Scott Riccardella
Product Manager

TIMP: Applying External Corrosion Direct Assessment (ECDA) and Guided Wave Testing (GWT)

Presentation Overview

- Direct Assessment Overview
- Application of ECDA in Difficult to Assess Environments
  - Challenges Posed by Facilities and Casings
  - Traditional Tools
  - Area Potential – Earth Current Survey (APEC)
  - Other Technologies – Guided Wave Testing (GWT)
- Case Study and Examples
- Guided Wave Testing - Overview of Fundamentals, Technology, and Applications

Direct Assessment (DA)

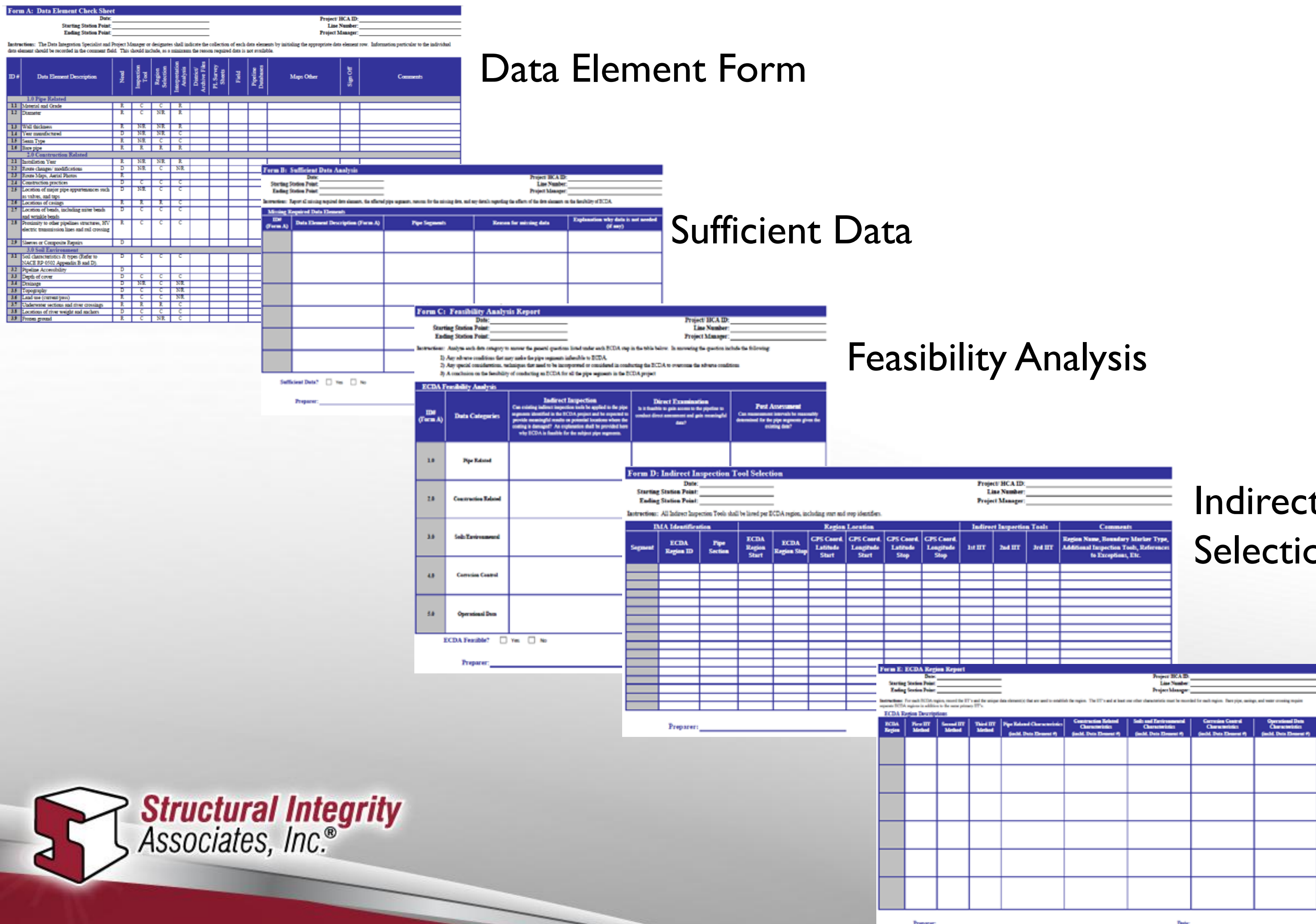
- DA is one of the four methods used to verify pipeline integrity as mandated by DOT
  - Hydrostatic testing
  - In-Line Inspection (pigging)
  - Direct Assessment (DA)
  - Other Technologies (such as GWT)
    - This method requires filing a Notification with PHMSA (OTN)
- Based upon the threats of concern for a pipe segment, DA can be used to assess pipe integrity in regards to:
  - External Corrosion
  - Internal Corrosion
  - Stress Corrosion Cracking
- DA is an applied practice consisting of four well documented steps
  - Pre-Assessment
  - Indirect Inspections
  - Direct Inspections
  - Post Assessment

ECDA: Pre-Assessment

- Data Intensive Process
- Collects and Evaluates Data
  - Pipe-related
  - Construction Related
  - Soils/environmental
  - Corrosion Control
  - Operational
- Determines Feasibility
- Identify and group Regions
- Selection of Indirect Tools (minimum #, per plan)

ECDA Documentation

- Advocate rigorous documentation for the ECDA process
  - Several detailed forms as part of the detailed report
  - Per PHMSA: “If you didn’t document it, you didn’t do it…”



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ECDA: Indirect Inspections

- Locate Coating Faults and Areas Most Susceptible to Corrosion
- Define Severity
  - Past versus Current Activity
- Applies Indirect Inspection Tools
  - Typical Survey Tools: CIS, DCVG, ACVG
  - Survey Entire Length of Each ECDA Region
  - Aligns, Integrates and Evaluates Survey Data

Form F: IIT Procedure Review Form

Date: ____________ IIT Method: ____________
Prepared By: ____________ Organization or Vendor: ____________
Reviewed By: ____________ Procedure Number: ____________

Procedure Content Review

Acceptable	Not Acceptable	Area	Comments
☐	☐	Procedure Number	
☐	☐	General Description	
☐	☐	Limitations	
☐	☐	Procedure Qualifications	
☐	☐	Safety	
☐	☐	Instrumentation	
☐	☐	Personnel Qualifications	
☐	☐	Calibration	
☐	☐	Equipment Connections	
☐	☐	Pipe Location	
☐	☐	Measurements	
☐	☐	Special Diagnostics	
☐	☐	Distance Measurements	

Survey Procedure Review

Form G: Indication & Classification Alignment

Date: ____________ Project/ HCA ID: ____________
Starting Station Point: ____________ Line Number: ____________
Ending Station Point: ____________ Project Manger: ____________

Line ID	HCA ID	Item #	Station/ Grid Begin	Station/ Grid End	Footage (ft)	CIS Category	ACCA Category	DCVG Category	APEC Category	ECDA Region	Initial Value	Urgency Level	Final Value	ECDA Category	Scheduled for Dig (Y/N)	Comments	Latitude Begin	Longitude Begin	Latitude End	Longitude End

Indication & Classification Alignment

ECDA: Direct Examinations

- Evaluate Indirect Inspection data to determine dig locations
- Collect Data (Bell Hole Inspection) to Assess Anomalies
  - Assess Coating Condition
  - Measure Pipe Surface Conditions
  - Measure Immediate Surrounding Environment Data

Direct Exam Summary Form

Form H: Direct Examination Summary Form

Date: ____________ Project/ HCA ID: ____________

Starting Station Point: ____________ Line Number: ____________

Ending Station Point: ____________ Project Manager: ____________

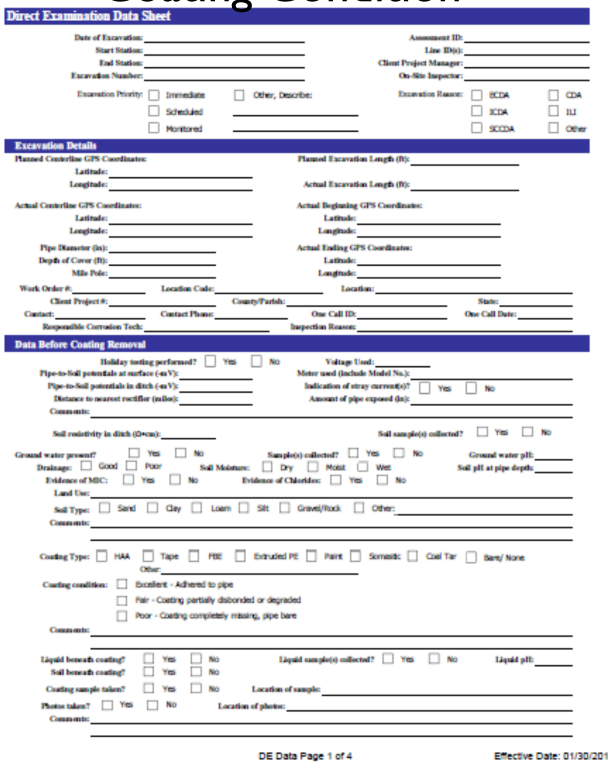
Instructions: This form serves to facilitate job planning in conjunction with the scheduling of excavations.

Pipeline Information				Anomaly Information							Survey Data & Excavation Location								
Line ID	HCA ID	ECDA Region	Item Number	Immediate	Scheduled	Monitored	NRI	Effectiveness	Discrepancy	Contingency	Begin Station/ Grid	End Station/ Grid	Length (ft)	Feature Description	Begin Latitude	Begin Longitude	End Latitude	End Longitude	Additional Comments

Preparer: ____________ Date: ____________

Direct Examination: In-Field Data Collection

Summary Details and Coating Condition



Direct Examination Data Sheet

Date of Excavation: Start Station: End Station: Excavation Number: Assessment ID: Line ID(s): Client Project Manager: On-Site Inspector:

Excavation Priority: Immediate / Scheduled / Monitored / Other, Describe:
Excavation Reason: ECDA / ICDA / SCCDA / CDA / ILI / Other

Excavation Details

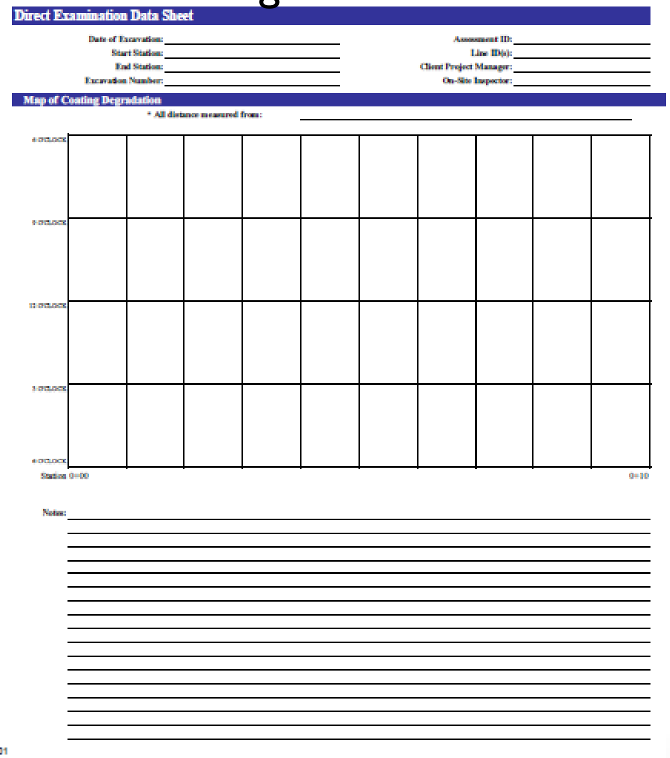
Planned Centerline GPS Coordinates: Latitude: Longitude: Planned Excavation Length (ft): Actual Excavation Length (ft):
Actual Centerline GPS Coordinates: Latitude: Longitude: Actual Beginning GPS Coordinates: Latitude: Longitude:
Pipe Diameter (in): Depth of Cover (ft): Mile Pole: Actual Ending GPS Coordinates: Latitude: Longitude:
Work Order #: Location Code: Location: Client Project #: County/Parish: State: Contact: Contact Phone: One Call ID: One Call Date: Responsible Corrosion Tech: Inspection Reason:

Data Before Coating Removal

Holiday testing performed? Yes No Voltage Used:
Pipe-to-Soil potentials at surface (-mV): Meter used (include Model No.):
Pipe-to-Soil potentials in ditch (-mV): Indication of stray current(s)? Yes No
Distance to nearest rectifier (miles): Amount of pipe exposed (ft):
Comments:
Soil resistivity in ditch (Ω•cm): Soil sample(s) collected? Yes No
Ground water present? Yes No Sample(s) collected? Yes No Ground water pH:
Drainage: Good Poor Soil Moisture: Dry Moist Wet Soil pH at pipe depth:
Evidence of MIC: Yes No Evidence of Chlorides: Yes No
Land Use:
Soil Type: Sand Clay Loam Silt Gravel/Rock Other:
Comments:
Coating Type: HAA Tape FBE Extruded PE Paint Somastic Coal Tar Bare/ None Other:
Coating condition: Excellent - Adhered to pipe / Fair - Coating partially disbonded or degraded / Poor - Coating completely missing, pipe bare
Comments:
Liquid beneath coating? Yes No Liquid sample(s) collected? Yes No Liquid pH:
Soil beneath coating? Yes No
Coating sample taken? Yes No Location of sample:
Photos taken? Yes No Location of photos:
Comments:

DE Data Page 1 of 4 Effective Date: 01/30/201

Map of Any Coating Degradation



Direct Examination Data Sheet

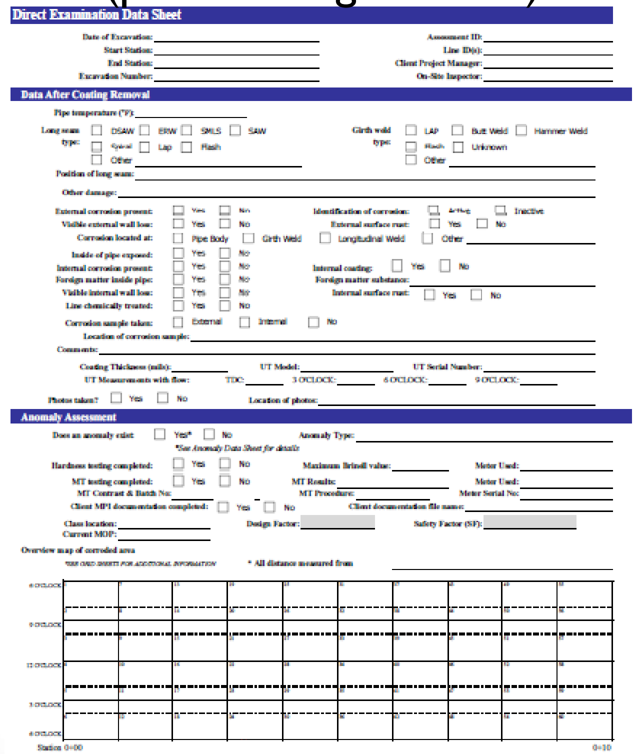
Date of Excavation: Start Station: End Station: Excavation Number: Assessment ID: Line ID(s): Client Project Manager: On-Site Inspector:

Map of Coating Degradation

* All distance measured from:

Notes:

Pipe Condition (post coating removal)



Direct Examination Data Sheet

Date of Excavation: Start Station: End Station: Excavation Number: Assessment ID: Line ID(s): Client Project Manager: On-Site Inspector:

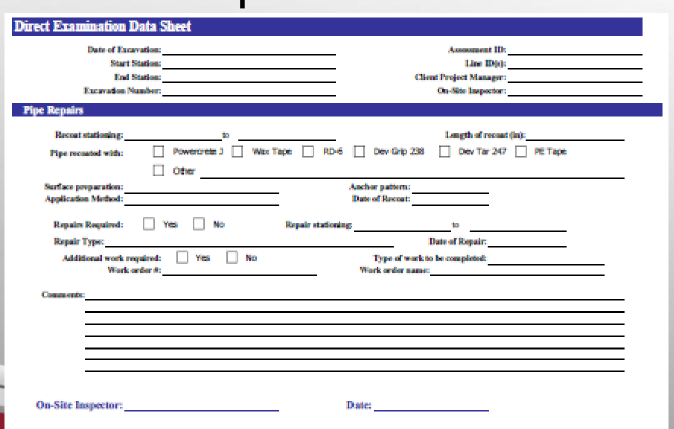
Data After Coating Removal

Pipe temperature (°F):
Long seam type: DSAW ERW SMLS SAW Spiral Lap Flash Other
Girth weld type: LAP Butt Weld Hammer Weld Flash Unknown Other
Position of long seam:
Other damage:
External corrosion present: Yes No Identification of corrosion: Active Inactive
Visible external wall loss: Yes No External surface rust: Yes No
Corrosion located at: Pipe Body Girth Weld Longitudinal Weld Other
Inside of pipe exposed: Yes No
Internal corrosion present: Yes No Internal coating: Yes No
Foreign matter inside pipe: Yes No Foreign matter substance:
Visible internal wall loss: Yes No Internal surface rust: Yes No
Line chemically treated: Yes No
Corrosion sample taken: External Internal No
Location of corrosion sample:
Comments:
Coating Thickness (mils): UT Model: UT Serial Number:
UT Measurements with flaw: TDC: 3 O'CLOCK: 6 O'CLOCK: 9 O'CLOCK:
Photos taken? Yes No Location of photos:

Anomaly Assessment

Does an anomaly exist: Yes* No Anomaly Type:
*See Anomaly Data Sheet for details
Hardness testing completed: Yes No Maximum Brinell value: Meter Used:
MT testing completed: Yes No MT Results: Meter Used:
MT Contrast & Batch No: MT Procedure: Meter Serial No:
Client MPI documentation completed: Yes No Client documentation file name:
Class location: Design Factor: Safety Factor (SF):
Current MOP:
Overview map of corroded area
* All distance measured from

Repair Data



Direct Examination Data Sheet

Date of Excavation: Start Station: End Station: Excavation Number: Assessment ID: Line ID(s): Client Project Manager: On-Site Inspector:

Pipe Repairs

Recoat stationing: to Length of recoat (ft):
Pipe recoated with: Powercrete J Wax Tape RD-6 Dev Grip 238 Dev Tar 247 PE Tape Other
Surface preparation: Anchor pattern:
Application Method: Date of Recoat:
Repairs Required: Yes No Repair stationing: to
Repair Type: Date of Repair:
Additional work required: Yes No Type of work to be completed:
Work order #: Work order name:
Comments:
On-Site Inspector: Date:

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ECDA Post Assessment

- Remaining Life, Safety Factors, Remediation
  - Implemented during Direct Examination
- Reassessment Intervals Determined
- Program Performance and Process Effectiveness

Reprioritization of Indications

Form K: Reprioritization

Date of Evaluation: ____________

ECDA Region Number: ____________
Line Number: ____________
Project Manager: ____________

Instructions: Chapter 4 - Section 3.6 provides instructions on Reclassification and Reprioritization.

