Facility Mechanical Integrity and Non-Intrusive Inspection Technologies

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OUTLINE

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- Effectiveness
- Economical
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Asset Integrity Goal

To ensure that the all assets, new and old, remain safe, economical, and effective for their entire life cycle.

Safety

- Ensuring equipment is safe to operate
  - Equipment Condition
  - Fitness for Service
- Safety of personnel that:
  - Operate
  - Maintain
  - Inspect
- Intrusive Inspections pose a risk to inspectors that can be avoided through the use of non-intrusive inspections
- Avoidance of or minimizing entry into confined spaces where possible

Economical

Severity \ Likelihood	A Rare	B Unlikely	C Possible	D Probable	E Almost Certain
5 Catestrophic	8	4	0	0	0
4 Major	6	14	6	0	0
3 Severe	3	24	20	3	0
2 Minor	3	4	12	15	6
1 Slight	0	3	2	6	8

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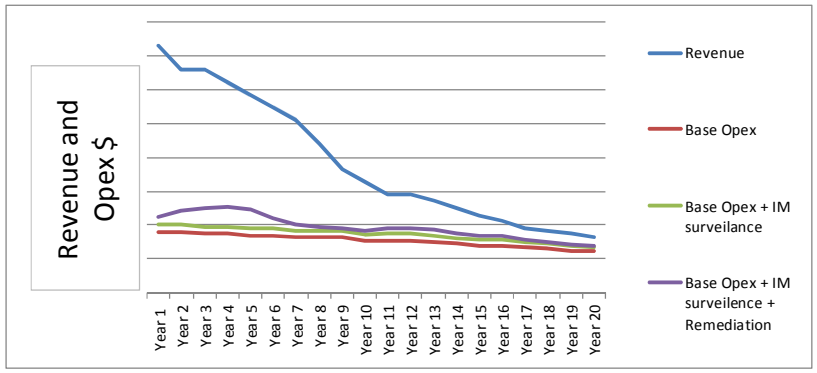

Severity \ Likelihood	A Rare	B Unlikely	C Possible	D Probable	E Almost Certain
5 Catestrophic	4	8	0	1	0
4 Major	8	6	12	2	1
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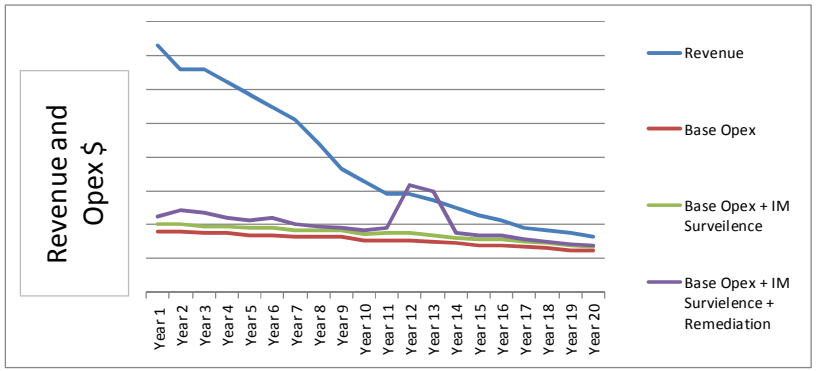


Effectiveness

- Proactive vs Reactive

- Inspection Planning
  - Have we appropriately identified the damage mechanisms expected?
  - Have we prioritized our equipment appropriately?
  - How do we inspect for the expected damage mechanisms?

- Inspection Findings
  - Have we updated our damage mechanisms to reflect new findings?
  - Have the risk ranks been updated to reflect new findings?
  - Has the remaining life been evaluated against the economic life of the facility?
  - Have we updated our inspection techniques?

Effectiveness

- Need to understand that the true remaining life changes over the course of an asset life. Determined through:
  - Economic Life
  - Remaining Life based on operating conditions / vessel condition
  - Damage Mechanism Rates
  - Risk

Facility Mechanical Integrity

- Pressure Vessels
- AST's – Aboveground Storage Tanks
- Pressure Piping
- Pressure Protection
- Utilization of industry accepted Codes and Standards
- Utilization of industry accepted Inspection Techniques
- Life Cycle Integrity Management – We will focus on the inspection of equipment aspect

Codes and Standards

- Pressure Vessels
  - ASME Boiler and Pressure Vessel Codes
  - API 510 – Pressure Vessel Inspection Code
  - API 572 – Inspection Practices for Pressure Vessels
  - NBIC 23 – National Board Inspection Code

- AST's – Aboveground Storage Tanks
  - API 650 – Welded Tanks for Oil Storage
  - API 12F – Specification for Shop Welded Tanks for Storage of Production Liquids
  - API 653 – Tank Inspection, Repair, Alteration, and Reconstruction

