

Friction Stir Weld Inspection Through Conductivity Imaging Using Shaped Field MWM®-Arrays

**6th International Conference on
Trends in Welding Research
Friction Stir Welding: Session 27**

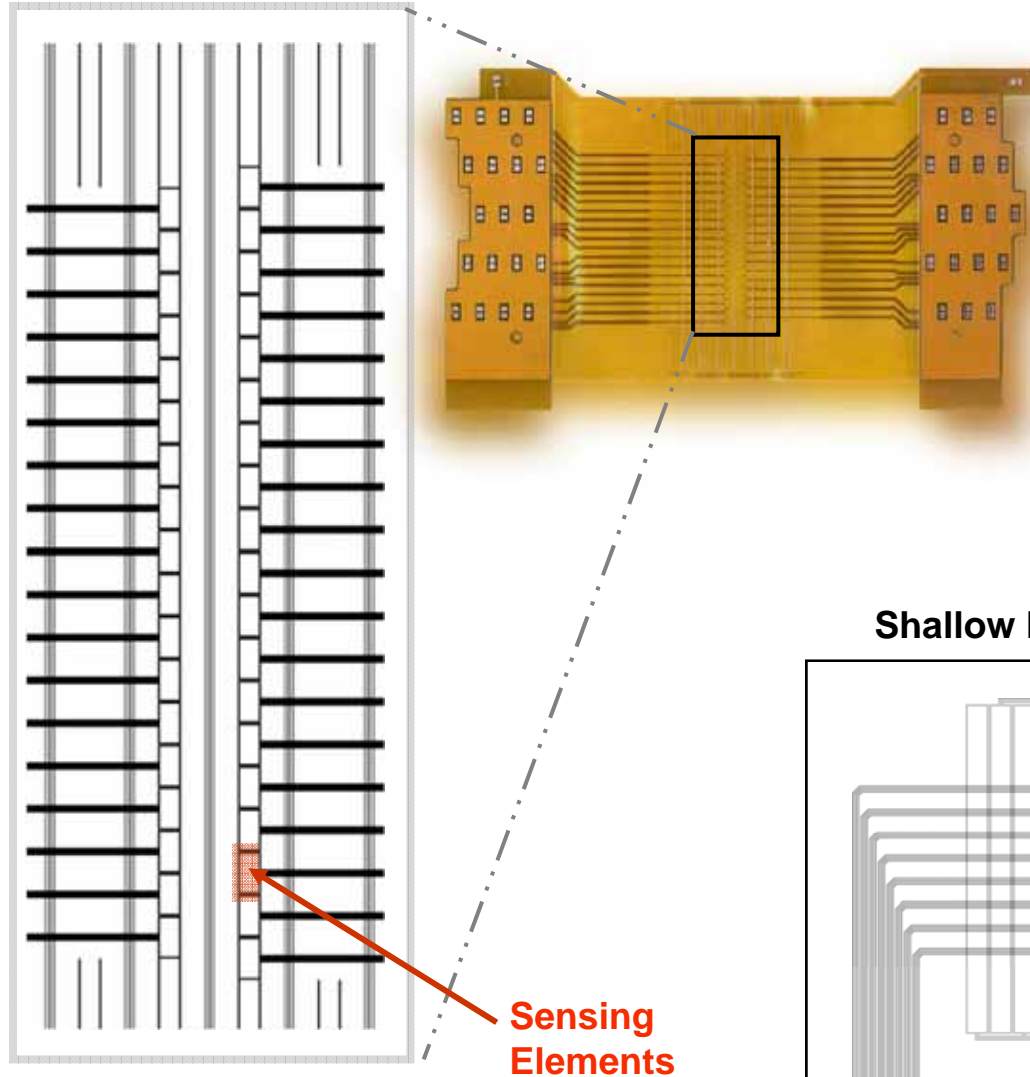
April 17, 2002

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JENTEK Sensors, Inc., Email: jentek@shore.net**