Prioritization Evaluation

Station or Station Range of Indication	DE Priority (Form G)	SF_{corr}	Class Location	SF_{DR}	Corrosion Present	Reprioritize (Yes/No)	Priority	Comments

Reprioritized Indications from Above Analysis

Station or Station Range of Indication	Original Priority	New Priority	Comments	Station or Station Range of Indication	Original Priority	New Priority	Comments

Preparer: ____________ Date: ____________

Remaining Life

Form L: Remaining Life Determination

Date of Evaluation ____________
Starting Station Point: ____________
Ending Station Point: ____________

Project/ HCA ID: ____________
Line Number: ____________
Project Manager: ____________

Instructions: Chapter 5, Section 2.0 and 3.0 provide instructions on Remaining Life and Reassessment Intervals.

Pipe Data

Diameter: ________ Wall Thickness: ________ SMYS: ________ MOP: ________ Class Location: ________

Remaining Life Calculation

Pipeline Station	Priority	Yield Pressure	Pf	SF_{DR}	MOP	t	CR	RL	Reassessment Interval

Notes:

Program Performance

Form M: ECDA Performance Report

Date of Evaluation ____________
Starting Station Point: ____________
Ending Station Point: ____________

Project/ HCA ID: ____________
Line Number: ____________
Project Manager: ____________

Instructions: Completion of this form is described in Chapter 5, Section 4.0.

Pre-Assessment Summary (Direct Examination data can also be used to supplement the requested information below)

1.0 Pipe Related		2.0 Construction Related		3.0 Soil & Environment		4.0 Corrosion Control		5.0 Operating Data	
Material, Grade		Year Installed		Soil Type		CP System Type		%SMYS	
Diameter		Casings (Yes/No)		Resistivity		CP Criteria		Leak/ Rupture History	
Wall Thickness		Depth of Cover		Topography		Coating Type (pipe/joints)		Frequency 3rd Party Damage	
Seam Type		Water Crossings		Land Use		Coating Condition		Other	

Indirect Inspection Summary

Length of Inspection (feet)	CIS	DCVG	ACCA	Other
No. of Indications (After Reprioritization)	Immediate	Scheduled	Monitored	NRI

Direct Examination Summary

	Immediate	Scheduled	Monitored	NRI
Number of Excavations				
Remaining Life (range of years)				
Immediate Responses				
	Raising Priority	Lowering Priority	Monitored to NRI	
Number of Reprioritizations				

Post Assessment Summary

Re-inspection Interval: ________

Missed Deadlines: ________ Description: ________

Exceptions: ________ Description: ________

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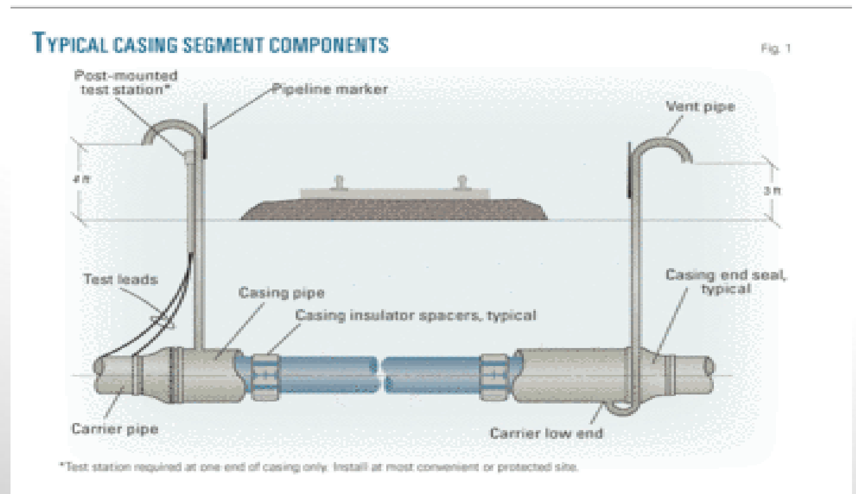
Application of ECDA in Difficult Environments

- Challenges in facilities (terminals, compressors and generating stations)
  - Multiple pipelines varying in design, operations and corrosion susceptibility
  - Site data (drawings, design specs, sources)
  - Limitations on traditional indirect tools
  - Digging more complex

- Challenges in Casings
  - Casings can shield reads of some tools making them not feasible
    - Also an issue in non-cased pipe
  - Evaluate these issues during the pre-assessment
  - Pick tools that can provide a consistent approach to testing, analyzing and prioritizing the data



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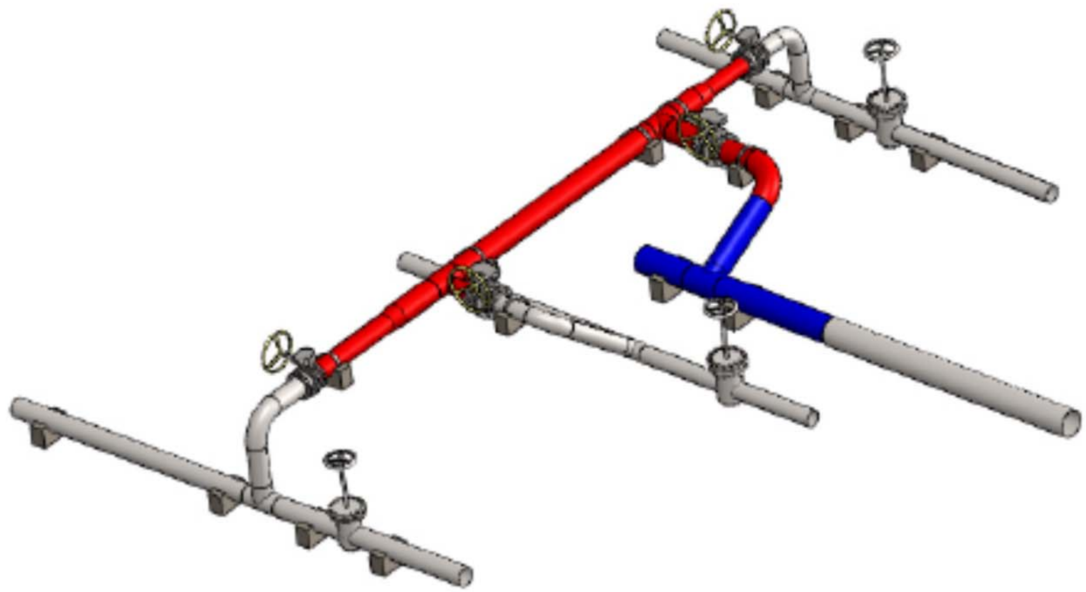
Application of ECDA in a Station or Facility

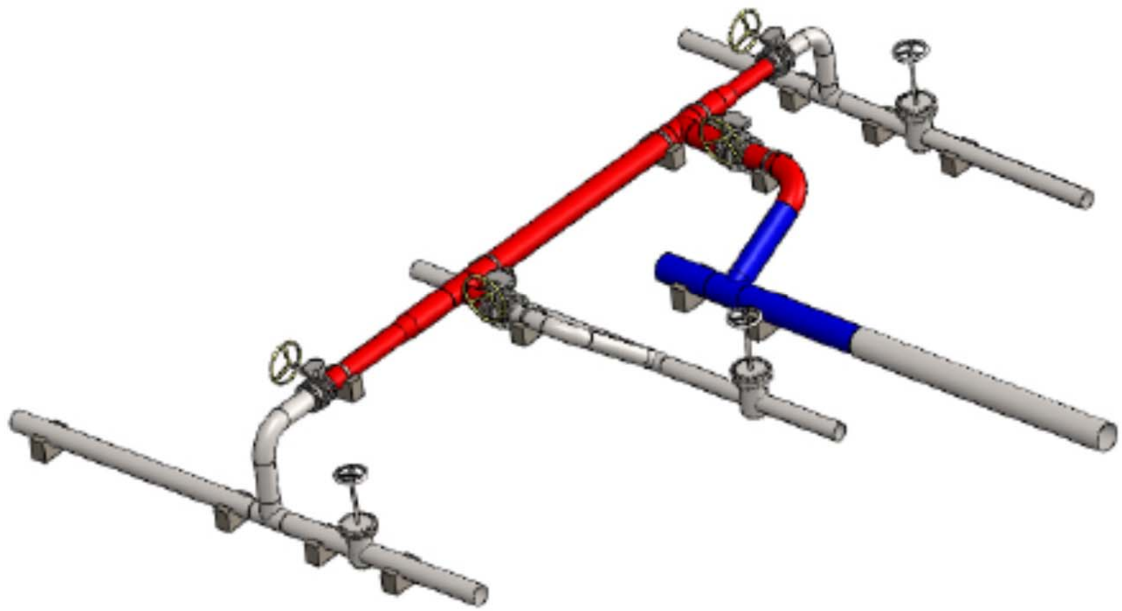
- To overcome obstacles with ECDA in facilities, it is critical to:
  - Perform a thorough collection of all available data
  - Develop a database to house available historical data
  - Implement this database to allow data integration throughout the DA process
  - Choose the appropriate indirect inspection tools for each pipe segment
  - Properly identify direct examination locations as well as difficulties that may occur during the excavation process
  - Complete a thorough lessons learned at the end of the project
- Keys to success:
  - GIS
  - Traditional inspection tools versus other inspection methodologies
  - Maintaining and updating data

3-D Modeling and Geographical Information Systems

- Digitization of available data and drawings allows for the integration of 3-D models of the site in a database format
  - Pre-assessment data easier to analyze
  - Selection of indirect inspection tools more efficient
  - Dig site selection readily available in a visual format
  - Post Assessment contains an auditable set of records in a database and visual format



3-D Geographical Information Systems



Fittings

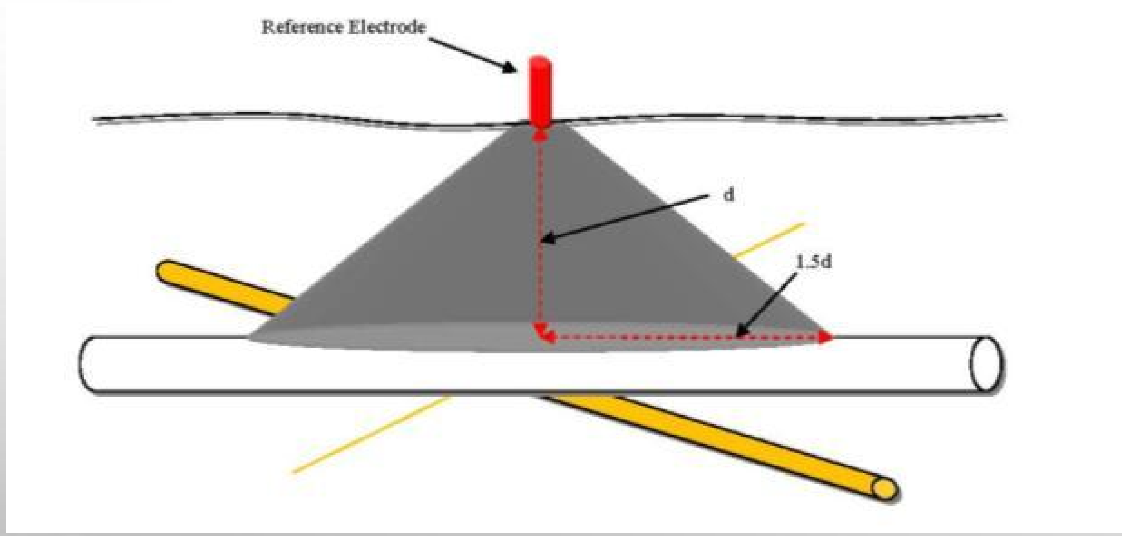
	Type	Diameter	Wall Thickness	Material	Grade	Install Date	Description
	Tee	36	0.516	Plain Carbon Steel	Y-60	5/25/1997	Tee, 36"x36"x36"
	Tee	30	0.5	Plain Carbon Steel	Y-52	5/25/1997	Tee, 30"x30"x30"
	Tee	26	0.5	Plain Carbon Steel	Y-52	5/25/1997	Tee, 26"x26"x26"
	Tee	42	0.602	Plain Carbon Steel	Y-60	5/25/1997	Tee, 42"x42"x36"
	Tee	26	0.5	Plain Carbon Steel	Y-52	5/25/1997	Tee, 26"x26"x26"
	Tee	36	0.516	Plain Carbon Steel	Y-60	5/25/1997	Tee, 36"x36"x26"
	90 Elbow	36	0.5	Plain Carbon Steel	Y-60	5/25/1997	90 degree L.R.
	90 Elbow	26	0.5	Plain Carbon Steel	Y-52	5/25/1997	90 degree L.R.
	90 Elbow	30	0.5	Plain Carbon Steel	Y-52	5/25/1997	90 degree L.R.
	90 Elbow	26	0.5	Plain Carbon Steel	Y-52	5/25/1997	90 degree L.R.

Difficult-to-Assess Piping

- Difficult-to-Assess Piping consists of locations where traditional indirect inspection tools such as CIS, DCVG and ACCA are limited in their ability to differentiate locations where corrosion control systems are functioning or inadequate:
  - Plants or stations that are tied to the common grounding system
  - Locations of congested piping
  - Multiple pipeline corridors
  - Casings....
  - Any location where electrical continuity adversely effects indirect inspection results

Half Cell Measurements and Mixed Potentials

- A half cell measurement is actually an area measurement of mixed potentials consisting of the soil and all subsurface structures that are exposed to the environment
  - For example, the steel piping below may have a native potential of around -400mV, but the copper may be closer to -200mV
  - The resulting area potential will most likely be closer to -300mV
  - Analysis of this location by potentials alone could lead to erroneous conclusions regarding active corrosion cells



Limitations of Traditional Techniques

<u>CIS</u>

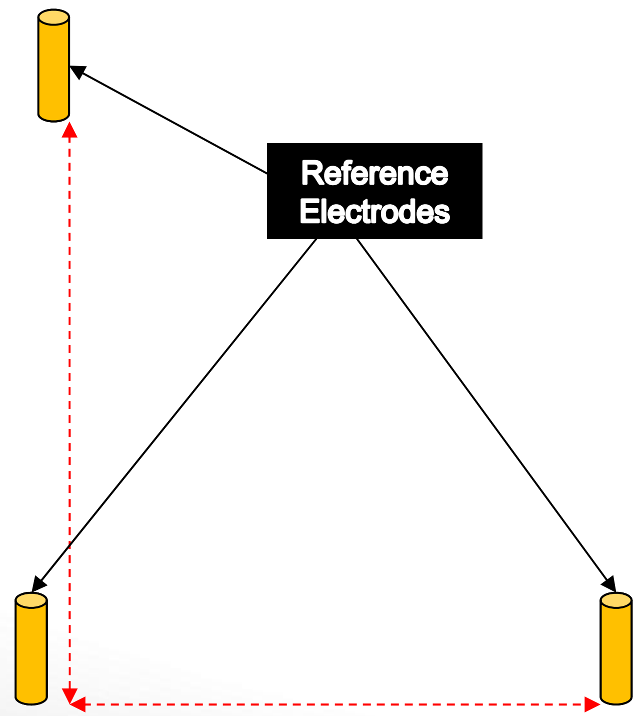
- Additional structures drastically influence the potential measurements of the structure intended for assessment.
- Low potential indications may be a factor of adjacent structures, not a lack coating or cathodic protection.

<u>DCVG</u>

- Voltage gradient indications may be masked by adjacent coating holidays or structures.
- Locating coating holidays and remote earth measurements may be infeasible.