Codes and Standards

- Pressure Piping
  - ASME B31 Piping Codes
  - API 570 – Piping Inspection Code
  - API 574 – Inspection Practices for Piping System Components

- Pressure Protection
  - API 520 – Sizing, Selection, and Installation of Pressure-relieving Devices
  - API 576 – Inspection of Pressure Relieving Devices

Inspection Planning

- New construction / currently in-service
- Baseline Inspections are integral
- Identify Damage Mechanism Threats
- Identify Inspection Techniques
- Identify Inspection Interval / Frequency
- Compare Mitigated / Unmitigated Risk
- Identify Measurement Points (CMLs) or Areas of Focus
- Develop Inspection Plan

Identify Damage Mechanisms

- Selection of appropriate degradation mechanisms from industry sources, such as API 571
- Past history of damage in similar vessels identified by previous inspections (if applicable)
- When identifying damage mechanisms, the following should be considered:
  - Operational Parameters
  - Fluid Phases
  - Fluid Contents
  - Materials of construction
  - Equipment design

Non-Destructive Inspection Techniques

- Standard NDE Techniques
  - Ultrasonic Thickness (UT) - Quantitative
  - Radiographic Technique (RT) – Qualitative
  - Penetrant Technique (PT) – Qualitative
  - Magnetic Particle Testing - Qualitative

- Advanced NDE Techniques
  - Automated Ultrasonic Testing (AUT)
  - Guided Wave UT (GWUT)
  - Alternating Current Field Measurement (ACFM)
  - Digital Radiography
  - Eddy Current
  - Phased Array UT
  - Shear Wave UT
  - Time of Flight Diffraction (TOFD)
  - Acoustic Emission
  - Infrared Inspection

Common DMs – Inspection Techniques

Damage Mechanism	Damage Type	NDE Type	Advanced NDE	Typical Equipment / Locations
Atmospheric Corrosion	Uniform Corrosion	VT, Pit Gauge	GWUT, PEC	All equipment, external, areas of failed coating.
Corrosion Under Insulation	Localized Wall Thinning		PEC, Profile RT, GWUT, IR, Neutron Backscatter	Equipment with damaged or improperly installed insulation, equipment with damaged or leaking steam tracing, anywhere that moisture or water can collect, includes under fireproofing.
General Internal Corrosion	Uniform Corrosion	UTT, MUT	C-Scan Straight Beam, AUT, TOFD	Any service with the potential for water
Microbiologically Induced Corrosion (MIC)	Localized Wall Thinning / pitting	MUT	C-Scan Straight Beam, AUT	Stagnant or low flow vessels, storage tanks, heat exchangers, etc
CO_2 Corrosion	Localized Wall Thinning / pitting	VT, UT, RT	C-Scan Straight Beam, AUT, TOFD	Carbon steel equipment, areas of turbulent flow
Sour Water Corrosion	Uniform Corrosion	UT, RT	C-Scan Straight Beam, AUT, TOFD	Any sour service equipment with chance for water. Will see iron sulfide scale, etc.
Fatigue Cracking	Cracking	VT, MT, PT	SWUT, PAUT	Can be Thermal or Mechanical Fatigue. Areas of stress raisers - weld seams, nozzles. Mole Sieves, Compressor vessels, piping
Wet H2S Damage	Cracking	VT, MT, PT	SWUT, PAUT	Weld Seams and Nozzles
Corrosion Under Saddle Supports	Localized Corrosion		PAUT, Guided Wave	Any equipment sitting on support saddles.
Preferential weld root corrosion - circ and seam welds, HAZ	Localized pitting at welds	MUT	TOFD	Circ and long seams on piping, vessels
Preferential weld root corrosion - nozzle to shell welds, HAZ	Localized pitting at welds	MUT	PAUT	nozzle to shell welds on pressure vessels
Under Deposit Corrosion	Localized Wall Thinning	UTT	C-Scan Straight Beam, AUT, TOFD	Areas of low flow or stagnant fluid where there is settlement.

Identification of CMLs / Selection of Inspection Methods

- Identification based on metal loss versus cracking and areas of expected degradation
- Automated/Semi-automated or manual Inspection techniques
- Selection of CMLs based on Damage mechanism identified
- Accessibility of areas expected to see damage
- Percentage of areas to be inspected
- Data retention Inspection technologies

Non-Intrusive Inspection – Case Study

Horizontal Separator Vessel in Sweet Service (Constructed in 1998)

Damage Mechanisms Expected

- General Wall Thinning
- Erosion/Erosion Corrosion
- Weld Root Corrosion
- MIC Corrosion
- Corrosion Under Saddle Supports

