Evaluating Wood Pole Structural Integrity using Ultrasound Non-Destructive Inspection Technology

Wayne Hall – President Utility Asset Management Inc

PEG PROTECTION ENGINEERS GROUP

Introduction - Services Provided

- **Customers**
  - 100 plus Utilities
  - 32 States
- **Pole Inspection**
  - Non-Destructive Evaluation (NDE) services
  - Training 3rd Parties Utilities / Contractors in use of technology
  - Process based on RUS 1730B-121 and AWPA M13-15
- **Fiber Consenting**
  - Minimum Clearances
  - PLA/ Make Ready

Introduction Services Provided

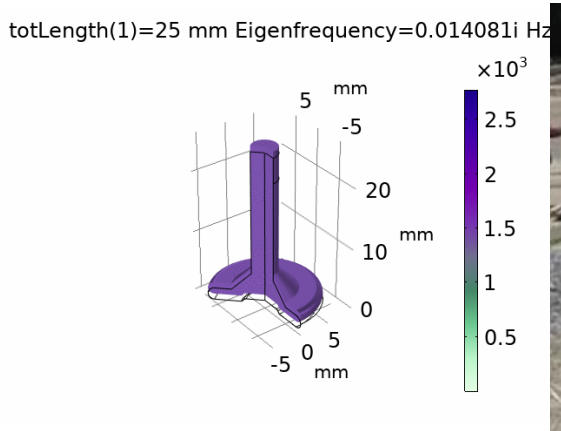
- **Joint Use Inventory /NESC Audits**
  - Communications Attachers
  - Heights/CWSZ
- **Pole Treatments**
  - GFume
  - Qualified Supervisor/Certified Operator
- **Network Hardening**
  - Consulting/Design Services
  - Physical Reinforcement

Industry Leading Research Team

Lead Research and Development University Partners

Daniel Felix Ritchie School of Engineering & Computer Science

MISSISSIPPI STATE UNIVERSITY
COLLEGE OF FOREST RESOURCES

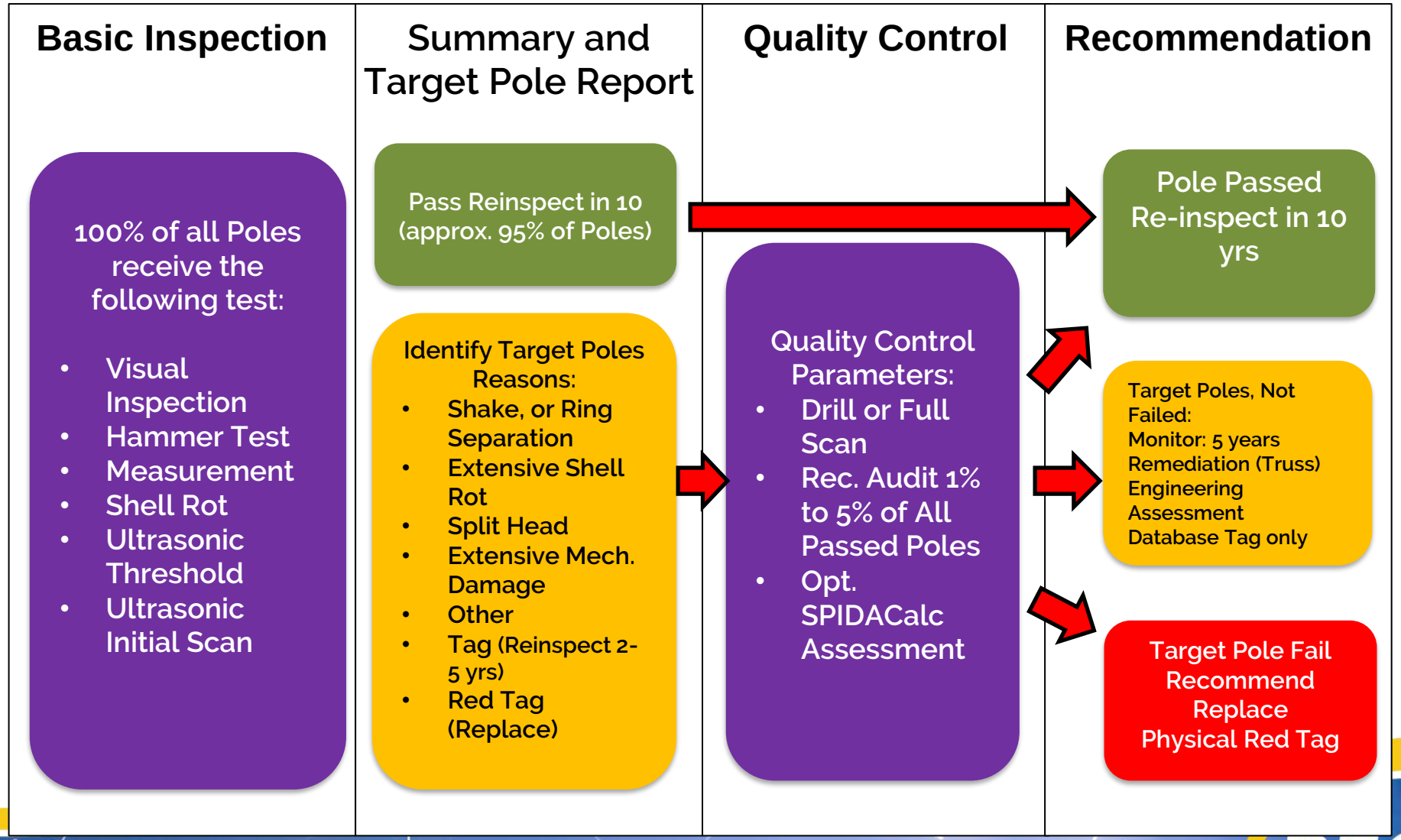


PEG PROTECTION ENGINEERS GROUP

RUS 1730B – 121 : Purpose

"The purpose of a planned inspection program is to reveal danger poles and poles which are in early stages of decay so that corrective action can be taken to prolong the service life of the pole. The end result of the inspection program is the establishment of a continuing maintenance program for extending the average service life of all poles on the system."

Basic Pole Testing Process –Guideline - RUS1730B-121/AWPA M13-15



PEG PROTECTION ENGINEERS GROUP

Ultrasound NDE Key Advantages

- **Concrete/Asphalt Embedded Wooden Poles can be Tested**
  - Can detect decay up to 18 inches below grade
  - No restoration Costs
- **Detection of Incipient Decay – Stage One Decay**
  - 5-7 Year Advance Notice on Issues with the pole
  - Traditional Inspection only detects ESD – Early Stage Decay – Stage Two Decay
- **Full Data Capture and infield Diagnostic Reports**
  - Audit Trail - ADC Signal – over 2000 Data Samples per file
  - Allows for Inspection Quality Control
- **No Damage to Pole versus Drill Testing**
  - IOU Engineering analysis damage estimates are around 3%-7%
  - SPIDACalc damage estimate shows 4.2% - 7% (SP 40/4)
- **Use Current Contractors Teams or UAM Teams**
  - Lease/Sell Units to utility contractors or provide direct service
  - Technology and Training Provided to Utilities and Contractors