APEC Overview

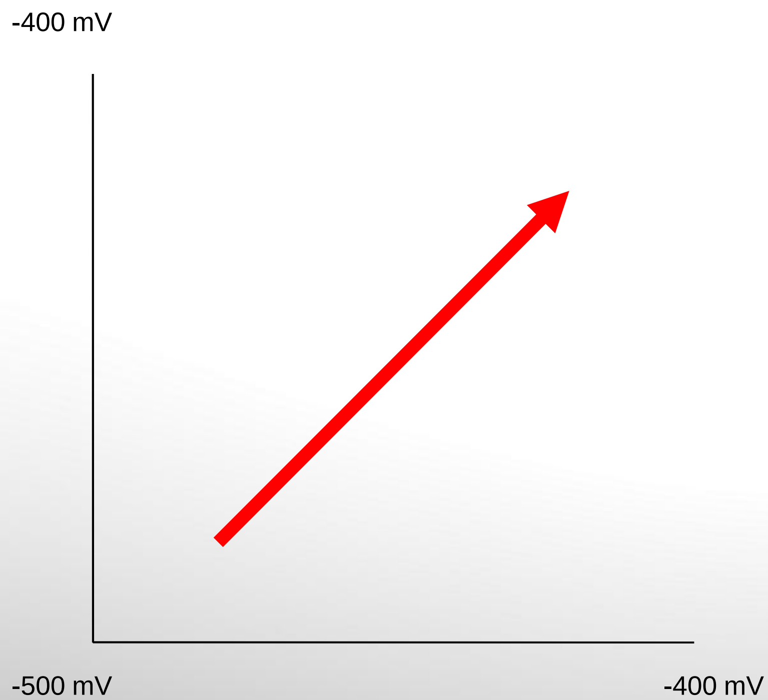
- Uses industry standard equipment
- Employs principles of both Close Interval Survey - CIS (used to gauge CP system effectiveness in controlling pipe corrosion) and Voltage Gradient Surveys - (used to identify coating degradation)
- The novelty is that we are using three half-cells simultaneously during the cell-to-cell survey. This permits the observation of corrosion currents within a highly congested area – which is an indication of the relative corrosion activity.



Further detail on the APEC approach can be found in the NACE Corrosion 2011 publication: “Methodology for Surveying Buried Plant Piping for Coating Condition and CP Effectiveness”, NACE Paper 11181

Voltage Gradients and Earth Current Vectors

- By collecting three half cell readings simultaneously in a grid pattern, voltage gradients can be measured between the half cell
- These voltage gradients can then be converted into earth current vectors in a polar coordinate system, allowing for easier data interpretation in a real world environment
- In the example on the right, the area potentials measured result in 100 mV gradients in the x and y coordinate directions, resulting in a 45 degree earth current gradient



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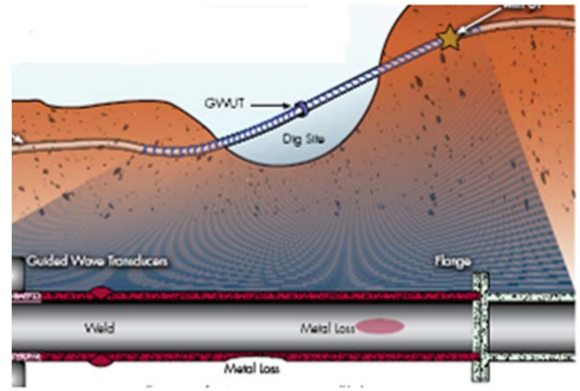
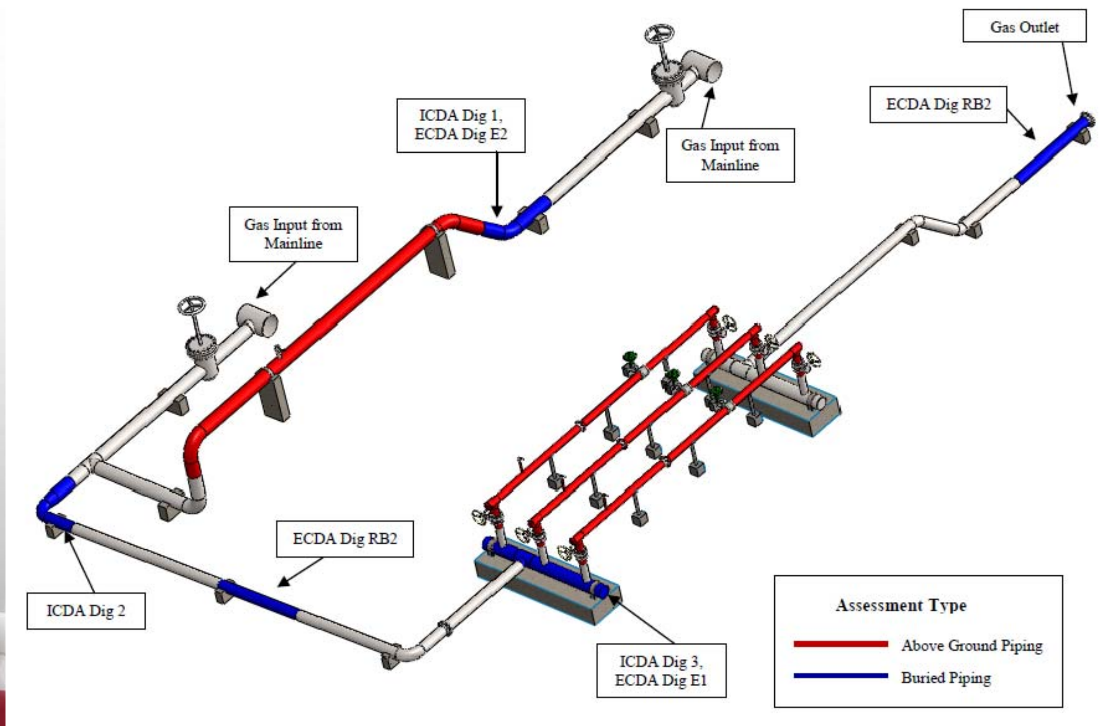
Direct Examinations

- In difficult-to-assess areas such as terminals, compressors, fabricated gates and generating stations, excavations can be complicated by unusual depths and multiple pipelines in the dig region
  - In these areas, the use of GWT can provide screening of difficult to access sections





- The 3-D GIS database can also be used to identify and more precisely define dig locations

Case Study

- ECDA was chosen to assess the integrity of buried piping in a crude oil storage and delivery facility. The objectives of the assessment were:
  - Evaluate the existing level of cathodic protection
  - Identify locations of coating anomalies
  - Determine the extent of low potential areas
  - Identify critical areas for excavation and direct examination
  - Perform direct examination supplemented by Guided Wave at identified locations
  - Determine the effectiveness and feasibility for applying ECDA to terminal station piping

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Case Study – Pre-Assessment

- Pre-Assessment concluded that ECDA was feasible
- Regions were defined as:
  - Region 1 – Non-Cased buried piping for the seven buried piping segments west of the manifold and pump units
  - Region 2 – Above grade piping and soil to air interfaces
  - Region 4 – Buried piping from the manifold to the pump units
- Indirect Inspection Tools were selected:
  - Close Interval Pipe-to-Soil Potential Survey (CIS) and Direct Current Voltage Gradient Survey (DCVG) for Region 1
  - B-Scan and Guided Wave Ultrasonic Testing (GWT) for Region 2
  - Area Potential Earth Current Gradient (APEC) for Region 4

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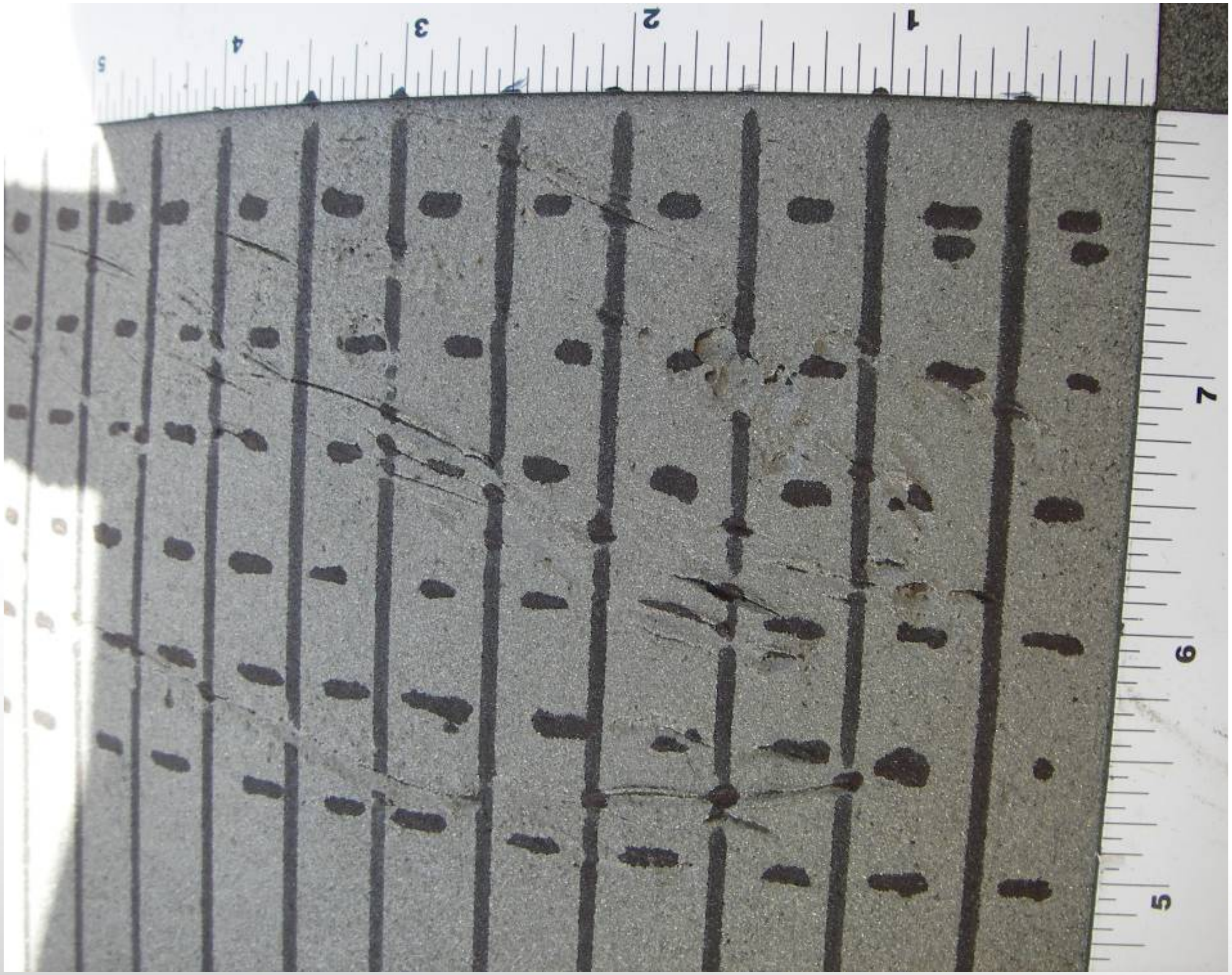
Case Study – Indirect Inspections

- Indirect inspections were completed
  - 8 digs sites were selected from the surveys
- Results included:
  - Region 1 – CIS & DCVG for 7 line segments
    - 4,700 feet (1,432.56 m) of piping
    - 4 Scheduled ECDA Categories
    - 11 Monitored ECDA Categories
  - Region 2 – GWT and B-Scan for over 400 feet (121.92 m) of piping
    - B-Scan testing identified two significant indications of corrosion on piping at the gated, southwest section of the facility
    - Internal wall loss was detected near the 6 o'clock position representing approximately 40-45% wall loss
  - Region 4 – APEC inspection completed for 138 grids in the manifold
    - Inspected surface area of 13,800 ft^2 (1,282.06 m^2)
    - 8 Scheduled ECDA Categories
    - 25 Monitored ECDA Categories
    - 44 grids displayed atypical current responses associated with possible coating damage

Case Study – Direct Examinations

- Results included:
  - Region 1(CIS &DCVG) – 5 sites
    - 3 excavations per the operator's ECDA Plan
    - 2 additional discretionary direct examinations
    - Mechanical damage due to trenched telephone cable was found at one excavation
    - No remediation beyond buffing the small gouges to surface level and recoat was required at this site
    - No other sites required remediation beyond recoat
  - Region 4 (APEC) – 3 sites on 4 lines in the manifold area
    - 4 direct examinations
    - Mechanical damage due to trenched conduit was found at one excavation
    - Type B Sleeve was installed
    - No other sites required remediation beyond recoat



APEC Excavation with Mechanical Damage After Coating Removal

APEC Excavation with Sleeve Installed

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Case Study – Post Assessment

- Post Assessment was completed in accordance with the operator's ECDA plan
- Direct Examination results were used to calculate the remaining life and re-inspection intervals
- Process was deemed effective and provided useful data
- All final data from the project integrated into a GIS database for future use
- Application of appropriate indirect inspection tools was essential

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Case Study Conclusions

- ECDA worked for Facility Piping!
- GIS and database was essential to organize inspections
  - GWT
  - UT
  - CIS
  - DCVG
  - APEC
  - Direct Examinations
- Indirect inspections and direct examinations utilized both traditional and other inspections methodologies
  - Optimized the results of the process

GUIDED WAVE TESTING (GWT) OVERVIEW & FUNDAMENTALS

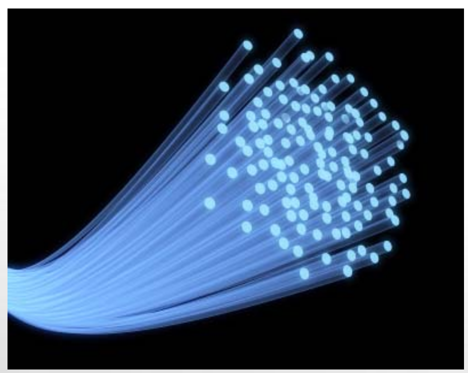
Definition

Guided Wave - a wave (acoustic, mechanical, or electromagnetic) whose propagation characteristics are dictated by the properties AND boundaries of the medium in which they travel.

Acoustic

http://www.bose.com/controller?event=VIEW_STATIC_PAGE_EVENT&url=/learning/waveguide_results.jsp

Electromagnetic



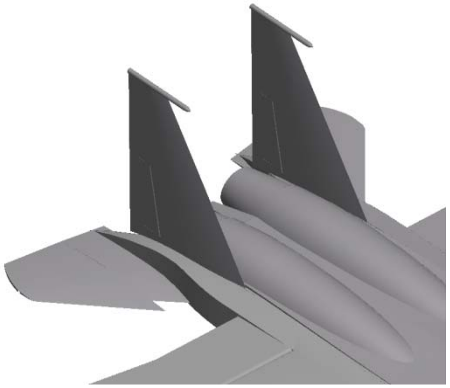
http://www.telecast-fiber.com/fiber-optic-video-news-perspective/?Tag=fiber%20optic%20cable

Mechanical

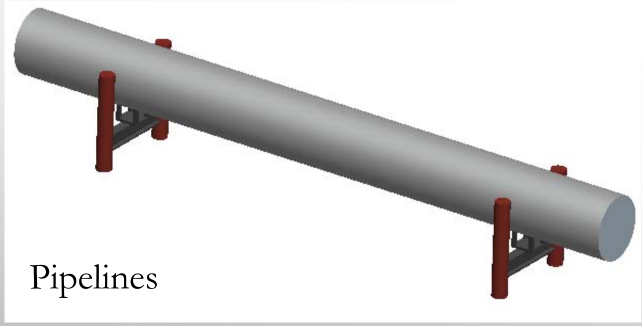
http://www.liquidsculpture.com/fine_art/image.htm?title=Classic03

Natural Waveguide Examples

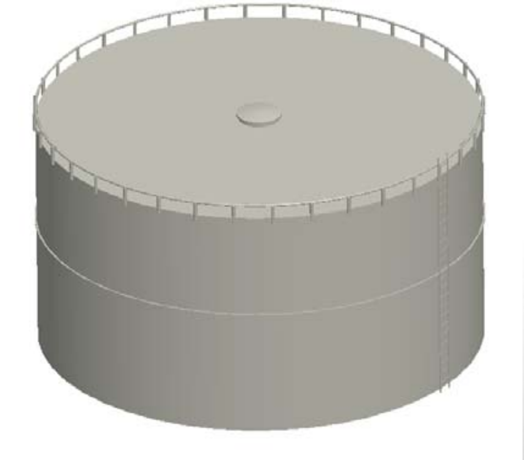
- Plates (aircraft skin)
- Rods (cylindrical, square, rail, etc.)
- Hollow cylinder (pipes, tubing)
- Multi-layer structures
- Curved or flat surfaces on a half-space



