Corrosion Mapping in Storage Tank Walls, Bottoms and Service Water Piping Using Guided Wave Magnetostrictive Transducers

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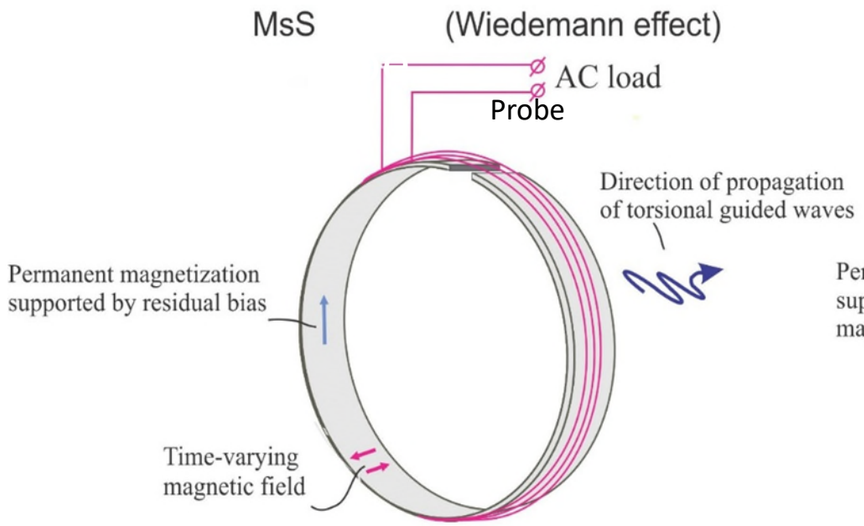
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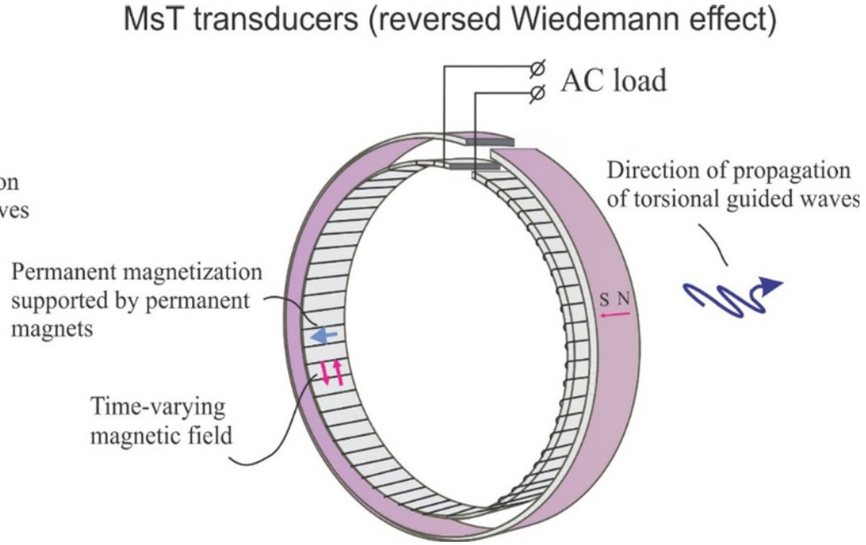
Introduction

- Guided wave testing methods are in high demand for screening of many industrial components, such as pipes, storage tank walls and bottoms, and various steel liners
- Aging of these components results in increased generalized corrosion and cracking, creating situations where the guided wave data are difficult to interpret
- In this presentation a new generation of magnetostrictive transducers (MsTs) will be presented, including the MsT 8x8 array probe, MsT Bracelet probe, and omnidirectional MST 360 probe
- In addition to automated data collection, these probes and the associated instrumentation and software are used to provide reports with high accuracy corrosion mapping information
- The data acquisition and analysis software allow quick reporting of anomalies using Full Matrix Capture (FMC) data acquisition and Total Focusing Method (TFM) reconstruction
- Case studies of technology application to guided wave screening of storage tanks and service water pipes and pipe supports will be discussed, along with future directions for the technology development.

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Magnetostrictive Probes



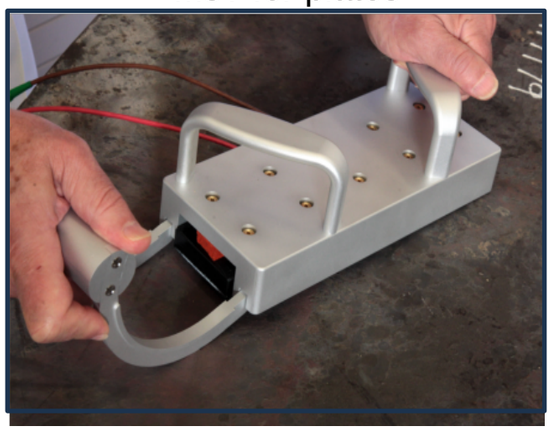


MsT for pipes



- Magnetostrictive Sensor (MsS) Probes were invented in 2002. They utilize the direct Wiedemann effect
- MsT probe was invented in 2008. It utilizes the reversed Wiedemann effect
  - A toroidal AC coil wound around an FeCo strip generates a pulsed circumferential field
  - An array of small permanent magnets creates a static axial field that creates a stable magnetic field in the FeCo strip
  - Greater time varying and static fields achieve up to 20 dB higher signal than MsS probes
  - 20 – 500 kHz frequency range typically possible
  - Known and stable beam characteristics
  - Applicable to any materials (magnetic or non-magnetic) that support guided waves