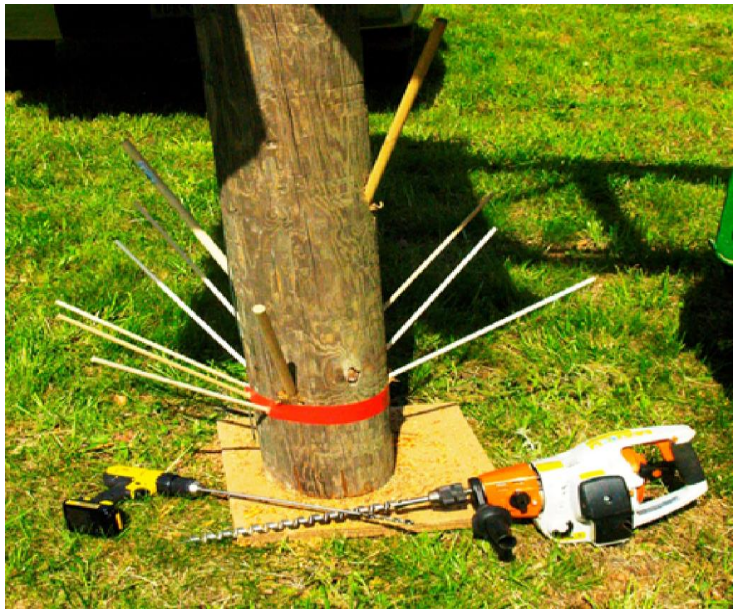
Why is Non Destructive Evaluation (NDE) Important?

Pole Longevity and Reliability

Leave good wood alone, focus on target poles to increase overall pole lifespan and reliability.

Less Damage

Current Drill Process
45 years expected but damaging inspections start at approximately yr 15-22



ANSI O5.1-2017
(New Wood Poles: Specs/Dimensions)
5.2 Prohibited defects
5.2.4 Holes, open or plugged, are prohibited...

PEG PROTECTION ENGINEERS GROUP

So How Much Damage Is Done?

			Remaining Strength			
C/L	Species	Circumference	7/8"	5/8"	3/8"	1/10" (IML)
40/4	SP	33.50	90.29%	93.04%	95.79%	98.65%
60/3	WRC	45.75	92.91%	94.98%	96.99%	99.04%
80/1	WRC	57.75	94.41%	96.01%	97.62%	99.21%

SPIDA CALC

- Estimates Vary
  - SPIDACalc shows 4.2% - 7% (SP 4/40)
  - IOU Engineering analysis estimates are around 3%-7%
  - Some Traditional Inspection Co's: "Negligible Damage"
- The true cost of drilling every pole
  - Economic Damage - 4/40 base cost of $500 means that over $20 is caused if a drill test is performed.
  - Increased risk – a 71% RSM pole after testing becomes a reject at 66.8%
- Treating a Pole results in more reduction of remaining strength
  - SPIDACalc shows 9% reduction (SP 40/4)

Source/s** IOU internal assessment/SPIDACalc

PEG PROTECTION ENGINEERS GROUP

Where Does NDE Fit in a Program

Important Complementary Tool for Inspectors

- UB1000 is used as the “Thermometer” to check the “temperature” of all poles.
- A high read means further investigation is required – Drill/Bore
- Key indicator: Peak Power (First/Second Arrivals)
- Hammer, Drill, Shell Gauge are also part of toolkit

Analogy: Doctors visit

- Thermometer first, Scalpel second

Pole Population Generic Aging/Decay Profile

- 0-5 years – Very small number of outlier rejects
- 22-25 year – Decay poles become apparent
- 65-75 years* – Poles generally become less strong

*Source: NORTH AMERICAN WOOD POLE COUNCIL TECHNICAL BULLETIN No. 17-D-202

The Decay => Ultrasound Relationship

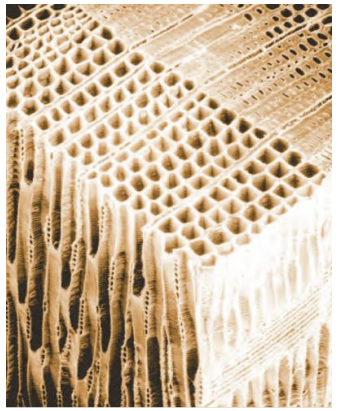
- Key Precursors for Decay *
  - Existence of Decay Fungi - Introduced or Pre-existing
    - » Brown Rot (heart rot in softwood),
    - » White Rot (Prevalent in hardwoods/conifers)
    - » Soft Rot (Shell Rot – Reduced Circumference)
  - Oxygen - Ground line and Slightly Below (approx. 18inches)
  - Moisture - Generally above about 20% Moisture Content
  - Temperature - Generally 60-80 Degrees (but begins at 32 degrees)
- Stages of Decay
  - Incipient Decay (Cell Breakdown)
    - » Detected with Ultrasonic Testing (allows better treatment decisions)
  - Early Stage Decay (Punky Wood, Dusty Wood, Doughy Wood)
    - Discoloration/Weakening
    - Detected with Ultrasonic or Traditional Drilling
  - Advanced Decay– Brown Rot /White Rot /Soft Rot
    - Detected with Ultrasonic or Traditional Drilling
    - Hollowness/Degradation

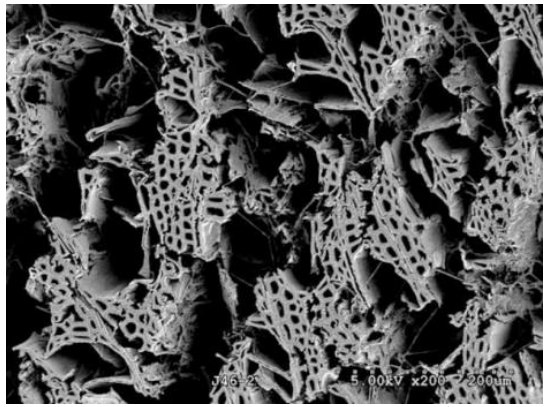
* Source – Dr Jeffrey Morrell – 2012. Wood Pole Maintenance Manual

Chemical Breakdown creates Energy Attenuation

Decay Fungi Types: soft rot, white rot, and brown rot

- Fungi spores develop fungus filaments (hyphae)
- Hyphae secrete enzymes to breakdown hemicellulose into sugars
- Hemicellulose is approx. 40% of weight of wood





Sound Scatters - Higher in Energy Attenuation

Source – Cho, Younho, and Joseph L. Rose. "A boundary element solution for a mode conversion study on the edge reflection of Lamb waves." The Journal of the Acoustical Society of America 99.4 (1996): 2097-2109.

Weight Loss in Incipient Decay Stage =>Strength Loss

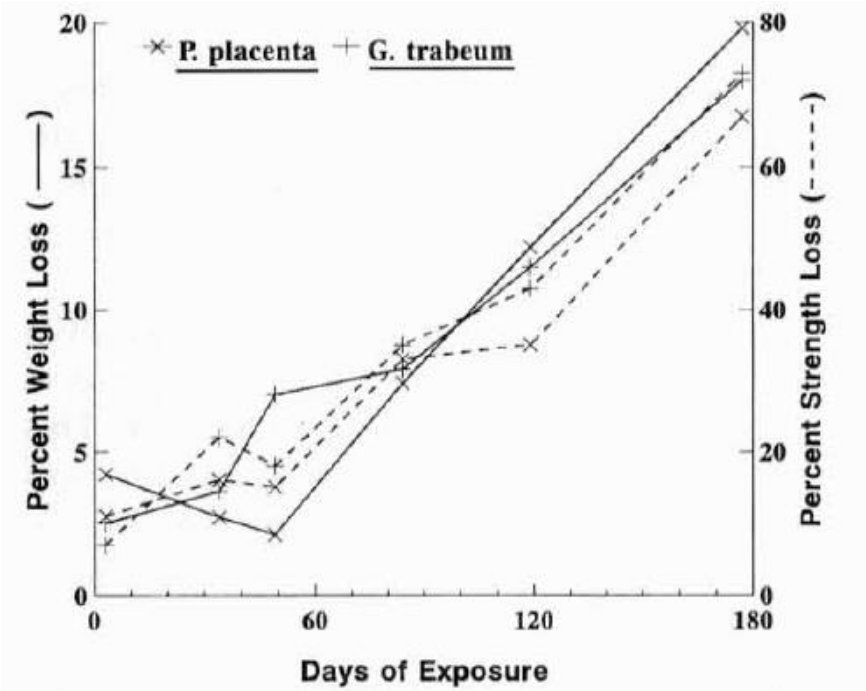


FIG. 3. Effects of two brown-rot fungi on wood weight loss and modulus of rupture of Douglas-fir heartwood microbeams.