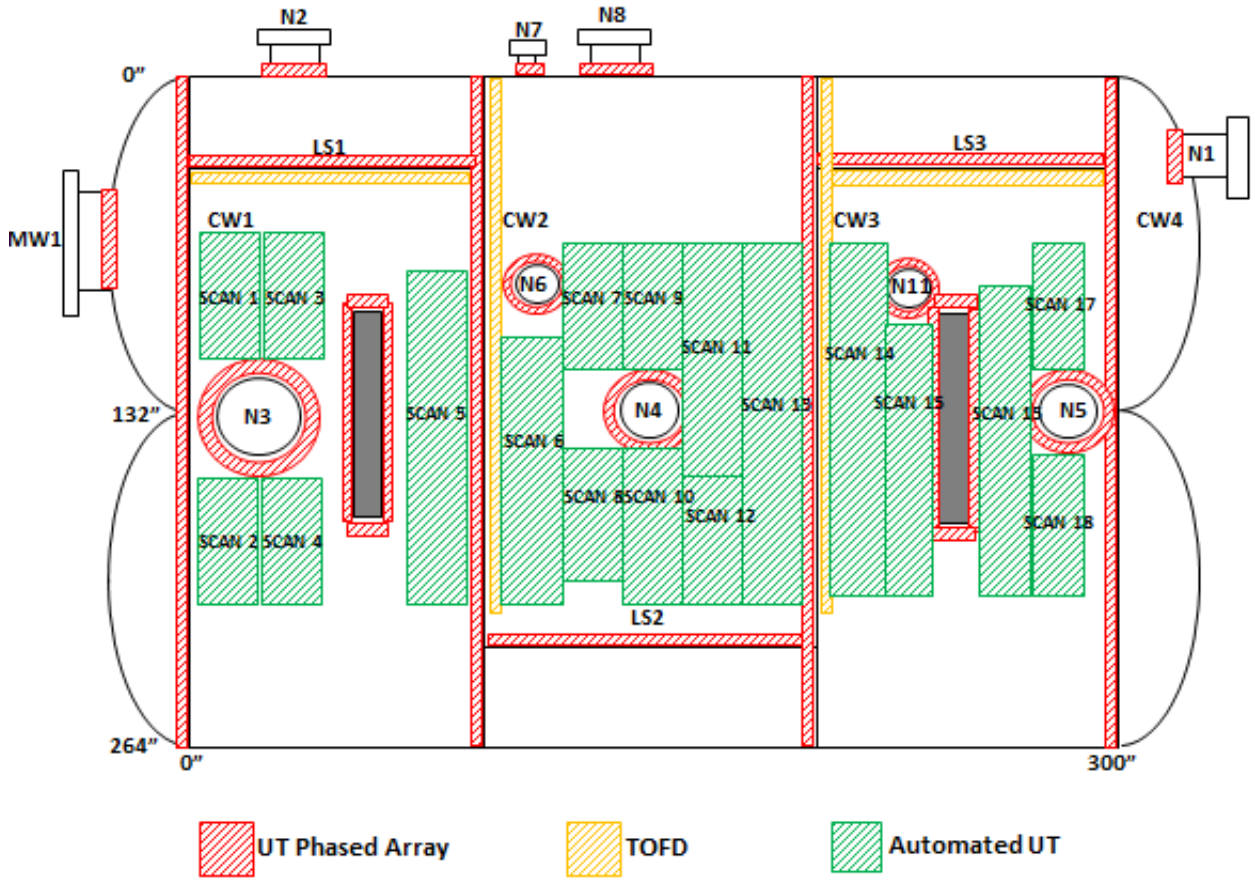
100% Insulation was removed prior to inspection