MsT for plates



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MsT Array System

MsSRV5m Instrument



MsT 8x8 Probe



Bracelet MsT Probe for 2 – 55 in. OD pipes



Bracelet MsT Probe for 6 – 8 in. OD pipes



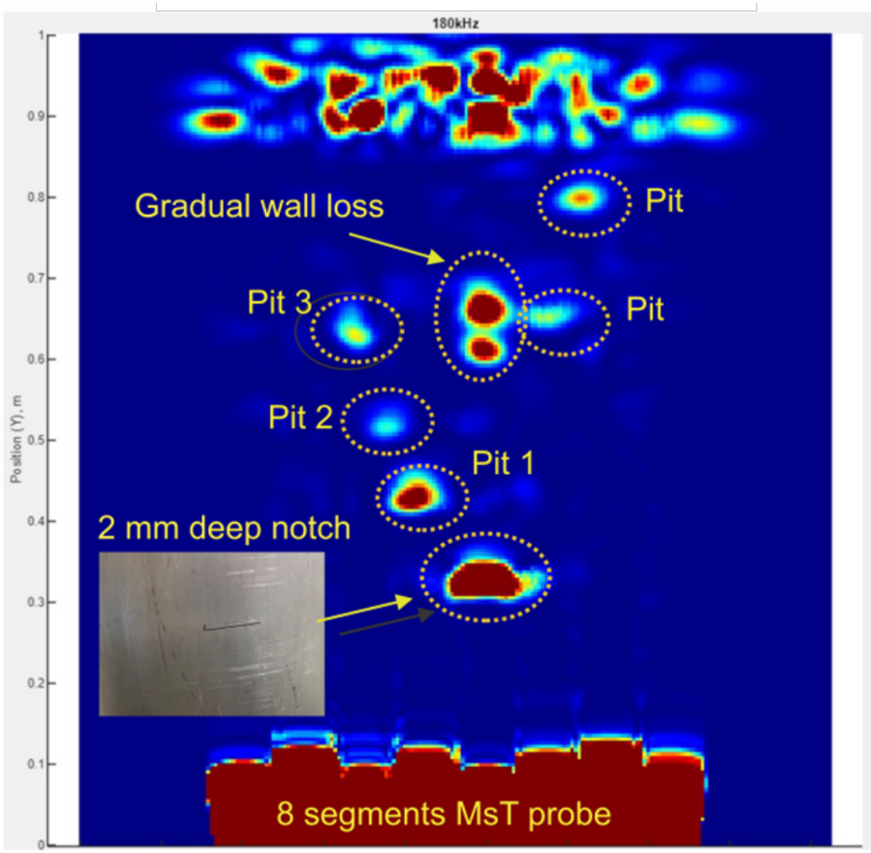


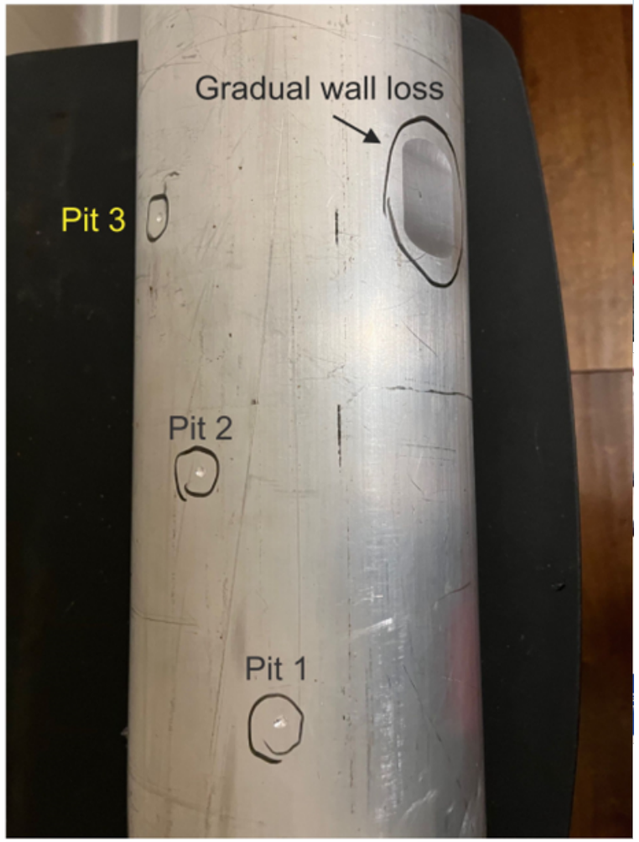
- Feld deployable MsSRV5M instrument can serve up to 16 paired magnetostrictive segments in a probe
- 8x8 MsT probe can be installed on shells with diameters 1.4 m (55 inches) and greater using a magnetic clamping fixture
- Bracelet MsT probes have 4-13 segments; They can fit a range of pipe diameters 50 – 1400 mm (2 – 55 inches) with whole or partial coverage; partial coverage is especially convenient for pipe support scans

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8 Segment MsT in 6 in. OD Schedule 40 Pipe





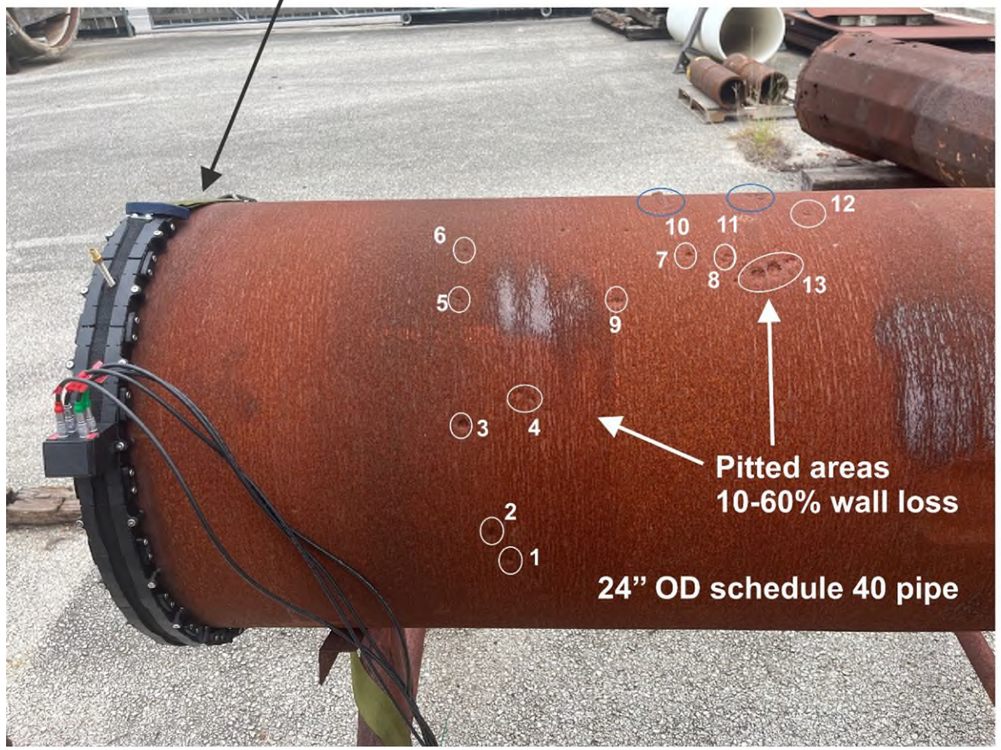


- Segmented MsT transducers can have 4 – 16 segments mechanically linked together
- Data collection is automatic; it takes 3 minutes to acquire data using FMC and 3 selected frequencies
- The example above shows detection of pitting corrosion, gradual wall loss, and a notch in 150 mm (6 in.) OD pipe at 180 kHz