Source – Winandy, Jerrold E., and Jeffrey J. Morrell. "Relationship between incipient decay, strength, and chemical composition of Douglas-fir heartwood." (1993).

A Trained Inspector Plus Process Plus Technology are Required

Source: Gerald L. Daugherty
The Realistic Expectation of an In-Place Wood Pole Inspection Program

Table 3. – Efficacy of conventional and newer sonic wood pole inspection programs (Osmose 1997a).

	Type of inspection	Reinspection cycle	Remarks
1.	Visual.	Several times a year	Provides little information to help improve pole plant. Misses most reject and priority poles.
2.	Sonic.	Yearly	Used with visual inspection, 40 to 50% of reject and priority poles will be found.
3.	Sound and bore.	Yearly	Used with visual inspection, 50 to 60% of reject and priority poles will be found.
4.	Partial excavation plus sound and bore.	3 to 5 years depending on decay hazard zone [a]	Used with visual inspection, 80 to 98% of reject and priority poles will be found.
5.	18 to 24 in. excavation plus sound and bore. [b]	6 to 10 years depending on decay hazard zone [a]	Used with visual inspection, 98% of reject and priority poles will be found. [c]

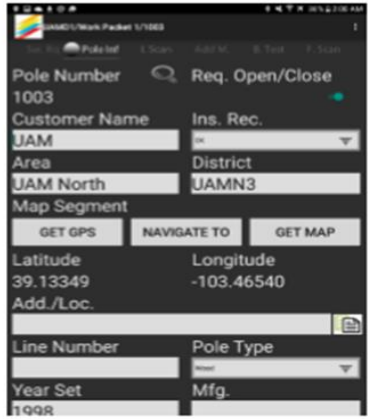
[a] Assumes supplemental treatment applied at time of inspection.
[b] Deep decay will not be found unless the specifications call for excavation below 18 to 24 in.
[c] Full effectiveness will not be achieved on poles which cannot be fully excavated due to obstructions beyond the control of the inspector such as rock, adjacent buildings, sidewalks, keys, roots, risers and underground cable.

"When inspection methods that do not utilize NDE devices are employed, determination of the suitability of a given wood pole, or lack thereof, is a subjective decision made by a human being. Since all inspectors are not alike – some are more skilled and conscientious than others – another variable affecting the efficacy of in-place wood pole inspection is introduced" - Gerald L. Daugherty

Technicians – IKE or Tablet Based Apps

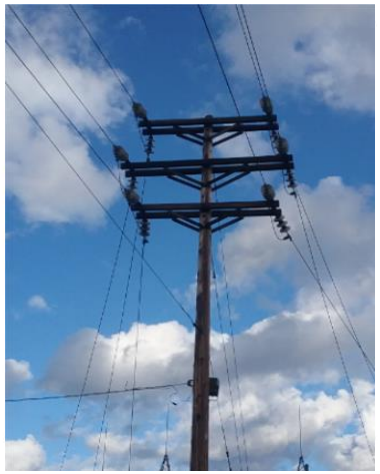
Offline Mapping

Open service requests in Red closed in Green..



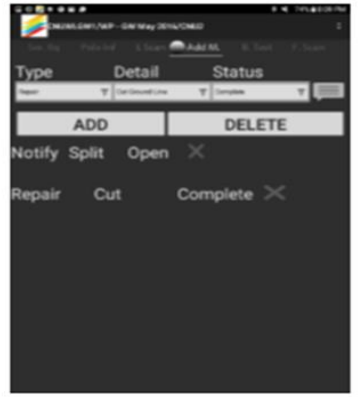
Multiple Data Capture Screens

NETMAP GIS Id
Street Address
SAP ID
Pole ID
Condition



Photos and Scan Data

Photos
Multiple Scan Files
IKE GPS Files
Other data files



Maintenance Tracking

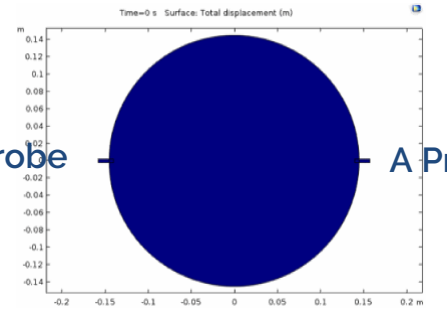
Service Contractor Integration
Status tracking