Aircraft Skins



Pipelines



Storage Tanks

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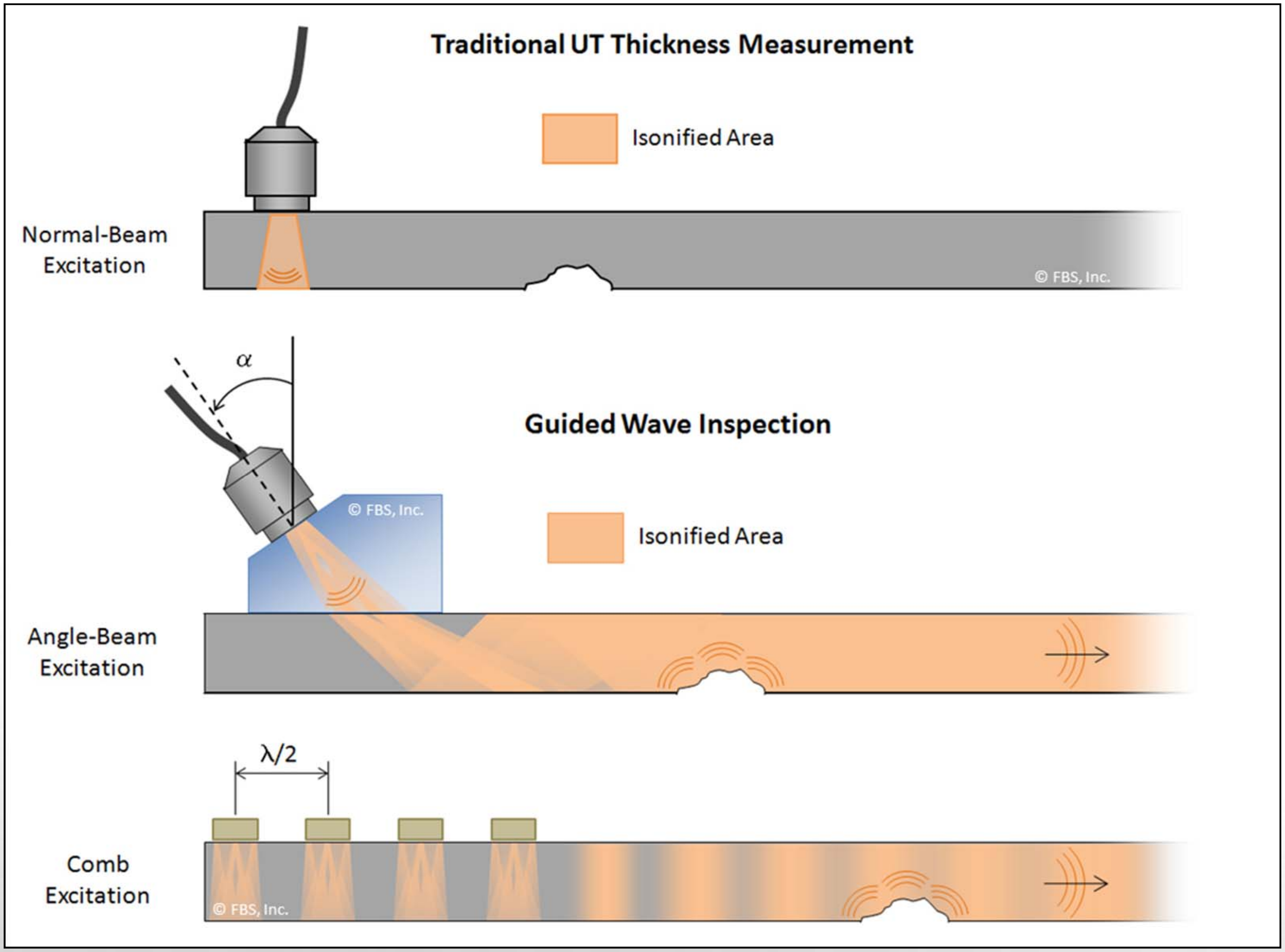
Principle Uses of GWT

- Used to detect internal or external wall loss
  - Volumetric: Change In **Cross Sectional Area**
- Difficult to assess areas, such as casings, CUI, station piping, ICDA
- Where large lengths and difficult to access piping need to be assessed
- Based on acoustic waves in the pipeline walls

GWT Piping Assessment

- Inspection over long distances from a single probe position.
- Scans the entire volume of pipe
- Qualitative to Semi-quantitative
- Excellent as a screening tool (similar to indirect inspection)
- Ability to inspect inaccessible structures
- More difficult, pattern recognition

Guided Wave Concept



Propagation along, not through, a structure

The pipe walls forms a guide for ultrasonic waves, which directs them down the length of the pipe

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Standard UT versus Guided Waves

Conventional UT

- high frequency
- short wavelength
- sensitive to wall thickness
- point measurement

GWT

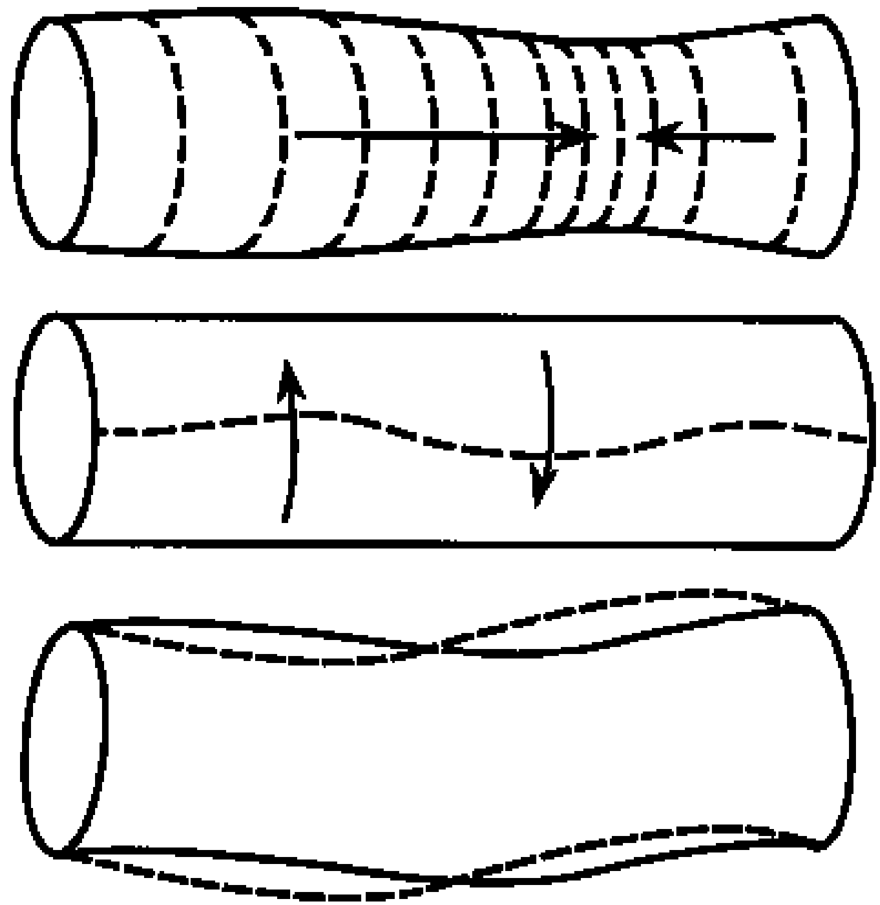
- low frequency
- long wavelength
- sensitive to cross sectional area and symmetry
- rapid screening

Wave modes in pipes

Longitudinal

Torsional

Flexural



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Reflection of a Guided Wave from a Feature

- Guided waves are reflected from a change in cross sectional area
- The change can be either an increase or decrease in area
- If the cross sectional change is symmetric then the reflected wave is primarily symmetric (torsional or longitudinal depending on excitation)
- If the cross sectional change is not symmetric then the reflected wave will have higher a higher flexural component
- Reflections cause less energy to propagate down the pipe incrementally reducing the sensitivity

GWT EQUIPMENT

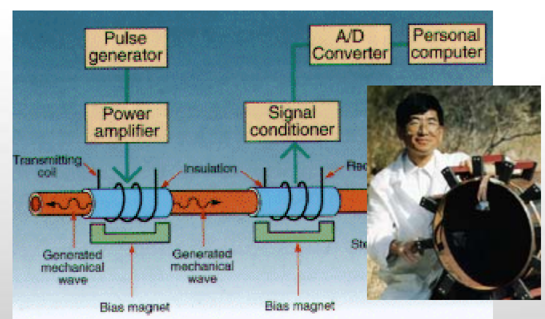
GWT Inspection Equipment Manufacturers

FBS

POWERFOCUS™
GUIDED WAVE FOCUSING TECHNOLOGY

GUL: G3 Wavemaker

Southwest Research



Plant Integrity:

TELETEST FOCUS

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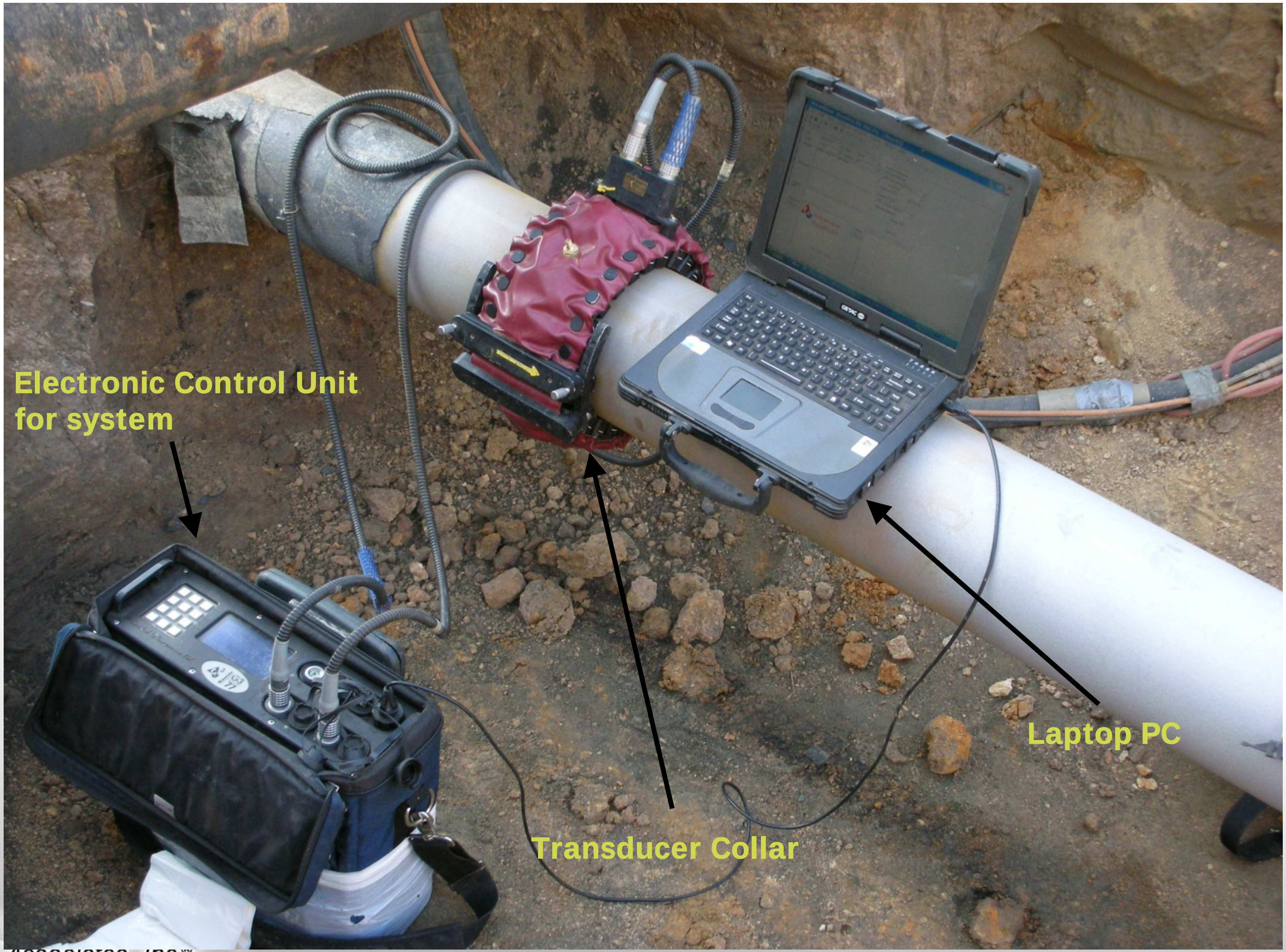
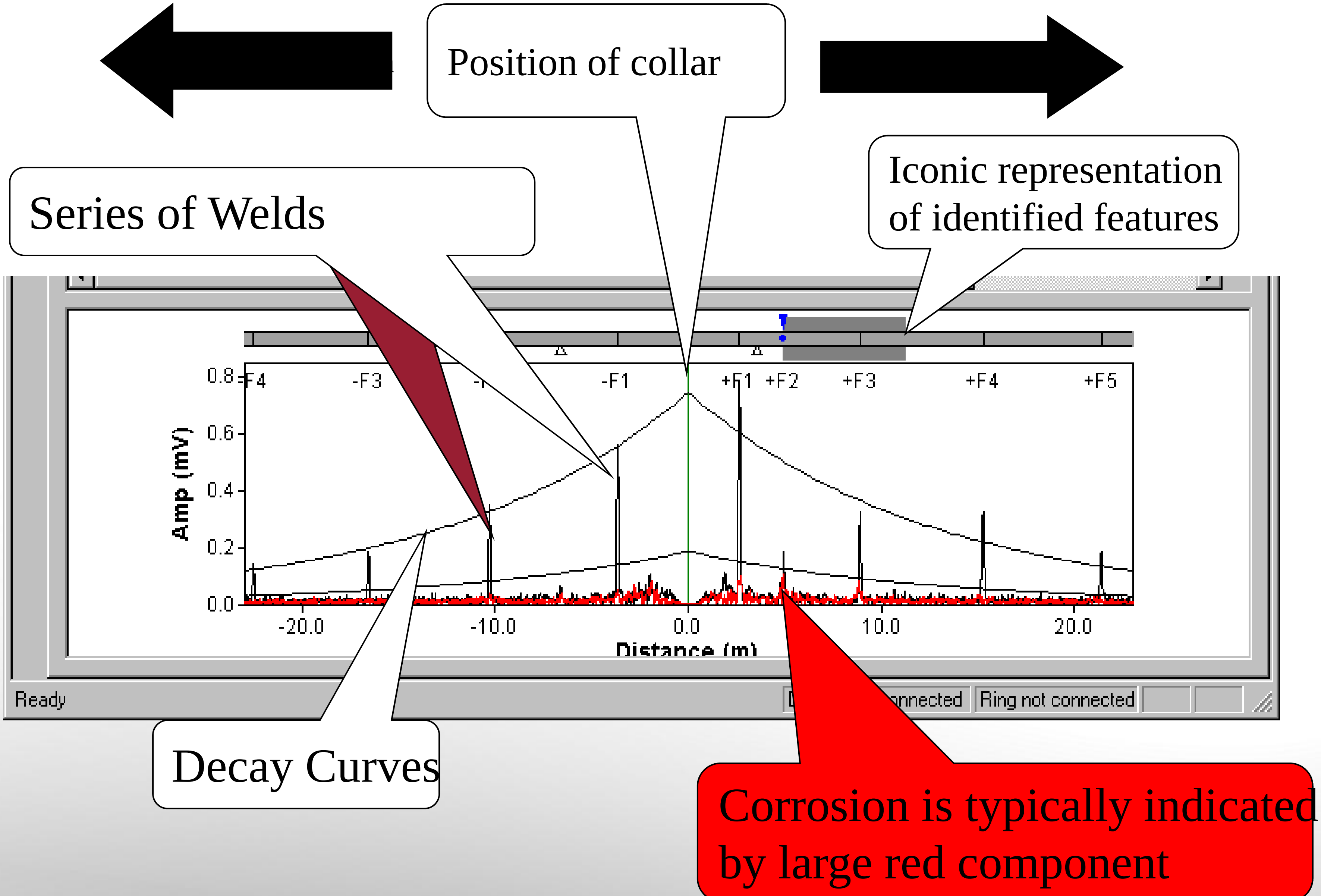
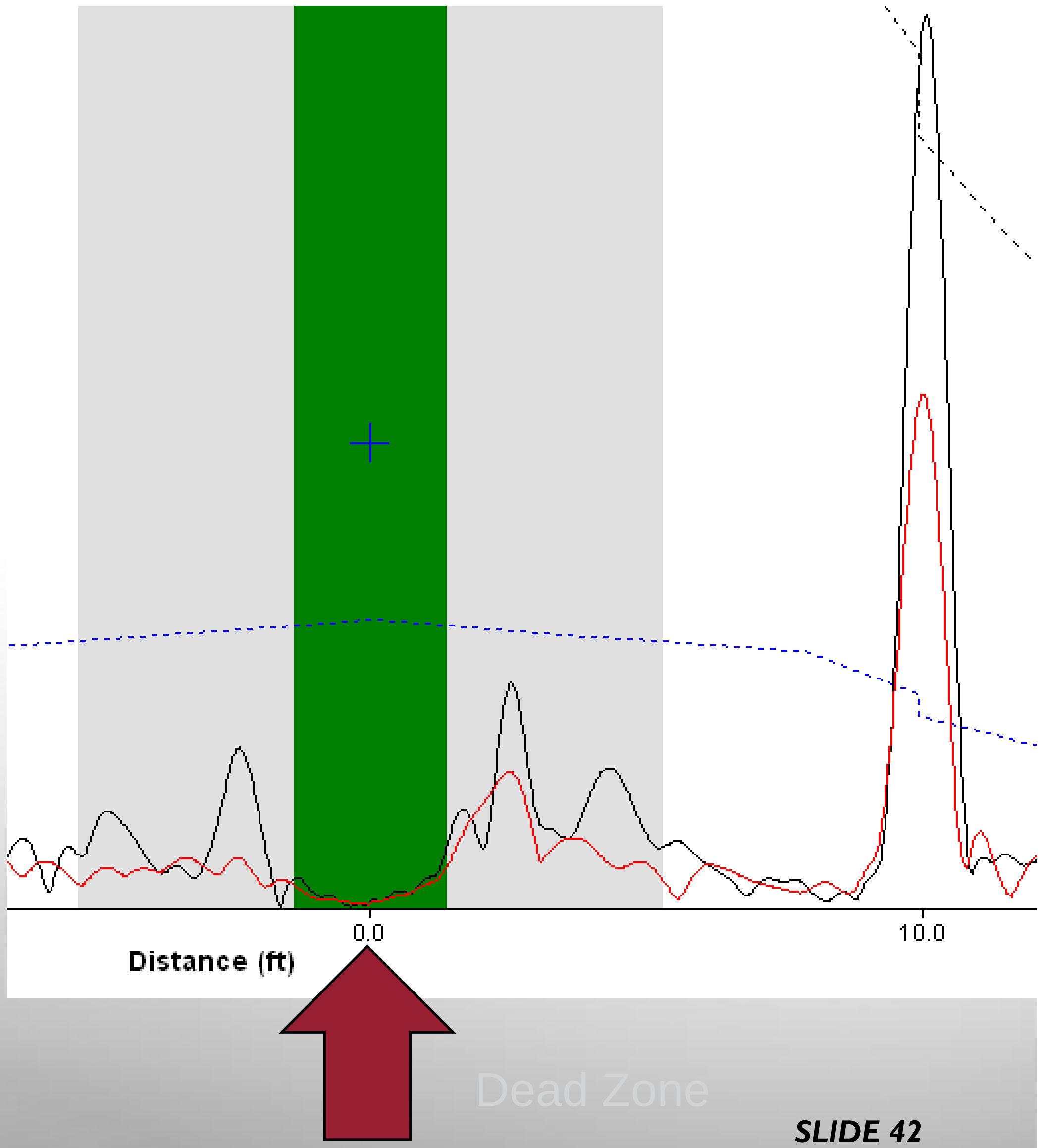
GWT Components



GWT ANALYSIS


Position of collar
Series of Welds
Iconic representation of identified features
Decay Curves
Corrosion is typically indicated by large red component
Amp (mV)
0.8
0.6
0.4
0.2
0.0
-F3
-F1
+F1
+F2
+F3
+F4
+F5
-20.0
-10.0
0.0
10.0
20.0
Distance (m)
Ready
Ring not connected

- Dead Zone
  - Collar cannot transmit and receive at the same time
  - This leads to dead zone shown in green on the data trace
  - Typically ~ 1ft. In length.



