ASNT Fall Conference and Quality Testing Show
Columbus, Ohio

Condition Assessment of Engine Component Materials Using MWM® Eddy-Current Sensors

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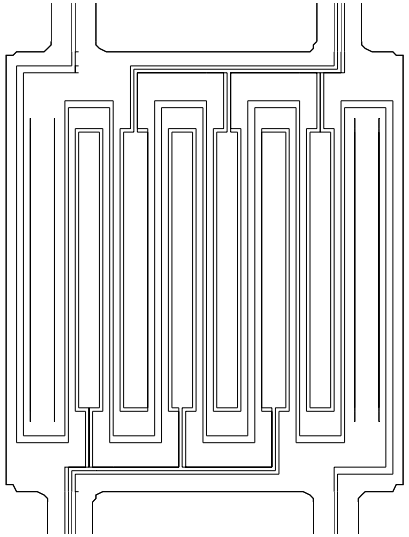
Outline

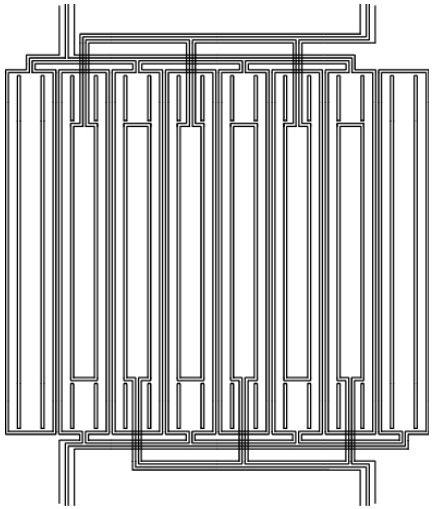
- MWM Sensors and MWM-Arrays
- Absolute Property Imaging
- Engine Component Applications
  - Examination of Rear Turbine Bearing Support
  - Characterization of Aged MCrAlY Coating
  - Inspection of F404 Compressor Blades for Weld Repairs
- Conclusions

Sensor Improvements for “Air” Calibration

Early single sensing element sensor design

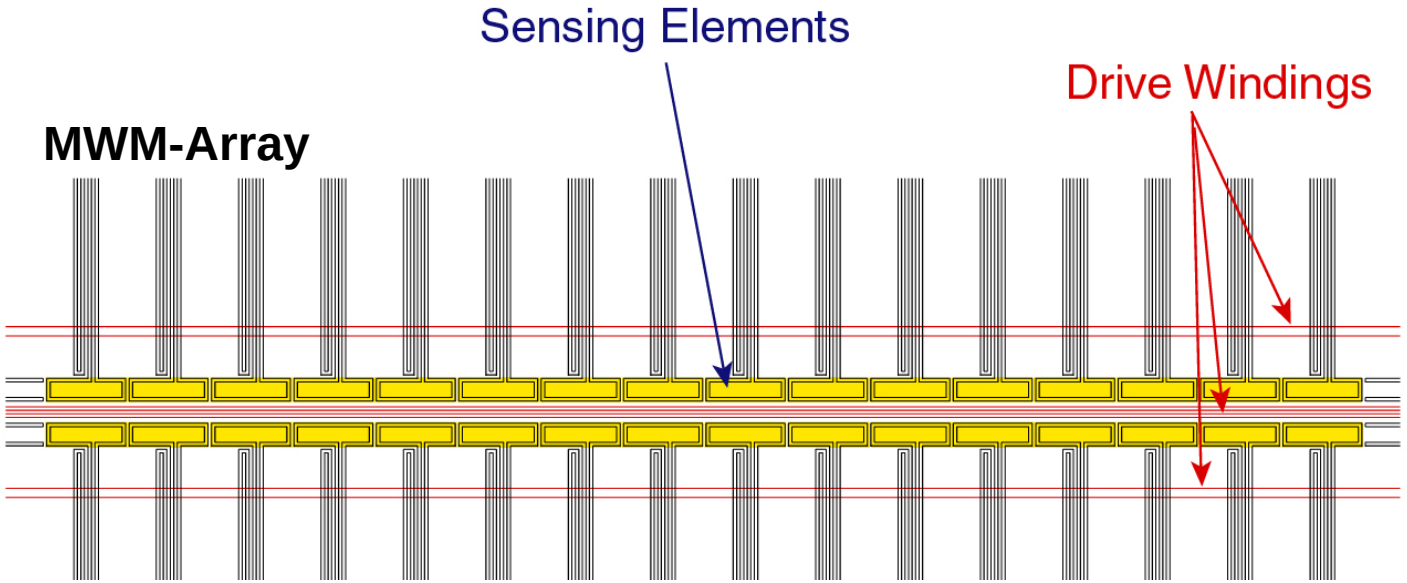


New design with improved drive winding construct

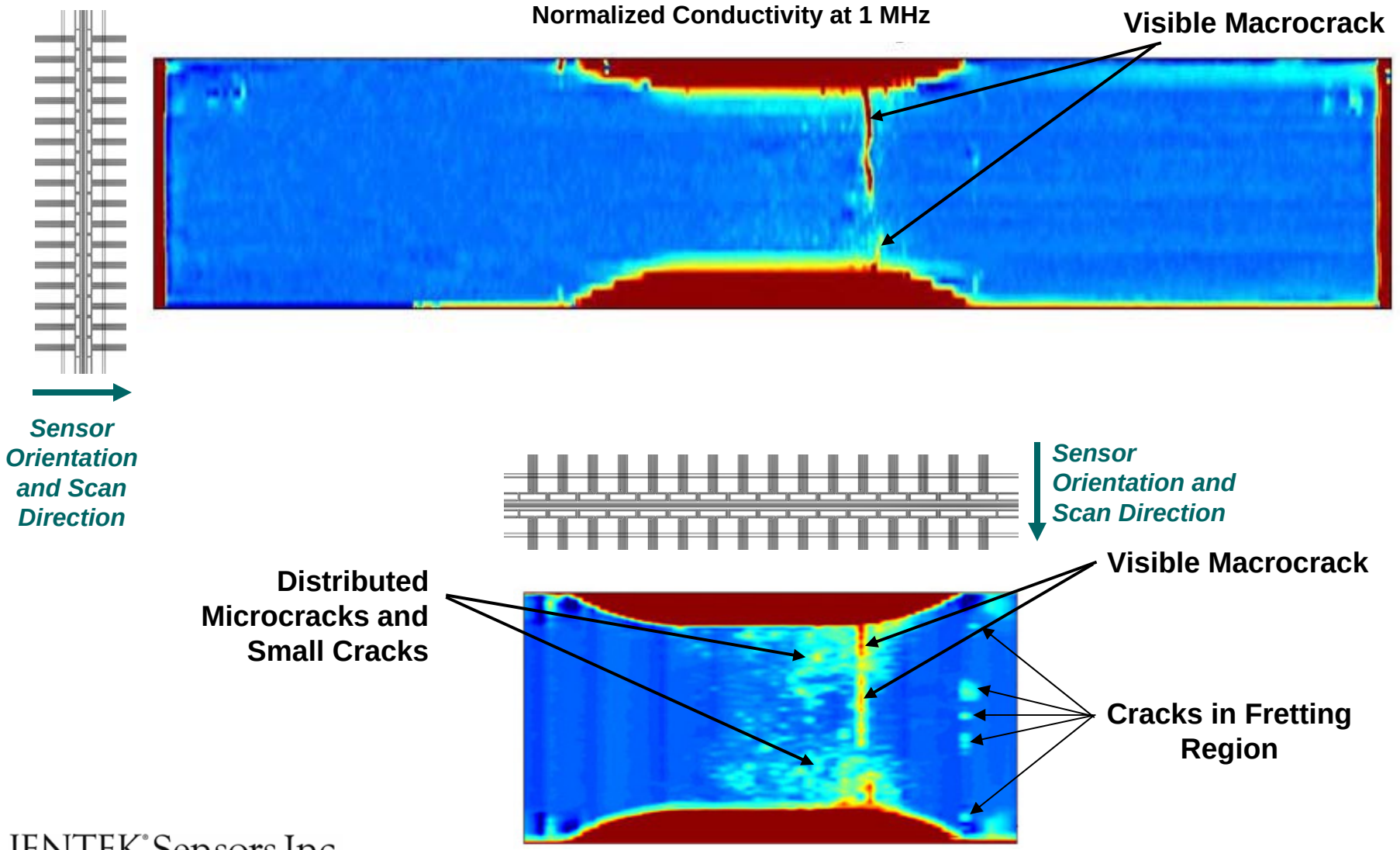


37-Channel MWM Array Probe

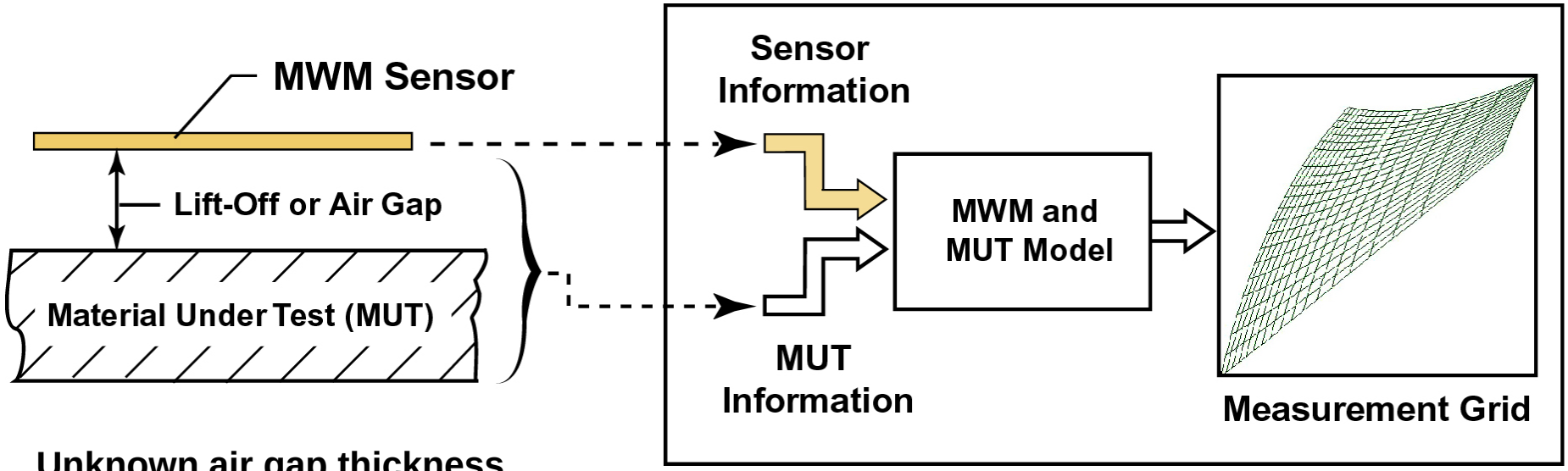
39-Channel Absolute Impedance Instrument