PEG PROTECTION ENGINEERS GROUP

Ultrasound through Wood – MATLAB Simulation

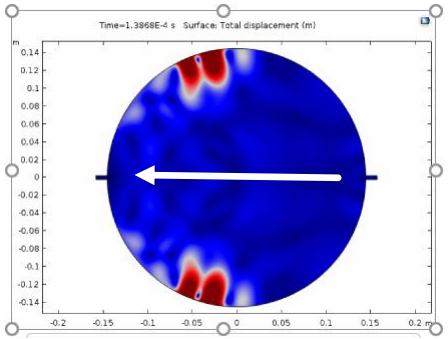
Probe A - B

B Probe

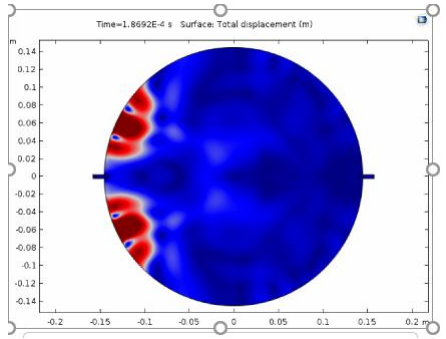


A Probe

Arrival 1 – Internal
Heart Rot Indicator



Arrival 2 – Shell
Shell Rot Indicator



Key Indicator 1: Time of Flight

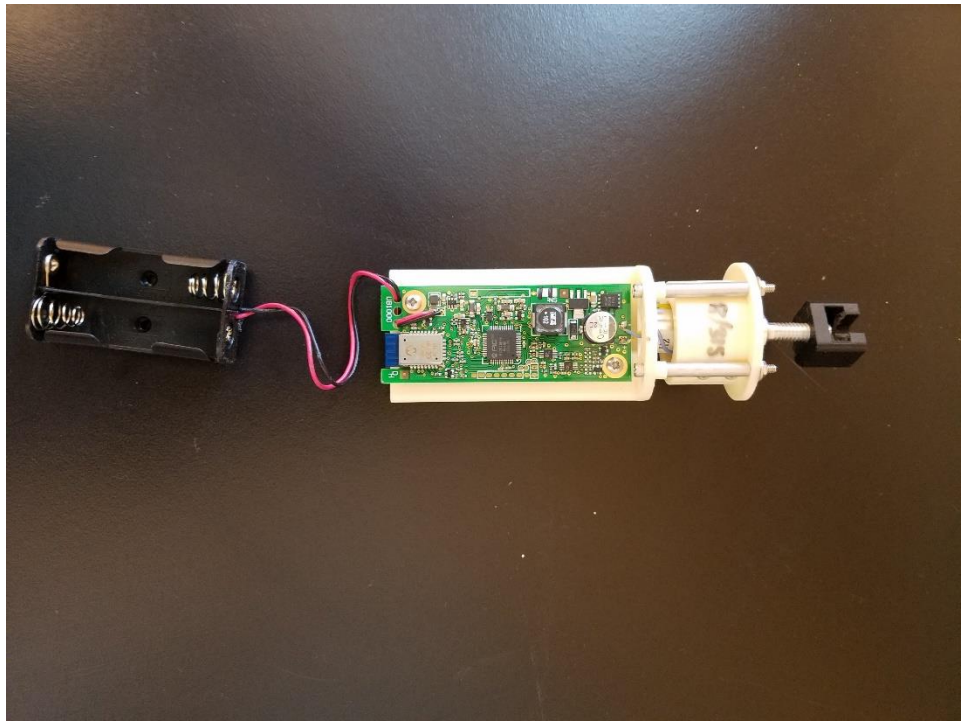
- TOF (Microseconds)
- First (TOF1a, TOF1b)/Second (TOF2) Arrivals

Key Indicator 2: Peak Energy

- Sound => Energy
- Measure Peak Energy Attenuation
- Peak Energy 1b and 2

PEG PROTECTION ENGINEERS GROUP

UB1000 Device



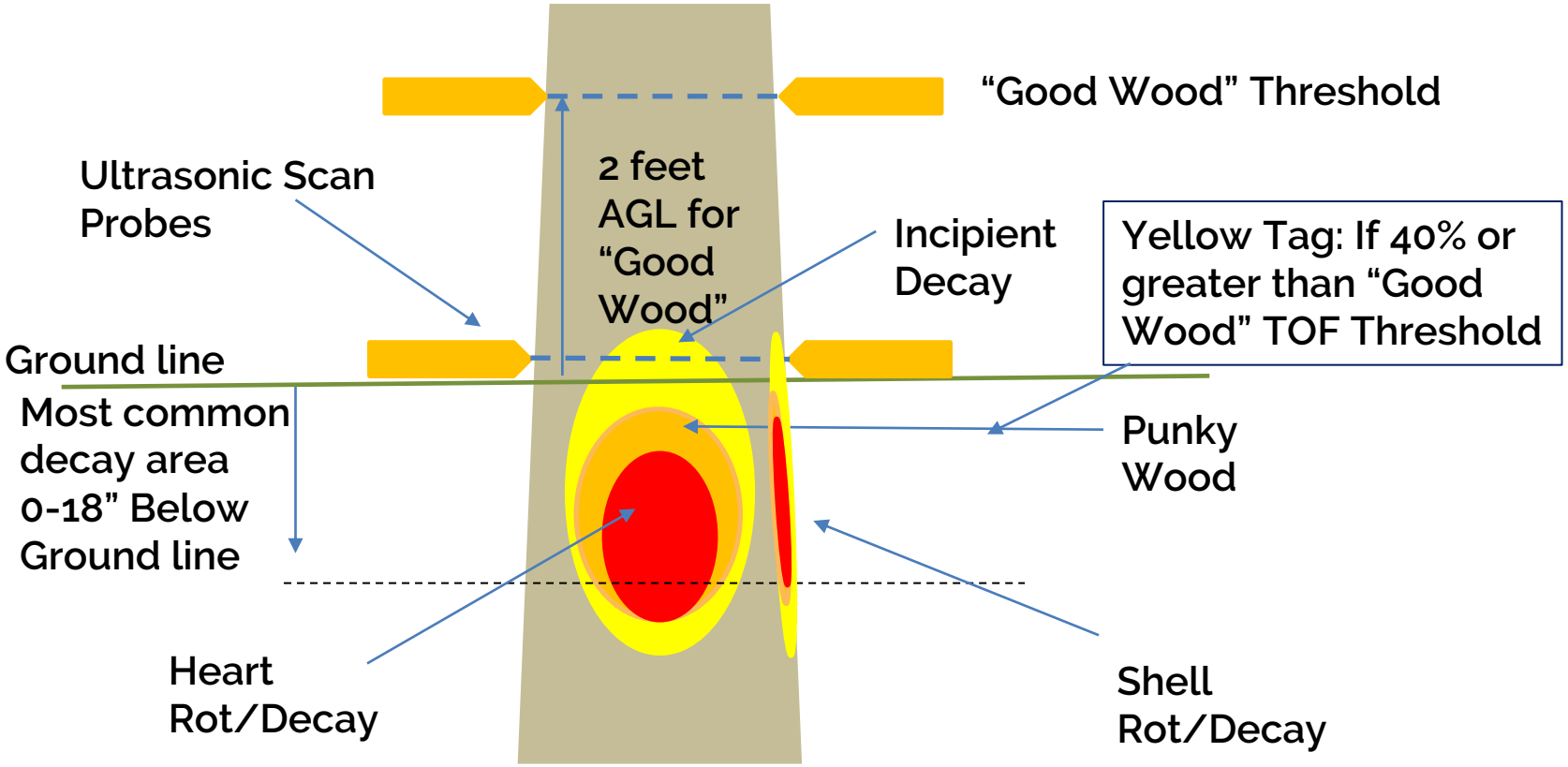
PEG PROTECTION ENGINEERS GROUP

UB1000 Device and Signal Analysis

- UB1000 - Ultrasound Device
  - Serves as both transmitter and receiver
  - Generate pressure wave at 50 KHz
  - Transmits raw signal to tablet via Bluetooth for further analysis
  - Over 8000 samples downloaded per double download

- Time Domain Energy Algorithm (TDEA) / Pole Analysis App
  - TOF Calculation Immediately
  - ADC (Analog Digital Conversion) downloaded and displayed
  - DSP (Digital Signal Processing) algorithm to avoid false detection.
  - Arrivals 1A, 1B and 2 Calculated
  - Report Generated Pole Analysis App (PAA)

Decay Stages – Ultrasound Advantage
(Identifies all Decay Stages)