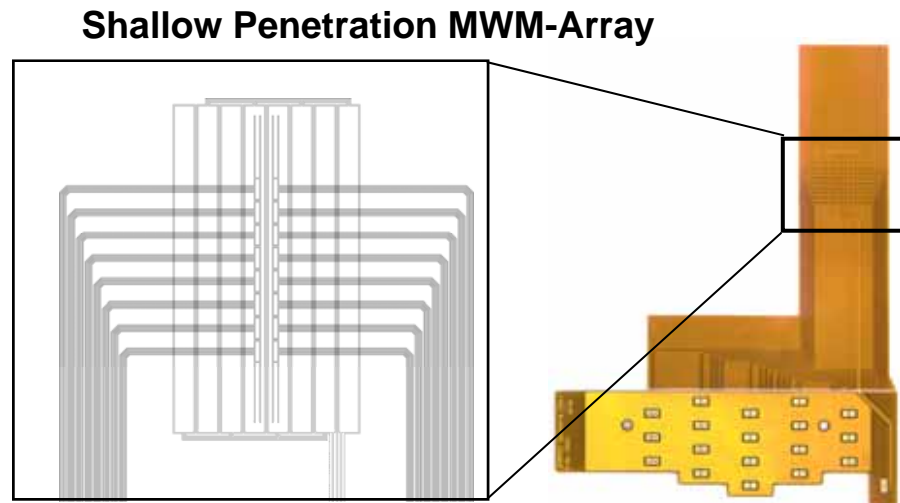
Objectives

- **Demonstrate capability of high-resolution MWM-Arrays to map microstructurally different regions for aluminum panels with Friction Stir Welds (FSW)**
- **Demonstrate capability of high-resolution MWM-Arrays to detect and size lack of penetration (LOP) in FSWs**
- **Investigate capability of high-resolution MWM-Arrays to estimate LOP size**

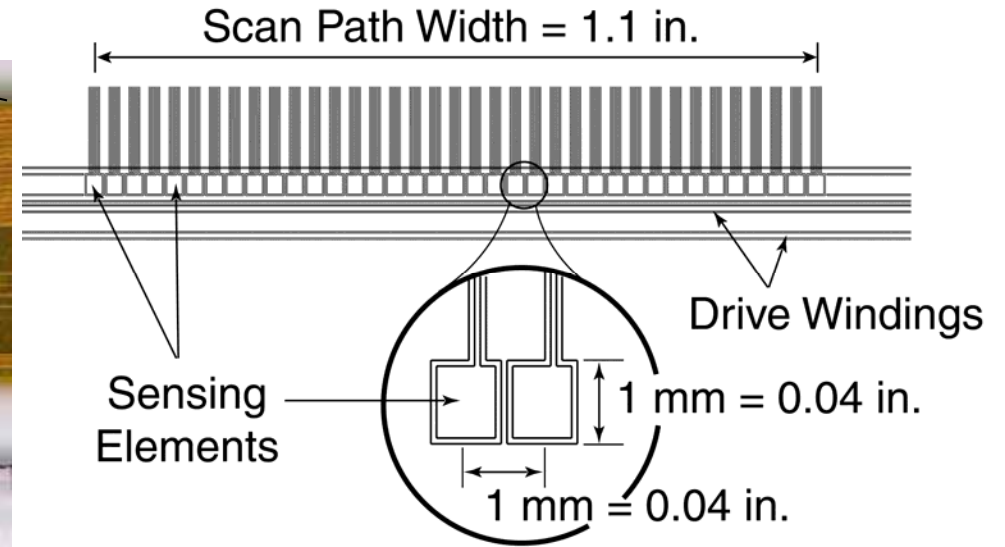
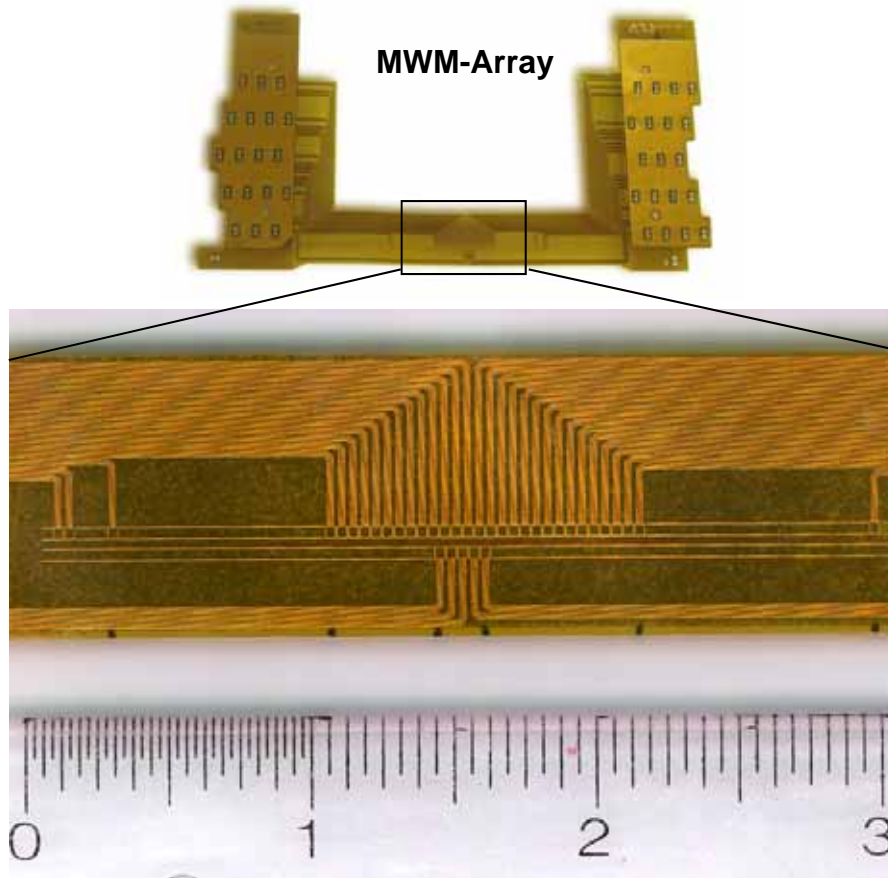
Example MWM-Array[®] Configurations