Distributed Microcracks and Macrocracks from Bending Fatigue



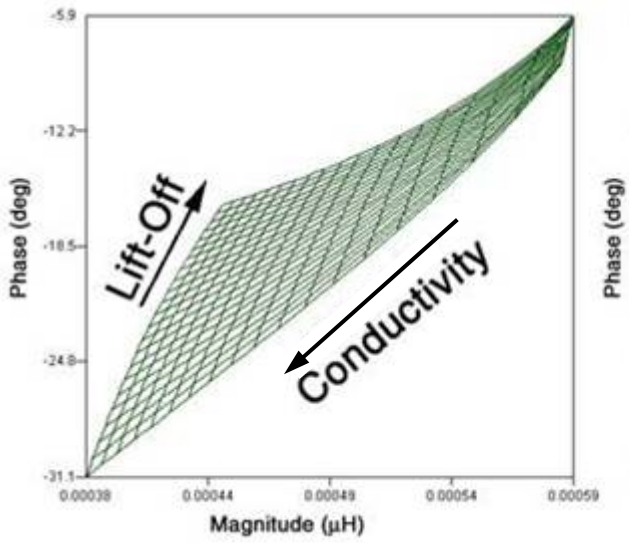
Grids Methods use Pre-computed Databases of Sensor Responses for Calibration and Measurement



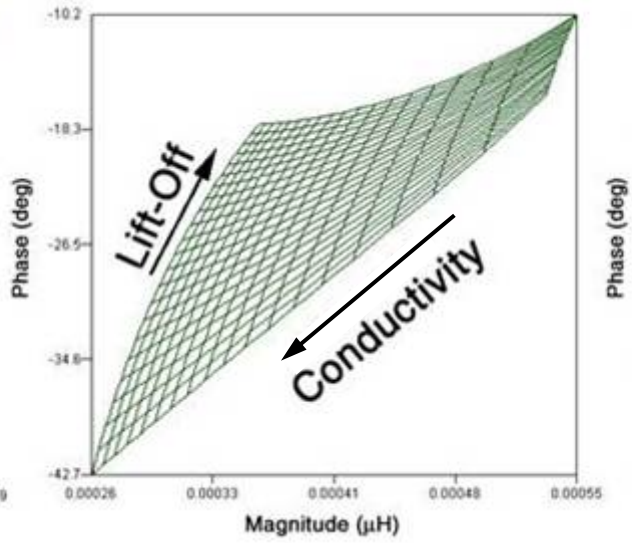
Unknown air gap thickness and electrical conductivity

Model-based generation of response databases

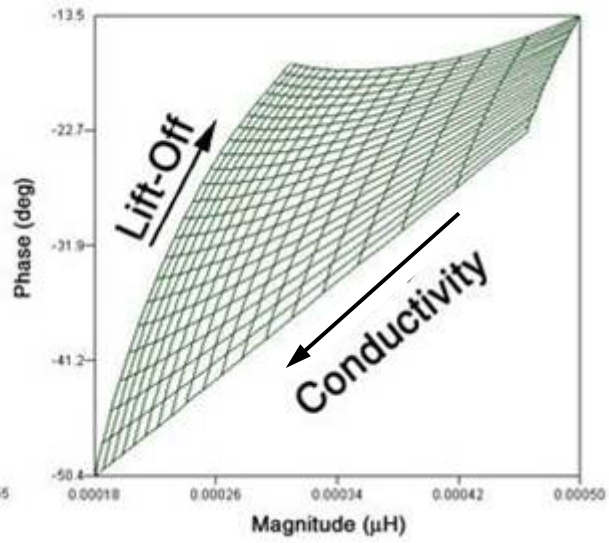
Conductivity/Lift-off Measurement Grids for Wide Frequency Range



2.5 MHz

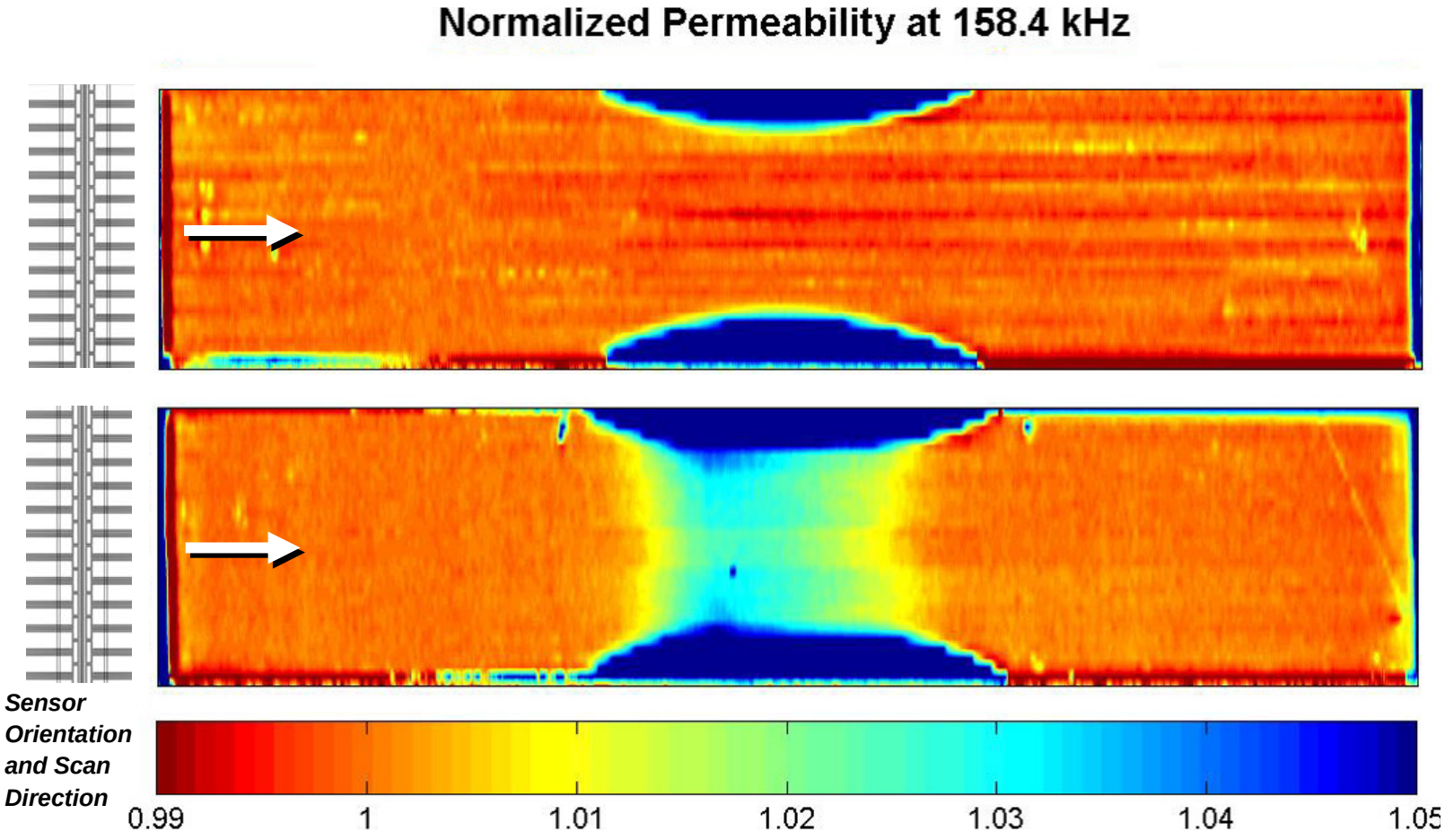


6.3 MHz



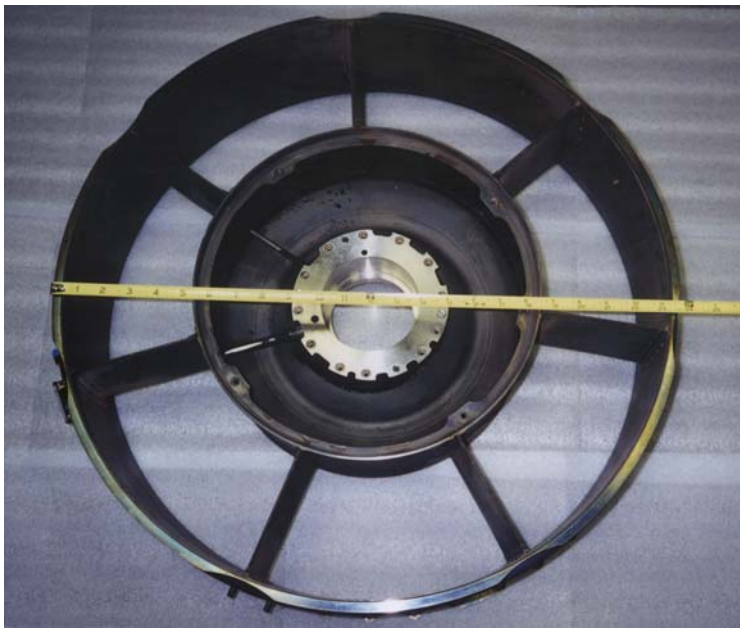
12.6 MHz

MWM-Array Magnetic Permeability Image



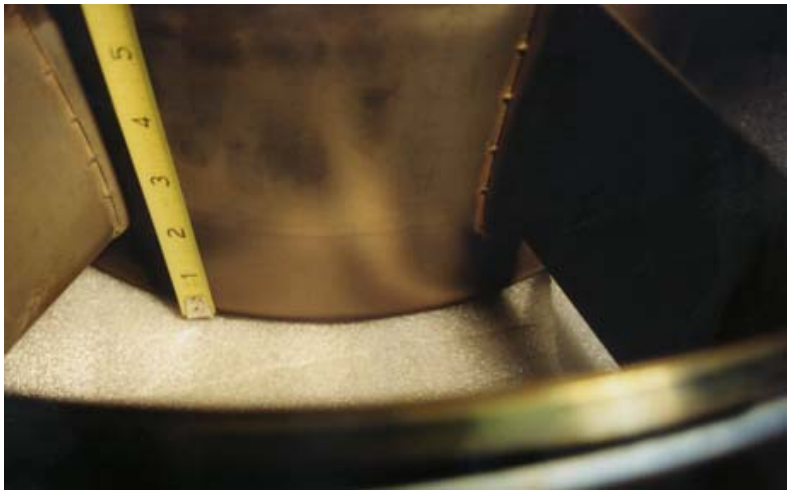
Control specimen that has not been subject to fatigue testing. (Top)
Specimen tested to 88% of fatigue life. (Bottom)

