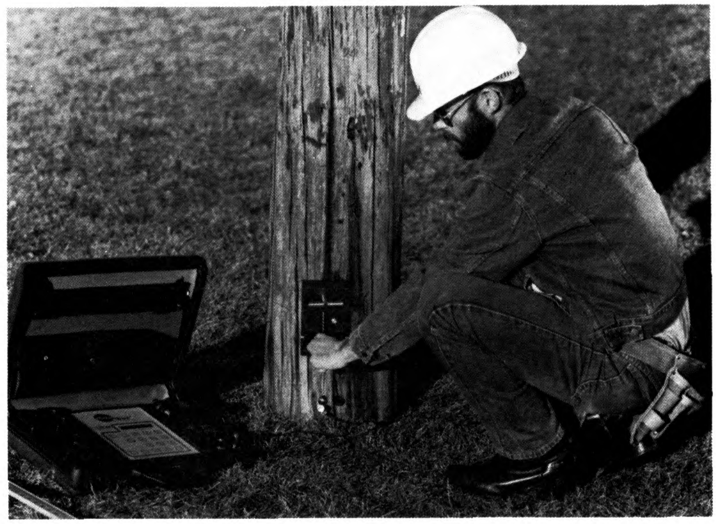
Why Strength?

The concepts of pole strength and quality have often been used interchangeably. Pole quality is generally evaluated by the degree of decay present in a pole. Prior to the development of **PoleTest™,** pole strength could not be directly predicted. Now for the first time, a direct pole strength prediction method is available and a distinction between quality and strength can be made when evaluating poles as defined below:

METHOD	PRIMARY PURPOSE
1. Pole Quality Assessment (conventional inspection, boring, etc.)	To assess treatment requirements to extend service life.
2. Pole Strength Evaluation (PoleTest™)	To determine load-carrying capacity of new and in-service poles

PoleTest™ is the ONLY in-service wood pole test device which directly predicts pole strength. The reliability of the strength prediction using **PoleTest™** is unmatched by any other method, technique or instrument.

PoleTest™ is the culmination of more than 9 years of research (sponsored by EPRI* and EDM) and is based on correlations of nondestructive test data with hundreds of full-scale tests to destruction. Therefore, **PoleTest™** is based on actual test data and not simply a theoretical approach. This extensive data base has not been incorporated in any other commercial device.



The cost of this device and accessories will be recovered many times over through efficient management of your utility line resources. The tremendous potential for cost savings and improved reliability make it a valuable component for engineering, operations, maintenance, inspection and management personnel.

"POLETEST™ - STATE-OF-THE-ART EVALUATION OF INDIVIDUAL WOOD POLE STRENGTH."

*PoleTest™ incorporates technology developed for the Electric Power Industry under the sponsorship of the Electric Power Research Institute (EPRI).

POLETEST PROVIDES DATA REQUIRED FOR:

- Determining the STRENGTH of new and in-service wood poles
- Decisions on maintenance and replacement of wood poles
- Incorporation into inspection and/or maintenance programs
- Upgrading and reconductoring considerations
- Structural assessment to evaluate reliability
- Evaluation of code conformance
- Failure assessment and litigation support

POLETEST USES AND BENEFITS:

POLE STRENGTH ASSESSMENT

Nondestructive evaluation enables the strength prediction of new and in-service poles. Monitoring pole strength through the use of PoleTest™ enables accurate tracking of the loss of strength of poles with time in service. Poles identified for replacement by present inspection methods alone may actually have sufficient strength to remain in service.

Destructive testing was conducted for Tampa Electric Co. on 24 southern pine poles that had been rejected using conventional inspection methods and 25 poles that were judged acceptable. Results showed that 50% of the rejected poles had adequate strength to remain in service, while 30% of the accepted poles did not have adequate strength.

INSPECTION PROGRAMS

Conventional inspection programs consisting of visual inspection, sounding, boring, etc. are valuable for identifying the quality of the pole (i.e. presence of decay, insect damage, etc.). Since PoleTest™ provides reliable strength information on individual poles, a complete understanding of the TOTAL condition and capacity of the structure is now possible. PoleTest™, used in conjunction with present inspection methods, is a useful and powerful tool for making cost-effective maintenance and management decisions.

A PoleTest™ study conducted by an inspection agency determined that conventional inspection combined with PoleTest™ provides the BEST possible data for wood pole management.

A recent study by Idaho Power Co. on approximately 1200 poles, showed that 40% of the 75 poles previously rejected, had sufficient strength to be serviceable according to PoleTest™. This resulted in approximate savings of $170,000.