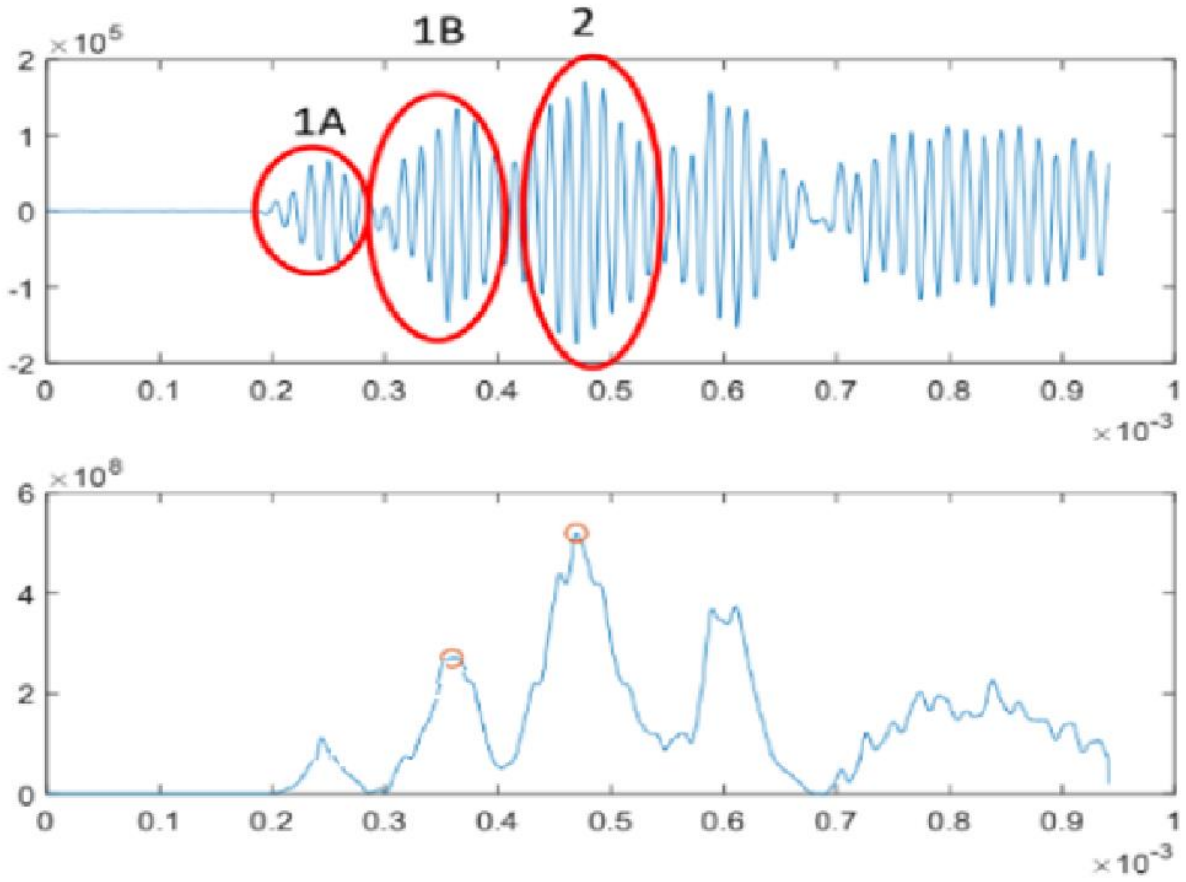
Ultrasonics Provides the same efficacy as the "Partial Excavate, Sound and Bore" process

PEG PROTECTION ENGINEERS GROUP

Example Signals – Good Pole

ADC

DSP

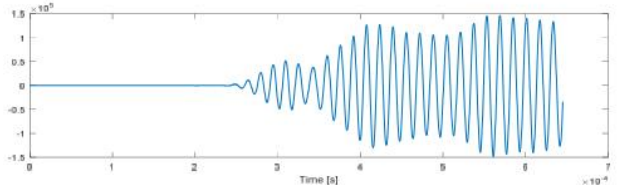


1A – First Arrival – Fastest / lightest signal through heart
1B – First Arrival – Stronger signal through Internal/heart
2 – Second Arrival – Strongest Signal around shell

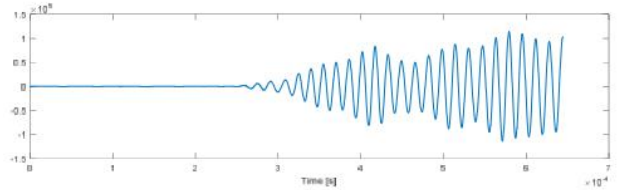
Example – Shell Rot – ADC Signal

Test Result
Pole ID 725186303

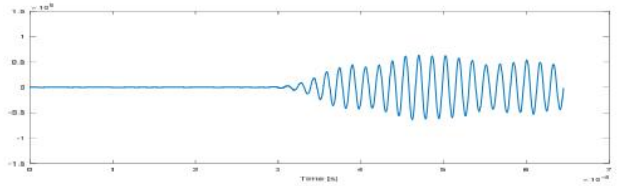
Red tagged for shell rot with GLC = 40 inches