General View of the RTBS

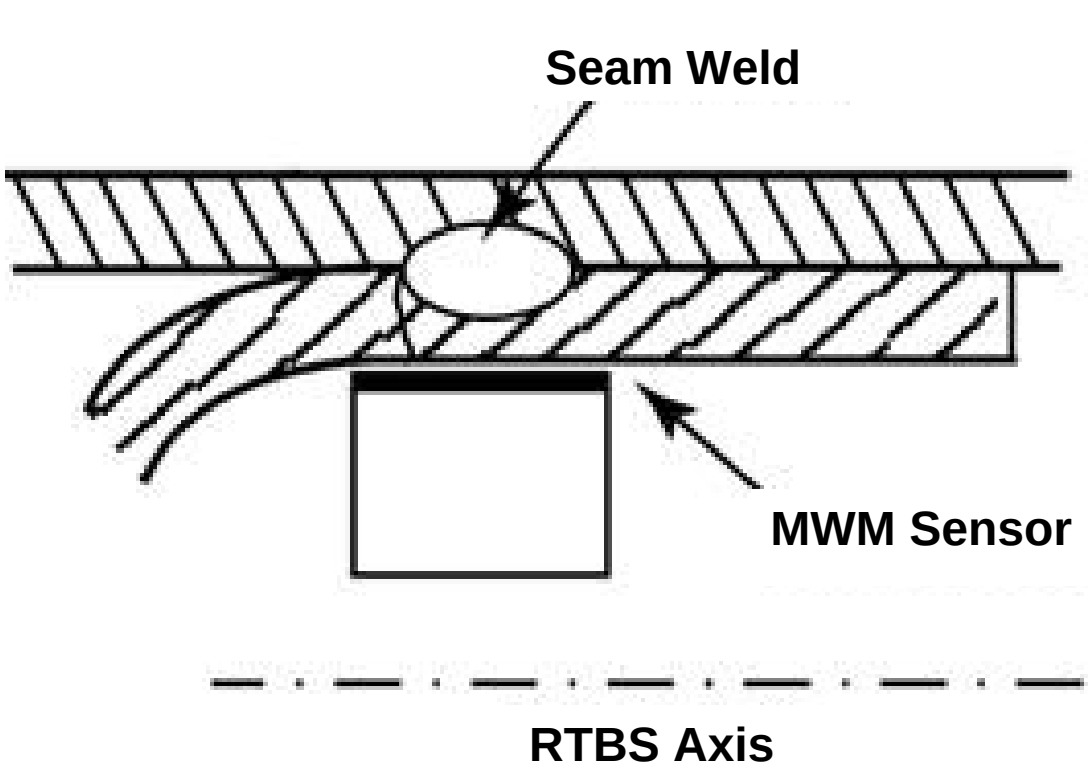


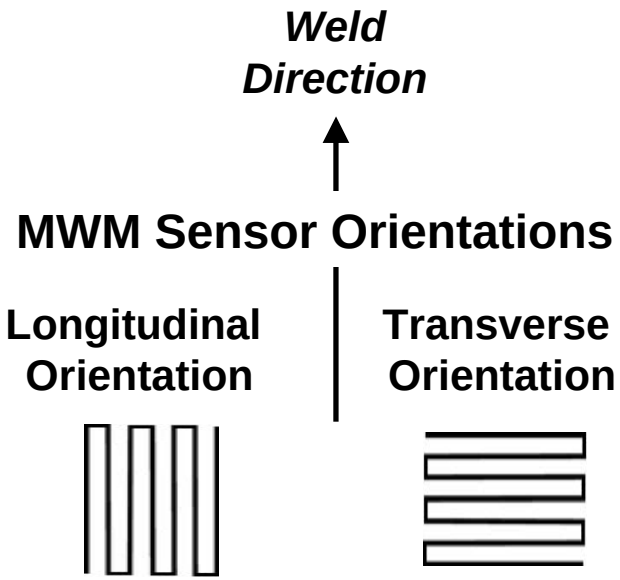
MWM Measurements on the I.D. Surface of the Internal Rim Opposite the Seam Weld