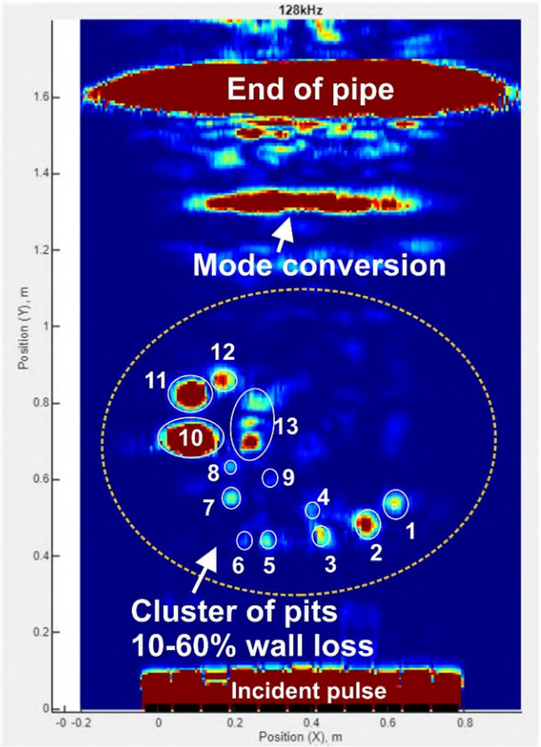
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Naturally Formed Pitting Corrosion in 24 In. OD pipe

11 segments bracelet MsT probe



TFM image at 128 kHz



List of indications

N	Diameter	Depth
11	25 mm (1 inch)	60%
12	12 mm (0.47 inch)	28%
5	6 mm (0.23 inch)	10%
2	12 mm (0.47 inch)	42%
8	7 mm (0.27 inch)	14%

- 13 anomalies were naturally formed in this pipe sample
- TFM image not only produced a map of pits distribution it also produced a realistic image of pit geometry
- This information can be used to estimate cross-sectional area of defects to help improve the depth estimate accuracy
- Longitudinal mode converted signal from end of pipe is only partially cancelled out by the TFM processing
- The entire test is quick – probe is mounted at one location; no scanning is required

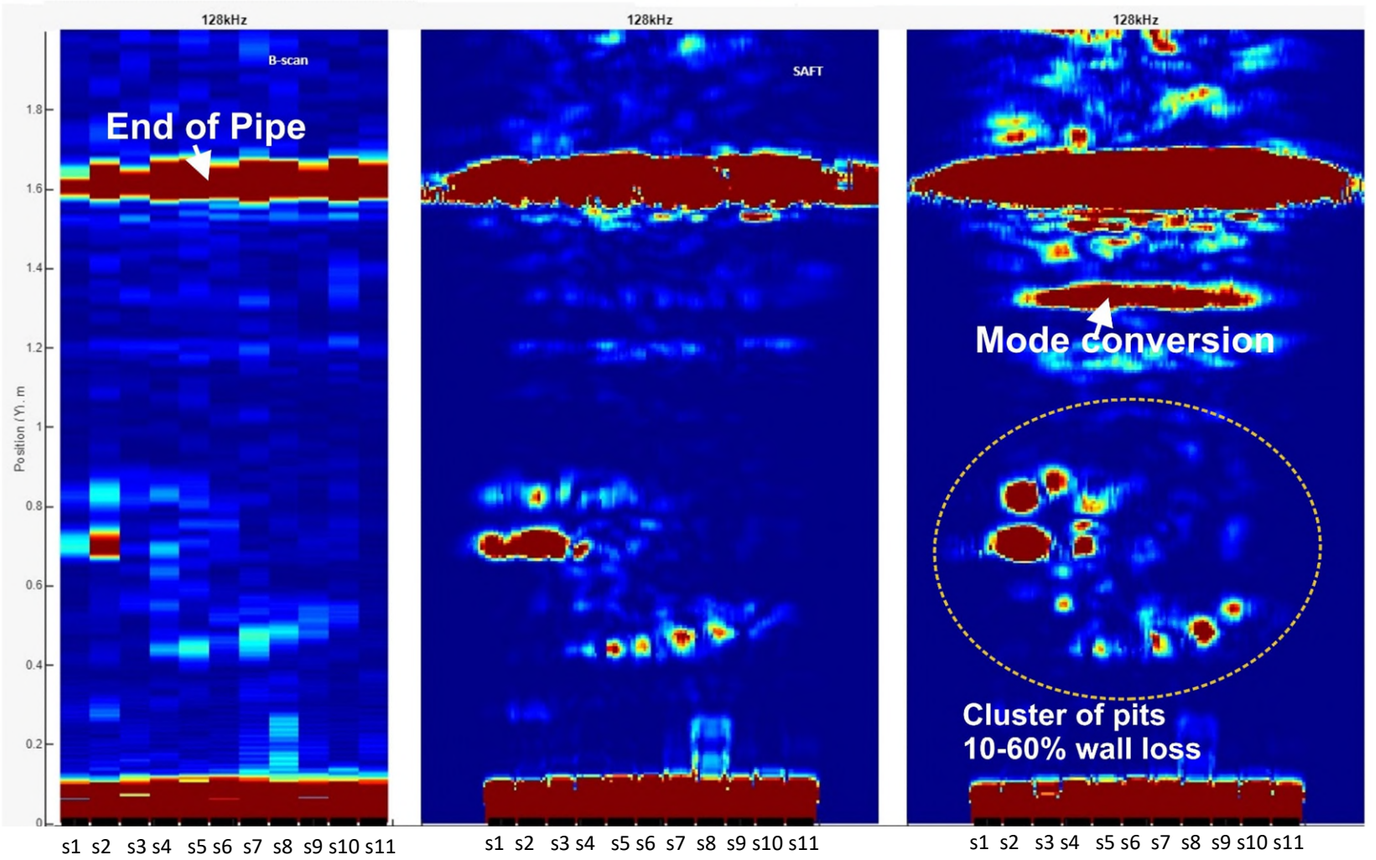
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Comparison of B-scan, SAFT, and TFM