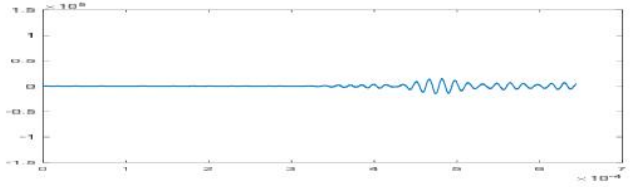
64 inches



24 inches



12 inches

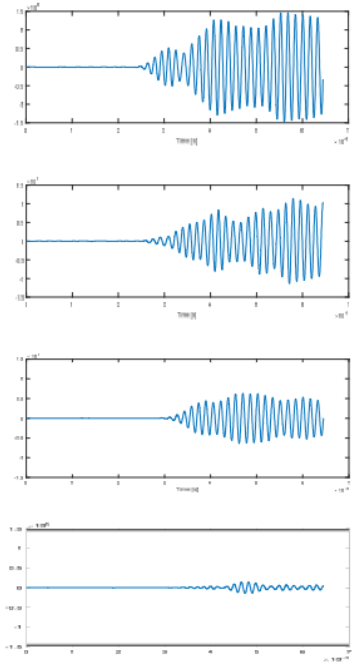


1 inch

PEG PROTECTION ENGINEERS GROUP

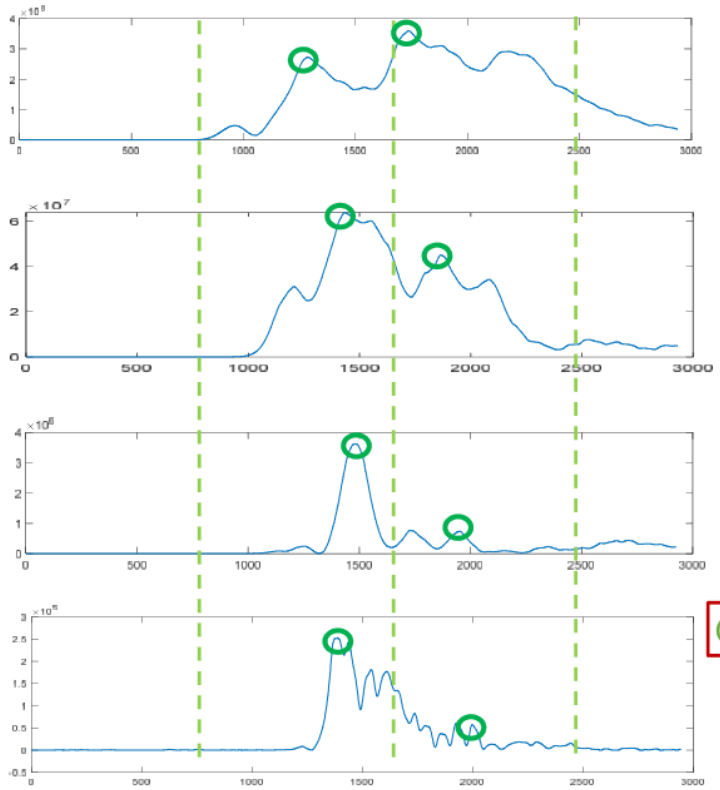
Example – Shell Rot – DSP Signal

Test Result
Pole ID 725186303



Internal/Heart **Circ/Shell**

1st Arrival Region 2nd Arrival Region



64 inches

24 inches

12 inches

Rev 4 algorithm

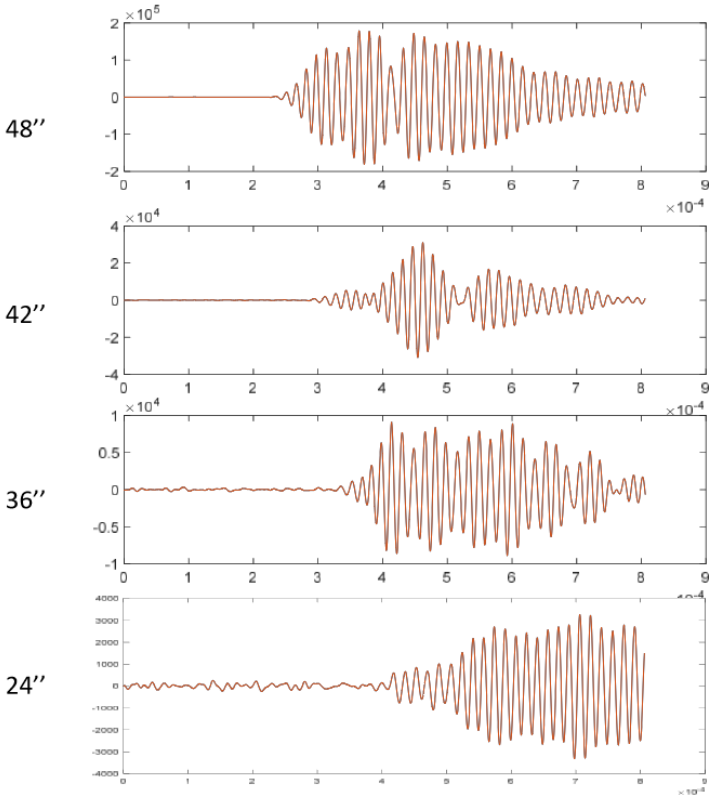
1 inch

PEG PROTECTION ENGINEERS GROUP

Example – Internal Decay– ADC Signal

Test Result
Pole ID C140

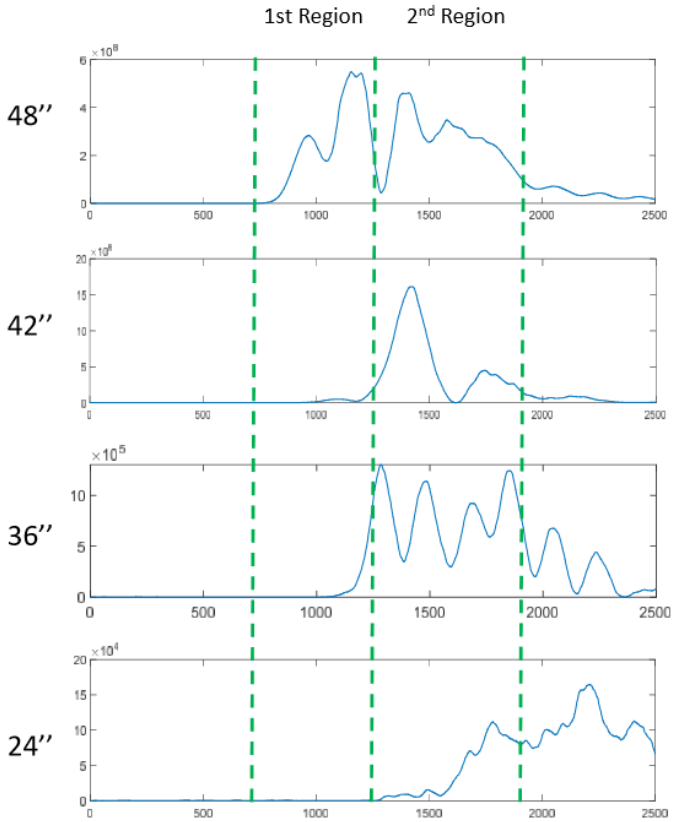
Red tagged for heart rot with GLC = 40 inches



PEG PROTECTION ENGINEERS GROUP

Example – Internal Decay – DSP Signal

Internal/Heart Circ/Shell



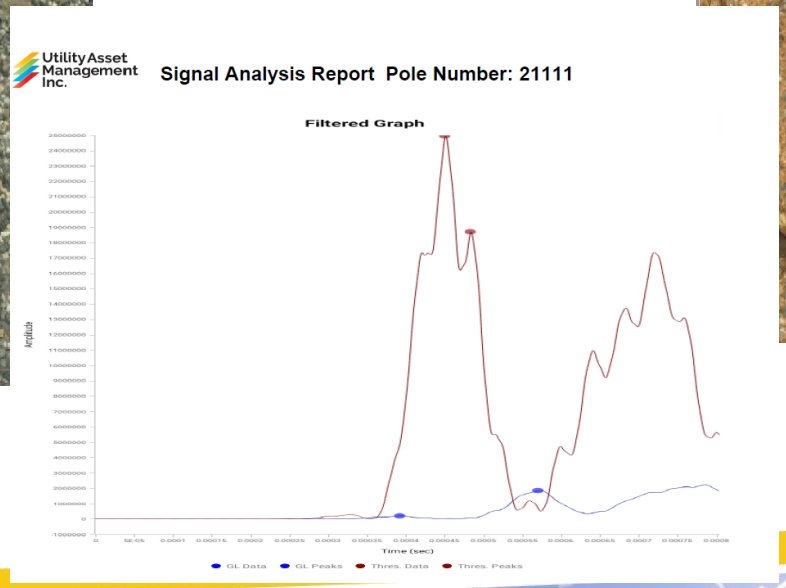
1st Arrival Region

AGL	TOF1B	Peak Energy
48	377	5.3
42	353	0.0048
30	374	0.0027
12	ND	ND

Huge attenuation in the 1st arrival region suggests heart rot decay.

PEG PROTECTION ENGINEERS GROUP

Hardwood Heart Rot Example



PEG PROTECTION ENGINEERS GROUP

Field Technician Analyzer Reporting

Utility Asset Management Inc.

Signal Analysis Report Pole Number: 84404

Pole Detail

Pole ID	84404	Pole RSM %	
Pole Species	Southern Pine	Pole Class	Unknown
Pole Length	Unknown	Pole Tag	OK

Analysis Results

% Difference		Diagnostic Result		Settings
High % is BAD		High % is BAD		
(1AM-1AT)/1AT	1.10865%	Heart Condition (TOF1b)	Green	40% 80%
(2AM-2AT)/2AT	12.62626%	Shell Condition (TOF2)	Green	40% 80%
Low % is BAD		Low % is BAD		
PE1M/PE1T	6.55738%	Heart Condition (PE.1b)	Yellow	20% 5%
PE2M/PE2T	2.1223%	Shell Condition (PE.2)	Red	20% 5%

GL Metrics		Threshold Metrics	
TOF 1bAM	456	TOF 1bAT	451
TOF 2AM	669	TOF 2AT	594
Peak Energy 1M	1804587	Peak Energy 1T	27519935
Peak Energy 2M	320572	Peak Energy 2T	15104912