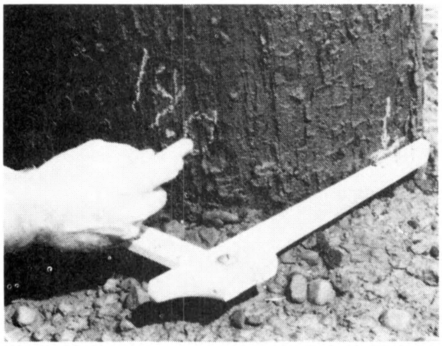
UPGRADING AND REBUILDING

With limitations on available rights-of-way, economic constraints and construction timing, upgrading to higher voltage levels or rebuilding of older lines is becoming an attractive consideration for many utilities. Due to the availability of individual pole strength data, the question of whether an existing line possesses sufficient excess capacity to allow reconductoring or other upgrading can be answered.

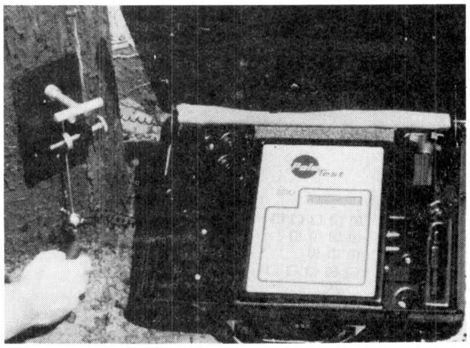
PoleTest™ evaluation of a line considered for upgrade for the City of Longmont, CO., found a key low strength pole in the line, thereby allowing selective replacement to insure reliability after upgrade.

PoleTest™ identified several weak poles in a line to be upgraded by United Power Association of MN. However, the majority of the poles had sufficient strength to allow a cost-effective upgrade.

POLETEST OPERATION SEQUENCE:



- Measure & Record Pole Diameter
- Mark Accelerometer Locations



- Drive Impact Nail into Pole
- Attach Pendulum
- Insert Accelerometers into Pilot Holes

MAINTENANCE AND REPLACEMENT

In the past, decisions on pole retreatment, replacement or repair have been based primarily on determining the extent of decay or other damage within a pole. Often these decisions relied heavily on judgement since a direct strength assessment of the pole was unavailable. PoleTest™ provides this strength information which, when combined with conventional inspection, allows these decisions to be made with confidence. Significant savings can result by replacing only those poles with inadequate strength, identifying poles which can be repaired, and by extending the service life of poles with adequate strength.

EPRI says: Using present inspection methods, approximately 667 poles of a 10,000 pole line would be replaced annually. If by using the EPRI developed NDE method to inspect poles, the useful life of only one-third of these 667 poles is extended 5 years, then the potential savings to the utility is on the order of $1,000,000 per year.

After several months of PoleTest™ use, Tampa Electric Co. is confident that this new technology is allowing better decisions on pole repair and replacement leading to substantial economic savings.

By using PoleTest™ on eleven lightning-damaged poles, Bonneville Power Administration saved $20,000 by salvaging instead of replacing four of the eleven poles.

STRUCTURAL RELIABILITY ASSESSMENT

To further enhance a wood pole management program, strength data from field testing with PoleTest™ can be compared to the structural requirements of the pole resulting from structural analysis. This comparison of actual pole strength to required pole strength can be made at any time in service. This enables the reliability of the line to be determined and maintained at a given level through selective pole repair or replacement as required. Often through structural analysis, additional savings will be realized, especially if the analysis is performed for each structure using as-built spans and loading information.

In a recent case, inspections indicated 10 poles in a transmission line should be replaced. PoleTest™, combined with structural analysis, revealed 8 of the 10 poles could be saved, resulting in a savings of about $10,000 for Idaho Power Co. In another case, $71,000 had been budgeted to replace 10 poles in a line near Salmon, ID. PoleTest™ indicated that the poles were good enough to be repaired rather than replaced, saving IPCO $40,000.

