Tube Support Plate Characterization with the Eddy Current Array (ECA) Technique

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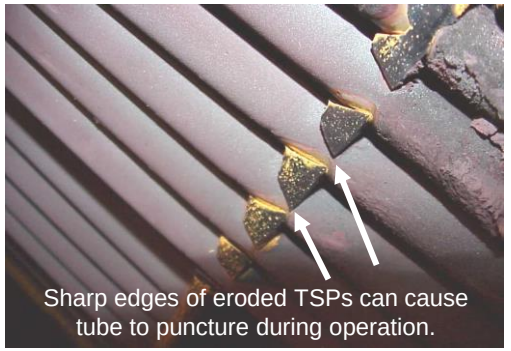
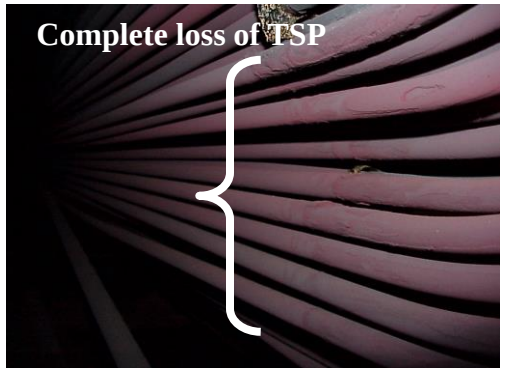
Annual NRC-Industry NDE Technical Information Exchange Meeting
Wednesday, January 22, 2025 – NRC Headquarters, Rockville, MD

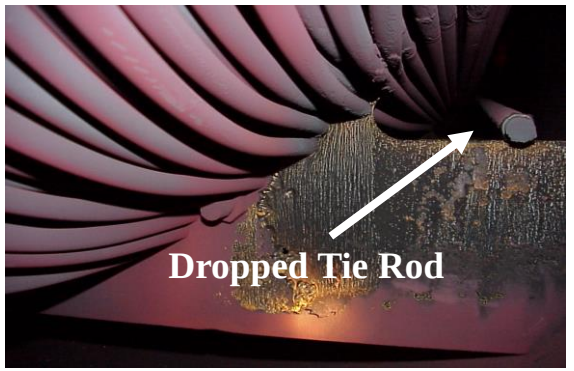
Driver

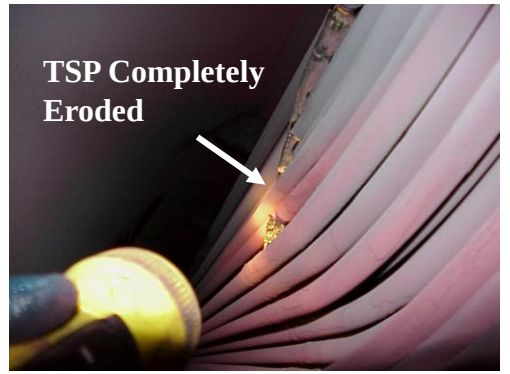
- Tube support plate (TSP) degradation occurs in feedwater heat exchangers.
- Bobbin coils can detect TSP damage but cannot characterize the extent of the damage in three critical areas;
  - **TSP Thinning**
  - **TSP Circumferential Loss**
  - **TSP Gap Opening**