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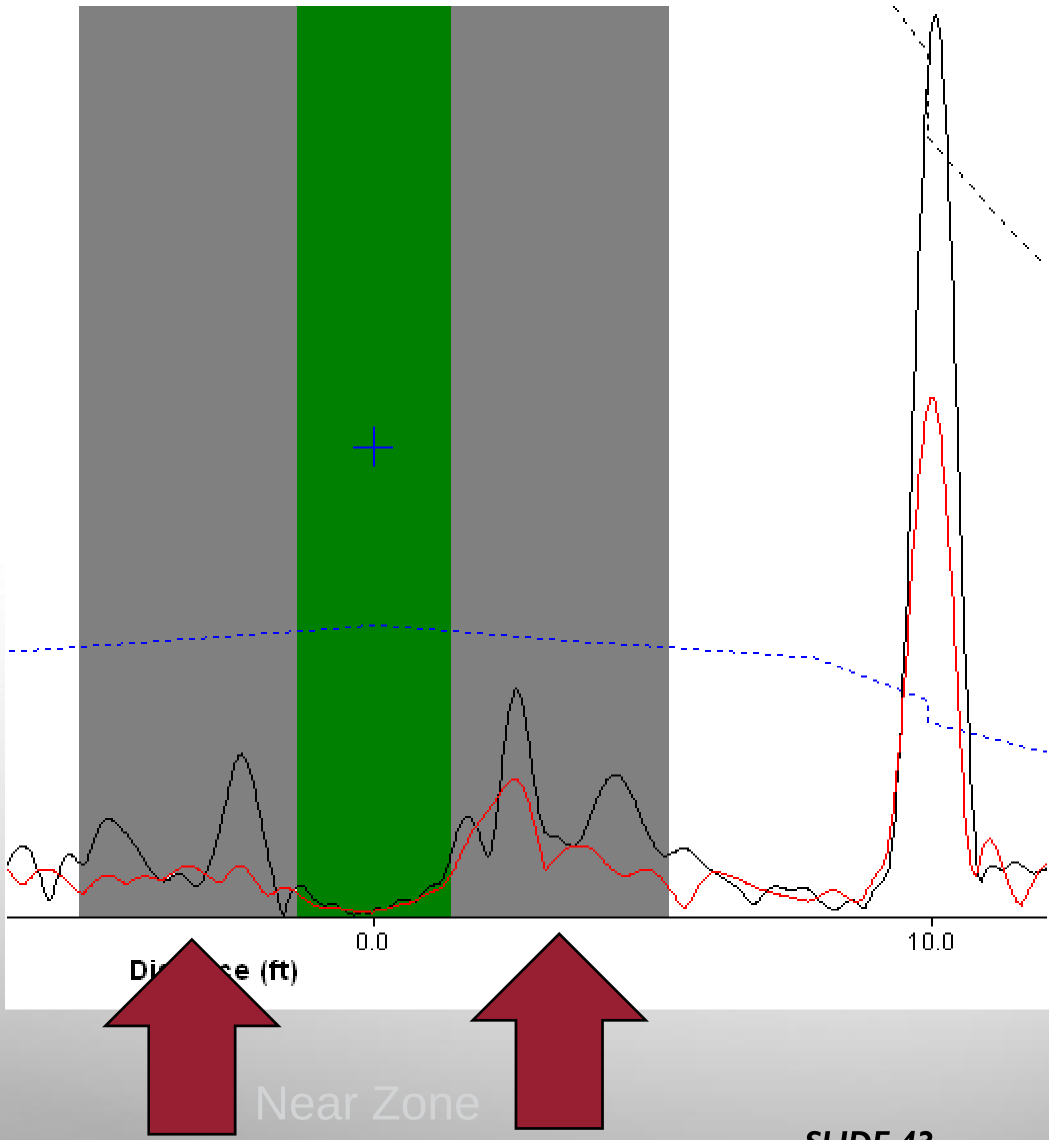
- Near Field
  - Region where the guided waves are forming
  - Length typically ~2-5 ft. depending on collar type
  - Features still detectable but sizing accuracy reduced



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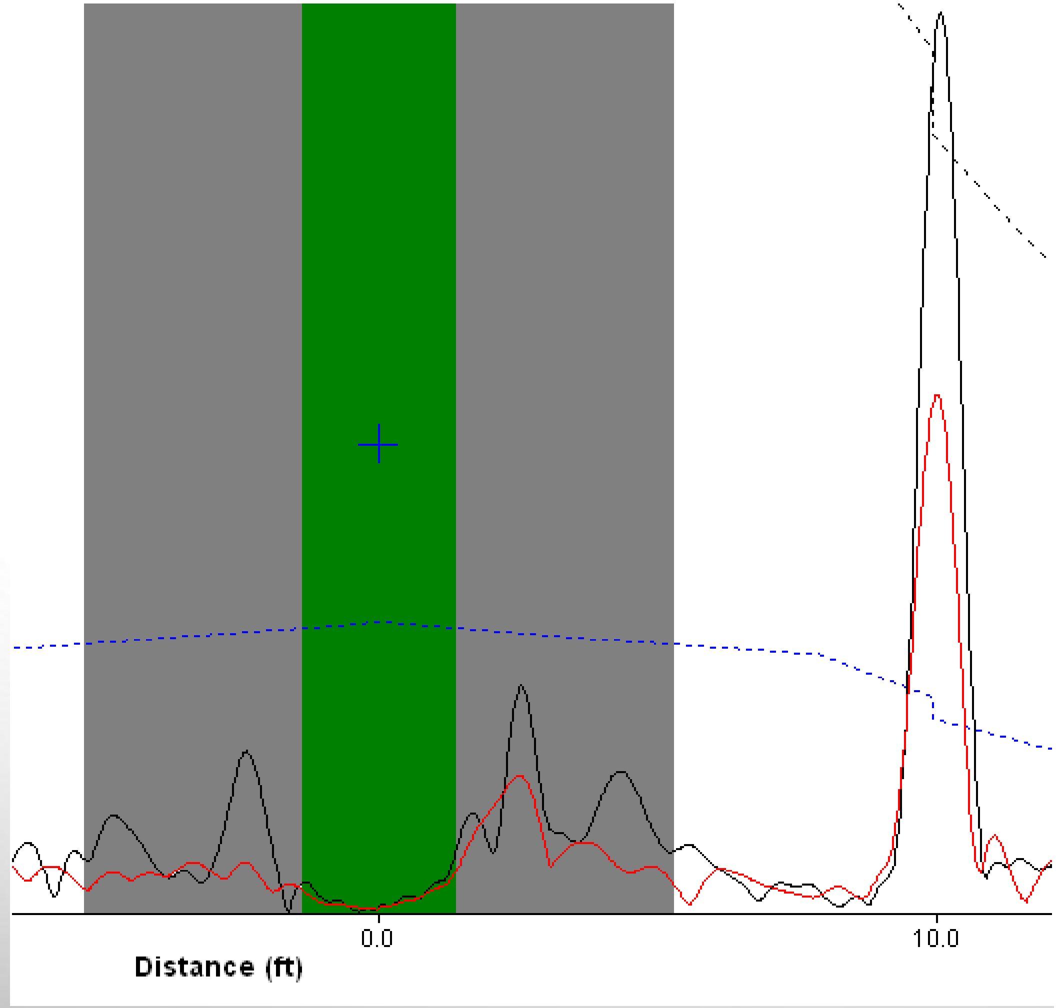
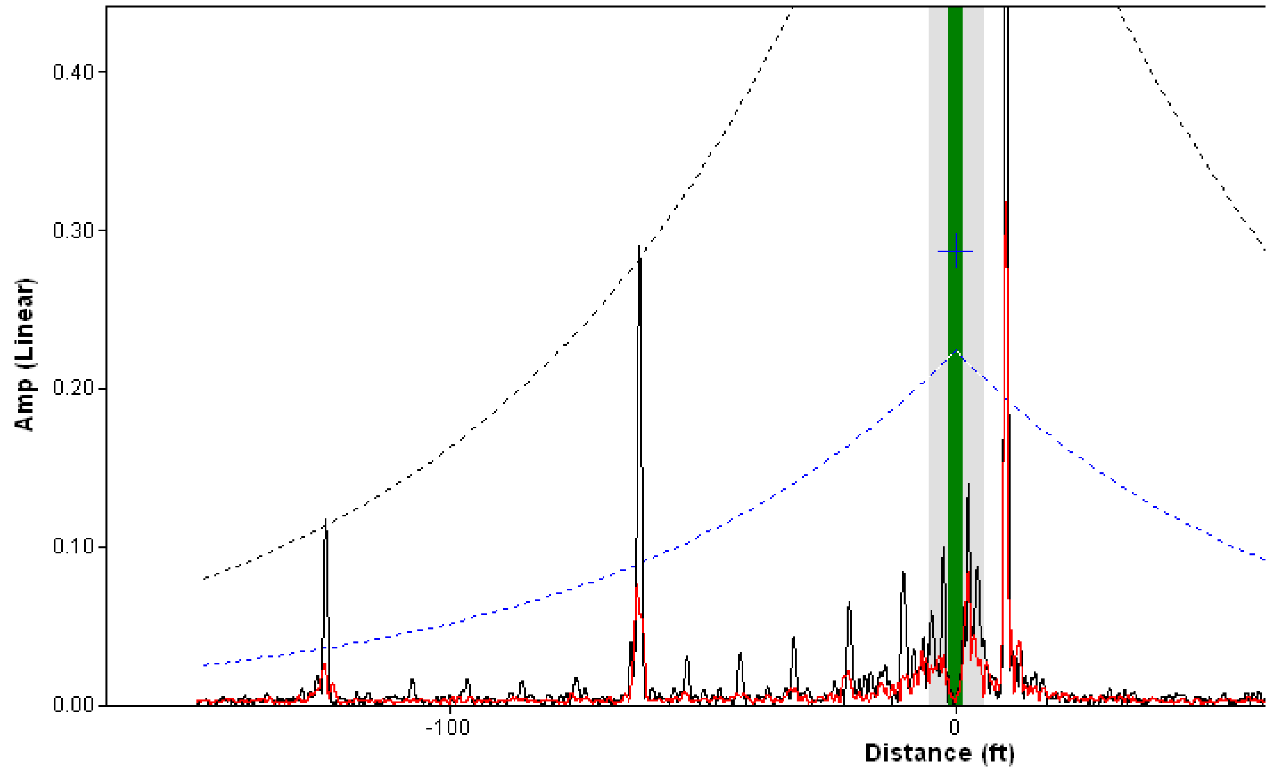
- Example data trace
  - 12" diameter
  - Dead Zone 1'4"
  - Near Zone 5'3"



Shot looks like this when data comes in:



X axis: distance from collar

Y axis: signal amplitude

Black signal: symmetric

Red signal: asymmetric

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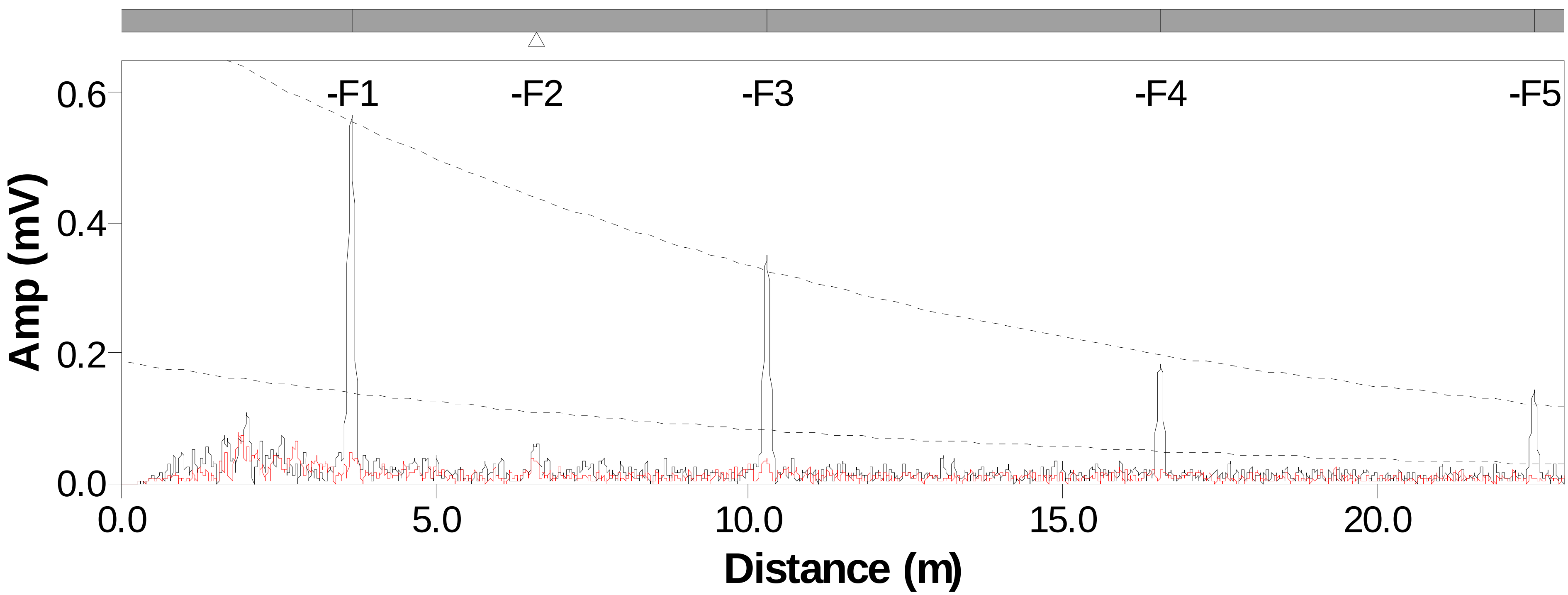
Amplitude decays over distance

- The reflected amplitude from distant features will be smaller than for close features
- The range is limited
- Two things that cause signal decay
  - Reflection from features
  - Attenuation from coating, soil, generalized corrosion, etc

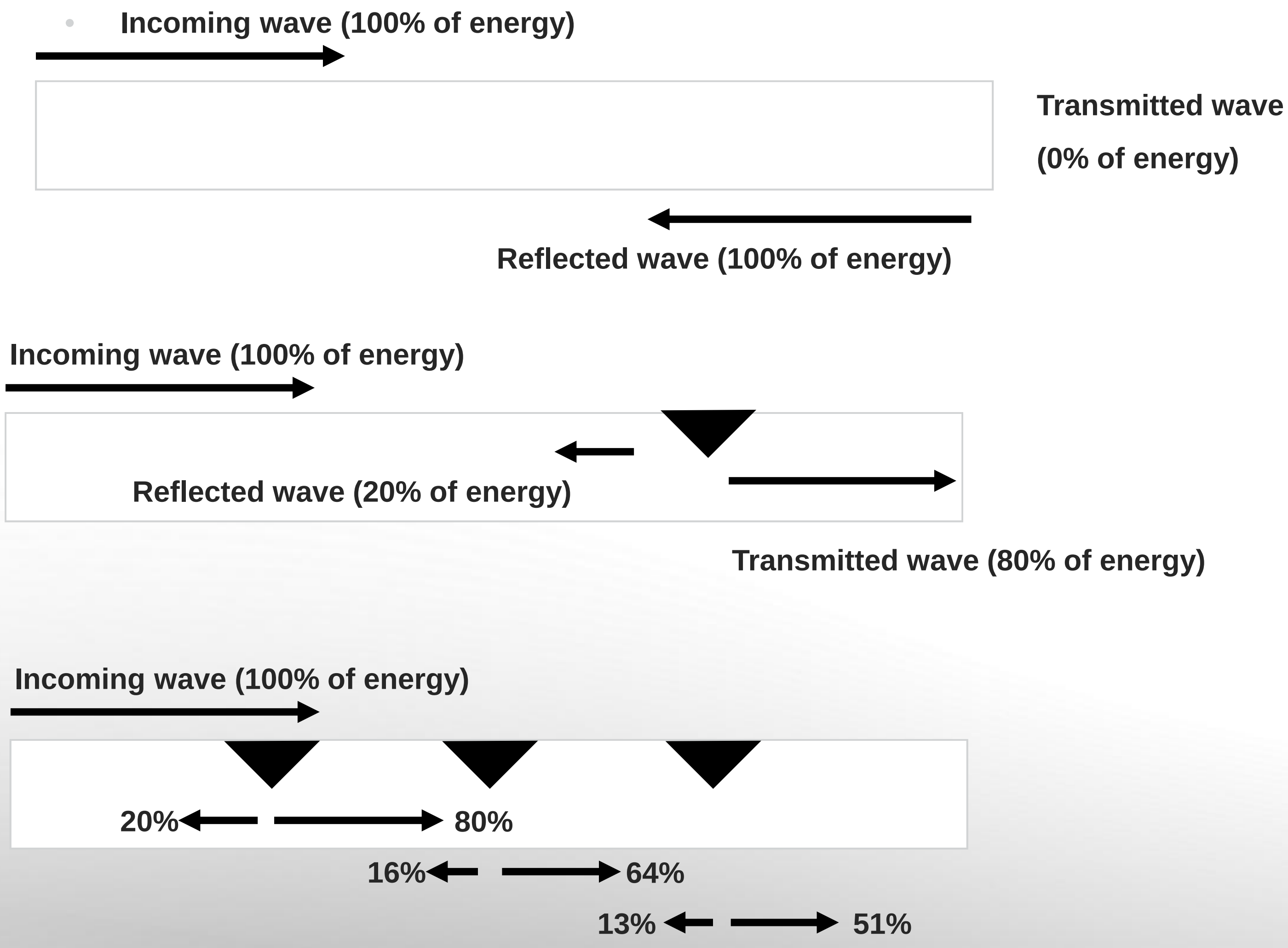


Decay of the amplitude is caused by:

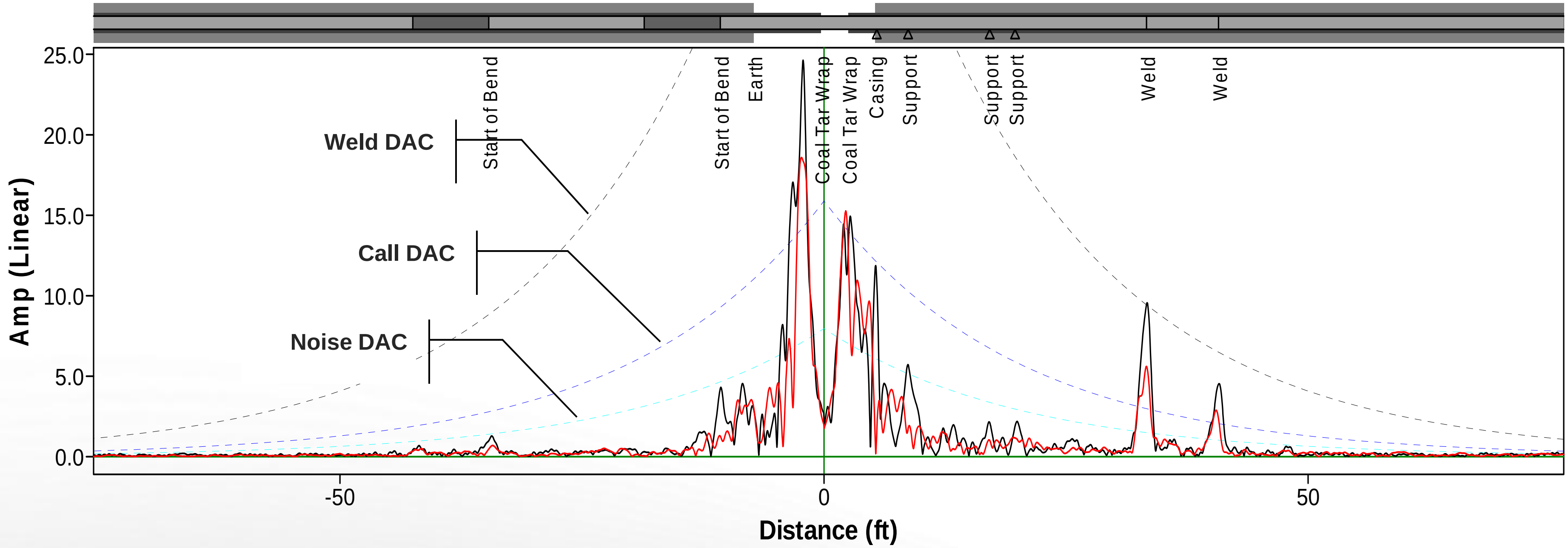
- Welds
- Fittings
- Branch connections
- Corrosion damage
- Supports
- External coatings
- Internal coatings
- Soil
- Material itself

Coatings generally have the greatest attenuating affect

Corrosion can also attenuate the sound significantly



Four Distance Amplitude Curves (DACs)



DAC levels can be changed for different applications.

Flange DAC: 100% ECL
Weld DAC: ~23% ECL
Call DAC: 5% ECL (detectability threshold/sensitivity level)
Noise DAC: 2.5% ECL (Set to 1/2 detectable threshold)

What is sensitivity?

- It is the percent cross sectional area that can be detected at a given signal to noise ratio (SNR)
- It is expressed as % ECL or CSC (change in cross-sectional area)

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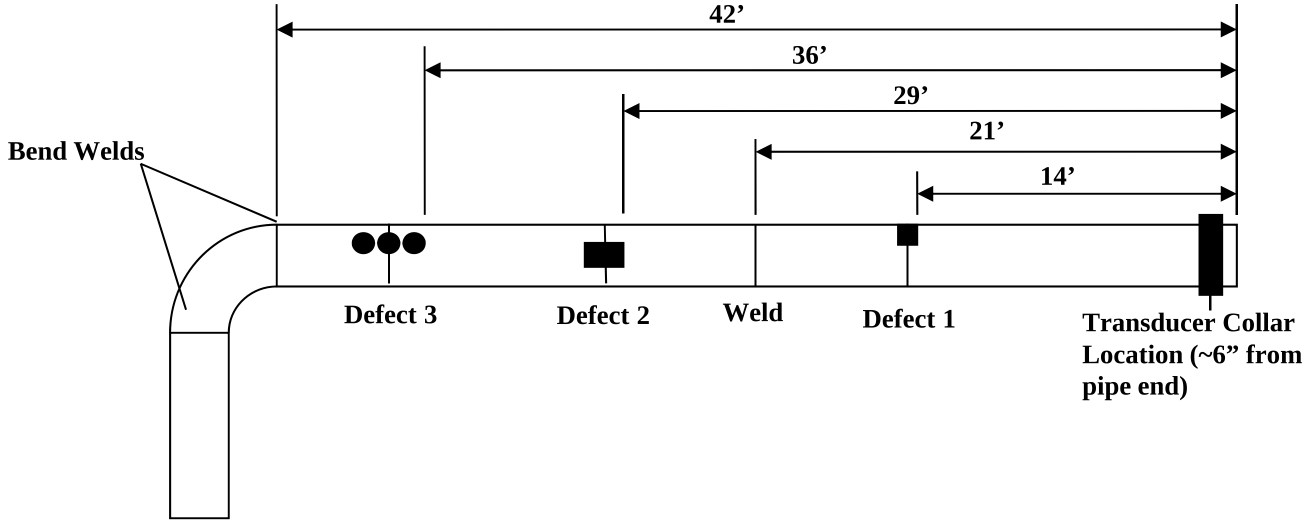
Things to Consider about Sensitivity

- DAC: Distance amplitude curve is expressed as percentage of cross sectional area. Weld DACs are usually 23% ECL.
- S/N Over Background: To have better confidence level a S/N ratio of 2:1 is needed. Noise DAC = ½ Call DAC
- Inspection Range: Is a function of required Sensitivity.

PHMSA (18 points require) 5% sensitivity or value corresponding to a defect that would fail a Hydrotest, whichever is less

GWT Example Result



Defect 1 - 0°

~3”x3” Blend Out

50% Max Wall Loss

Defect 2 - 270°

~4”x4” Blend Out

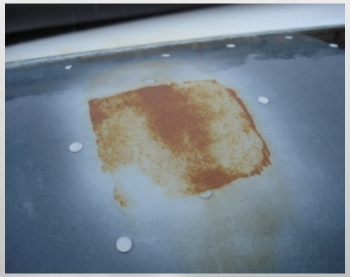
50% Max Wall Loss

Defect 3 - 315°

Three Flat Bottom Holes

1” Diameter, Depth=60%

Spacing between holes = 1 ft.



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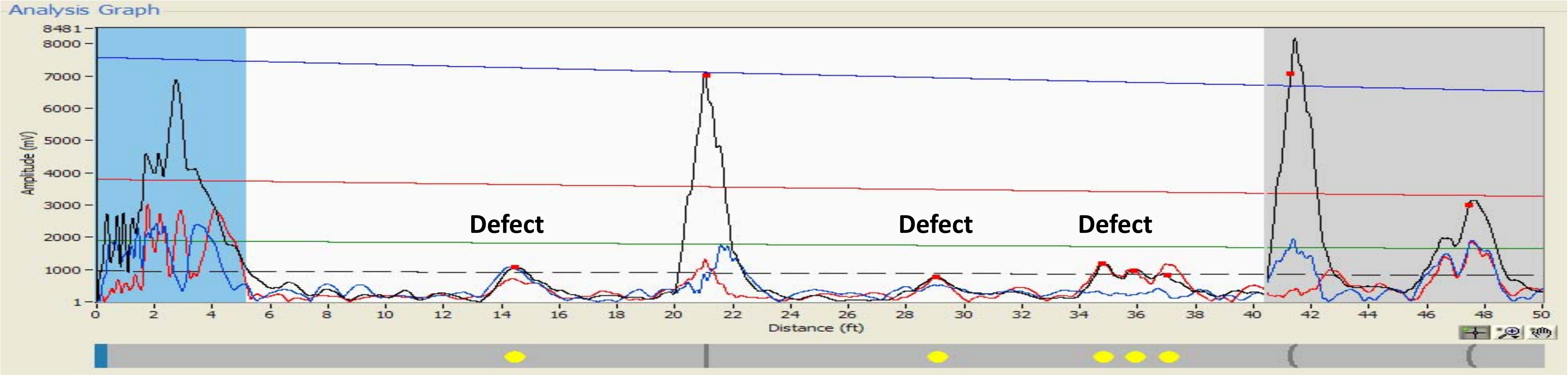
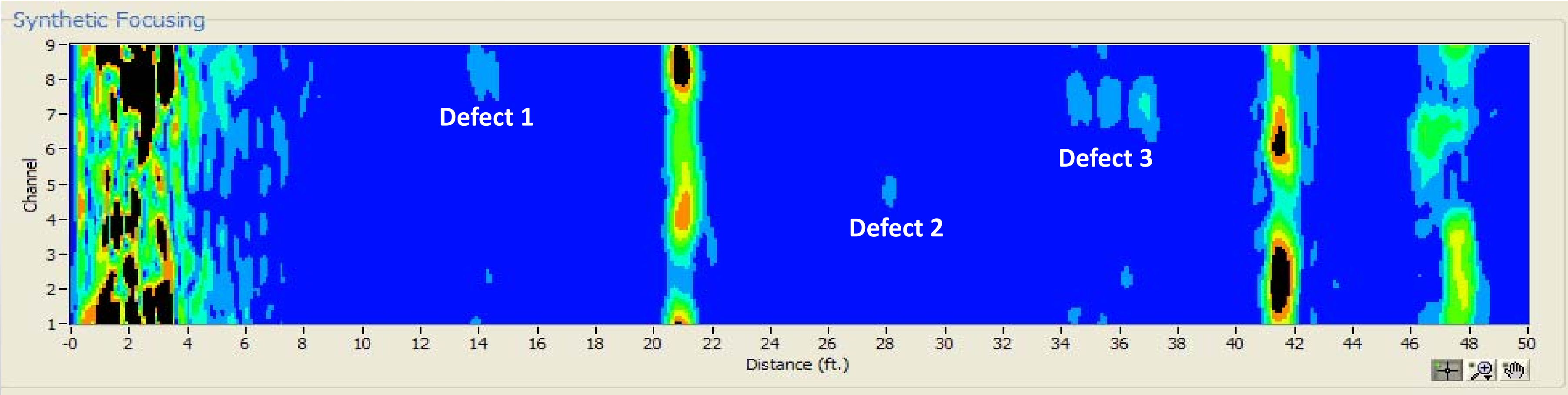
GWT Example Result

A-Scan



"C-Scan"



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GWT on Buried FBE Coated Pipe (Sample)

- Piping was accessed from excavations; the excavation locations were selected by based on other above ground indirect assessment data.
- The objective was to use GWT to assess the condition of the piping outside of the excavations.
- The piping configurations here are ideal for good GWT penetration power as the exterior coating present on the piping is FBE (~0.030” thick)

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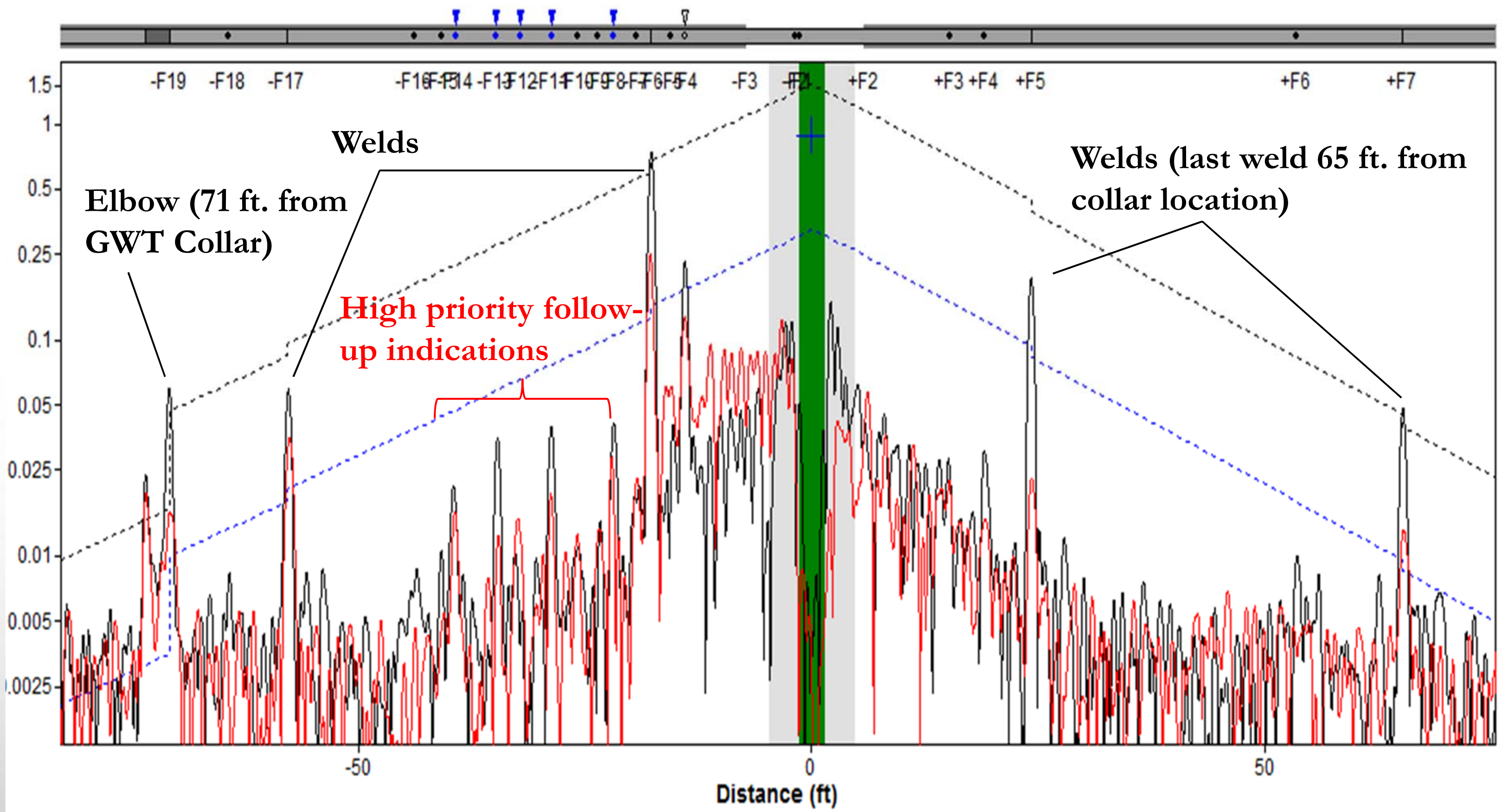
Sample GWT Data Trace



As shown, good penetration was achieved (136 ft. of pipe assessed from one location) with a high signal to noise ratio allowing for easy analysis and prioritization of indications for follow-up.

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Photographs of Severe Corroded Areas Identified with GWT and Subsequently Excavated for Prove-Up

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GWT TECHNOLOGY ADVANCEMENTS

GWT Focusing

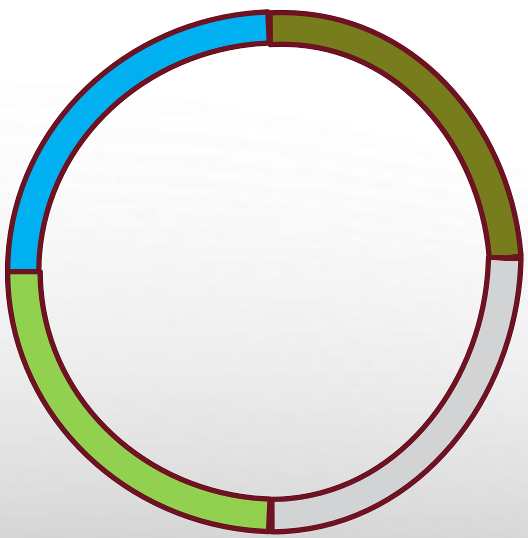
- GWT Focusing is a new development that has the potential to increase sensitivity, confidence, and provide approximate defect sizing information.
- There are different types of GWT focusing
  1. Frequency tuning
  2. Passive focusing / Synthetic focusing
  3. Active focusing / Phased array focusing
- The term focusing in this context is referring to methods that improve the signal to noise at a location through manipulation of sending and/or receiving the guided wave signal.