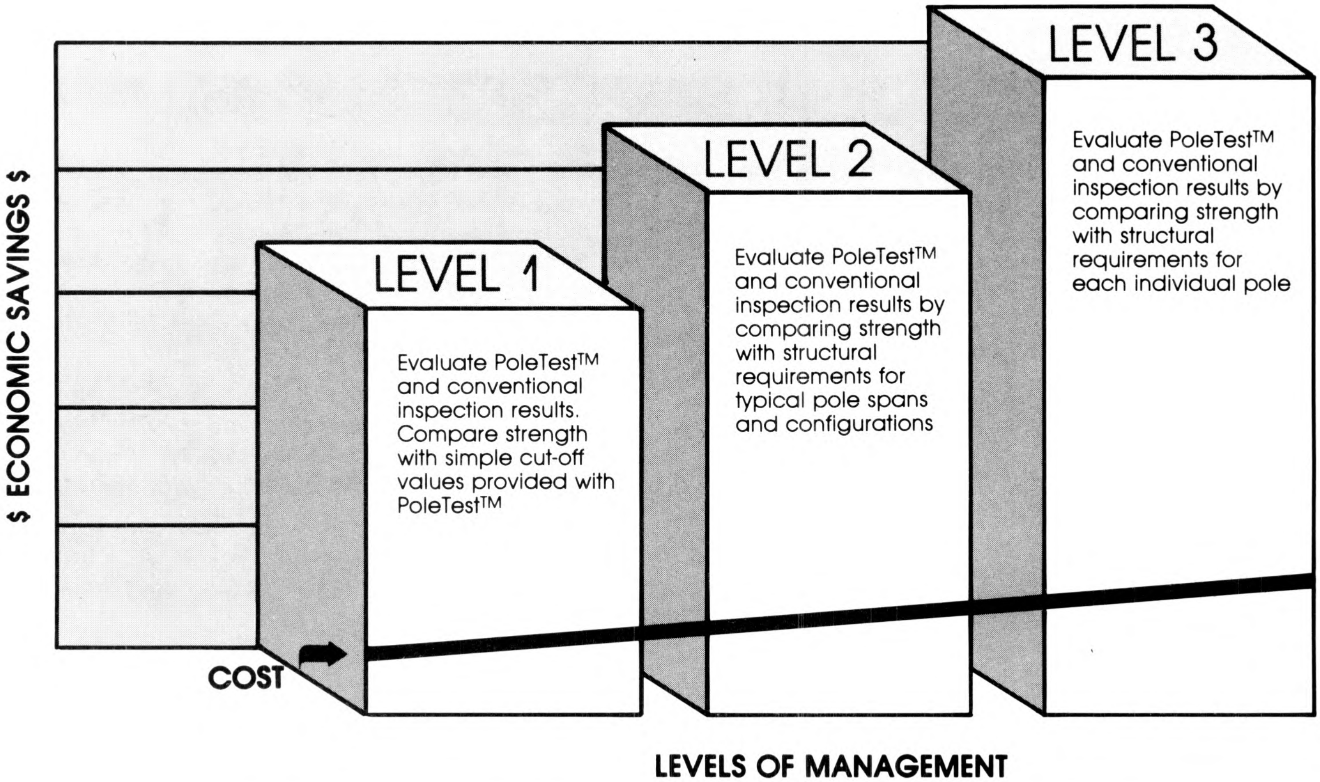
... this entire test sequence can be performed in 3-4 minutes...

- Press "START"
- Enter Species
- Impact Pole as Prompted by **PoleTest™**
- Enter Pole Diameter
- **PoleTest™** Displays Strength in psi, Species and Entered Diameter

DOUGLAS FIR

DIA: 19.0, PSI: 7590

HOW TO GET STARTED IN WOOD POLE MANAGEMENT:

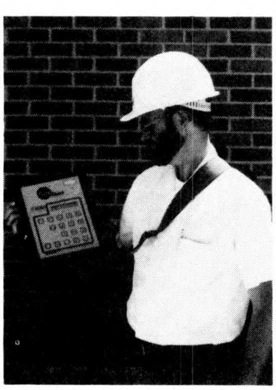


Many utilities are wondering how PoleTest™ can be incorporated into their current maintenance/management programs. EDM will custom tailor a wood pole management program for your utility. While the use of PoleTest™ is as easy as comparing a predicted strength to a cut-off level, increased management efforts provide additional significant benefits. EDM can provide wood pole management services for your utility or train your personnel in pole management areas.

In addition, EDM can perform low-cost wood pole management pilot studies on selected utility lines to allow you to assess the benefits of NDE of pole strength. Typical pilot programs involve:

- Inspection of Poles Using PoleTest™
- Structural Analysis
- Comparison of Predicted Strength to Required Strength
- Management Recommendations on Structural Adequacy

FOR MORE INFORMATION:



Pole Climbing Model

Ask for FREE PoleTest™ demo videotape!

Standard Model

TECHWARE DIVISION

A product of the TechWare Division of EDM, Inc., Ft. Collins, CO, USA

In-field and videotape training services are available.

For more information on PoleTest™ or wood pole management programs, pilot studies or consulting services, contact:

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