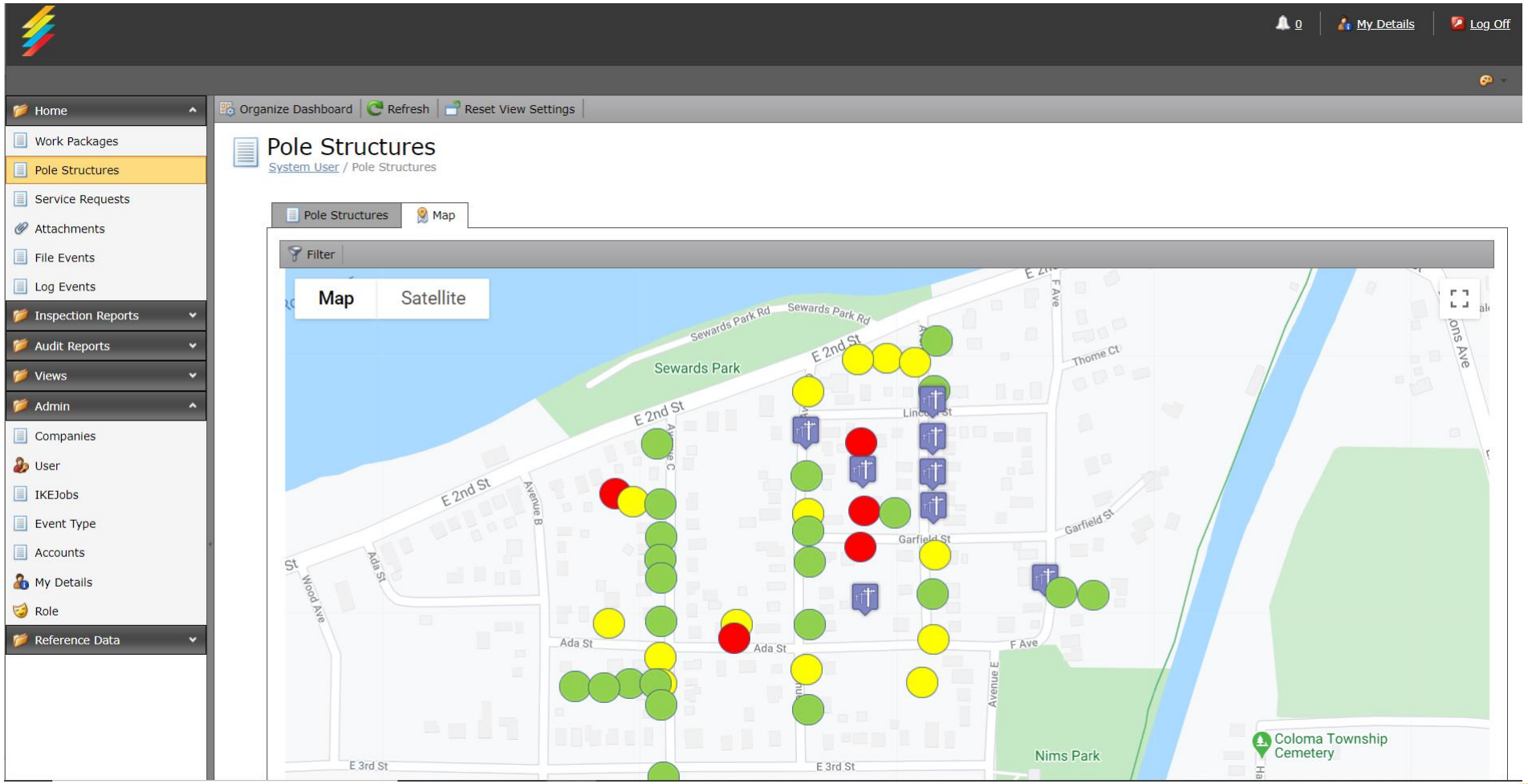
Diagnostic Results / Possible Issues

This signal analysis indicates the following possible pole issue/s for further investigation.

Possible Condition	Weight	Rule Description
Internal Decay	Medium	If Peak Energy 1< Amplitude Yelow and Peak Energy 1 is > Amplitude Red
Shell Rot	High	If Peak Energy 2 < Amplitude Red