Frequency Tuning

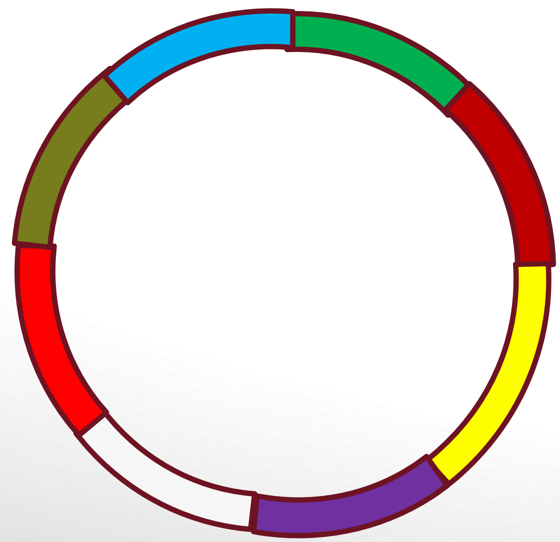
- Most equipment providers can provide frequency tuning
- GUL equipment has the frequency slider bar which makes it easier for interpretation
- The Teletest equipment has selected frequencies that can be toggled between. A bit more difficult with interpretation.
- PowerFocus (PF) has a mapping feature to identify optimal features / signal response at different frequencies
- Frequency tuning/focusing is the first type of focusing that is almost always used and required in the 18 Points.

Channel Segments

- GWT transducer collars are divided in either four to eight segments around the pipe
- Loading or receiving from a given segment can provide location data and improve signal to noise ratios of a reflection



4 Segment or 8 Channel



8 Segment or 16 Channel

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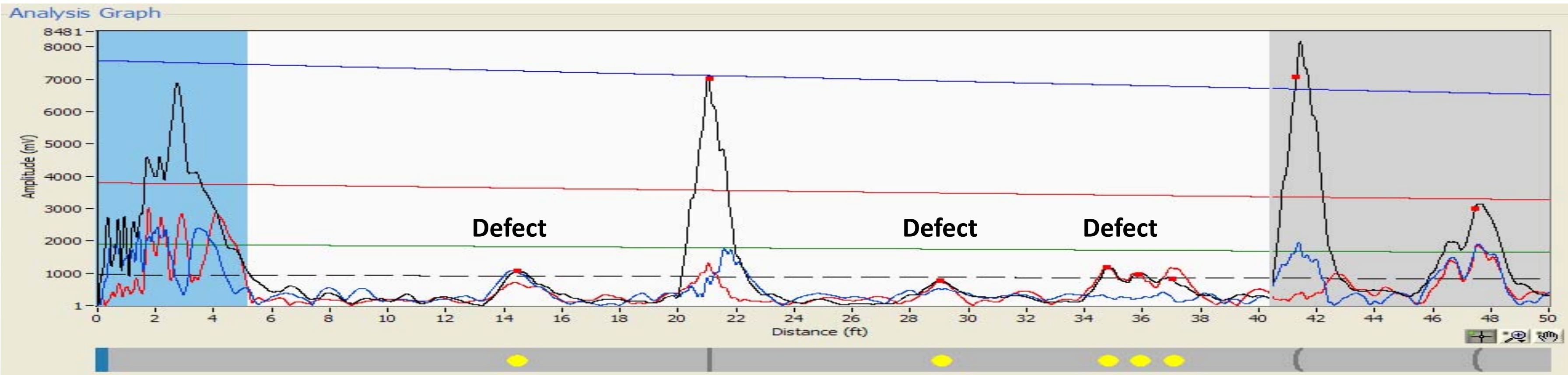
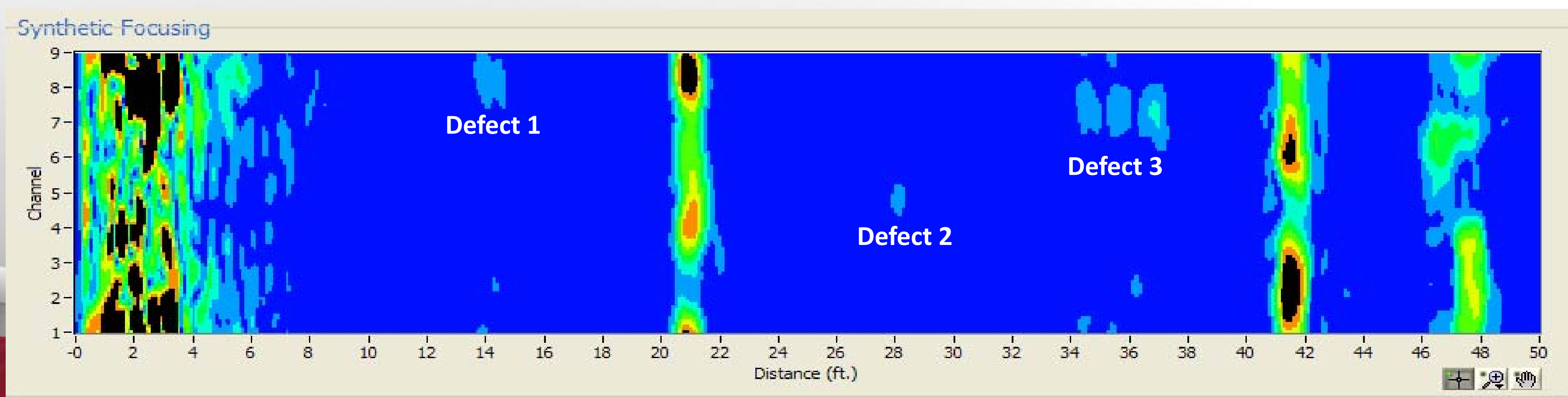
Passive/Synthetic Focusing

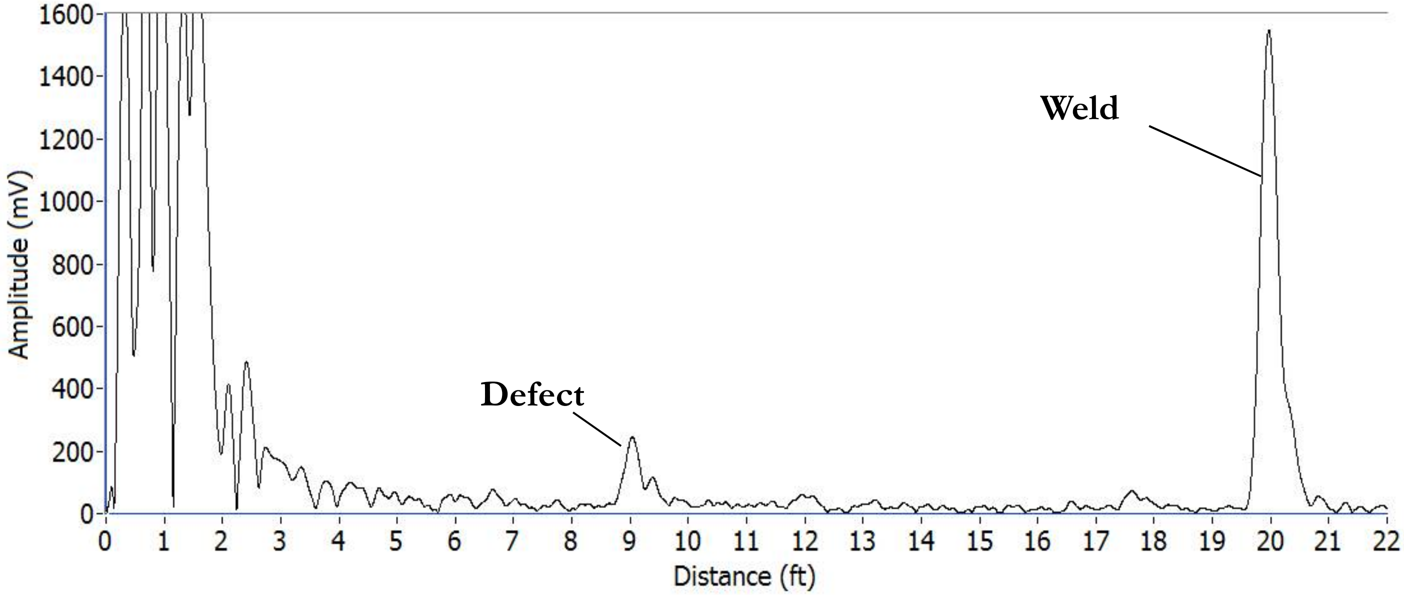
- Some manufacturers uses segment focusing / synthetic focusing to develop an unrolled pipe display
- The segment focusing is just on receiving the signal, not transmission.
- This focusing can provide information on the circumferential extent of a reflector

A-Scan



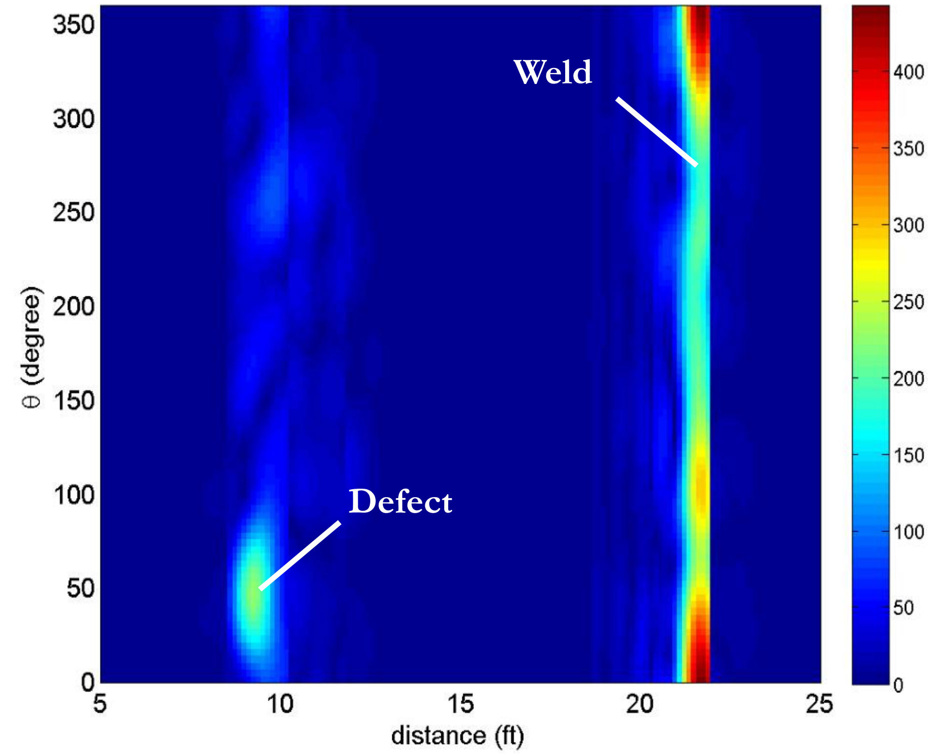
“C-Scan”





Axisymmetric Scan

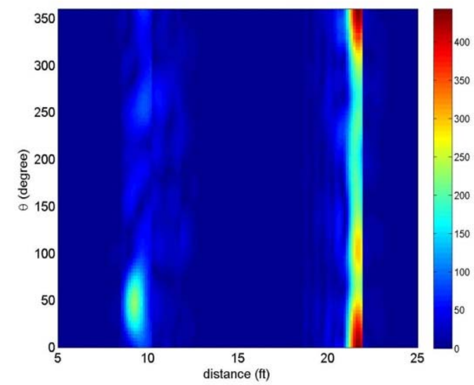
Synthetic Focus Scan



Key Advancements

- Breadth in technical capabilities offered by ***operating multiple platforms***
- **Focusing**
  - **Passive Focusing** – Unrolled Pipe Display
  - Through FBS – new **active focusing** can improve sensitivity
  - Three Ring torsional/longitudinal versus two Ring configurations
- Crews trained on the **fundamental operating concepts** of the methodology **in addition to operation of a particular platform**.

Synthetic / Passive:



Active:

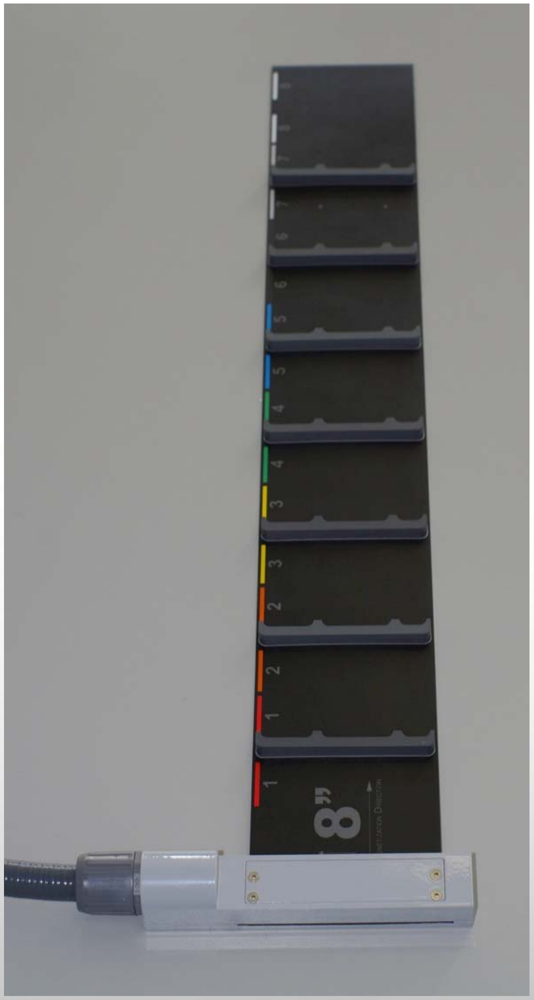
EMERGING GWT ASSESSMENT TECHNOLOGIES

Guided Wave Monitoring (GWM)

PowerFocus MagnetoElastic Focusing (MEF) Collar

- Developed by FBS, Inc.
- Utilizes magnetostrictive effect to maximize loading area and transduction efficiency while minimizing the size of the near field.
- Swept-frequency excitation using torsional guided waves.
- Capable of active (during excitation) wave focusing and passive (via post processing) wave focusing.
- Has a low profile, can be permanently installed, will be more cost-effective than the competing technologies, and will be unique to SI.

PowerFocus© MagnetoElastic Focusing Collar for SHM (Developed with FBS)



- Potential for improved penetration power and sensitivity.
- Small Near Field (<2ft)
- Low Profile (2" axially, <1" circumferentially)
- Only requires installation of a single low-cost sensor strip (see picture below)
- Potential for monitoring for corrosion under supports, repairs, and penetration areas.
- Can be used for buried pipe monitoring (dig once inspect often).

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Guided Wave Monitoring (GWM)

- A guided wave sensor is permanently mounted to the structure.
- A reference (baseline) data set is collected at the time of installation.
- Future data sets are compared to the baseline data set to monitor for changes in the component.
- Can be installed in excavations, high-rad areas, difficult-to-access locations, or on critical components.
- Facilitates “removal” of coherent noise for improved sensitivity and data trending.
- Facilitates inspection of more complex piping geometries.

FBS ME Sensor

GUL gPIMS

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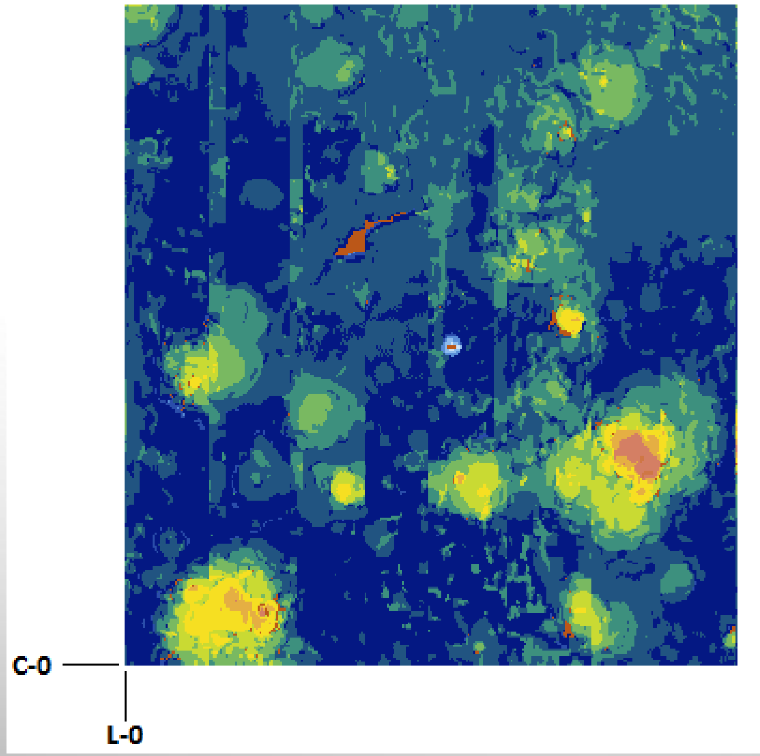
Comparison of Results with MEF Sensor

- From a GWT perspective, typical inspection distances achieved in buried piping are ~25ft, often at ~10% sensitivity.
- With new MEF technology, ~5% sensitivity has been demonstrated for a similar configuration.
- From a GWM perspective, much smaller sensitivities (or larger diagnostic lengths) may be achieved due to monitoring capabilities.