Circumferential Seam Weld Location in the RTBS

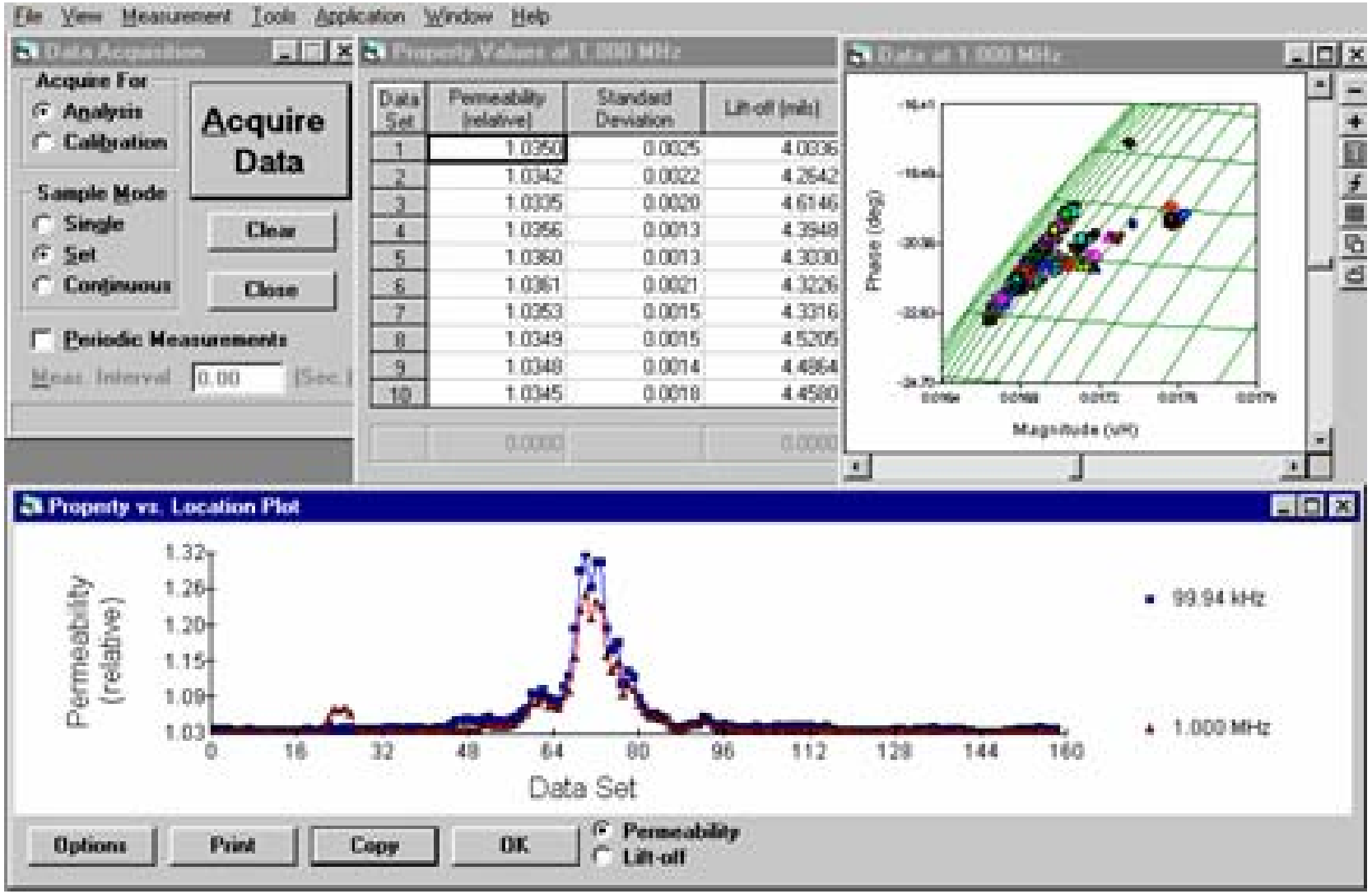


Relative Position of the MWM Sensor and Seam Weld

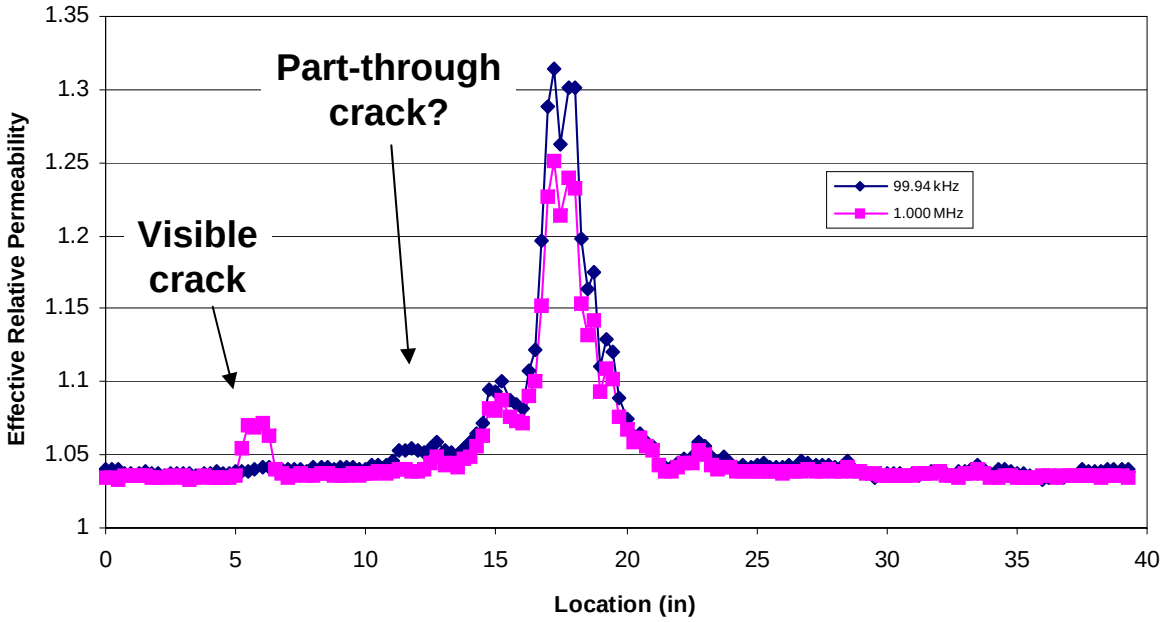




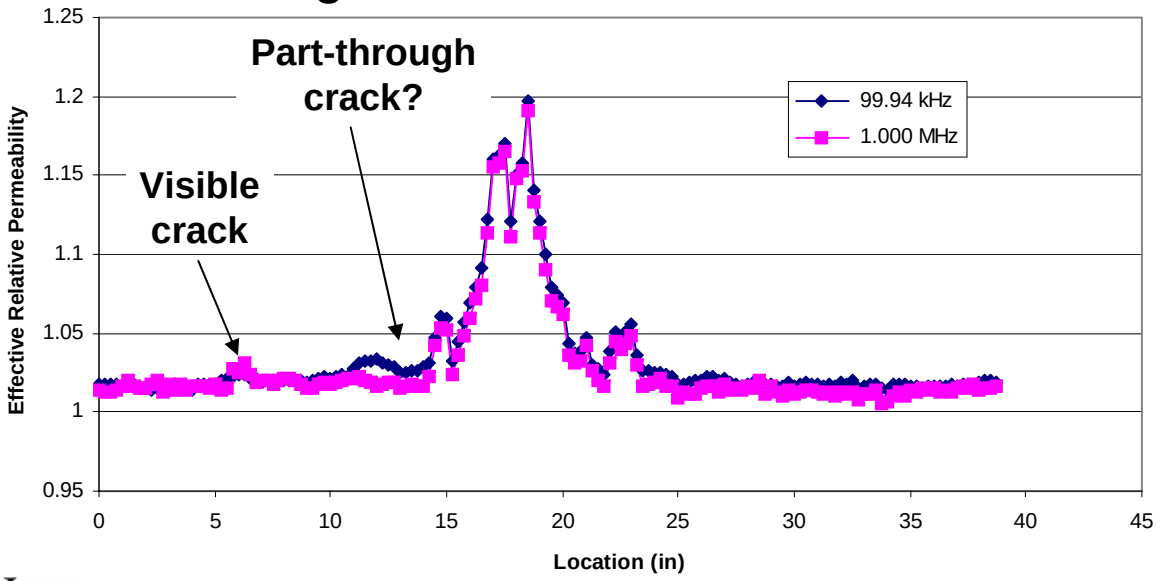
GridStation Display of the MWM Measurements



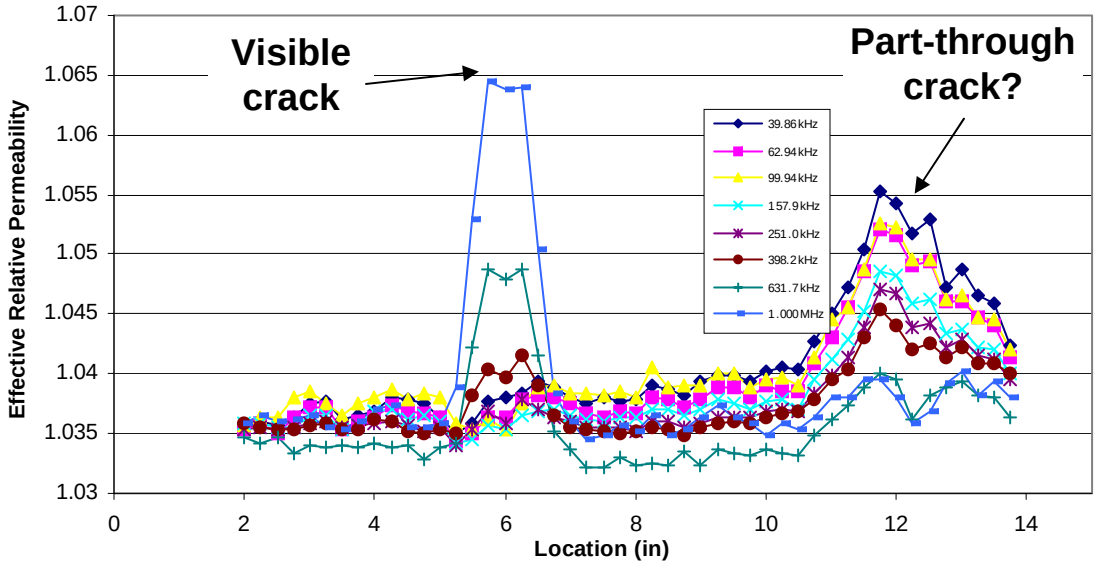
Transverse MWM Orientation



Longitudinal MWM Orientation

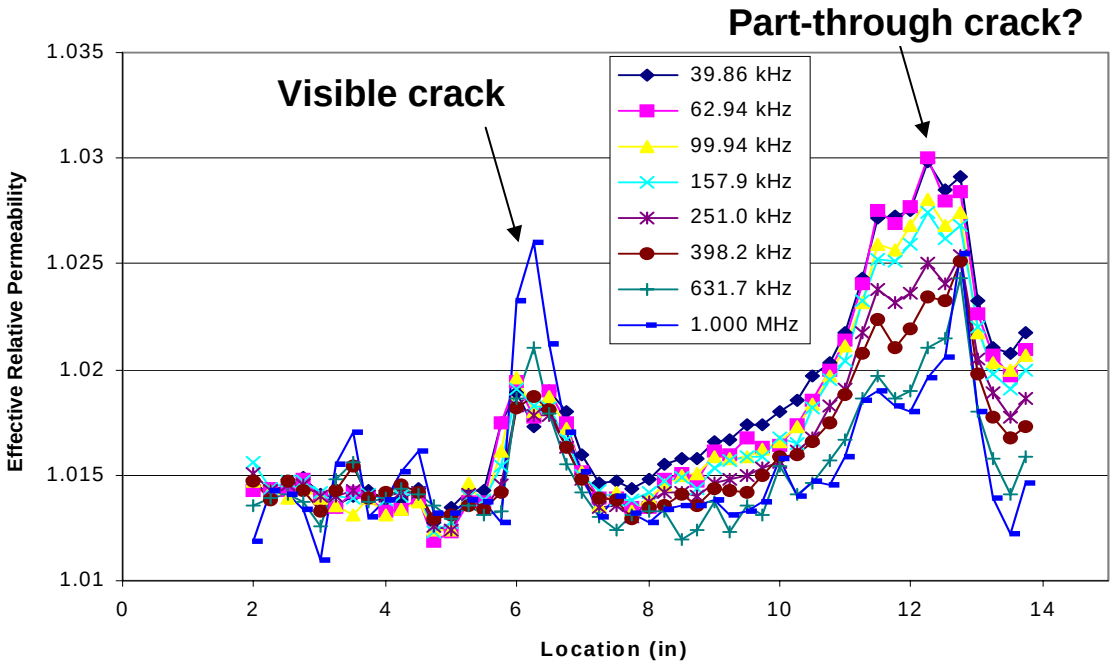


“Effective” Relative Permeability



Transverse

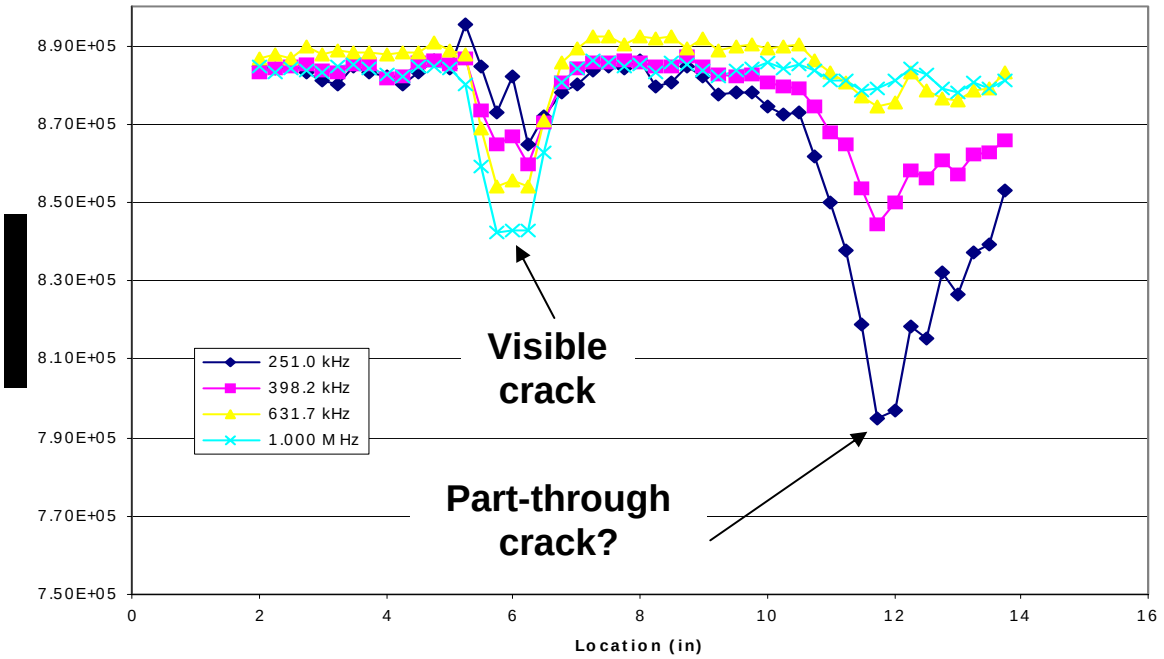
Measurements over a 12-in. segment containing the visible crack (transverse MWM orientation)