Surface was prepared per NDE Inspector Requirements

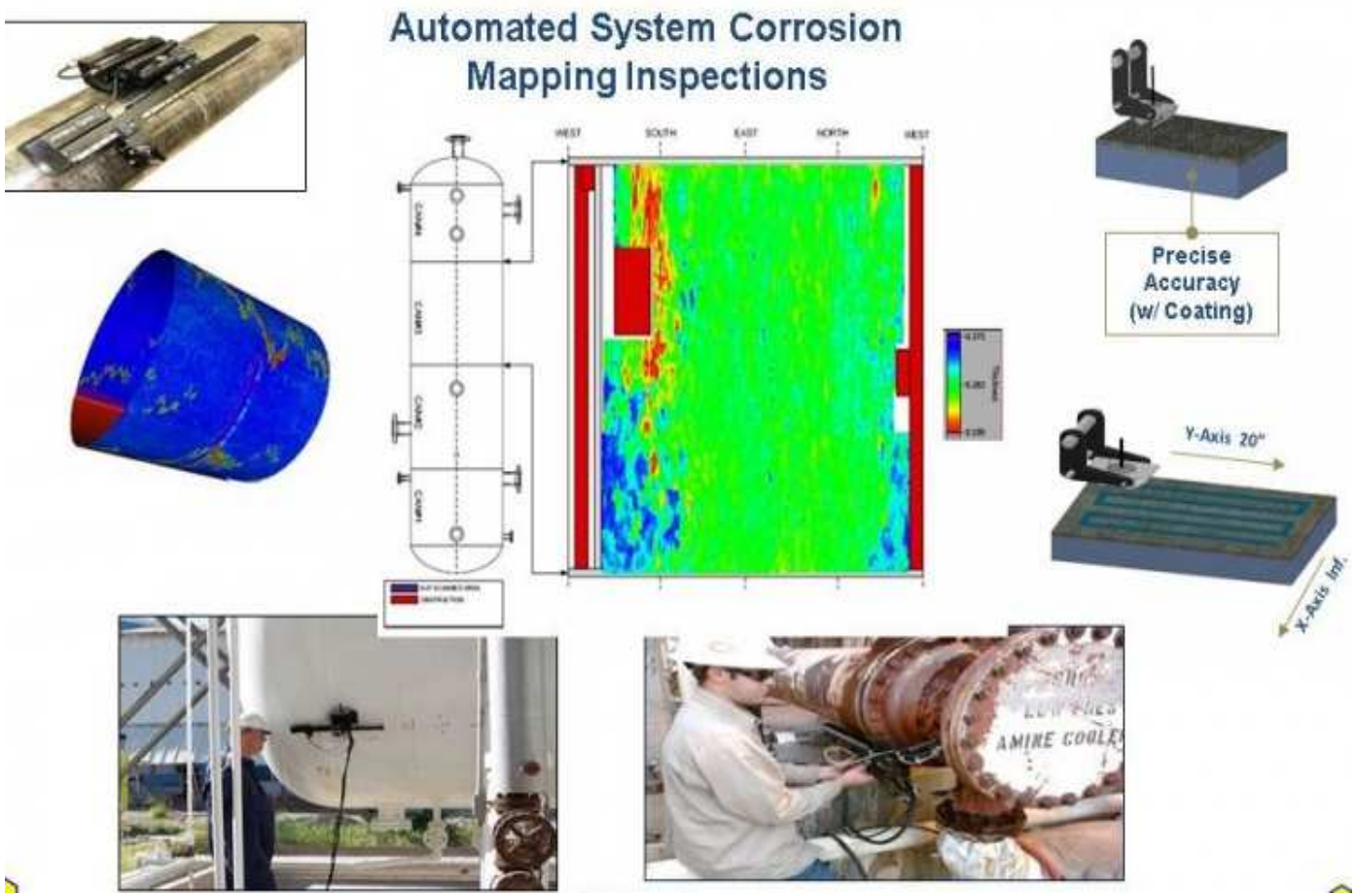
API 510 Visual External Inspection – 2012

No history of failures, production upsets, etc.