PAUT Roller Probe

- Light-weight, rugged, portable
- Adaptable to different pipe sizes
- Encoded data capable of capturing of 90,000+ points over a 1 sq. ft. area
- Quick – Scanning speed of up to 4 in./s

http://www.ndtsolutions.com/news/story5.html



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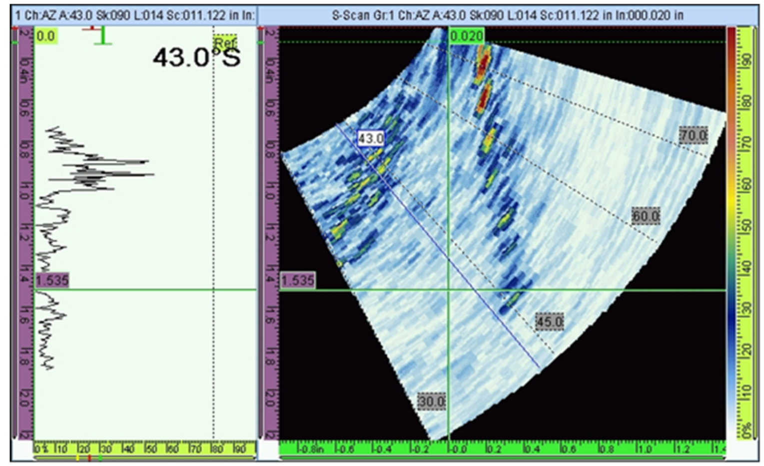
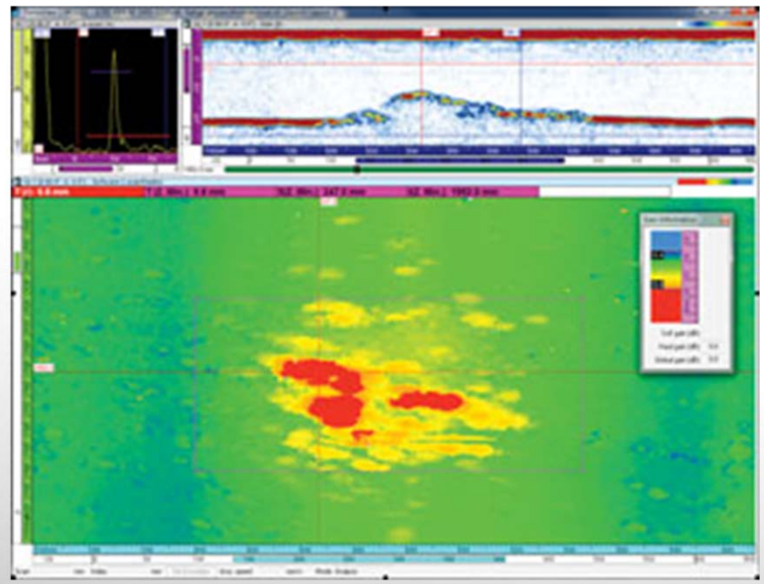
Encoded Phased Array UT

The Sonatest Array Wheel Probe

- Designed for efficient hand scanning of large flat or slightly curved surfaces using phased array ultrasound.
- Compatible with the Olympus Omniscan and other portable phased-array systems.
- Acquires thickness data over a 2-inch wide path as the probe is rolled along the surface





Sample result from a scanned area of corroded piping showing accurate representation of defect shape and depth.

GWT AND CASINGS (SPECIAL APPLICATION)

The Million Dollar Question and major challenge to cased segments: What will be the Shot Distance?

- Estimates can be provided based on piping and coating characteristics, but you don't really know until you shoot the pipeline
- Distance should be referenced with regards to sensitivity
  - Correlates to what size defect will be detected
  - Industry practice (and defined in 18 points) to have a 2:1 SNR

Review of the 18 Points

18 Points were defined to help standardize on some industry best practices to eliminate missed / false calls

- ✓ Generation of Equipment & Software
- ✓ ***Inspection Range (5% CSA, 2:1 SNR)***
- ✓ ***Complete Inspection (2:1 SNR, 5% Overlap)***
- ✓ ***Sensitivity (5% at max. range and minimum sensitivity achieved must be able to identify the smallest defects that will fail by rupturing in a hydrostatic test.)***
- ✓ Frequency (at least 3 frequencies analyzed)
- ✓ Signal or Wave Type (at least torsional)
- ✓ DAC required for inspection
- ✓ Dead Zone (adjacent area to collar must be inspected and/or multiple shots)
- ✓ Near Field Effects (not extend into casing)
- ✓ ***Coating Type (impact on range must meet inspection requirements)***
- ✓ End Seal (dampening effect on range, remove and evaluate to validate)
- ✓ Weld Calibration (welds are used to set DAC curve)
- ✓ Validation of Operator Training
- ✓ Traceable Equipment (vendor to contractor)
- ✓ On-site Calibration
- ✓ Use on shorted casings (cleared if interferes, must be addressed by operating procedure)
- ✓ Direct Examination of all indications above testing threshold (5% CSA) be assessed
- ✓ Direct Examination Schedule / Timeline

	Required Pipeline Response		
GWUT Criterion	**Less than 30%**	**Over 30 to 50% SMYS**	**Over 50% SMYS**
Over 5% CSA and identified for examination	Interval < 12 month	Interval < 6 months	Interval < 6 month
	Leak survey once /month	Direct Examination +	Direct Examination +
	Direct Examination	MOP < psi @ discovery	Reduce to 80% MOP @ Discovery
		Leak survey once /month	

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ANALYSIS AND REPORTING

Core Components of a GWT Report

- Basic information: Pipeline name, inspected sections, location, date of inspection, date of report and description of scope
- Overall assessment and conclusions on piping inspected.
- A summary / table summarizing GWT results identifying indications representing wall loss
- Schematic drawings and/or GIS Location Maps/Files
- Reviewed GWT data results / shot record
- Photographs collected
- Technician certifications
- Equipment calibration certificate
- Specialized Forms similar to ECDA

18 Point Compliance Table

GWT-07: Piping GWT Target Items - Compliance Table

Date: ____________________ Client Project Manager: ____________________
Project ID: ____________________ Site Designation: ____________________
Pipeline ID(s): ____________________ HCA ID: ____________________

Instructions: The Client Project Manager or designate shall indicate compliance with each target item by marking the appropriate row. The Client Project Manager or designate shall prepare exception report documentation for any target items marked "No" for which compliance could not be achieved.

ID #	Target Type	Specific Target Recommendations	Target Item Compliance		Comments
	Guided Wave UT Target Items	The following recommendations are prescriptively required when applying GWT as a Direct Inspection Tool. Please provide exception report documentation for any target items for which compliance "would not be" or "was not" possible.	Indirect Inspection Compliance Achieved?	Exception Report Required?	
1	Equipment Software	Applicable software revisions maintained	☐ Yes ☐ No ☐ N/A	☐ Yes ☐ No ☐ N/A	
2	Length of Casing	Inspection Range 60' to 100', 80' Good Maximum Use	☐ Yes ☐ No ☐ N/A	☐ Yes ☐ No ☐ N/A	
3	Overlap	5% Overlap Needs to be Provided or Alternative Specified	☐ Yes ☐ No ☐ N/A	☐ Yes ☐ No ☐ N/A	
4	Sensitivity	All indications equivalent to a 5% change in CSA or 5% CSC shall be detected with at least a 2:1 SNR	☐ Yes ☐ No ☐ N/A	☐ Yes ☐ No ☐ N/A	
5	Frequency	Various Frequencies to Run for Each Shot Between 15 & 50 kHZ	☐ Yes ☐ No ☐ N/A	☐ Yes ☐ No ☐ N/A	
6	Signal or Wave Type	Consider both Types of Torsional and Longitudinal	☐ Yes ☐ No ☐ N/A	☐ Yes ☐ No ☐ N/A	
7	Distance Amplitude Curve	Measurement of Effective Range of a GWT Test for each Inspection	☐ Yes ☐ No ☐ N/A	☐ Yes ☐ No ☐ N/A	
8	Dead Zone	Place Collar to Account for Dead Zone (3 to 6 feet from collar)	☐ Yes ☐ No ☐ N/A	☐ Yes ☐ No ☐ N/A	
9	Near Zone	Testing to Account for Near Zone (1 to 2 feet out from dead zone)	☐ Yes ☐ No ☐ N/A	☐ Yes ☐ No ☐ N/A	
10	Pipe Coating Type	Coal Tar Enamel, FBE, Wax, Extruded	☐ Yes ☐ No ☐ N/A	☐ Yes ☐ No ☐ N/A	
11	Casing End Seal Type	Removal necessary to visually inspect under end seal	☐ Yes ☐ No ☐ N/A	☐ Yes ☐ No ☐ N/A	
12	Weld Calibration	Expose Weld Location & Measure for Calibration DAC or Use 25% Default	☐ Yes ☐ No ☐ N/A	☐ Yes ☐ No ☐ N/A	
13	Operator Training	Certified to a Level II Minimum on Specific Equipment	☐ Yes ☐ No ☐ N/A	☐ Yes ☐ No ☐ N/A	
14	Equipment	Traceable to Manufacturer and have applicable software revisions maintained	☐ Yes ☐ No ☐ N/A	☐ Yes ☐ No ☐ N/A	
15	Equipment Calibration	Calibrated per Manufacturer's Specifications	☐ Yes ☐ No ☐ N/A	☐ Yes ☐ No ☐ N/A	
16	Direct or Electrolytic Short	Interfering shorts must be cleared prior to final testing	☐ Yes ☐ No ☐ N/A	☐ Yes ☐ No ☐ N/A	
17	Direct Examination	Indications > Testing Threshold (5% or hydrotest equivalency for CSA sensitivity)	☐ Yes ☐ No ☐ N/A	☐ Yes ☐ No ☐ N/A	
18	Direct Examination Deadline	>30% SMYS - 6 Months, <30% SMYS - 12 Months	☐ Yes ☐ No ☐ N/A	☐ Yes ☐ No ☐ N/A	

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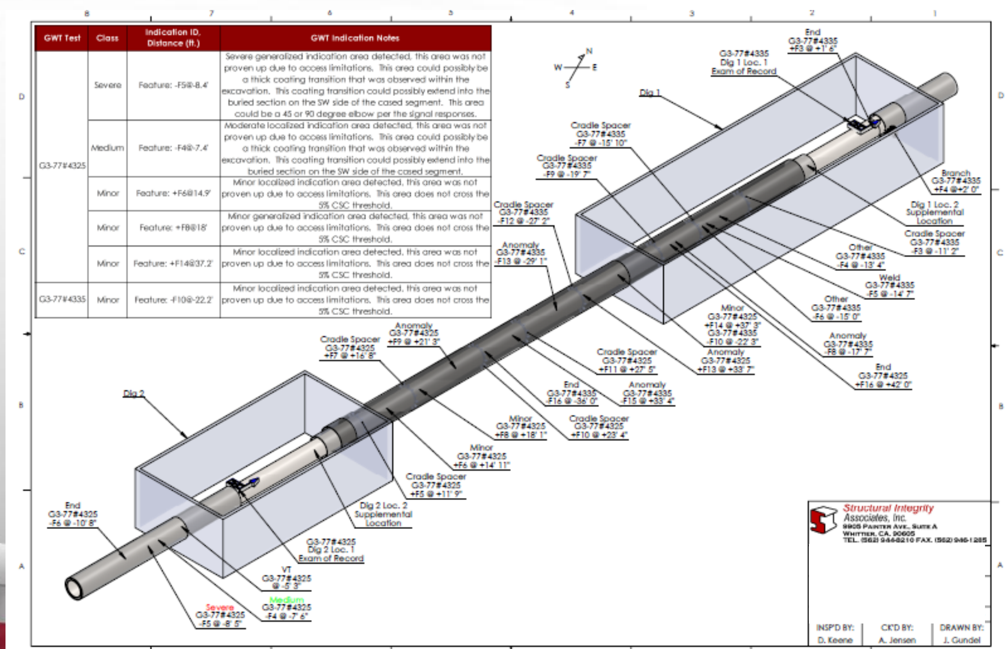
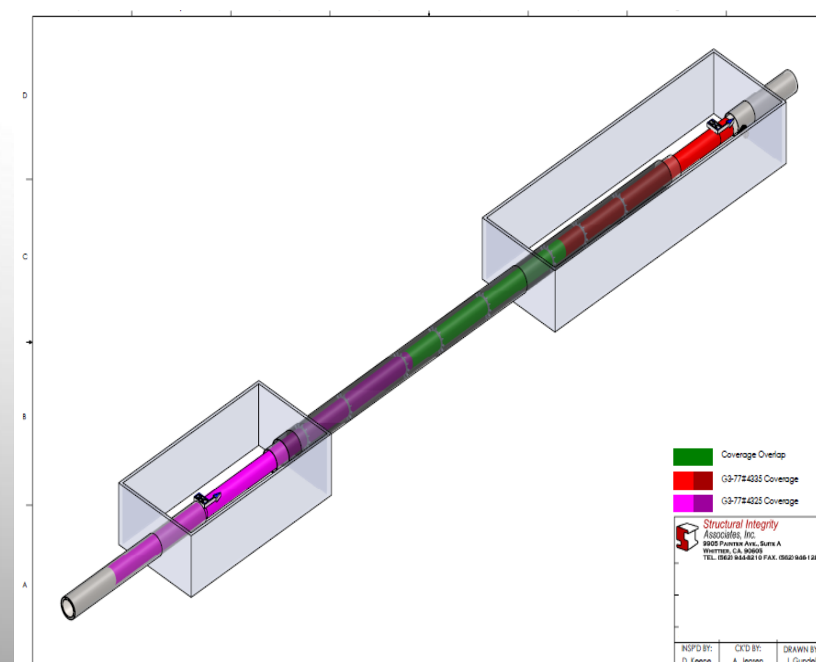
Analysis Tools: 3-D Modeling and GIS

- Geodatabase systems, digitizing pipeline information and modeling / analyzing data can be very useful in analysis
- Recent integration of assessment data into 3-D models, key benefits:
  - Assessment data easier to view and analyze
  - Selection of indirect inspection tools more efficient
  - Dig site selection readily available in a visual format
  - Post Assessment contains an auditable set of records in a database and visual format

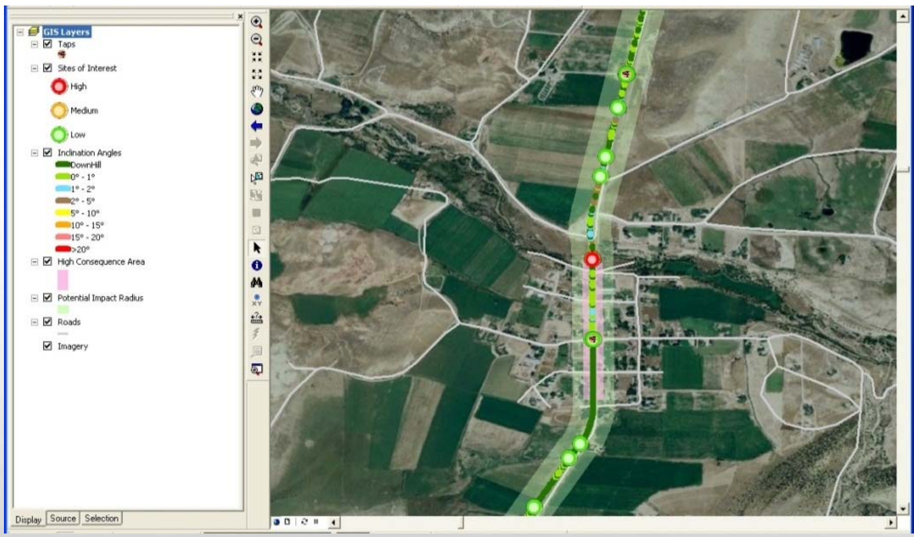


GWT Test	Class	Indication ID, Distance (ft.)	GWT Indication Notes
G3-77#4325	Severe	Feature: -F5@-8.4'	Severe generalized indication area detected, this area was not proven up due to access limitations. This area could possibly be a thick coating transition that was observed within the excavation. This coating transition could possibly extend into the buried section on the SW side of the cased segment. This area could be a 45 or 90 degree elbow per the signal responses.
	Medium	Feature: -F4@-7.4'	Moderate localized indication area detected, this area was not proven up due to access limitations. This area could possibly be a thick coating transition that was observed within the excavation. This coating transition could possibly extend into the buried section on the SW side of the cased segment.
	Minor	Feature: +F6@14.9'	Minor localized indication area detected, this area was not proven up due to access limitations. This area does not cross the 5% CSC threshold.
	Minor	Feature: +F8@18'	Minor generalized indication area detected, this area was not proven up due to access limitations. This area does not cross the 5% CSC threshold.
	Minor	Feature: +F14@37.2'	Minor localized indication area detected, this area was not proven up due to access limitations. This area does not cross the 5% CSC threshold.
G3-77#4335	Minor	Feature: -F10@-22.2'	Minor localized indication area detected, this area was not proven up due to access limitations. This area does not cross the 5% CSC threshold.

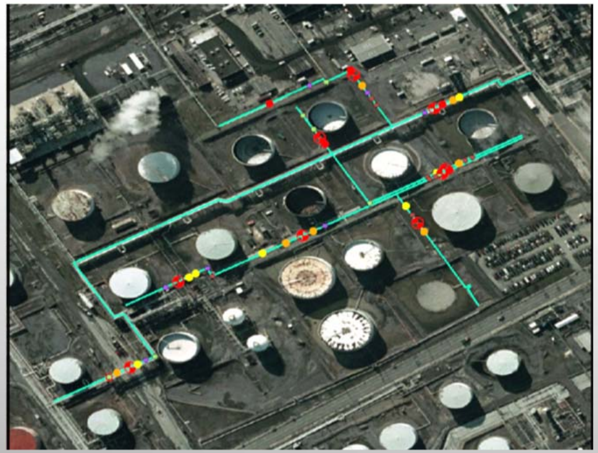


Data Management via GIS (web based)

- Industry trend migrating inspection results to a Geodatabase with GIS
  - Overlay of results on facility map



- Layers and/or Grouping application specific
  - Examples:
    - Inspection Date, Risk Level
  - Fully customizable
- Centralized location for data
  - Design, Inspection, etc…



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Thank You

Questions?

Scott Riccardella
Oil and Gas, Product Manager
(303) 542-1432
sriccardella@structint.com

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