Operating Experience from Low Pressure Feedwater Heaters



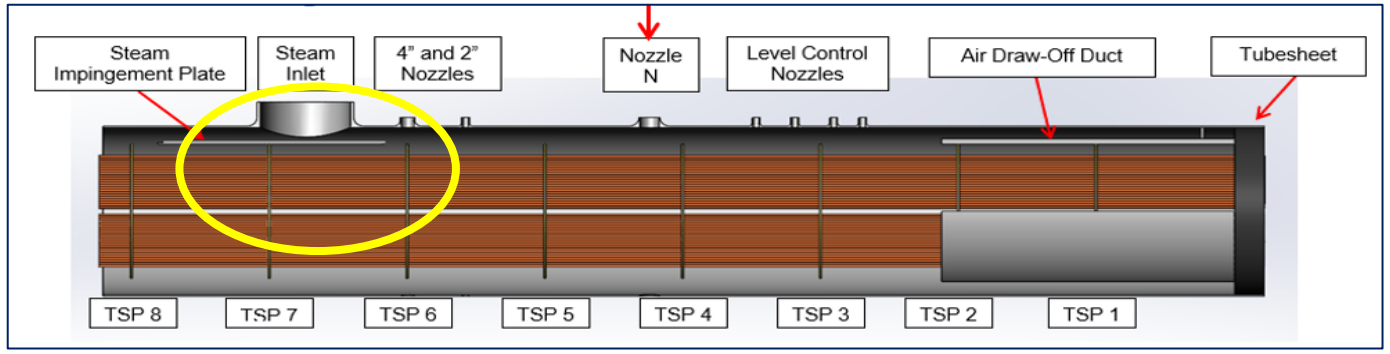


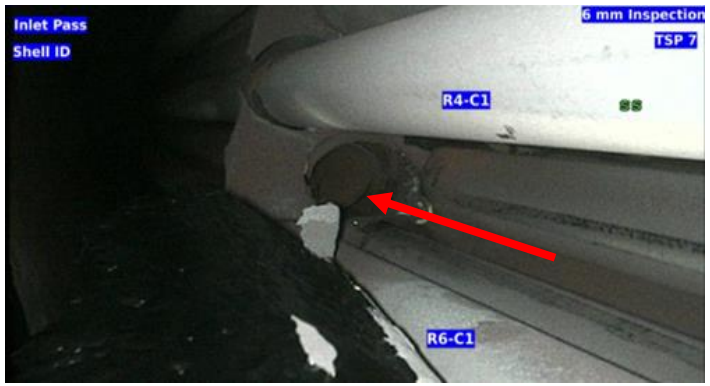


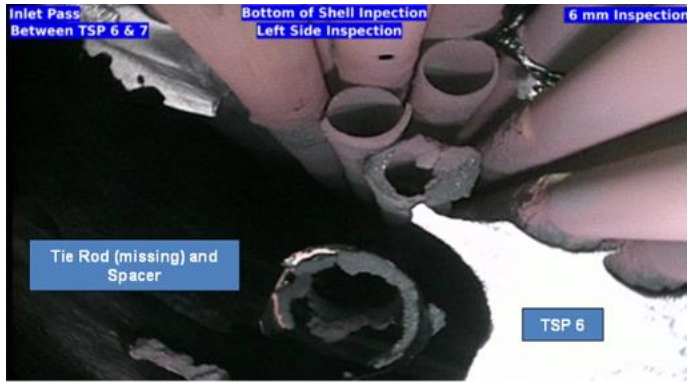


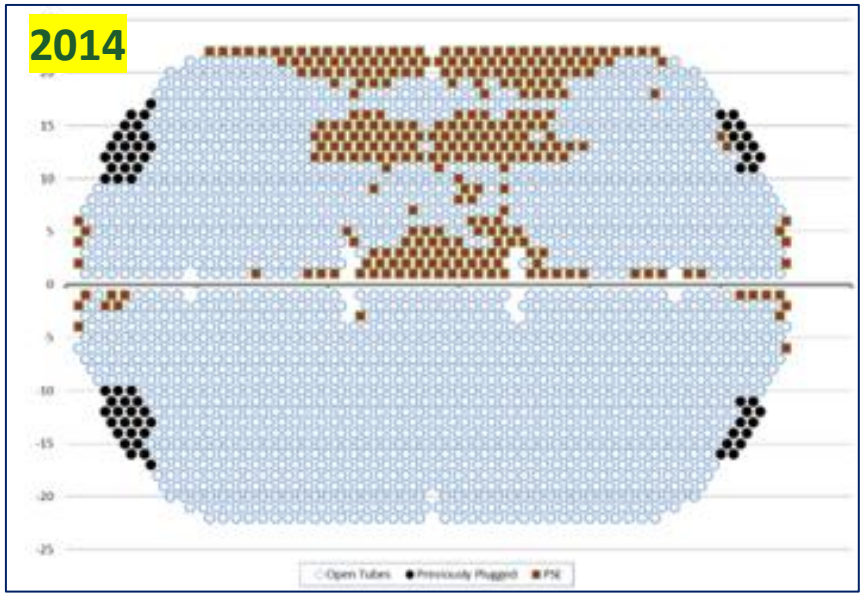
TSP Degradation

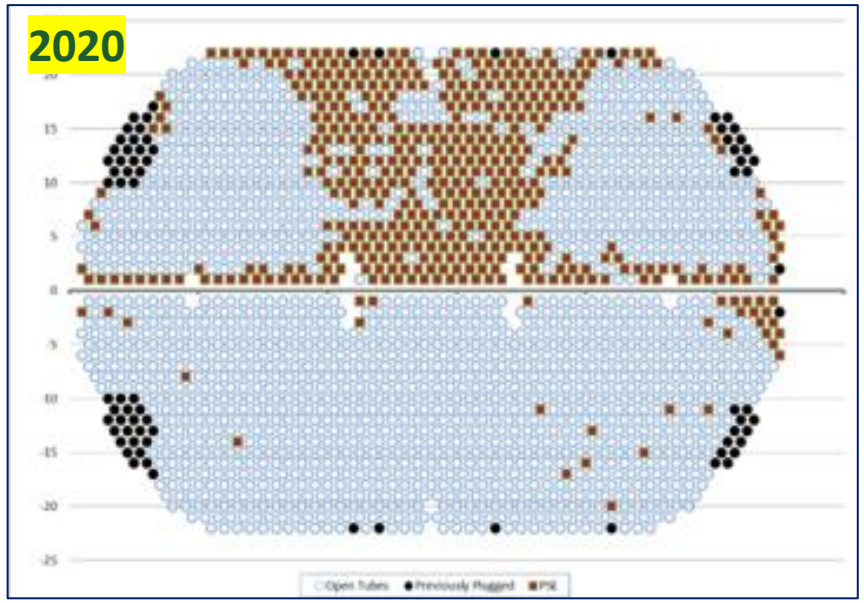
- TSP locations # 6 and #7 reflected on tube sheet map.
- Indications also found at other TSP locations.











EPRI Research

Research Approach

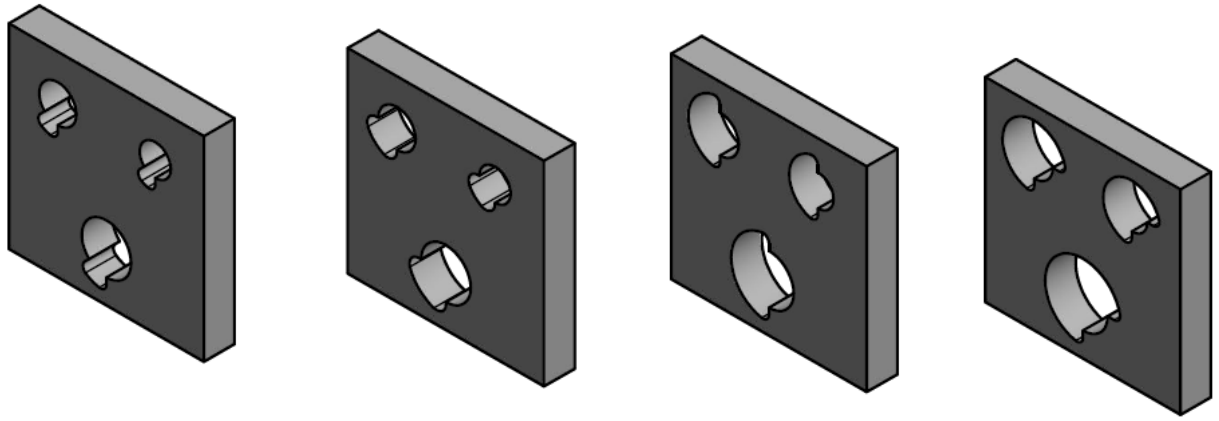
- 7 mockups were fabricated.
- Mockups contain three different tube sizes set in varying levels of TSP degradation.
- Tubes include fabricated flaws: ASME pits, OD wear / thinning, OD axial and circumferential notches.
- A combination bobbin / array probe is used to investigate:
  - Tubing defects
  - TSP degradation *(Thinning, Circumferential Loss and Gap Opening).*

Mockups Used in the Research

Types of Tube Support Plate Degradation

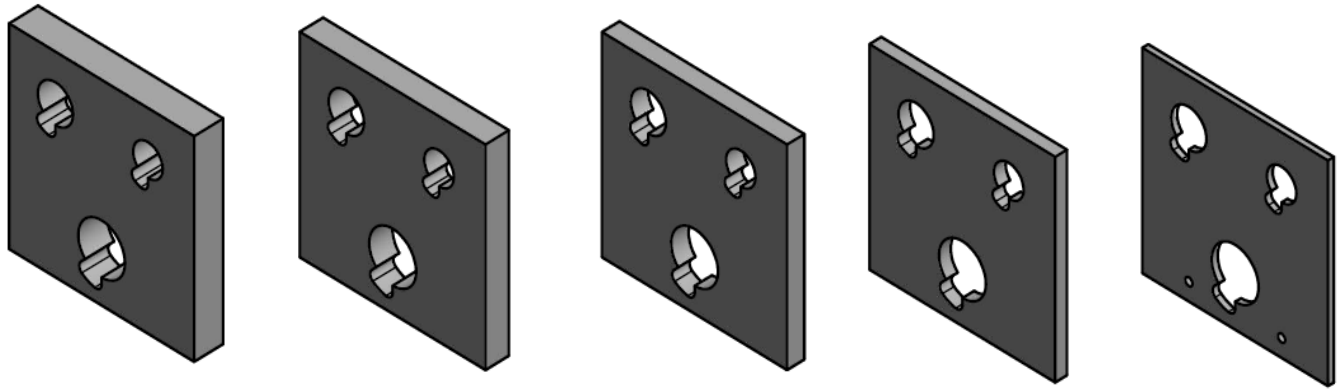
Circumferential Metal Loss:

45°, 90°, 180°, and 270°. Each mockup contained one nominal TSP with 100% contact to the tube



TSP Thinning:

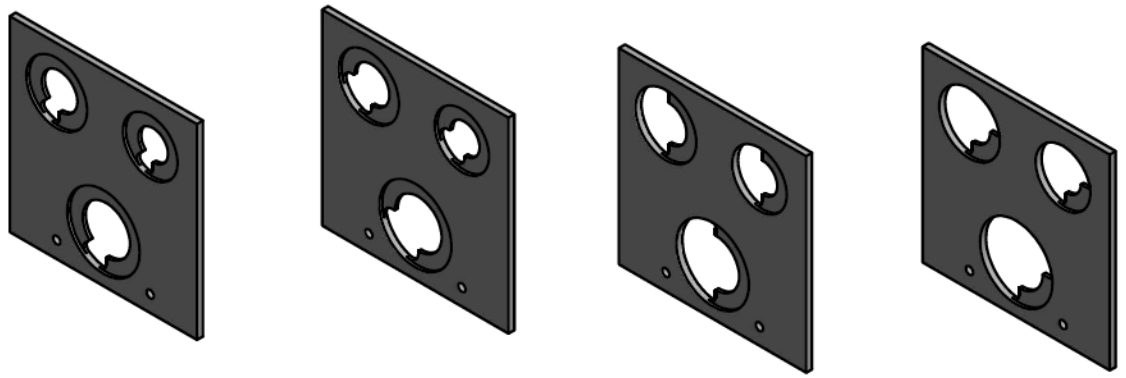
0.625”, 0.500”, 0.375”, 0.250”, 0.125”



Types of Tube Support Plate Degradation

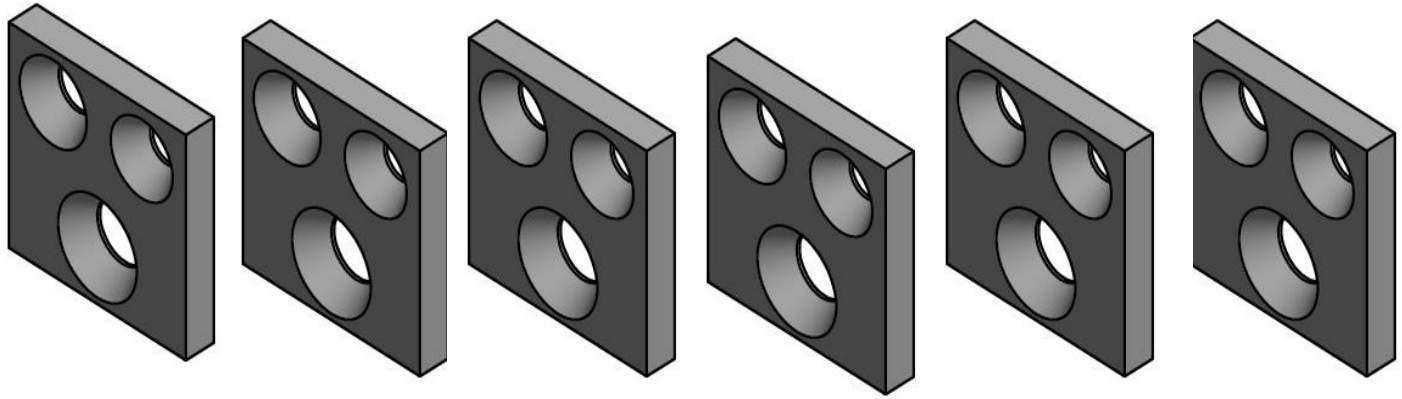
0.125” plate thickness with 50% base wall removed and circumferential metal loss:

45°, 90° 180° and 270°



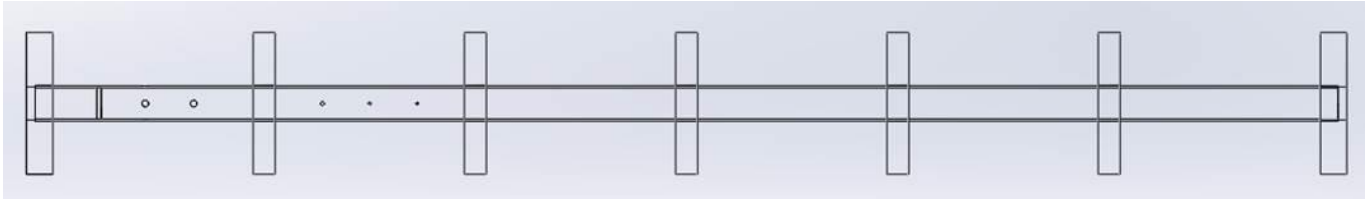
Funneling damage with increasing gap spacing from tube to TSP:

0.008” 0.013” 0.024”, 0.034”, 0.048”, 0.065”

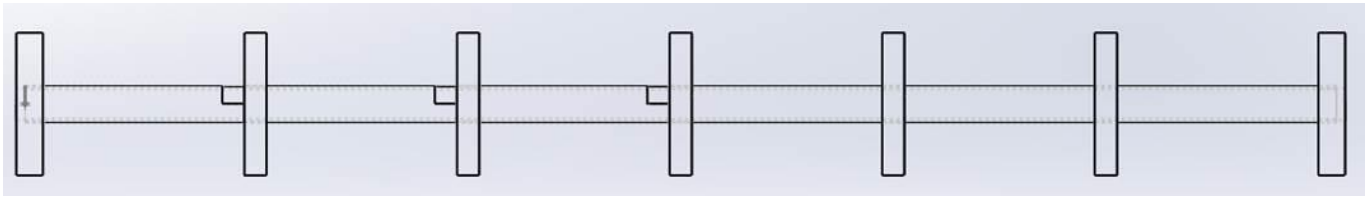


Tube Defects Added to the Tube Support Plate Mockups

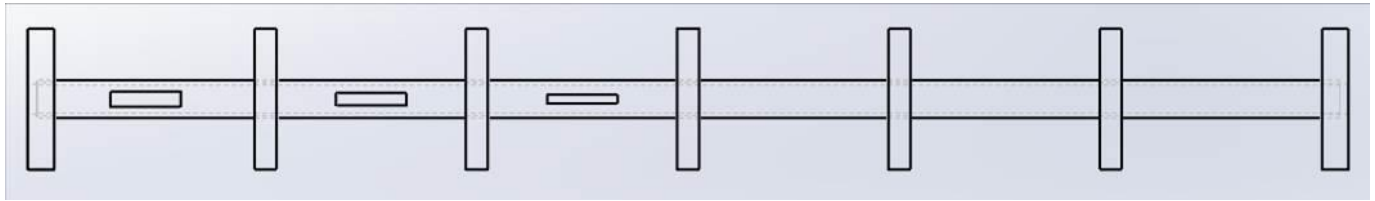
ASME Pits



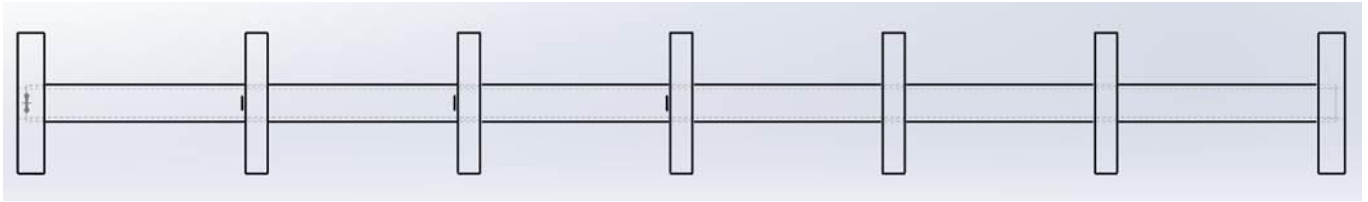
180° OD Wear



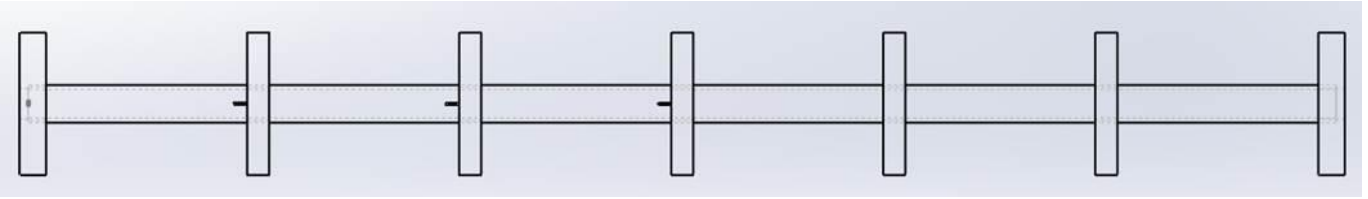
OD Thinning



OD Circumferential Notches



OD Axial Notches



Eddy Current Array (ECA) Probes

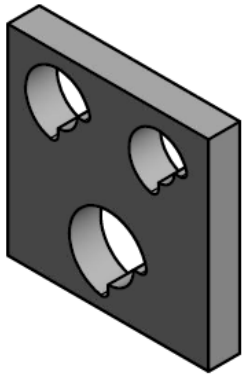
Two ECA probes from different vendors were used to acquire data from the TSP mockups.

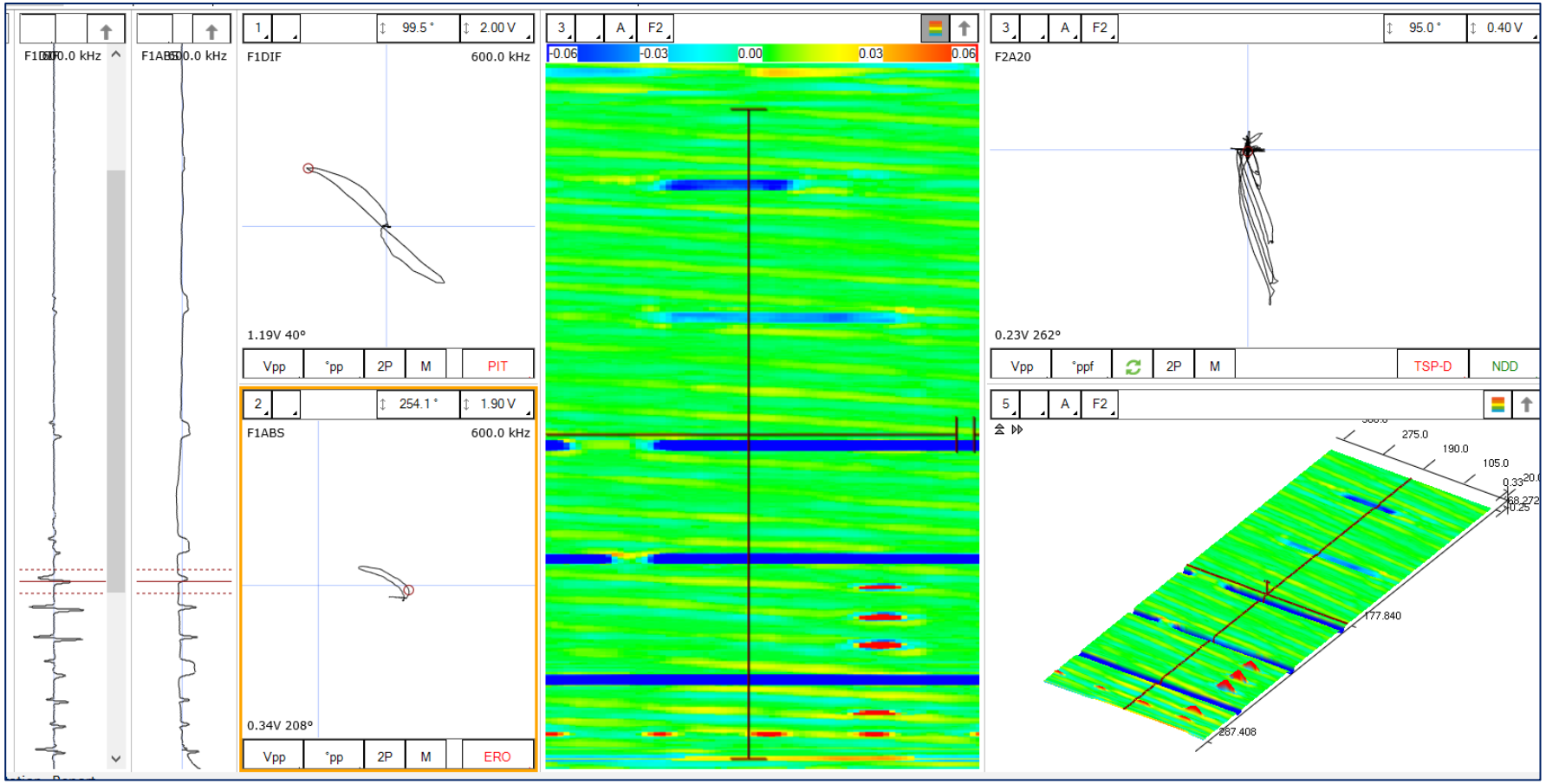
Each probe has three data channels:

- Bobbin Channel.
- Circ. Channel (sensitive to circumferential cracks).
- Axial Channel (sensitive to axial cracks).

Detection of TSP Circumferential Metal Loss *(Probe 1)*

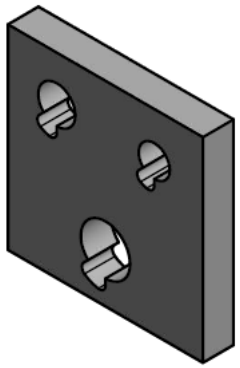
Circumferential Metal Loss: 45°, 90° 180° and 270° (0.625” TSP)

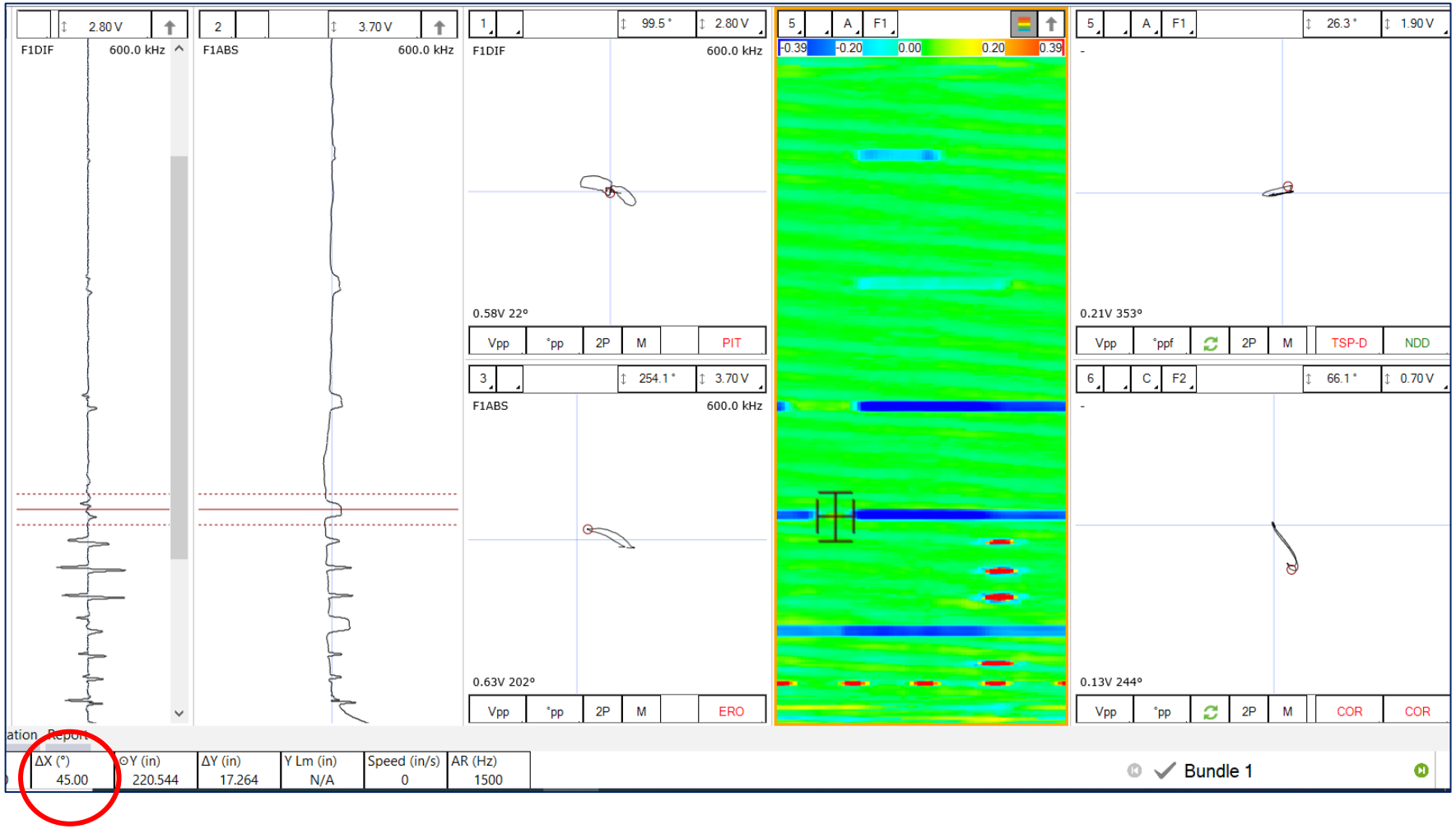




Angular Measurement of TSP Circumferential Metal Loss

45° TSP Degradation (0.625” TSP)