Test Mockup



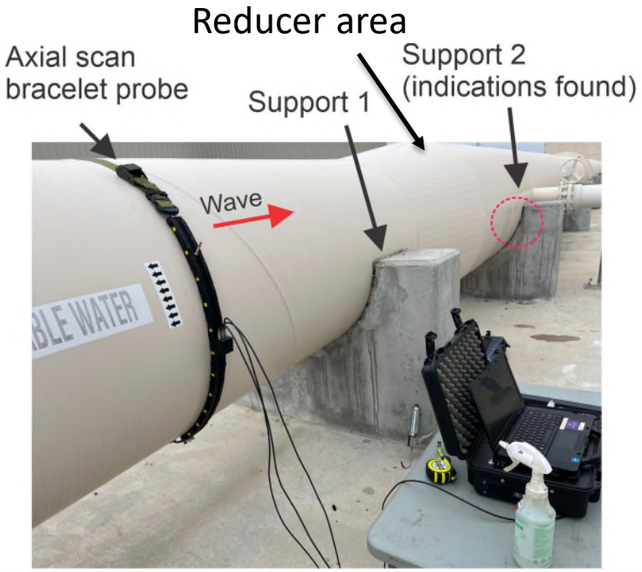
B-scan SAFT TFM

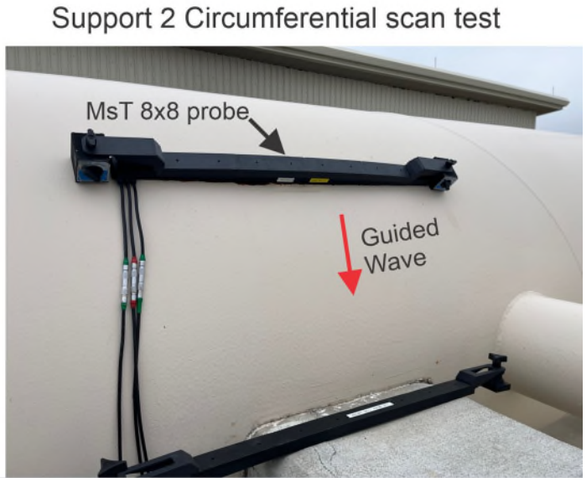


Based on this comparison, TFM image produced the most accurate map of pitting distribution

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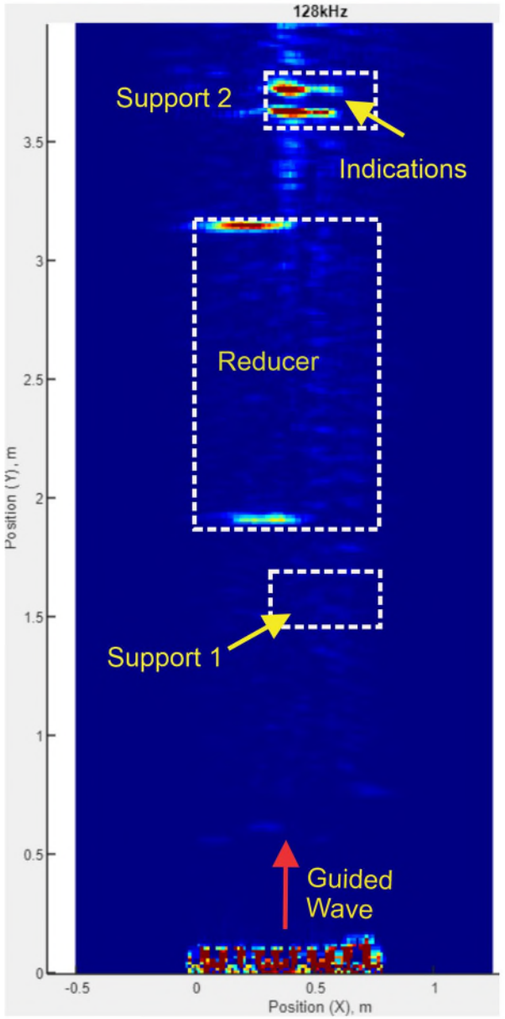
Concrete Pipe Support Screening Using Axial and Circumferential Scans



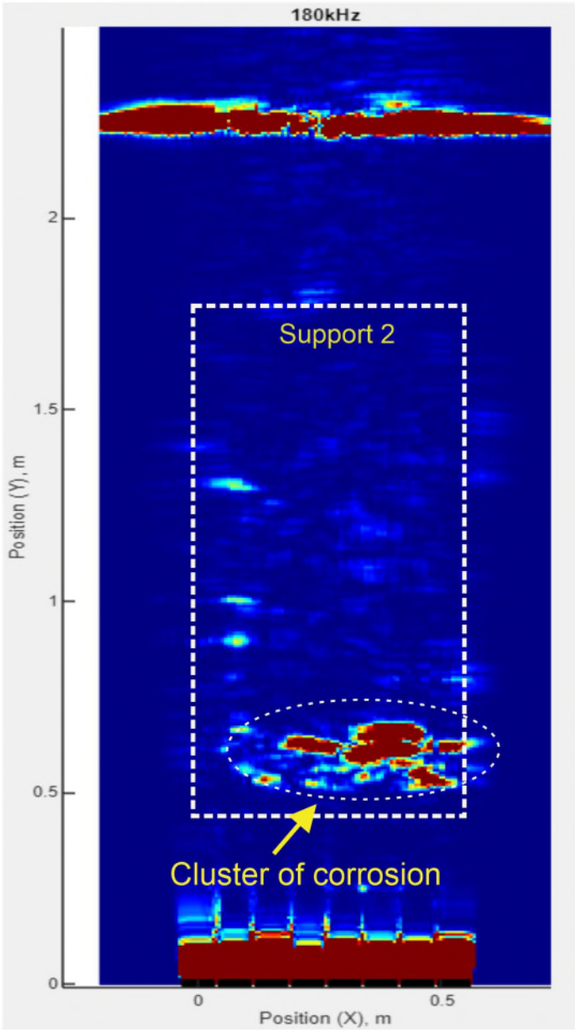


- Bracelet probe with 11 segments was placed on 1.07 m (42 in.) OD 10 mm (0.4 in.) wall CS pipe for axial scan
- Conditions under two concrete pipe supports were evaluated, with a suspect area found under support 2
- MsT 8x8 probe was placed on top of support 2 for a circumferential scan
- A corrosion cluster was identified at a distance 0.5 m (20 in.) from the probe)