Longitudinal

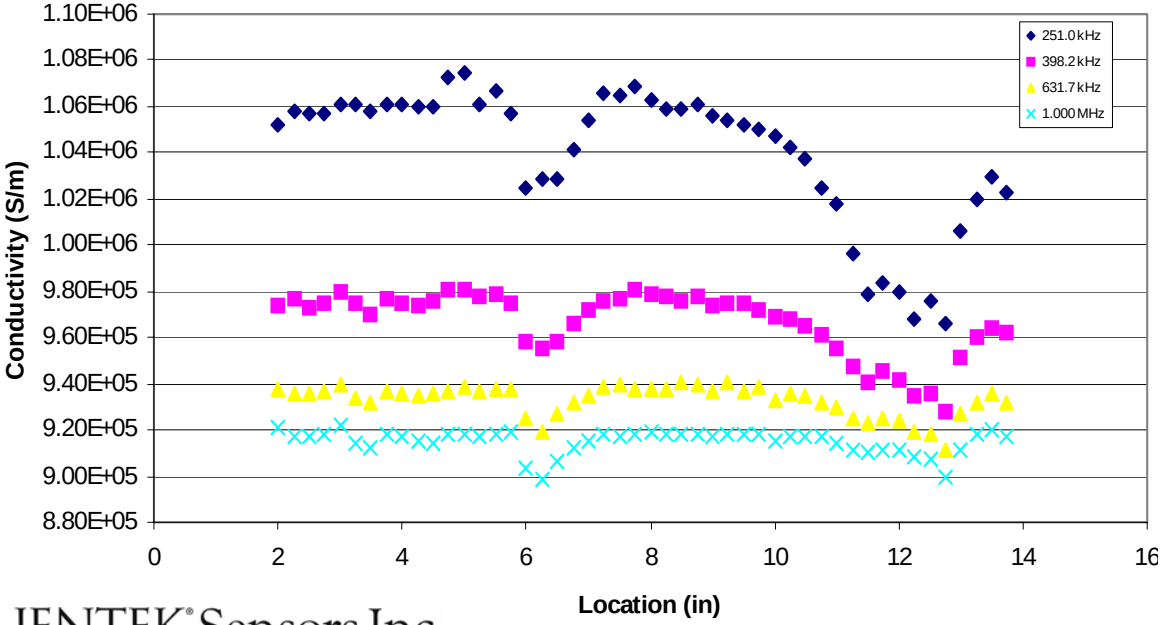
Measurements over a 12-in. segment containing the visible crack (longitudinal MWM orientation)

“Effective” Conductivity



Transverse

MWM measured conductivity vs. location along the circumference. Measurements over a 12-in. segment containing the visible crack (transverse MWM orientation)

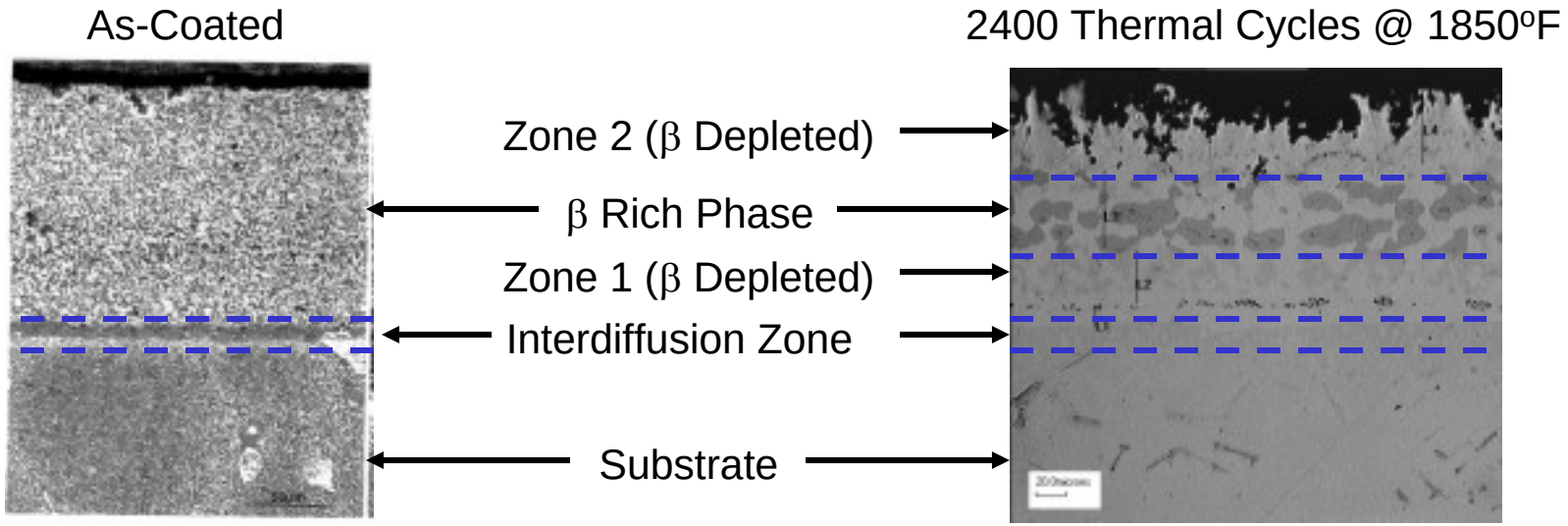


Longitudinal

MWM measured conductivity vs. location along the circumference. Measurements over a 12-in. segment containing the visible crack (longitudinal MWM orientation)

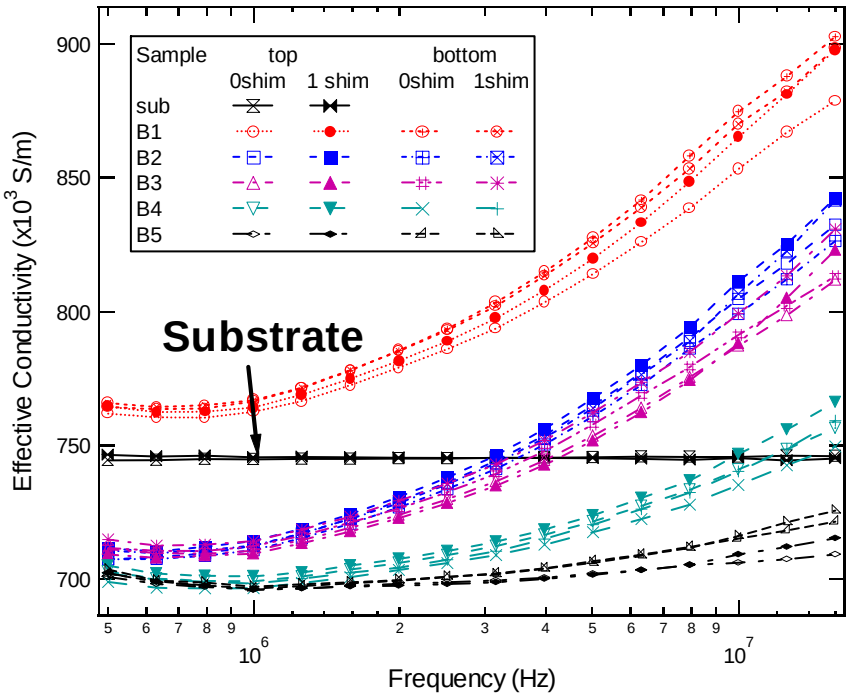
Aged MCrAlY Coating Characterization

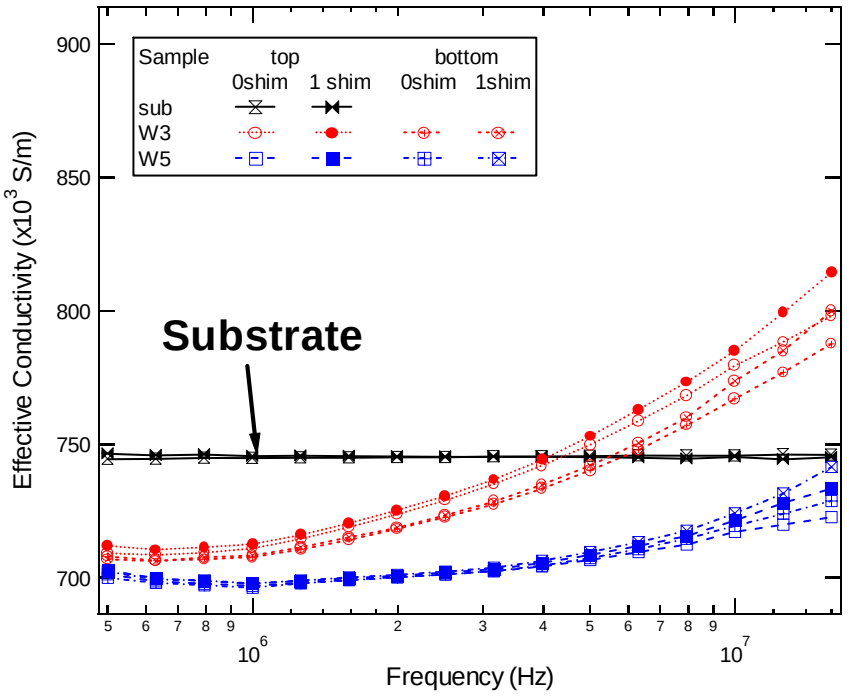
- Artificial aging of coated coupons to simulate service aging
  - GTD-111 substrate
  - PWA 286 coating
- EPRI Round-Robin study
  - Training set and “blind” sample set used for study
  - Metallography determined layer thicknesses after study



Aged MCrAlY Coating Measurements

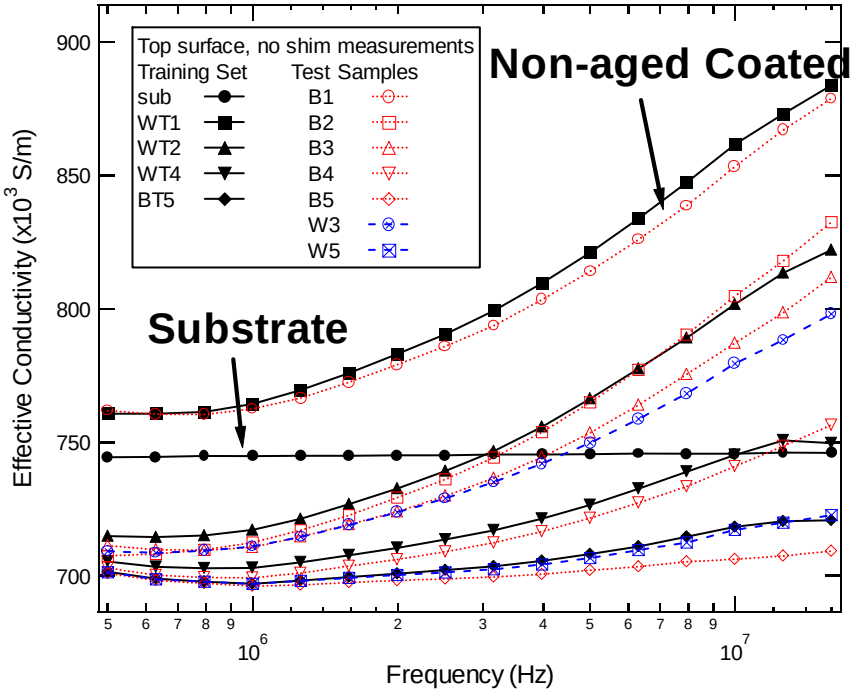
- Measurements on top and bottom of coupons
  - Post-study metallography indicated slight differences between sides
- Measurements with and without shims
  - Highly reproducible effective conductivity measurements