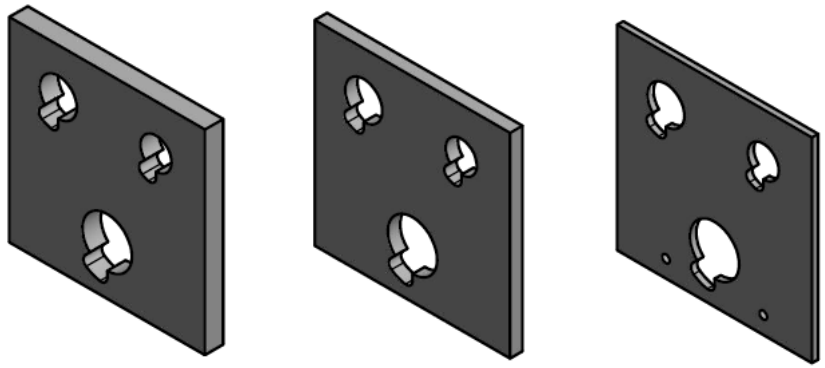


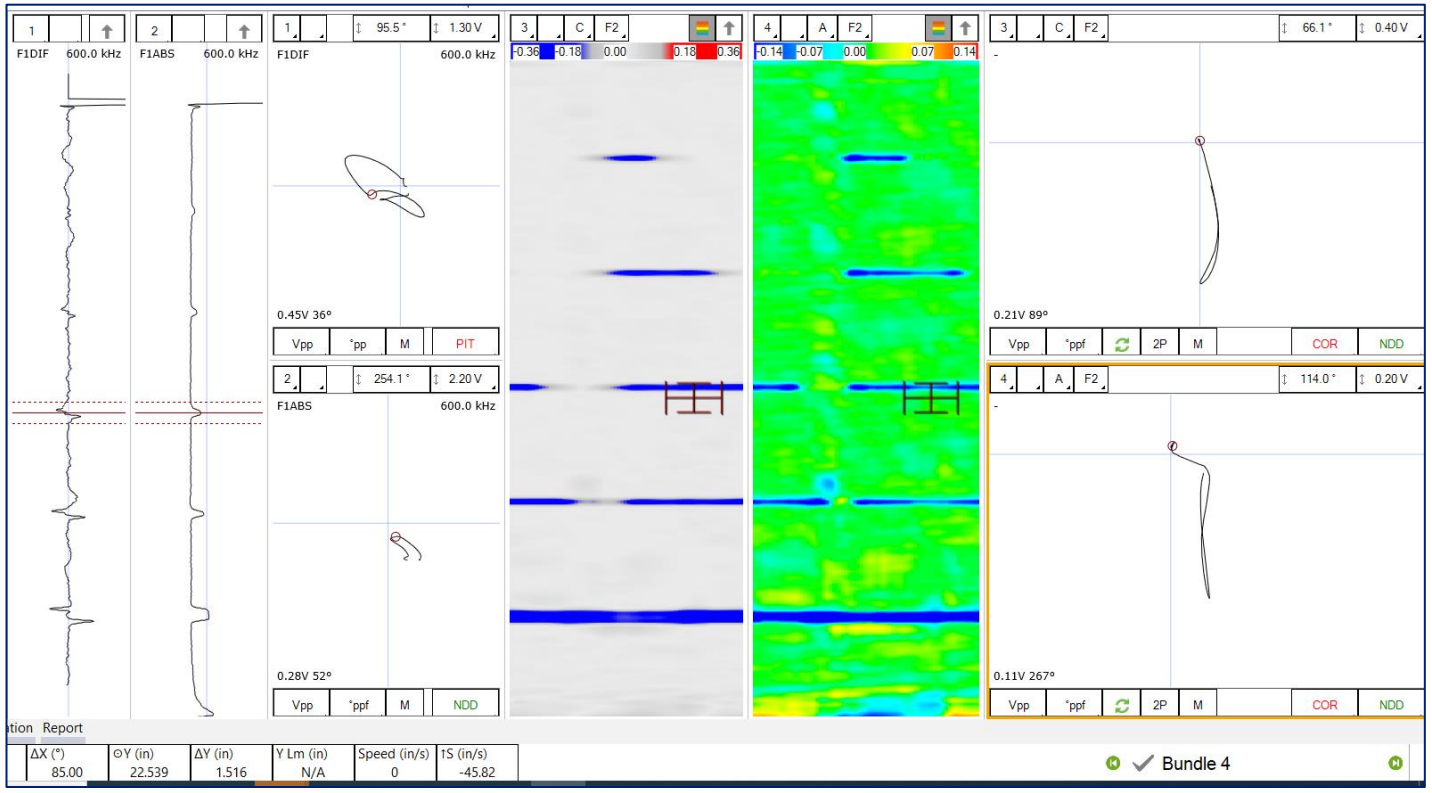
Detection and Measurement of TSP Thinning

Comparison of 0.625” and 0.250” TSP Width.

Two methods to measurement TSP thinning (encoded data or TSP amplitude-based calibration curve).

- Encoded data allows sizing of TSP thinning utilizing only the measurement cursor.
- Lissajous display utilized to characterize TSP thinning.
- Amplitude based sizing curve.





Detection of Circumferential Loss with Thinning

0.125” plate thickness

50% base wall removed

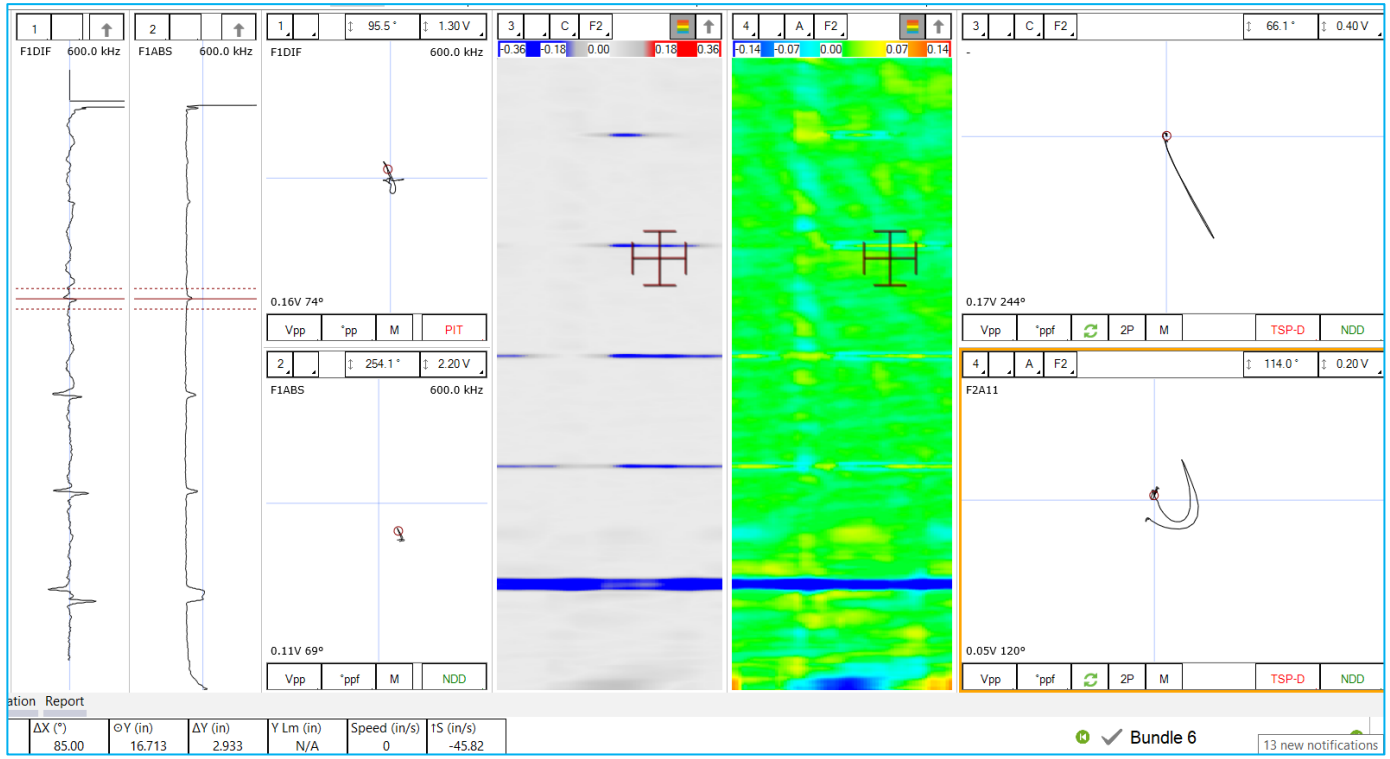
Circumferential metal loss: 45°, 90°, 180°, 270°

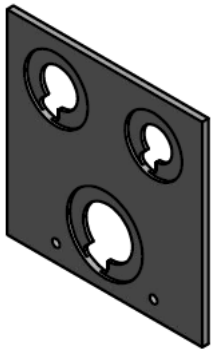
Circ. Channel F2:

Plate thinning detected.

Axial Channel F2:

Additional 50% thinning characterized by upward formation of Lissajous signal.





Detection and Measurement of Tube to TSP Gap

Funneling damage with increasing gap spacing from tube to TSP:

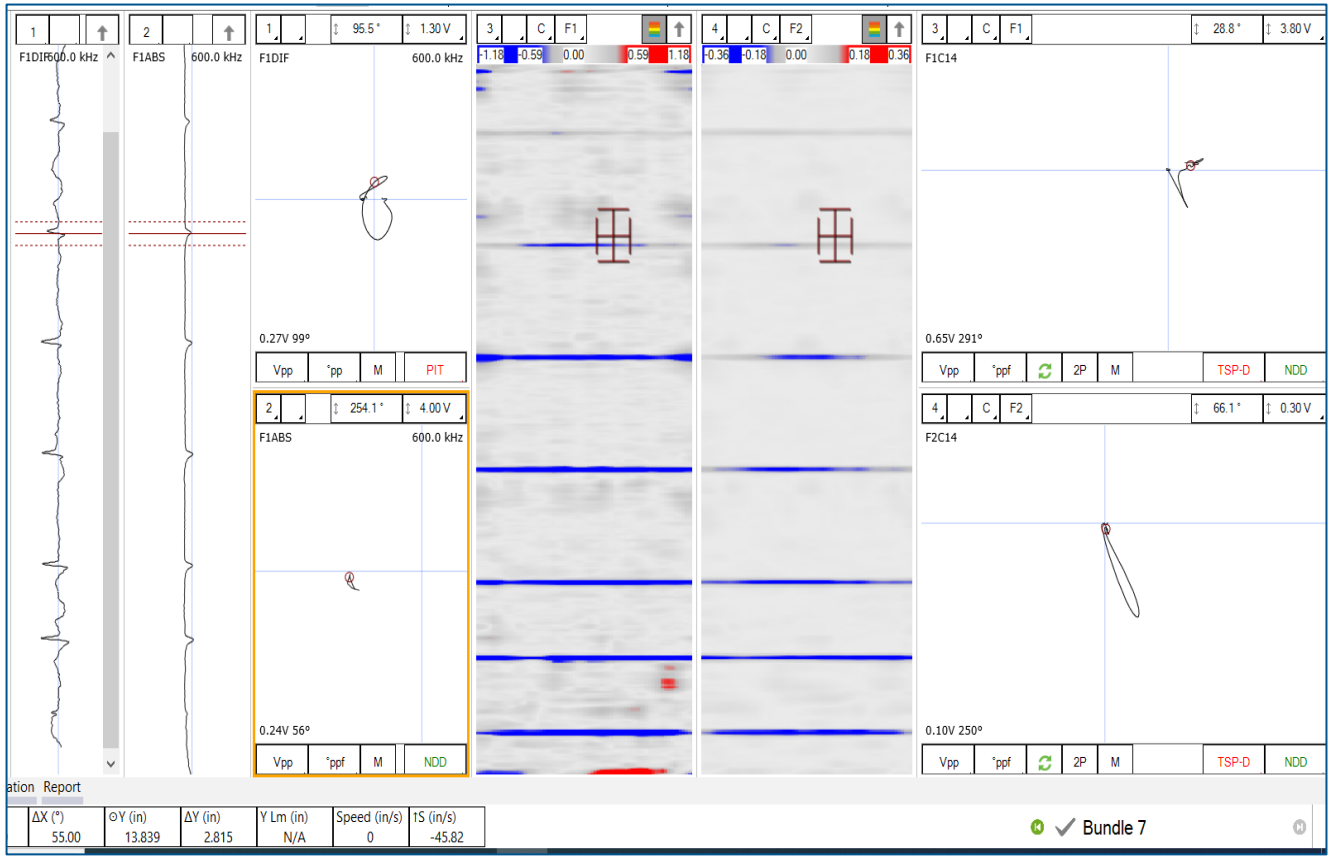
0.008” 0.013” 0.024”, 0.034”, 0.048”, 0.065”