Non-Intrusive Inspection Planning



Non-Intrusive Inspections – Corrosion Mapping



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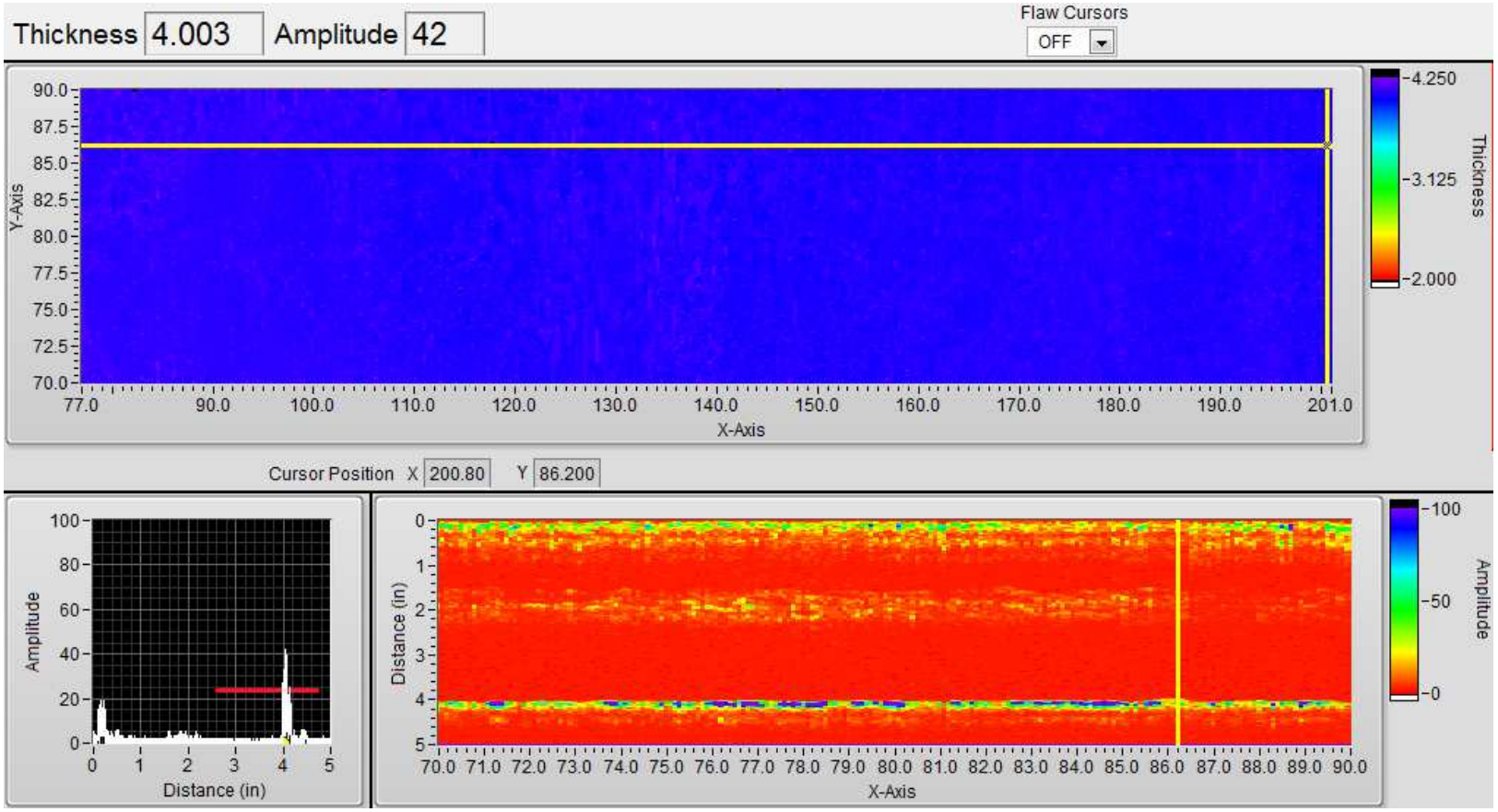
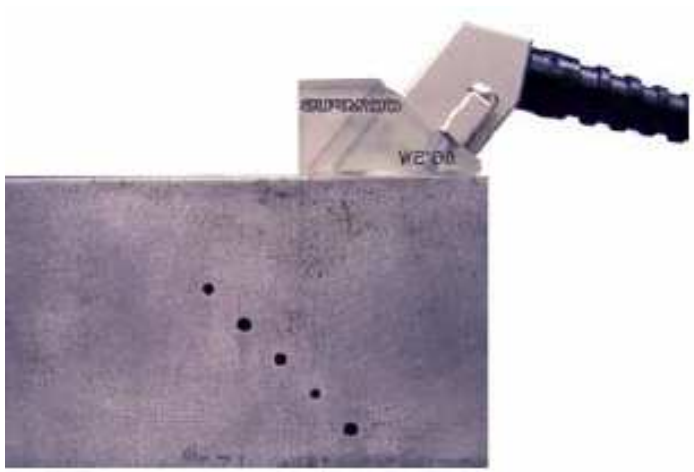
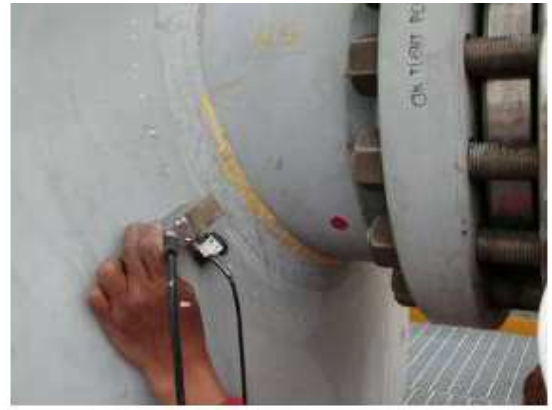
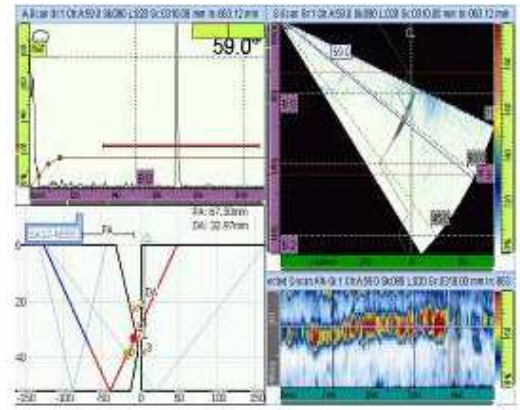
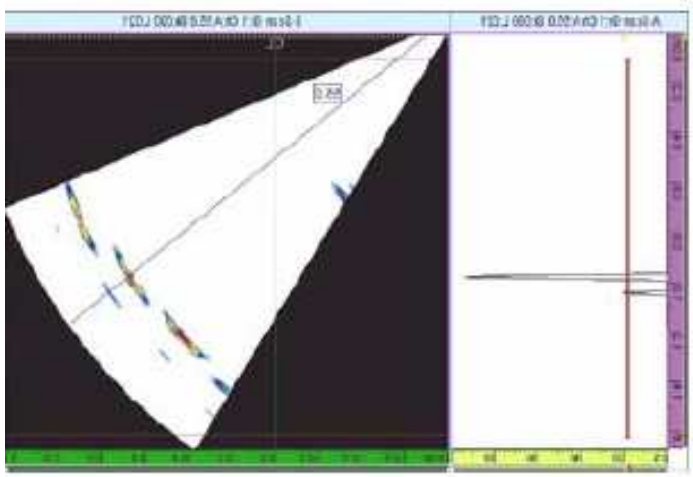