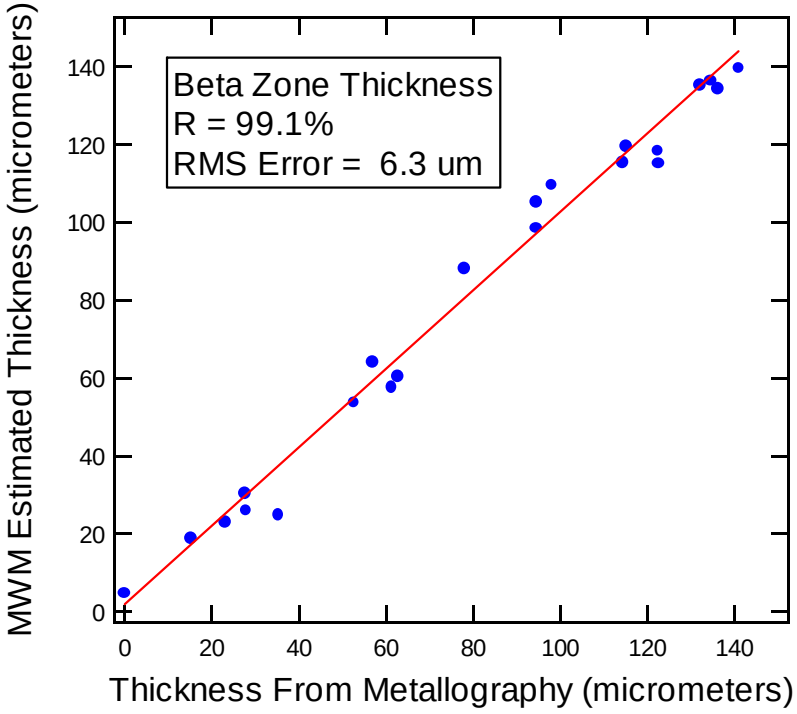




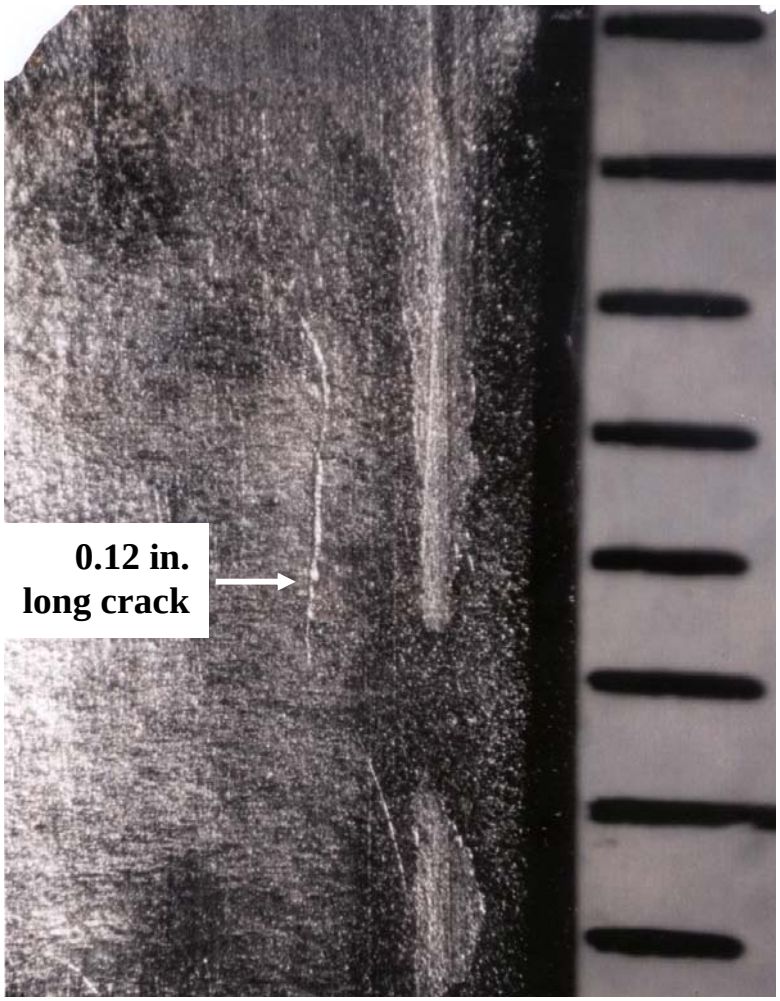
Aged MCrAlY Coating Characterization Results

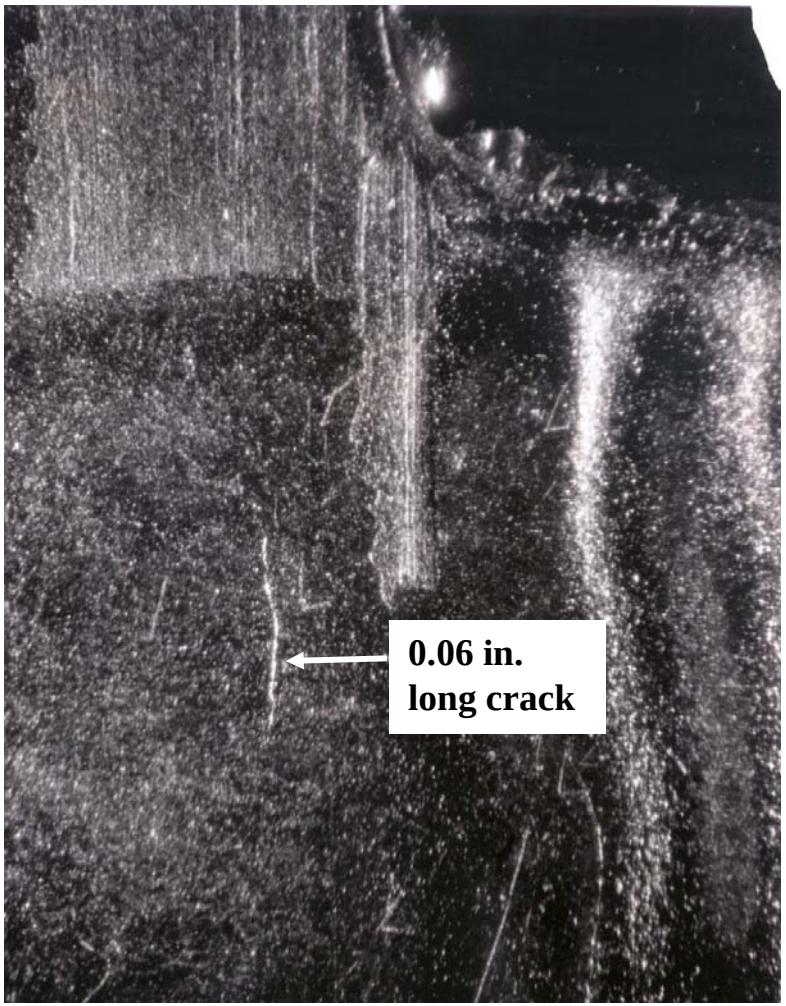
- Blind set samples had frequency variations similar to training set
- For remaining Beta Zone thickness on blind samples:
  - High correlation between MWM estimates and metallography
  - Low RMS error in MWM estimates (6.3 um, 0.25 mils)



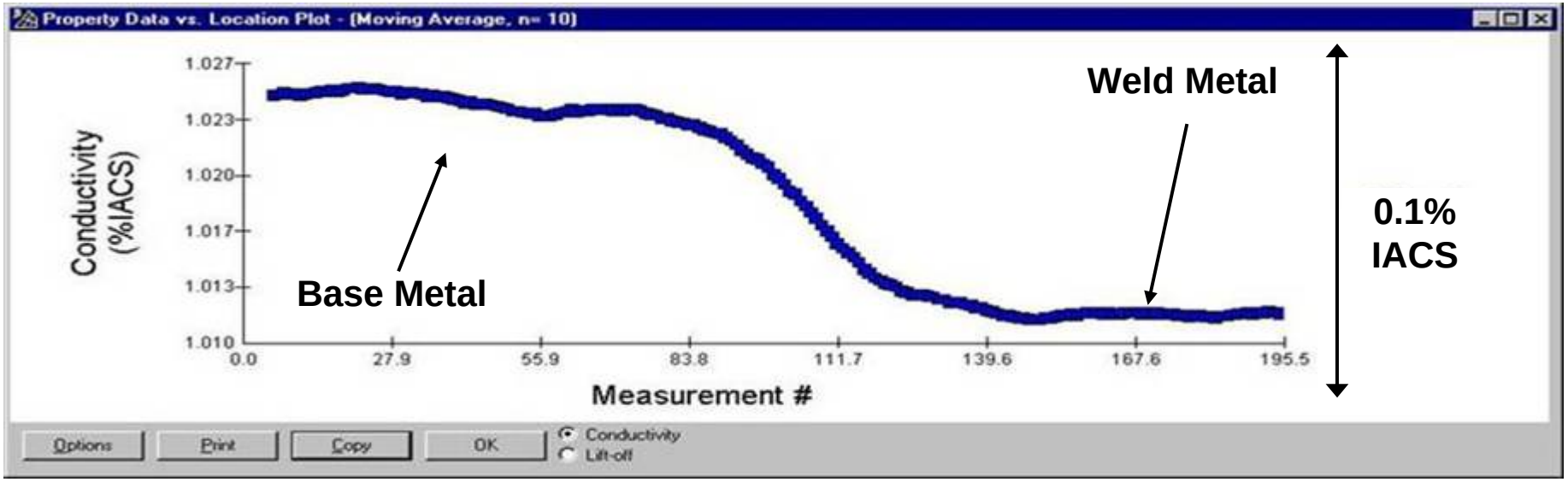


Images of cracks in Slots 19 (0.12 in. long) and Slot 37 (0.06 in. long)