Results of axial scan

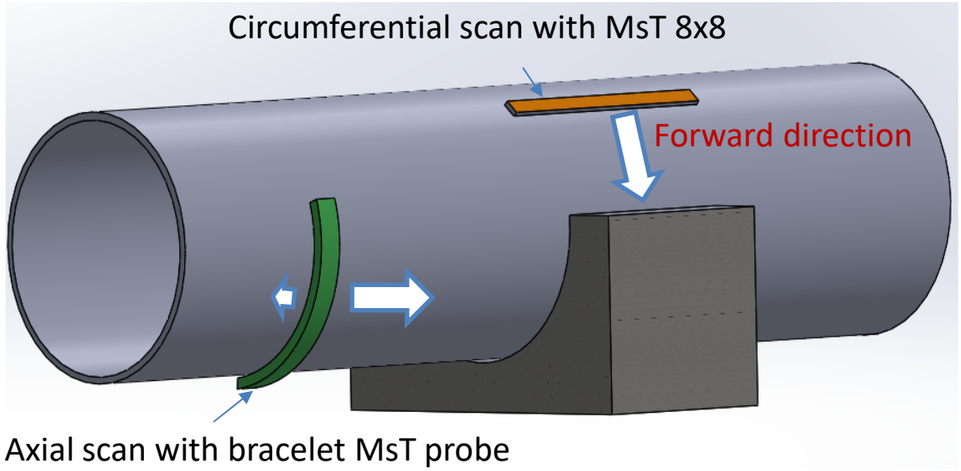


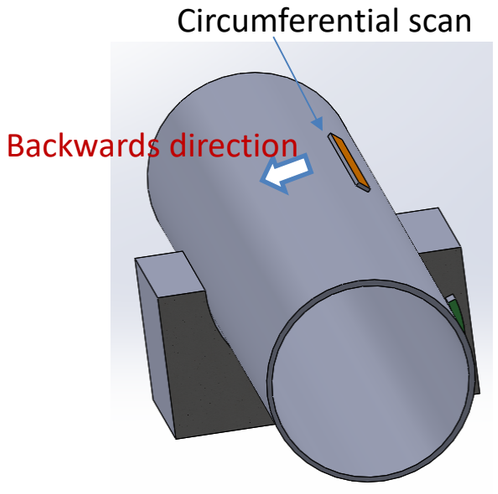
Results circumferential scan

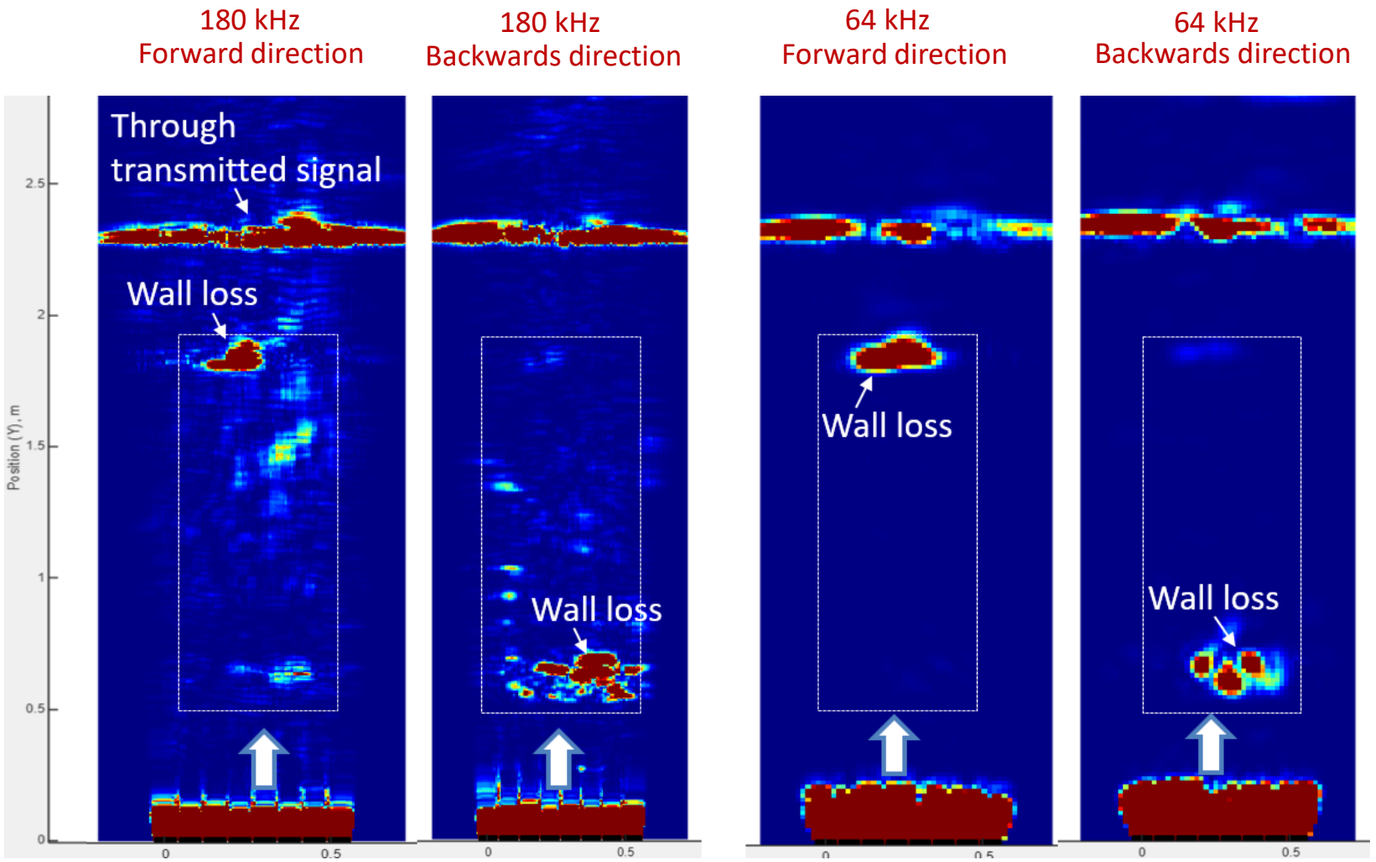


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Pipe Support Scans Options







- Guided waves can be sent in forward and backwards directions to look at the same area twice
- Multiple frequency (20 – 250 kHz) data can be collected automatically
- The probes have a very short dead zone - 100 – 150 mm (4 – 6 inches) from the area of interest.

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Example of Pipe Support Scans In good Condition