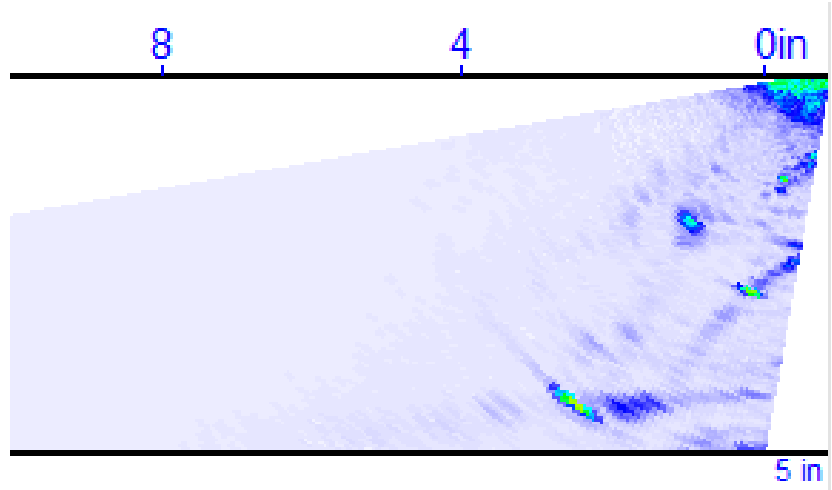
Non-Intrusive Inspections – Phased Array