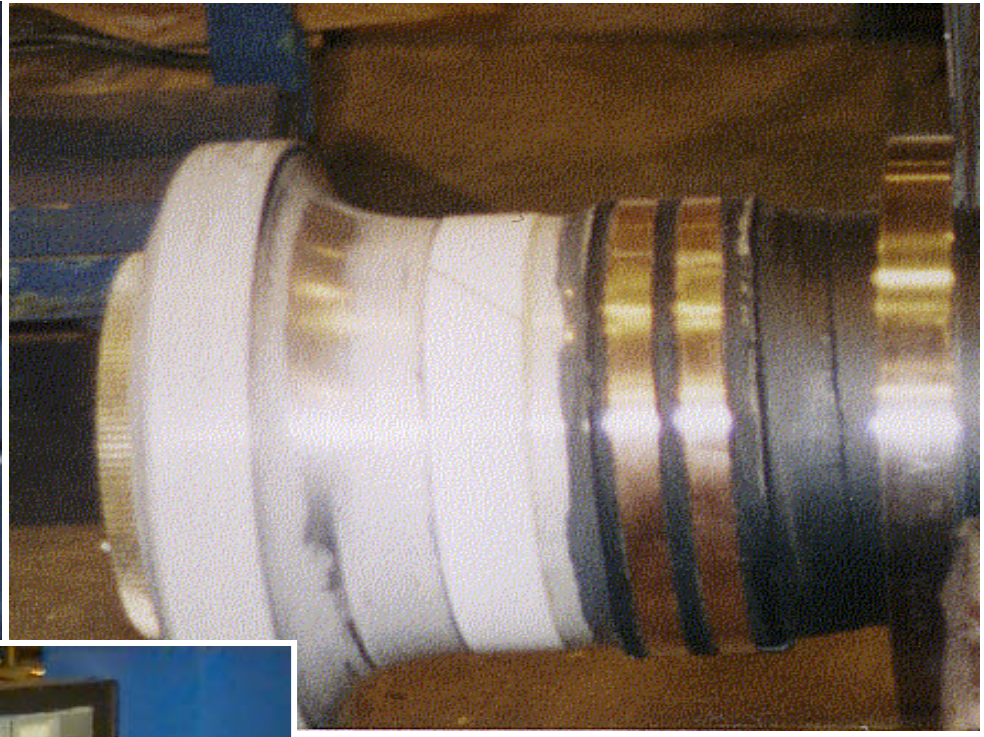
Weld Detection in Ti Compressor Blade



Conductivity Change = 0.01 % IACS

= 1 % of Absolute Conductivity

Inspection of Cold Rolling Integrity on C-130 Propeller Blades



GridStation Display

Printer/
Label Maker

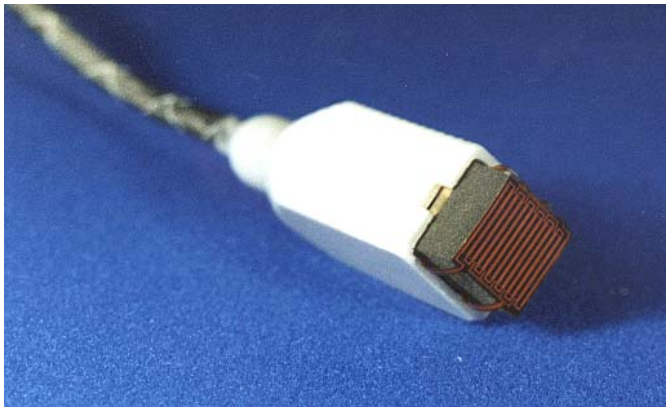
Inspection Station/
Production Area

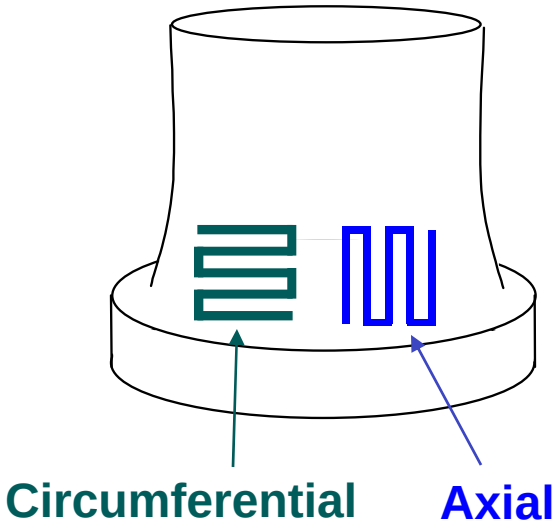
Bi-Directional Conductivity Measurements and Definition of Conductivity Ratios

Ratio Analysis

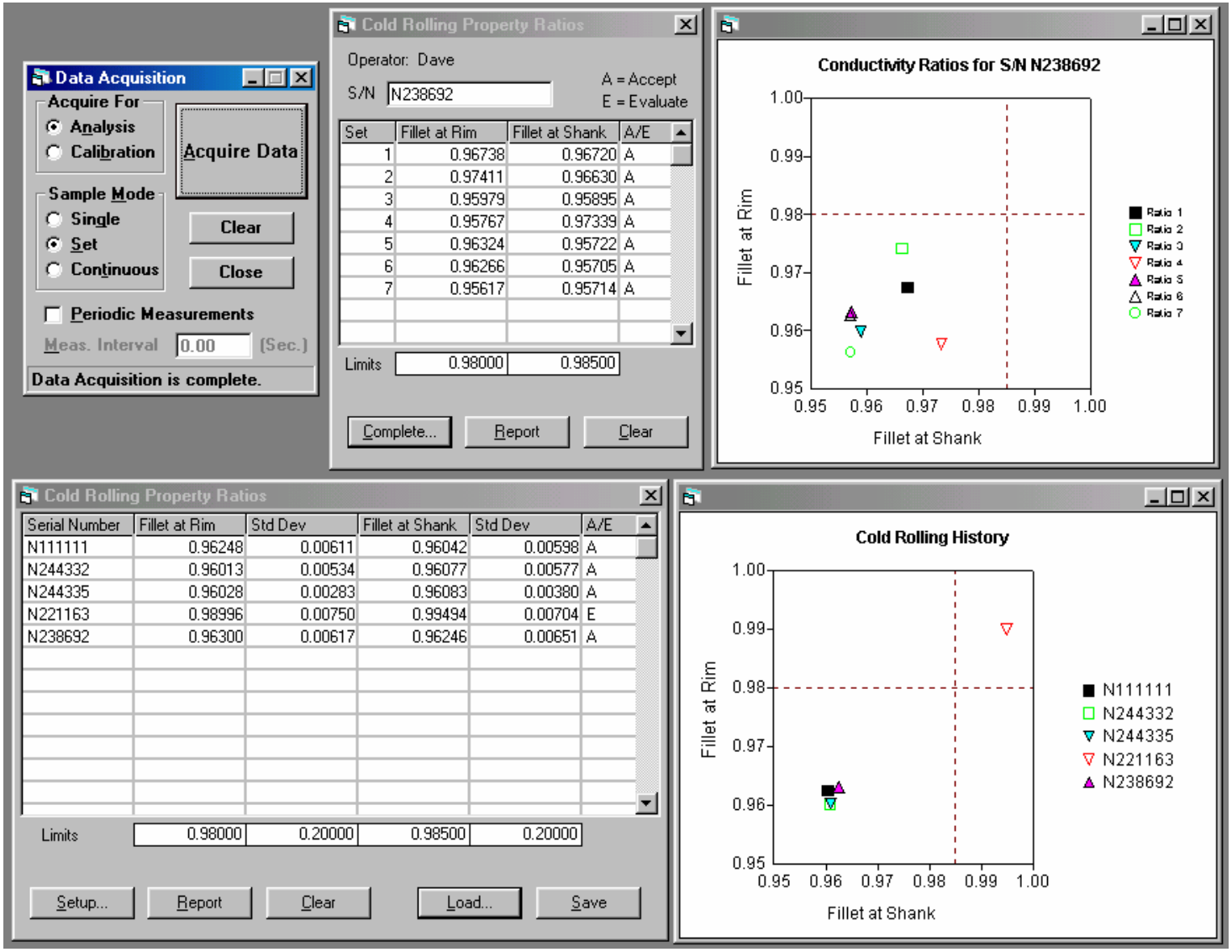
$$\text{Fillet Ratio} = \frac{\text{Fillet Axial}}{\text{Fillet Cir.}}$$