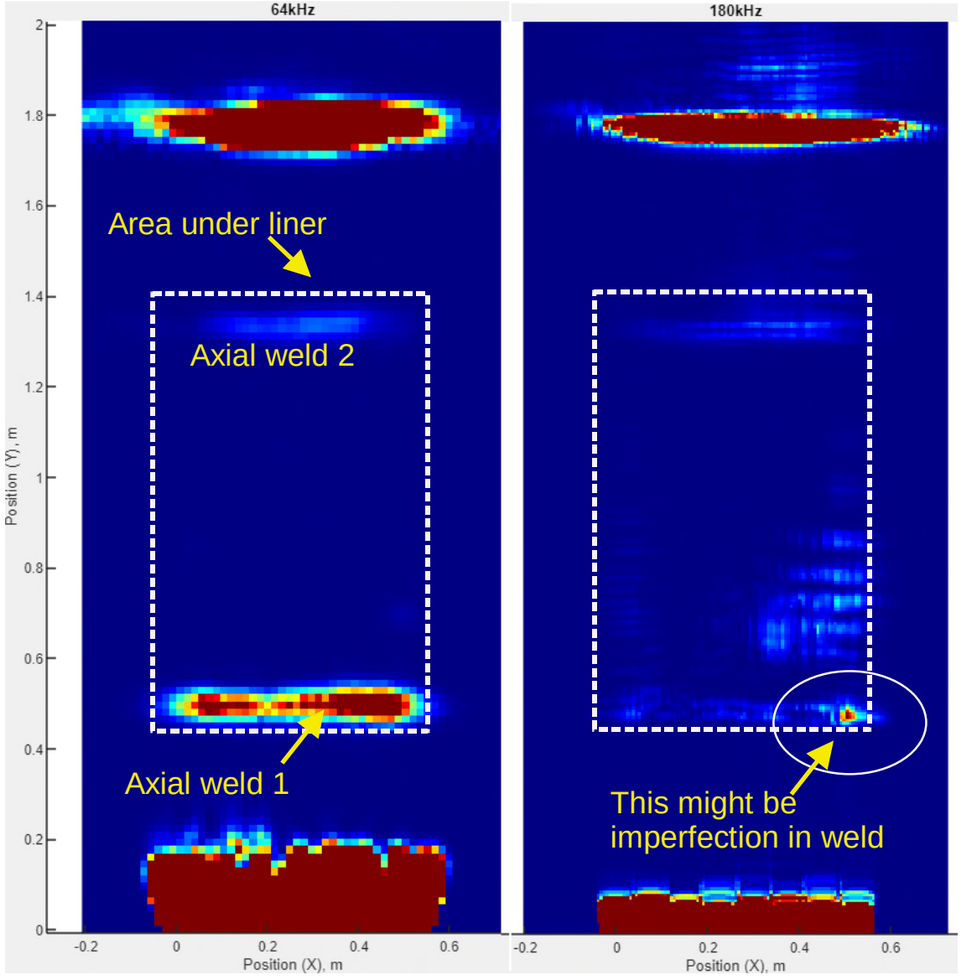
Support with axial welds



- Area under pipe support liner appeared to be free of defects.
- At 180 kHz the weld signal is small, probably because of destructive interference between the front and back edges of the weld.
- Cancelling out the main weld reflection reveals an anomaly in the weld at 180 kHz (shown in circle)

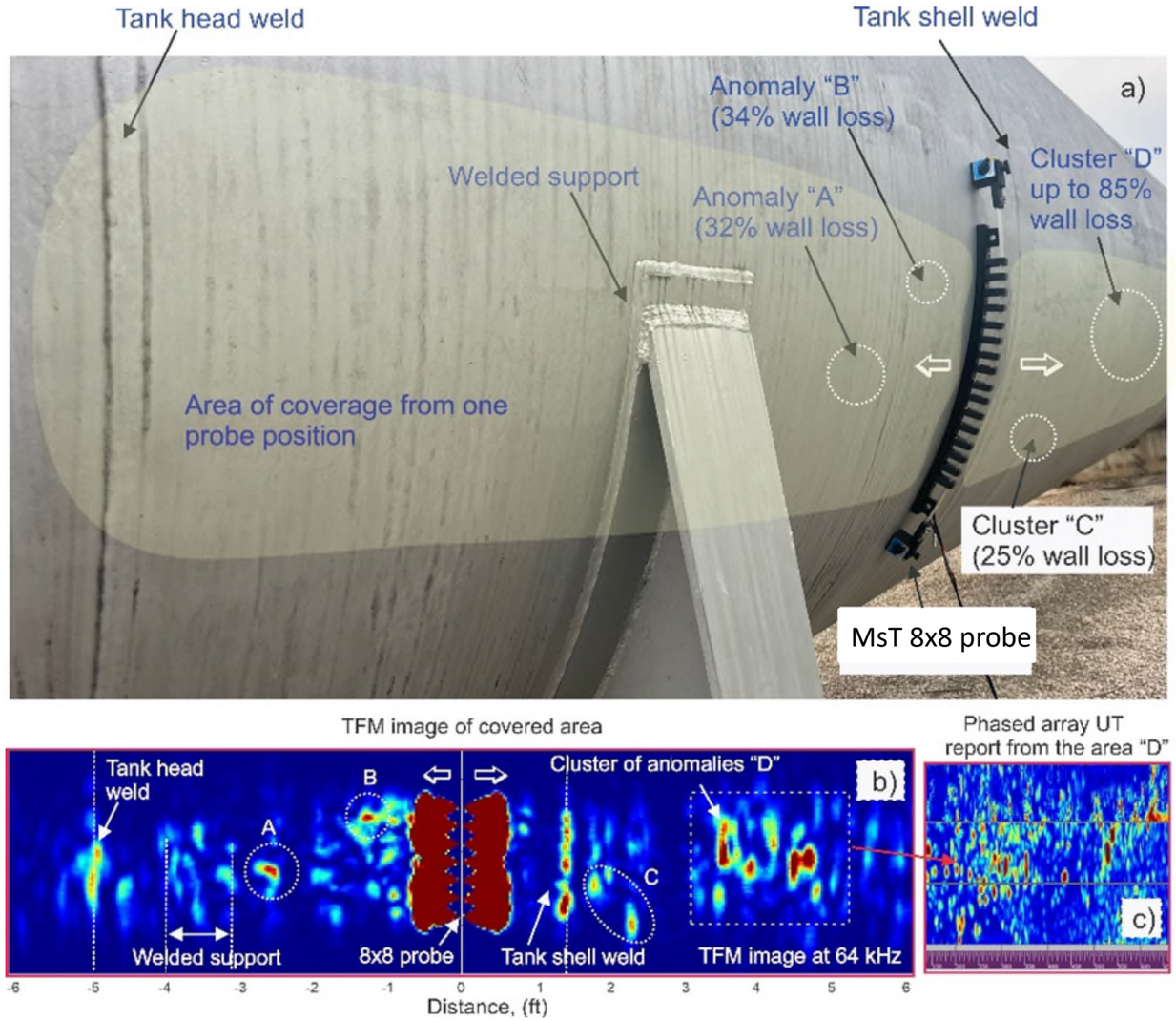
Results of circumferential scan at 64 kHz