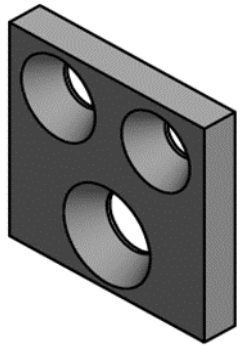
Circ. Channel F2:

Funneling induced plate thinning detected.

Circ. Channel F2:

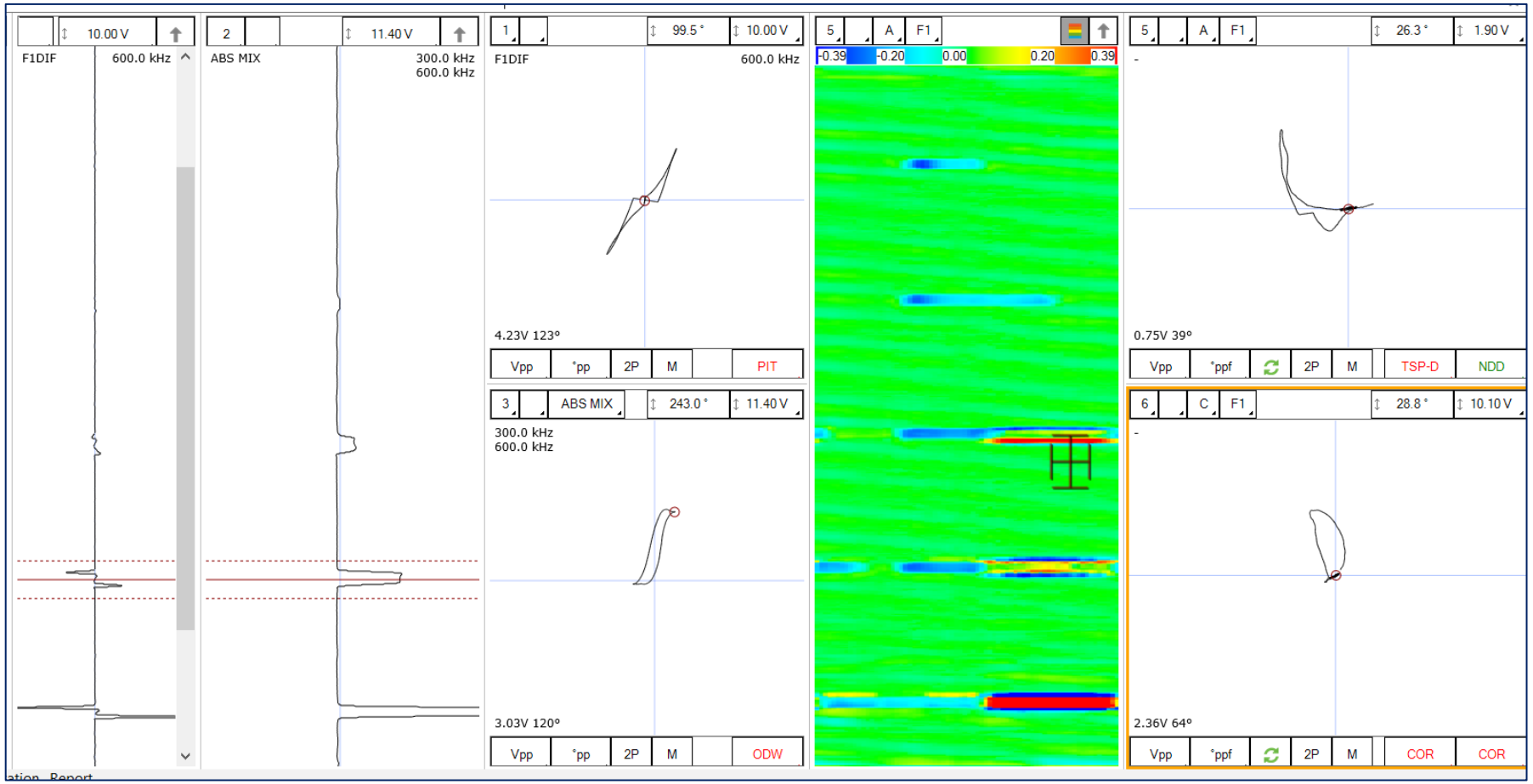
Detect uniform 360° TSP metal loss. Measure gap spacing based on signal amplitude. Work in Progress