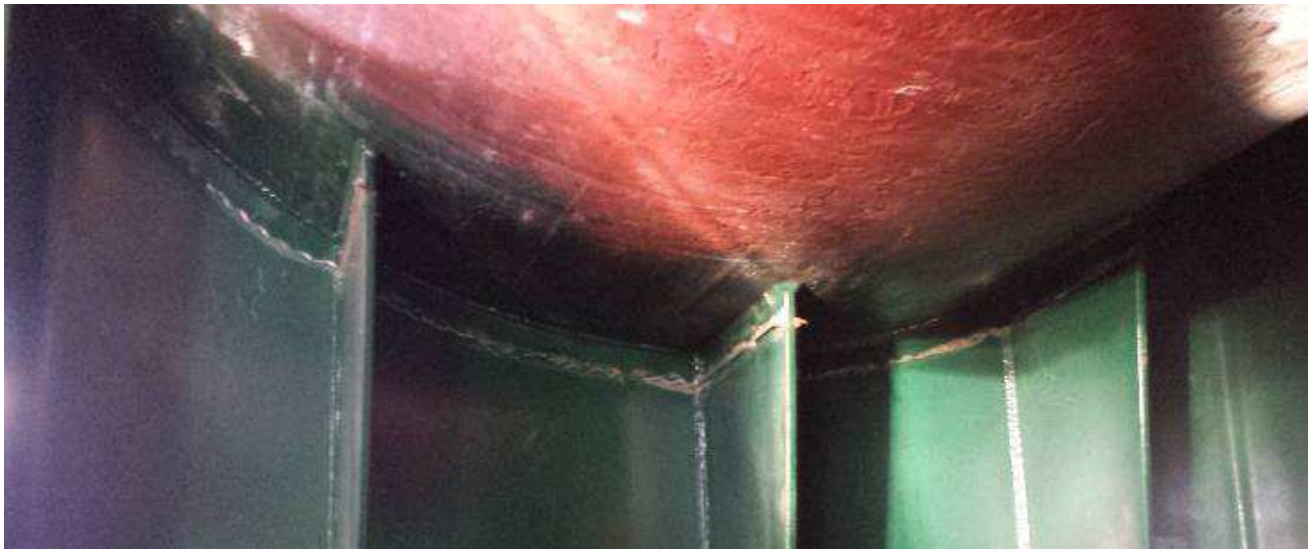


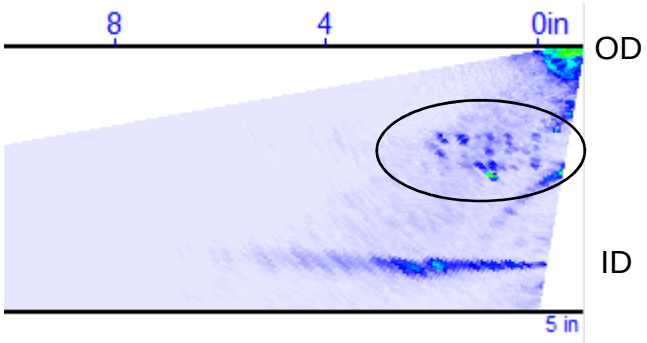


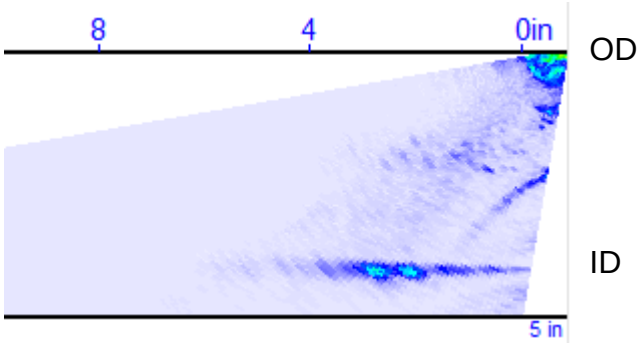




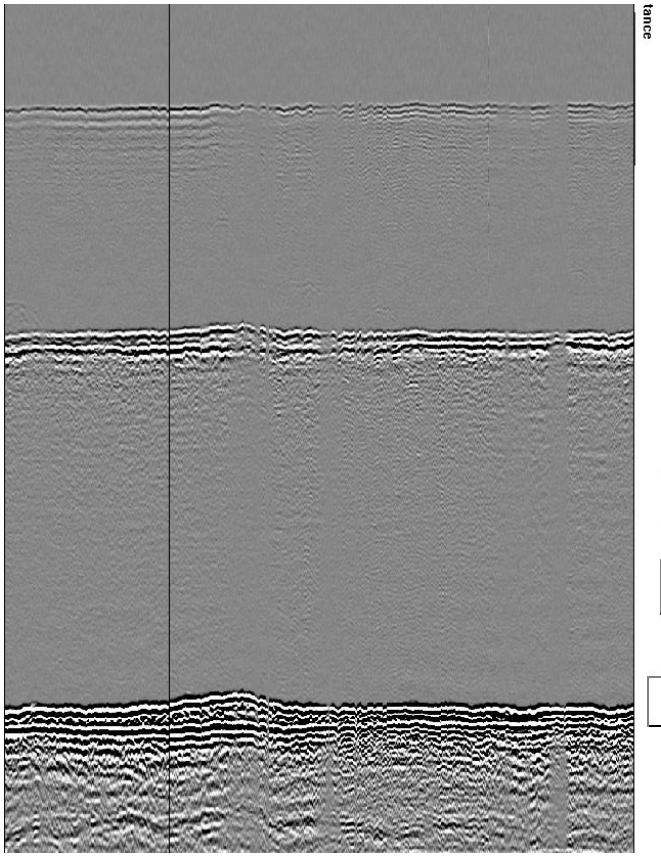
Non-Intrusive Inspections – Corrosion Under Saddles