Results circumferential scan at 180 kHz



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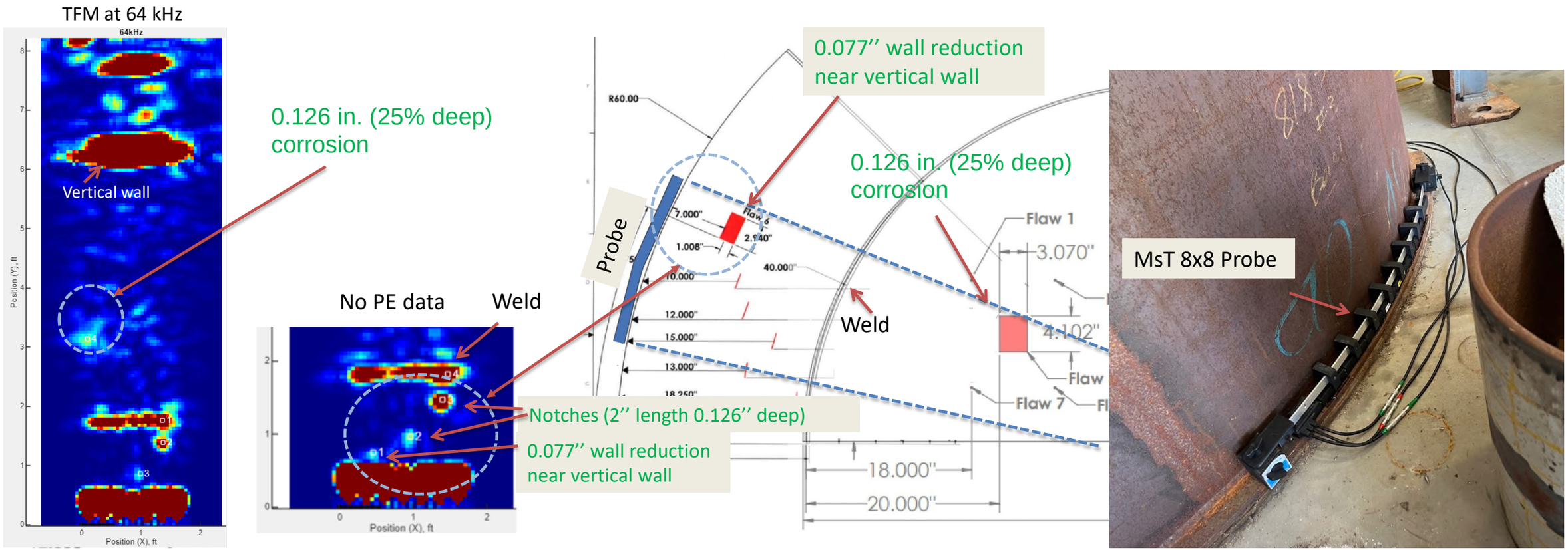
Detection of Pitting Corrosion in Storage Tank Walls



- The 40-year old storage tank has verified wall loss up to 90% in 9.5 mm (0.375 inch) wall
- Coverage range at 60 kHz was 6 ft in both directions
- Two welds – cap weld and a shell weld - were clearly detected from both sides of the probe together with four other areas (A.B,C,D) that were identified as suspected corrosion clusters
- Cluster D was later mapped using a UT phased array wheel probe. The resulting scan over area D is shown in c Based on phased array probe reading, the most severe wall loss in the area reached 85%
- Note PA inspection requires a good inner surface reflection; this is not always available with severely corroded structures
- The corrosion morphology was rather complicated, but the location of the deepest damage observed by PA correlated well with the map produced by the 8x8 probe
- The tank support had welds on both sides; the guided waves covered the area under the support

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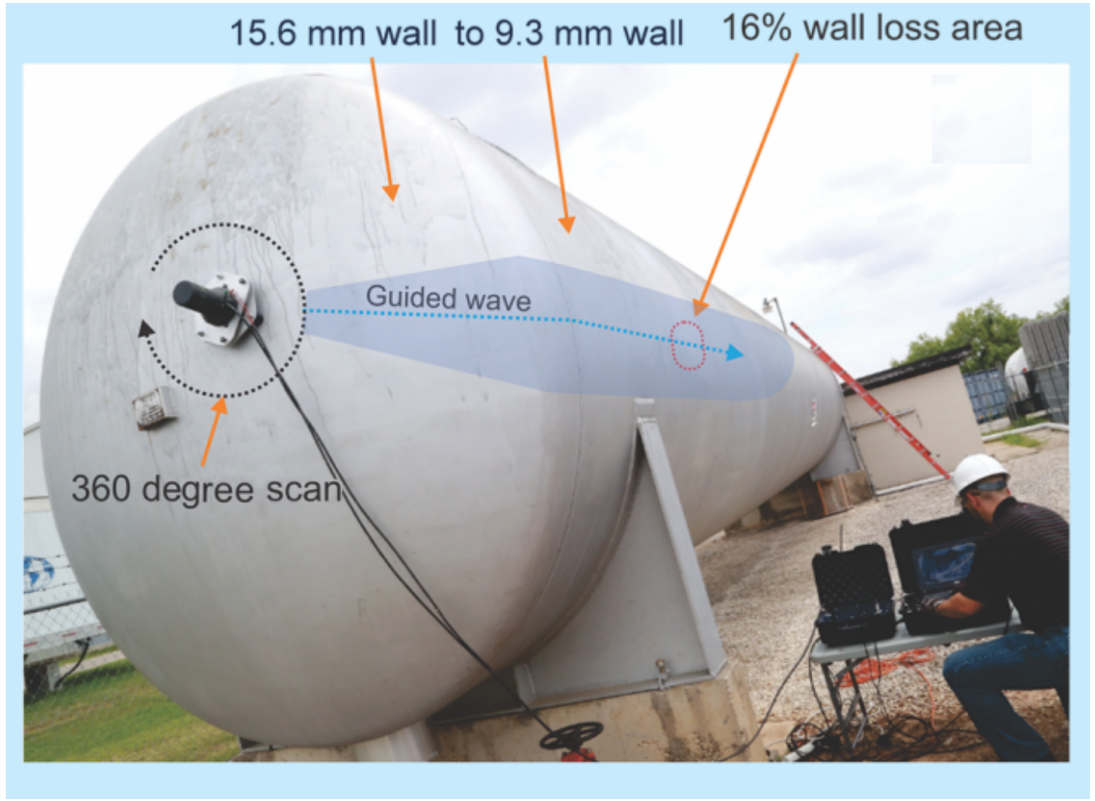
Detection of Anomalies in Storage Tank Bottoms