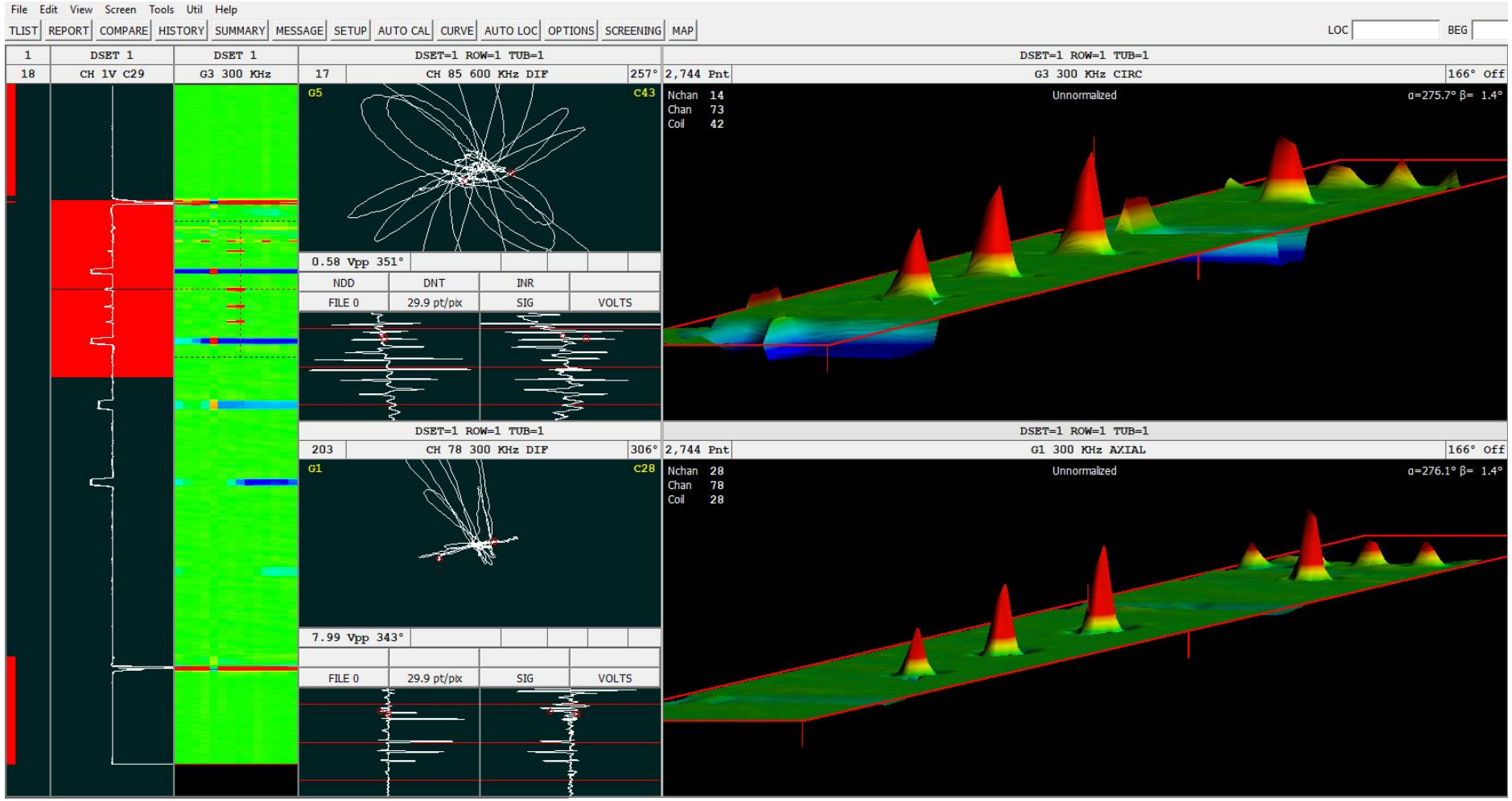
Detection of Tube Defects Under TSP

50% OD wear under TSP



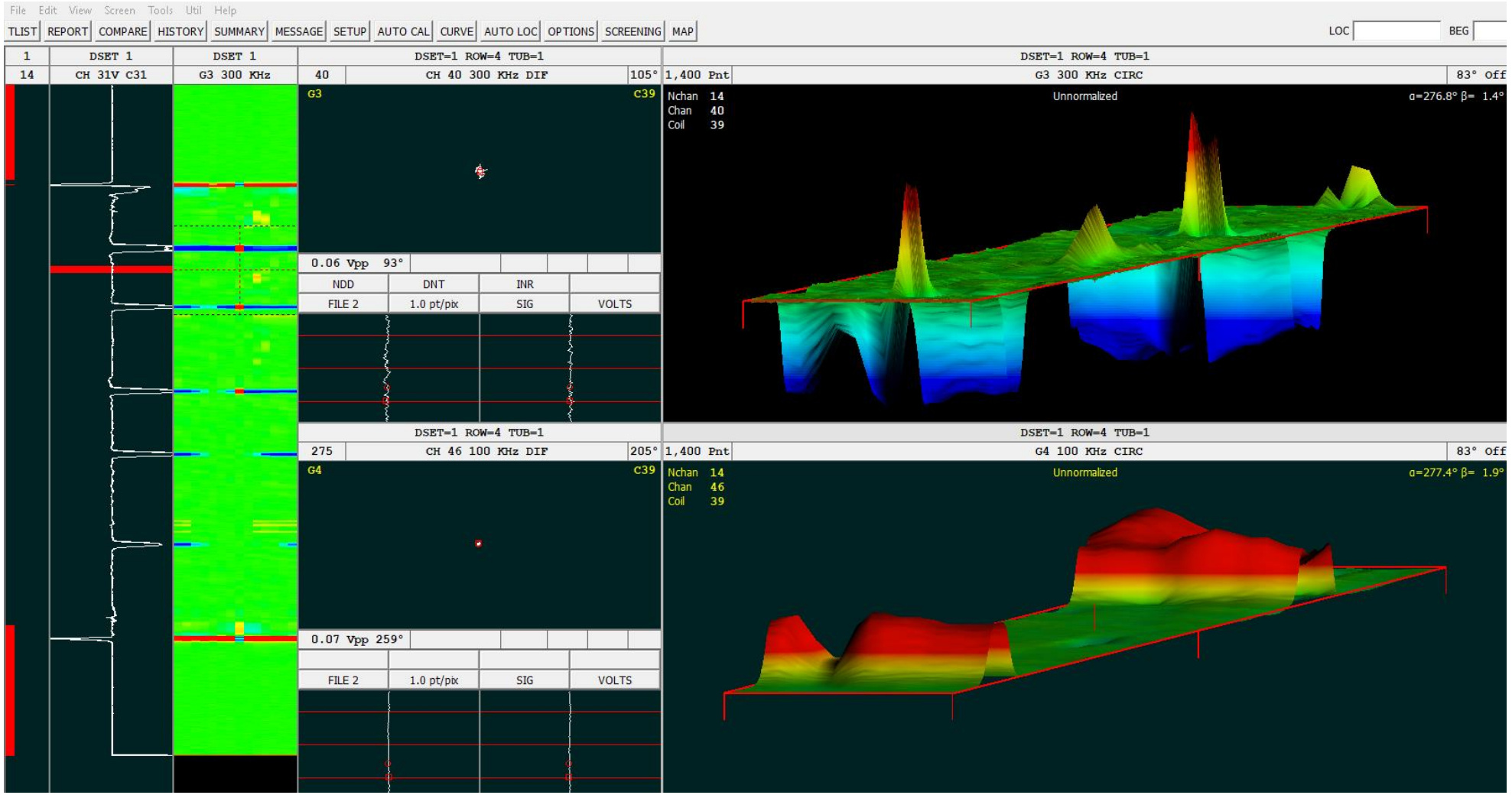
Detection of Tube Defects in Free Span Region *(Probe 2)*

ASME Type Standard Flaws in Circ and Axial Channels



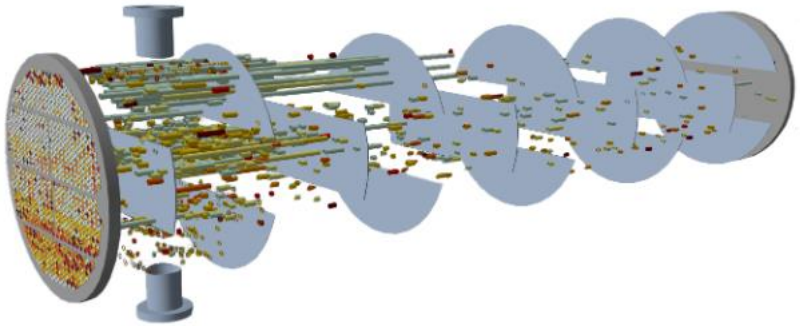
Detection of Tube Defects in Free Span Region

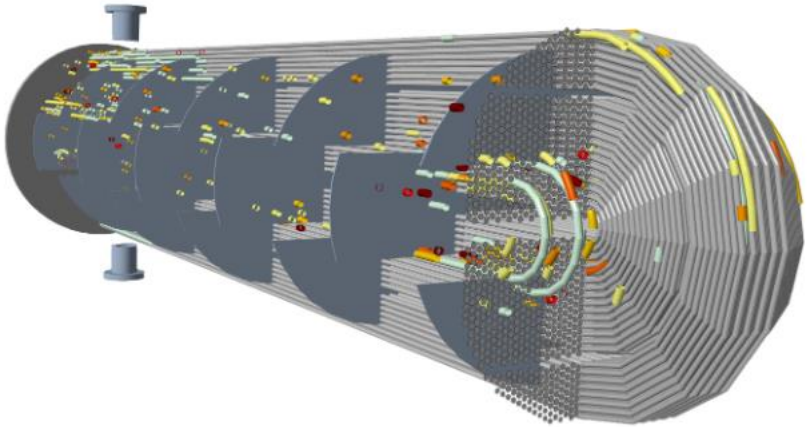
Nominal TSP and 45° TSP Loss Signals



Summary – ECA for Tube Inspection

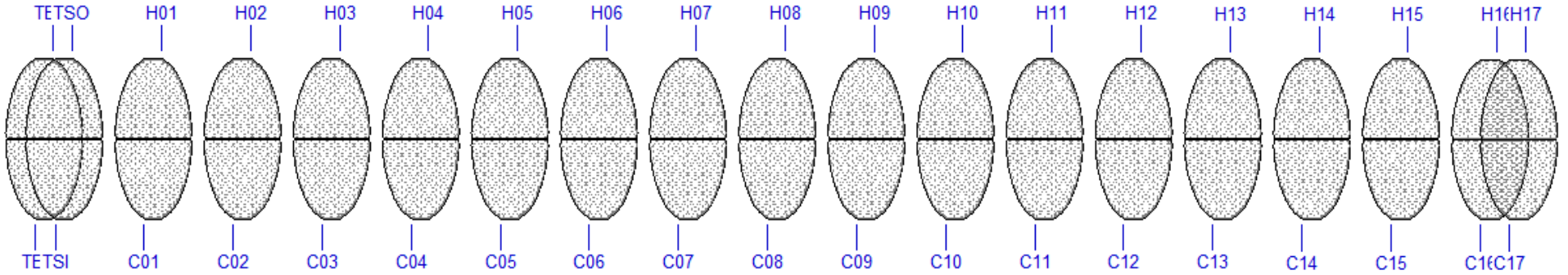
- ECA probes have both standard bobbin coil as well as the sensitive array coils.
- ECA probes are capable of advanced defect detection, characterization and sizing for the heat exchanger tube lengths including regions below the tube sheet.
- Analysis of ECA tube inspection data in conjunction with 3D heat exchanger bundle models allows for a comprehensive interrogation of tube wall damage mechanisms throughout the entire bundle.
- Root cause damage mechanisms related to tube integrity can be identified and arrested.