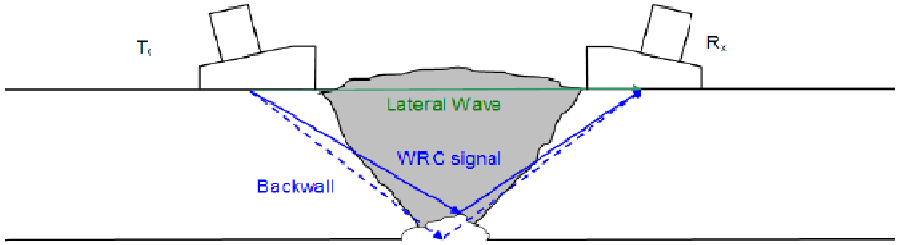




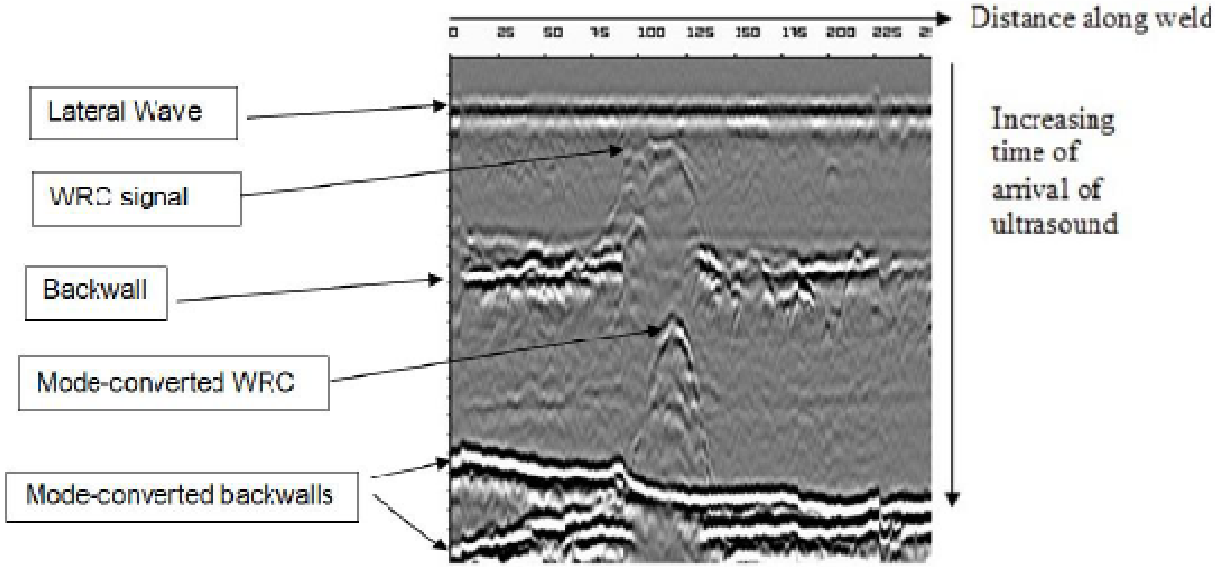


Non-Intrusive Inspections - TOFD





Schematic of weld corrosion inspection using TOFD



TOFD D-Scan of an isolated area of severe weld corrosion/erosion.

Non-Intrusive Inspections – Summary of Findings

Corrosion Mapping revealed maximum of 2% wall loss on the bottom half of the vessel (0.005 mpy)

No significant damage noted on nozzles

No significant corrosion noted under saddles

No weld root corrosion detected

Vessel is deemed fit for continued service with remaining life of > 10 years

Removal of insulation allowed us to perform CUI Inspection – no damage found

Non-Intrusive Inspections – Significance of Findings

Per API 510 Section 6.5.2

On stream inspections can be used in lieu of internal inspections if:

Vessel entry is possible, but the following conditions are met:

- Known corrosion less than 0.005 in./year
- Remaining Life > 10 years
- Corrosive character of contents (and trace components), has been established by at least 5 years of the same or similar service
- No questionable condition discovered during external inspection
- Operating temperature does not exceed lower temperature limits for creep rupture range of the vessel material (> 650 F)
- Vessel not subject to environmental or hydrogen damage from internal fluid
- Does not have nonintegrally bonded liner such as strip or plate lining

Non-Intrusive Inspections – Future Inspections

Vessel in question met all requirements listed

Techniques selected add to the inspection confidence and can be supplemented by:

- Monitoring Production Concerns/Upsets
- Fluid Sampling
- Sand Monitoring
- Establishing IOWs

Non-Intrusive Inspections – Cost/Benefits Analysis

Estimate: Facility produces 10,000 BPD @ $50/BBL = $500,000 USD/day

Cost of Intrusive Inspection:

Lost Production (~ 5 days) - $2,500,000
Scaffolding / Cleaning – $50,000 - $100,000
Inspection - ~ $20,000

Cost of Non-Intrusive Inspection:

Lost Production - $0 (No downtime)
Scaffolding / Insulation Removal - $50,000
Inspection - $30,000

Conclusions

Requirements are to meet integrity goals

- Safely
- Economically
- Effectively

Safety

- Current day technology can minimize risk / exposure to personnel

Economic Benefits

- Reduced downtime meaning reduced lost production
- Preventive Maintenance vs Reactive

Effectiveness

- Detection of damage is not limited to relying on the human eye
- Pin pointing damage mechanisms based on operational data, fluid data
- Accurately quantify damage for fitness for service assessments and predictive analysis

Conclusions

Industry best practices are available for all facets of asset integrity and should be utilized.

Technologies listed are proven and accepted within industry

Accurately determine the integrity of pressure equipment

More tools in the toolbag. Allows more creativity.

Questions

QUESTIONS?

Contact Information

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