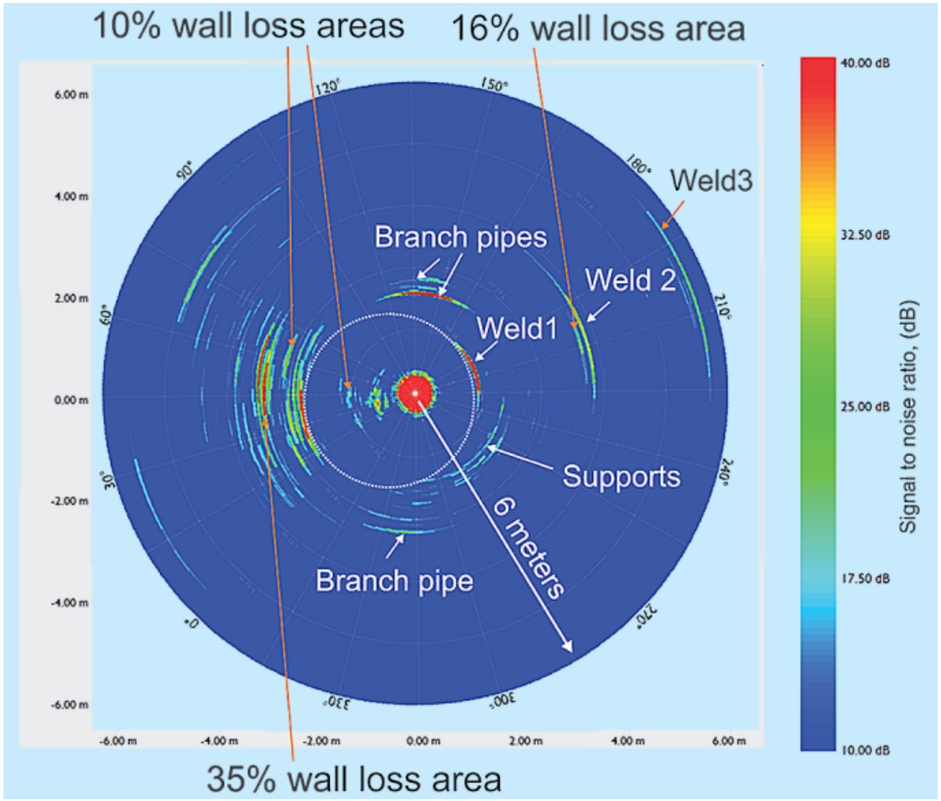


- The mockup represents a 3.65 m (12 ft) diameter storage tank with 12.6 mm (0.5 in.) thick bottom plate and 6.3 mm (0.25 in.) thick vertical wall
- 2 mm (0.077 inches) or 15% wall reduction near vertical wall was detected at 178 mm (7 inches) distance from the vertical wall
- 2.4 mm (0.126 inches) or 25% deep corrosion was clearly detected at 64 kHz 3 ft from the probe
- Notches 3– 5 (25% depth) were detected at 64 kHz

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MsT 360: Automated Scanning of Large Shells for Corrosion





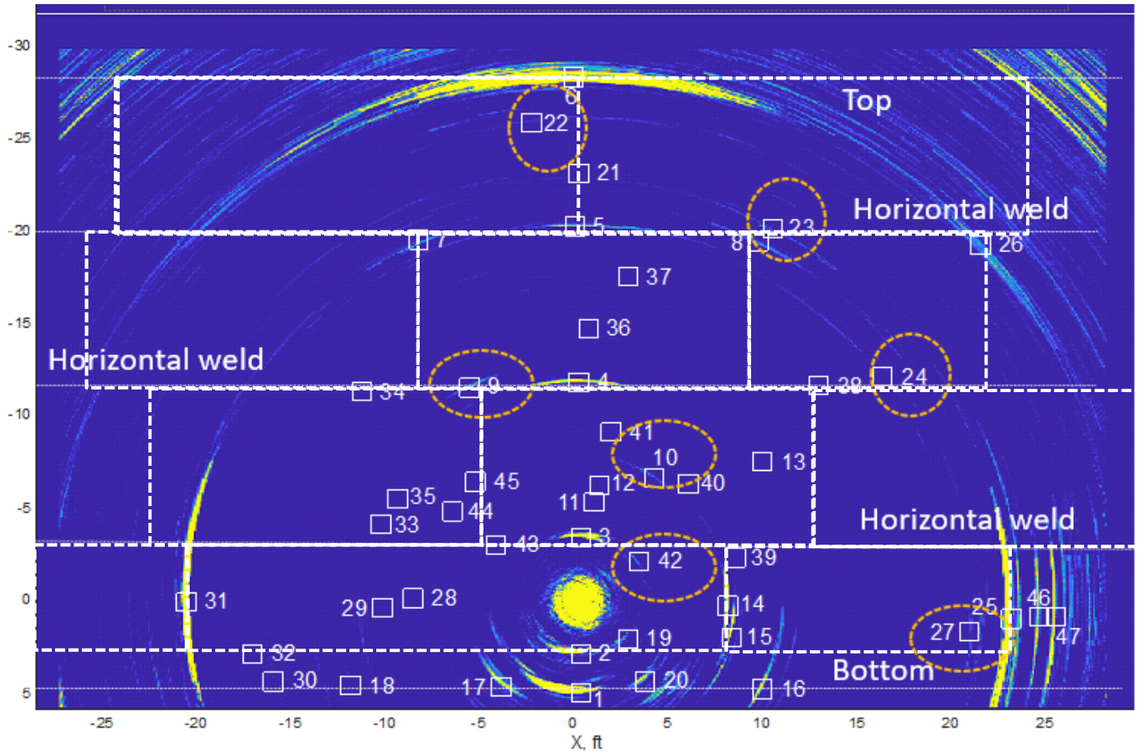
- Standard frequencies of 20-250 kHz; Up to three frequencies can be acquired at a time
- Probe rotated in 0.2 to 5.0 degree increments
- Shear Horizontal mode guided waves is used for testing
- The area of probe coverage is 10-100 square meters, depending on the structure's geometry and condition
- Cost-effective solution for screening of corrosion under insulation, including applications with up to 90°C wall

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Scanning of Large Shells for Corrosion: Reporting







- Data were acquired from storage tanks with surface temperature up to 90° C
- Portable probe design allowed installation using rope access
- Indication reports were generated taking into account all known geometry features of the vessel
- Typically, all welds, plate corners, welded attachments, and branch piping produce indications

N	X position	Y position	Suggested origin
24	16.4	-12.1	Indication
25	23.2	1.0	Vertical weld
26	21.6	-19.2	Plate corner
27	21.0	1.7	Indication
28	-8.5	-0.1	Indication

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Conclusions

- New magnetostrictive probes and instrument with automated data acquisition function have been developed
- Utilization of array probes, FMC data acquisition and TFM based imaging allows generation of accurate 2D corrosion maps over a wide area (examples included pipes, pipe supports, storage tank supports, storage tank bottoms and walls)
- Experimental tests on mockups and field tests indicate that this method can provide much better reporting capability for multiple cases, including detection of pits and notches in free spans and in hidden areas
- MsT 360 Omni-directional probe could be utilized for initial scans of large (up to 100 square meters) areas from one probe position. Suspect areas could be tested using array probes for obtaining detailed corrosion map

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Thank you!



Questions?

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