$$\text{Shank Ratio} = \frac{\text{Shank Axial}}{\text{Shank Cir.}}$$

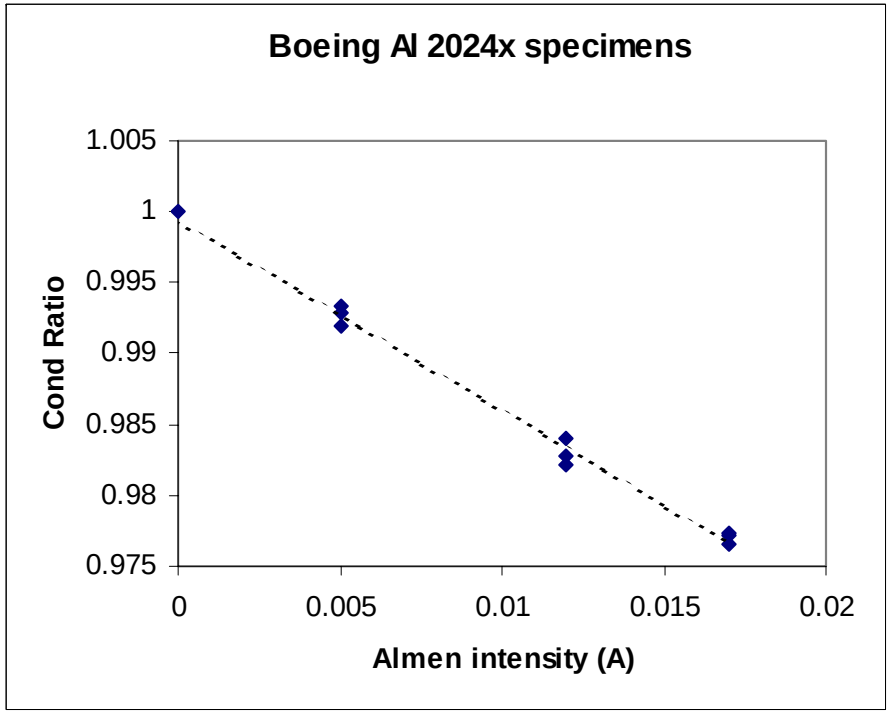


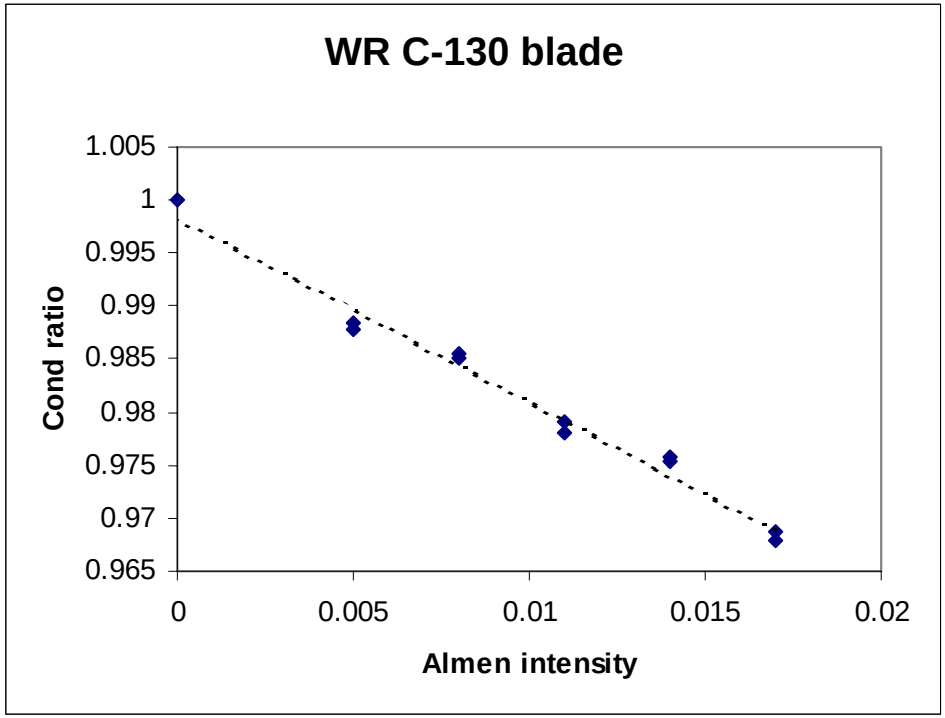


Typical Interface for Cold Work Quality Control

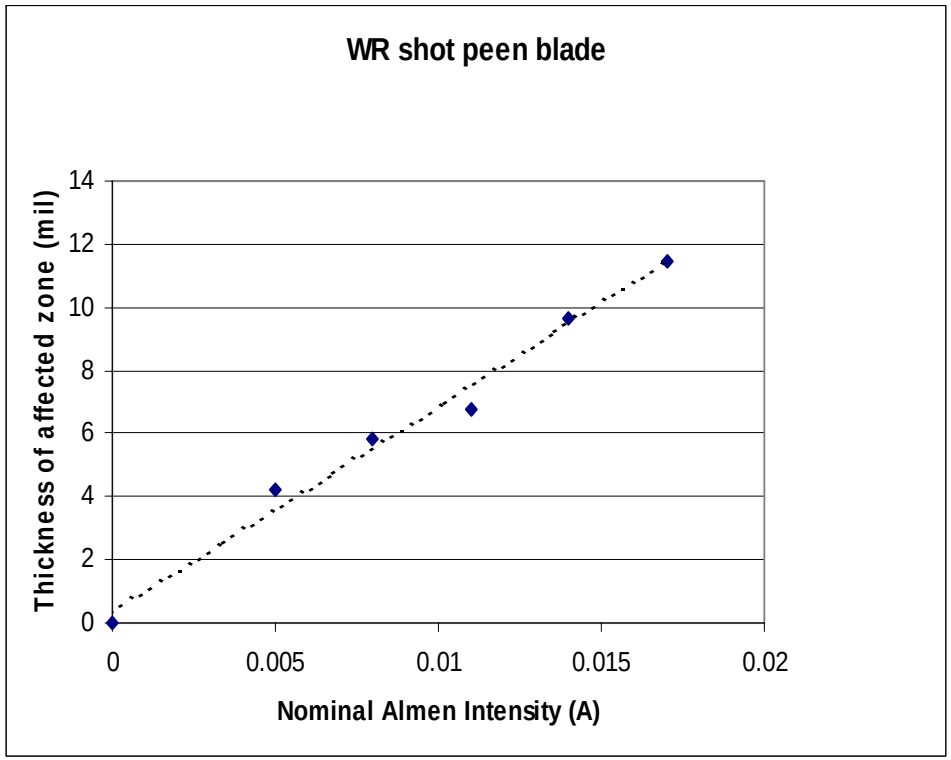


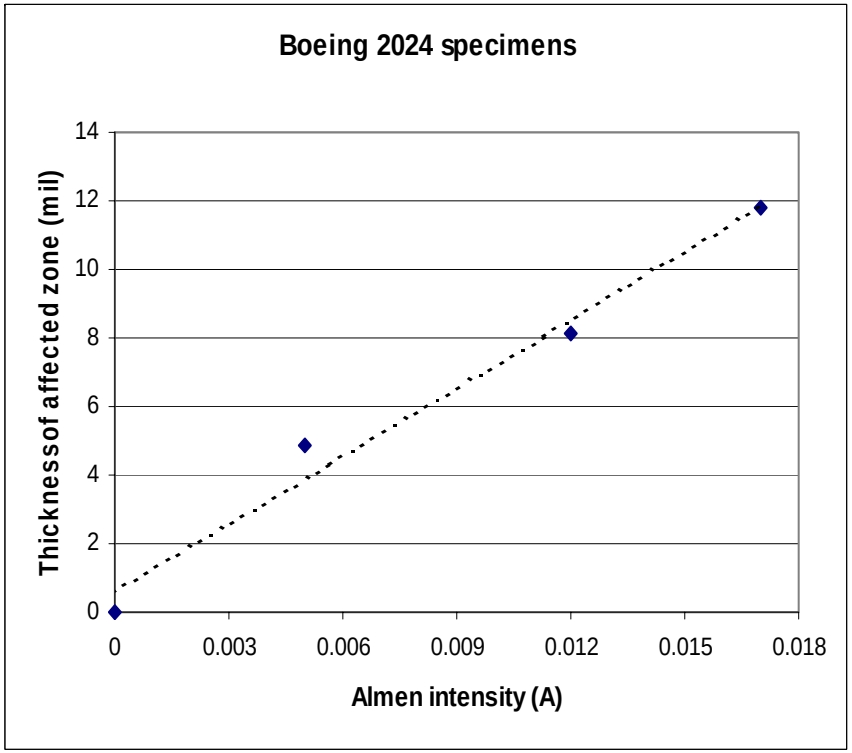
Shotpeen Correlation — 2 Frequency Conductivity Ratio



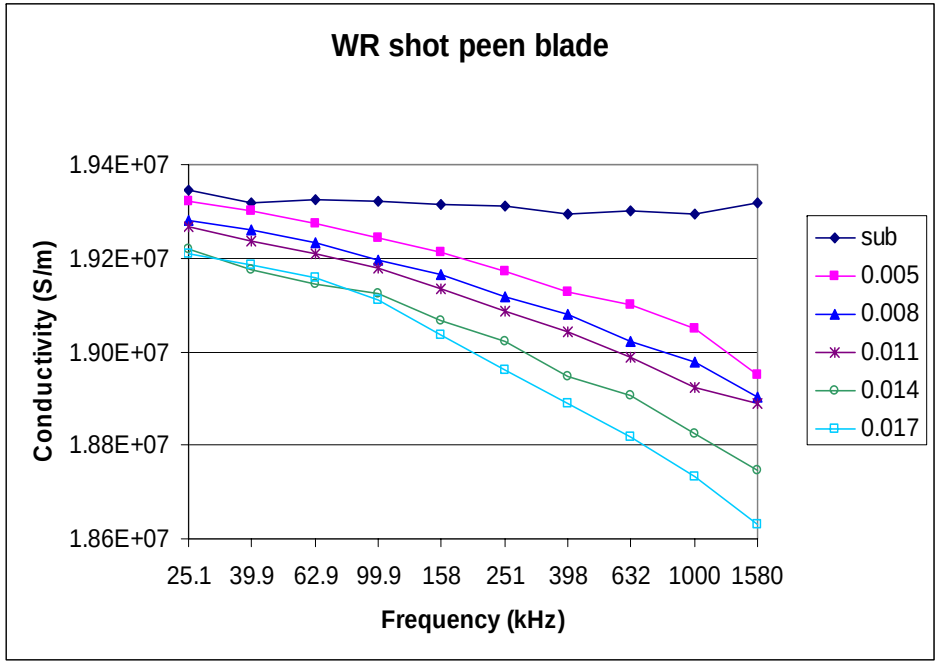


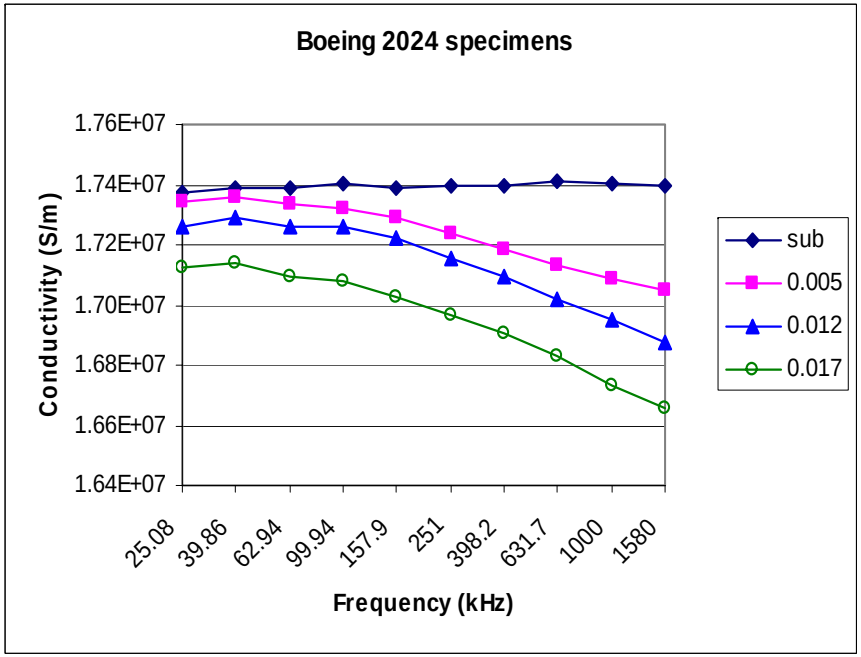
Effective Thickness Estimation on Shotpeen Specimens, FS33





Multi-Frequency Profiles of Shotpeen Specimens, FS33





Summary

- MWM demonstrated capability:
  - Surface and subsurface crack imaging
  - Coating degradation
  - Cold work assessment
- New Development focussed on field and depot implementation for specific applications