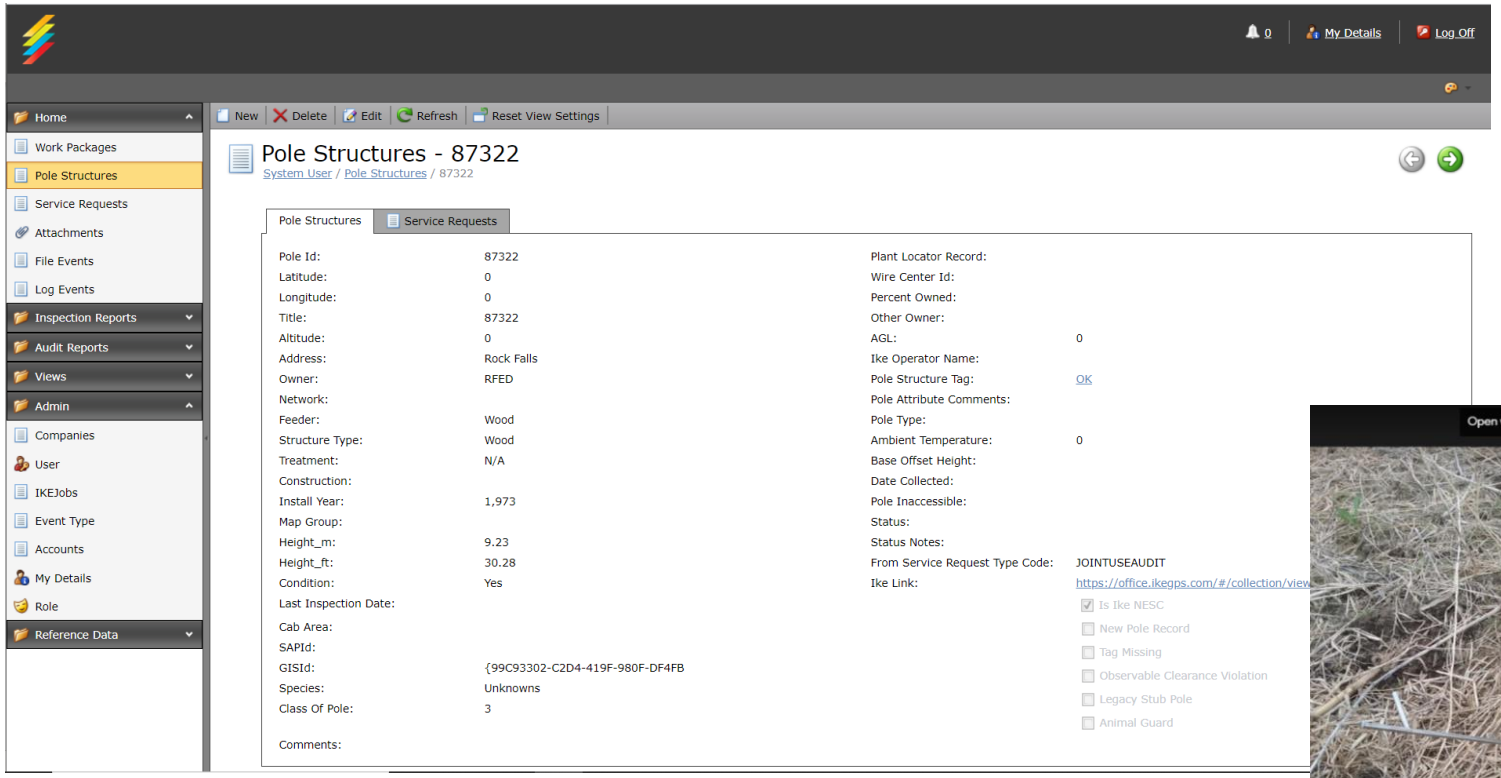
PEG PROTECTION ENGINEERS GROUP

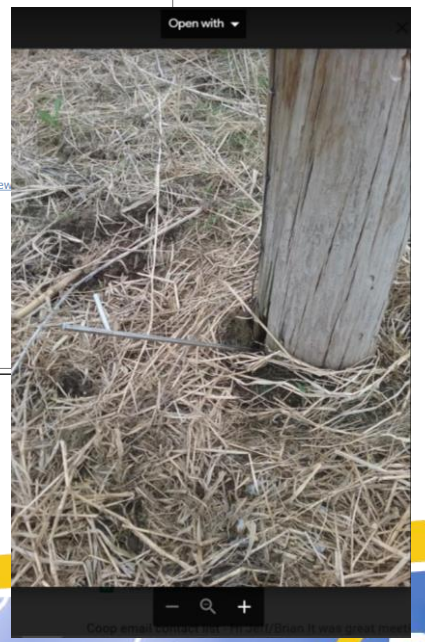
Cloud Based Data-warehouse



PEG PROTECTION ENGINEERS GROUP

Cloud Based Data-warehouse





PEG PROTECTION ENGINEERS GROUP

Fiber Consenting / NESC Audits / Joint Use Audits

IKE 4 Device

The IKE 4 device incorperates the latest mobile technologies to produce a best-in-class high-performance, lower-power field data collection solution. Key device features include:

Android™ 5.1, Lollipop
Easy to use, smartphone user interface and experiences

Wireless Connectivity
Wi-Fi, bluetooth and broadband data

13-Megapixel Digital Camera
Larger viewing angle, reducing distance of capture point

Class 1M Laser
300m and 650m distance options

Outdoor Screen Readability
4.8" capacitive, multi-touch Gorilla Glass screen: 1280 x 720 resolution

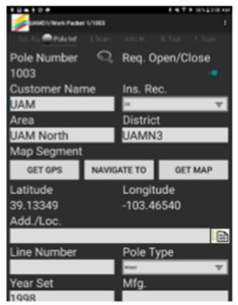
ARM High-performance, low-power optimization
MediaTek 64-bit quad-core ARM® Cortex®

Extended Battery Life
8 to 10 hours of continued usage

GPS Receiver
GPS L1 with RTK option

PEG PROTECTION ENGINEERS GROUP

UAM Inc - Joint Use NESC Audit - Process



Offline Mapping

Open service requests in Red closed in Green..

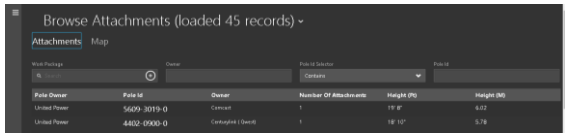
Multiple Data Capture Screens

Cloud Database

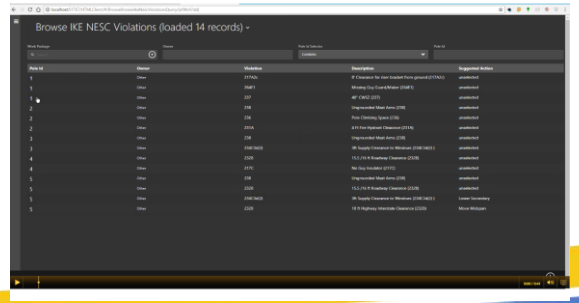
Integration to IKE Cloud

Pole Structures

Attachments

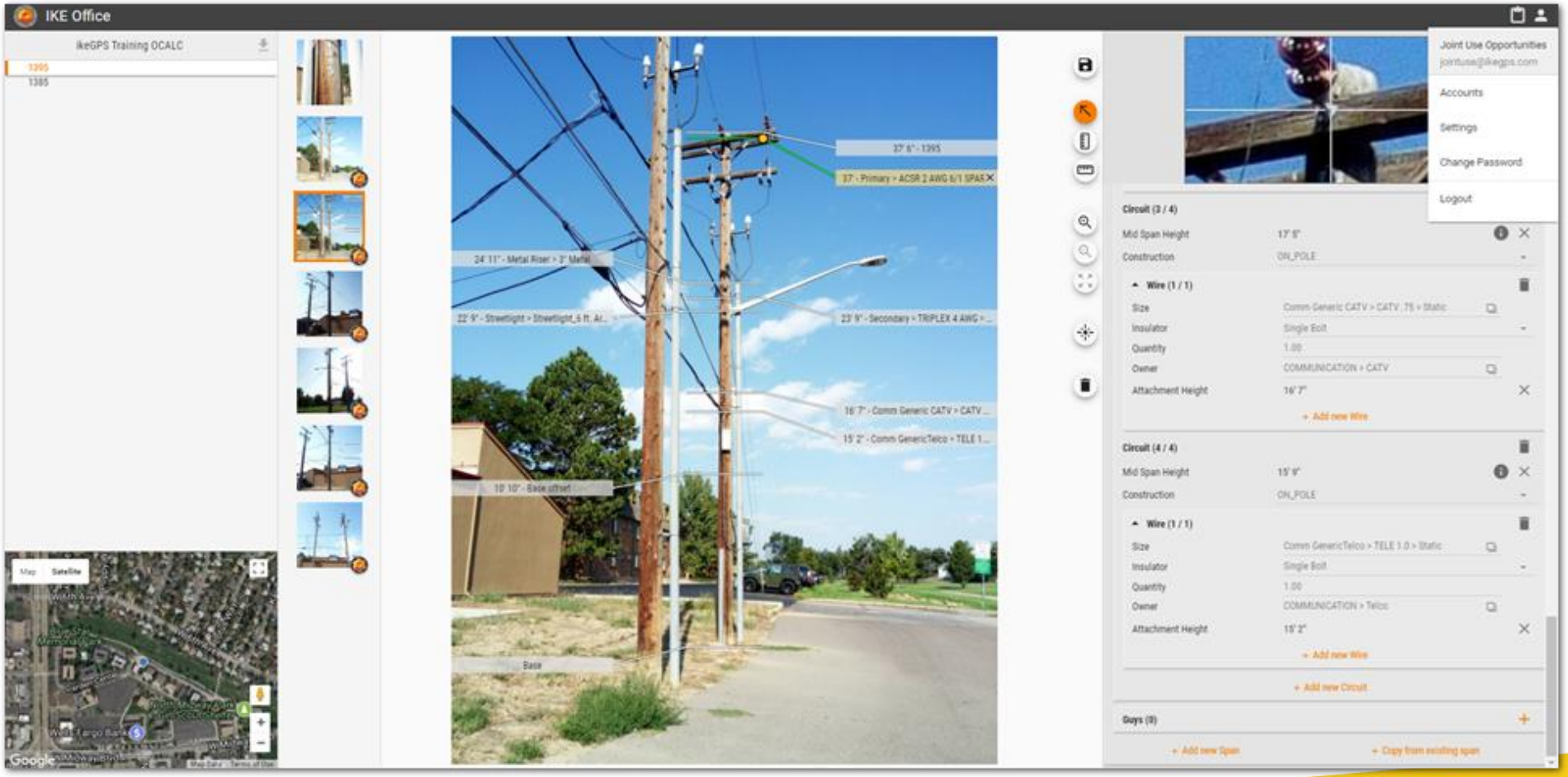


NESC Violations



PEG PROTECTION ENGINEERS GROUP

UAM Inc - Joint Use NESC Audit - Process



PEG PROTECTION ENGINEERS GROUP

Questions

wayne.hall@utilityassetmanager.com

www.gridmgr.com