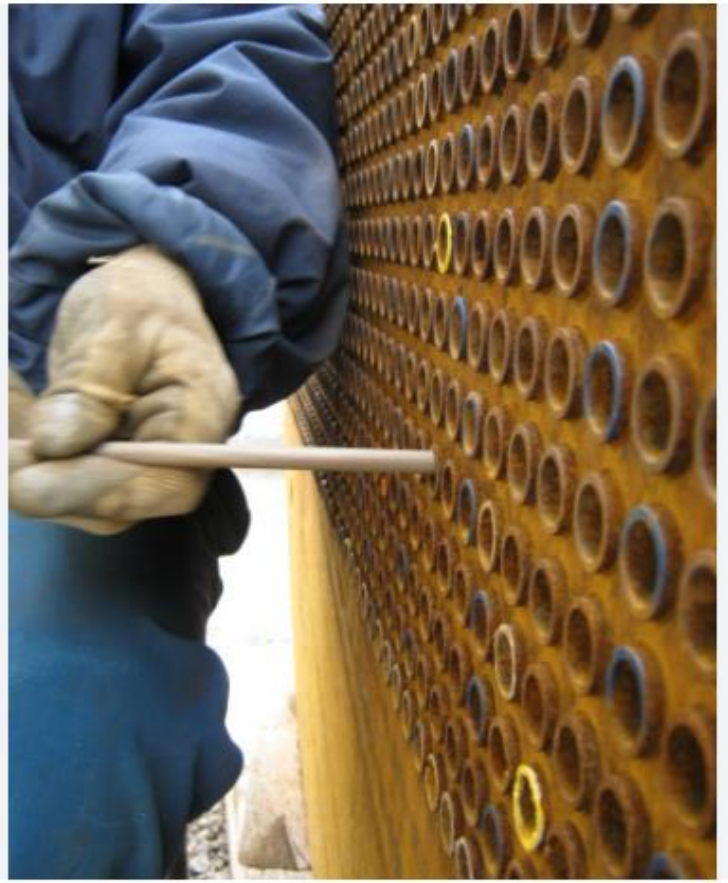
Summary – ECA for Tube Support Plate Degradation

- Within the same tube inspection data, ECA provides detection, characterization and damage extent for tube support plate degradation.
- Analysis of degraded tube support plate allows for determination of altered steam flow path which can be used to target regions of heat exchanger shell erosion.
- Root cause damage mechanisms related to steam flow can be identified and arrested.



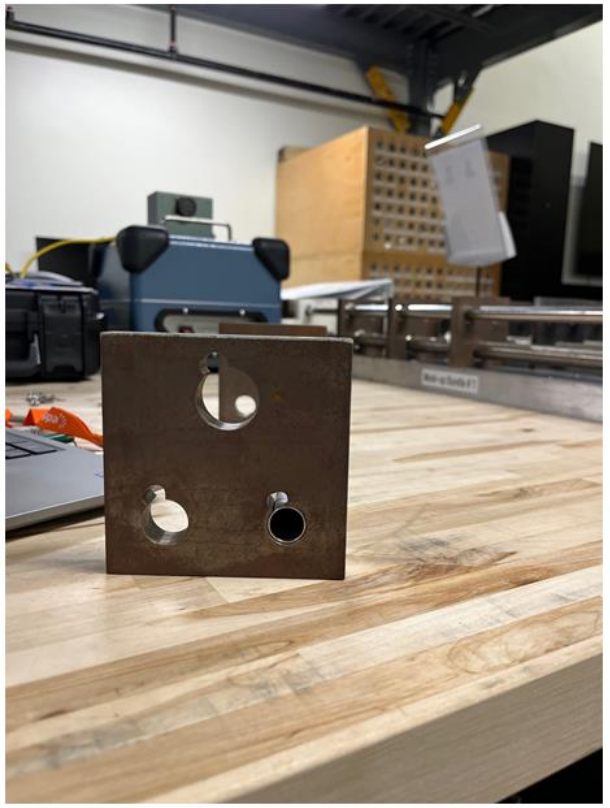
Next Steps

- Continue investigation of both array probe designs
- Prepare Eddy Current Technique Sheets (ETSS) for both probes.
- Investigate custom color palettes.
- Investigate processed data channels (C-Scan Mix).
- Generate sizing curves.
- Achieve equivalent results from both probes.
- Field trials.
- Publish results.



Additional Applications - Tube Sheet Degradation

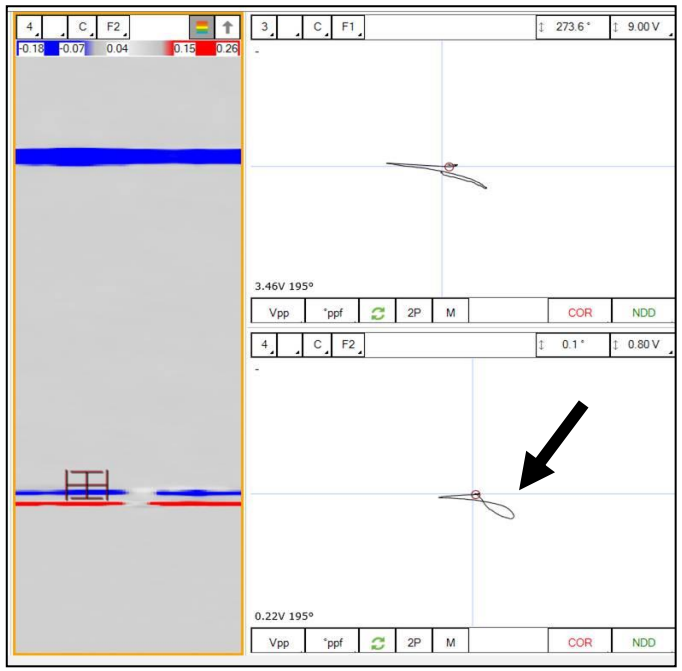
- ASME defects
- Typical TSP
- 45° simulated degradation at tube sheet.



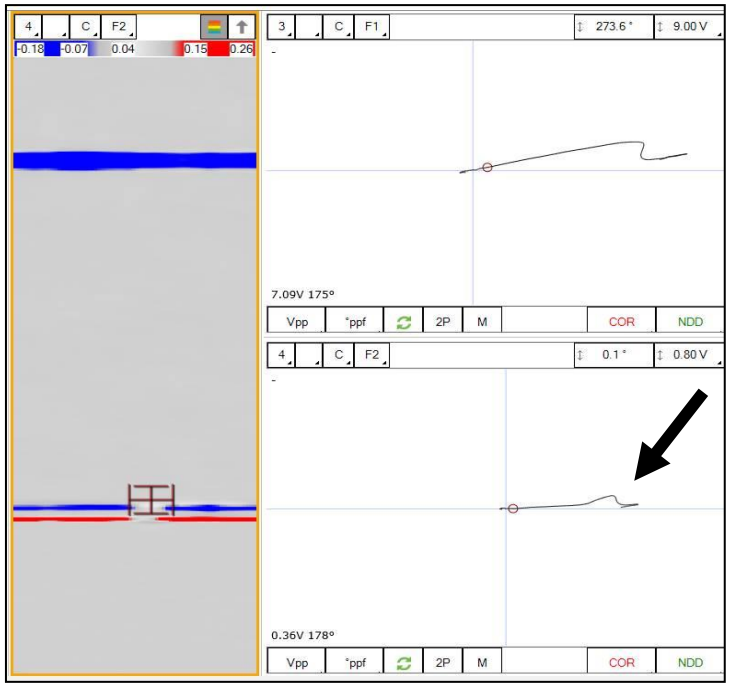
Additional Applications - Tube Sheet Degradation

- Comparison of signal for nominal tube sheet thickness vs. region of degradation (best viewed on Circ. Ch. F2).
- Counterclockwise phase rotation for degradation signal.
- Subtle changes to Lissajous signal can become valuable information when utilizing array data and choice of custom color palette.

Nominal Tube Sheet Signal



Degradation Signal



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