- **Thin and conformable**
- **Multiple overlapping sensing elements**
- **Fully parallel channels**
- **Essentially identical replacement tips**



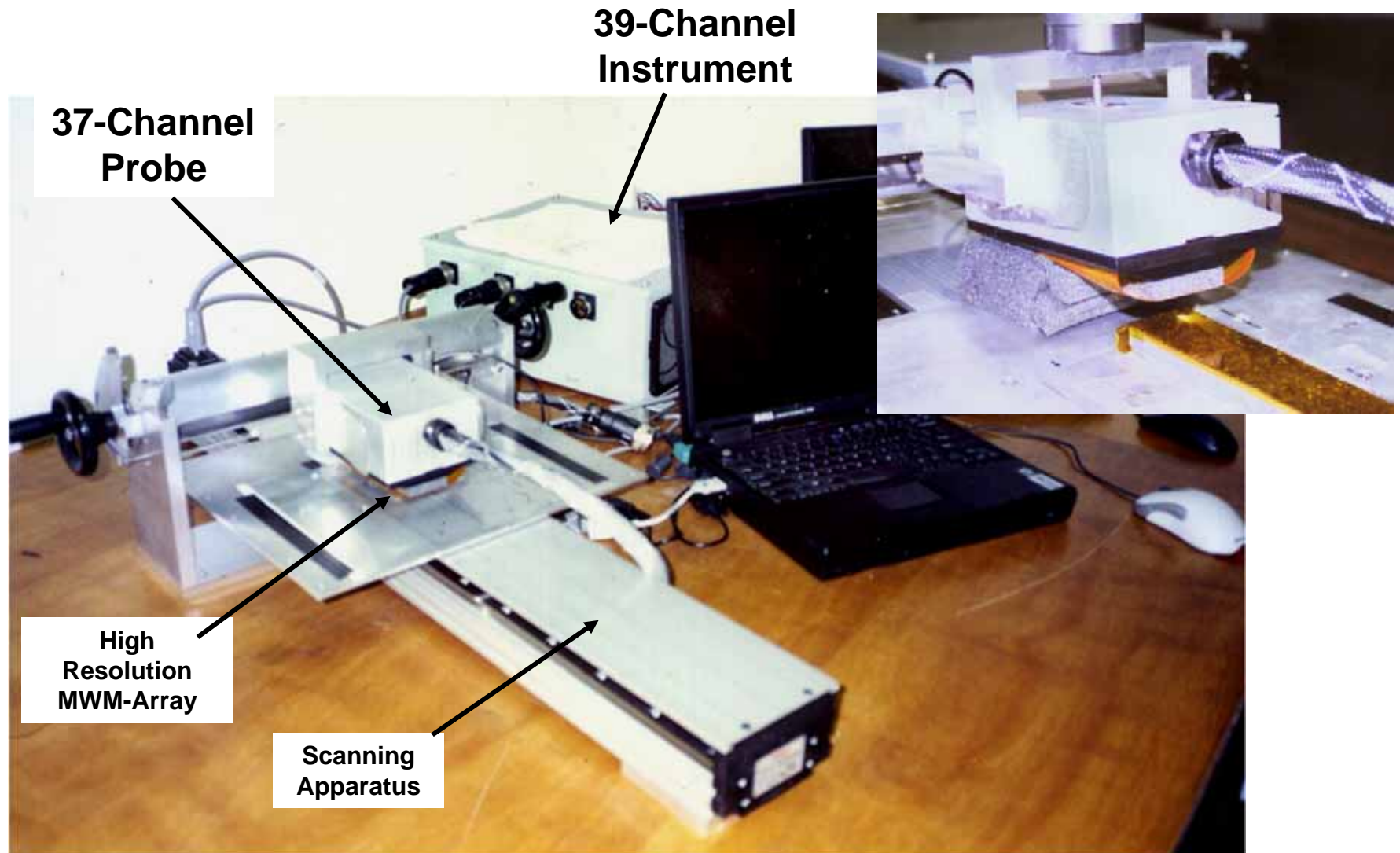
High Resolution MWM-Array Technology



Advantages of MWM Sensors and MWM-Arrays

- The MWM has unique advantages:
 - Thin and flexible
 - Lift-off compensated
 - Arrays produce high resolution images
 - Reduced calibration and training requirements
 - Bidirectional measurements

Parallel Architecture Instrumentation and MWM-Array Probe for High-Resolution Imaging



JENTEK Sensors, Inc. Systems

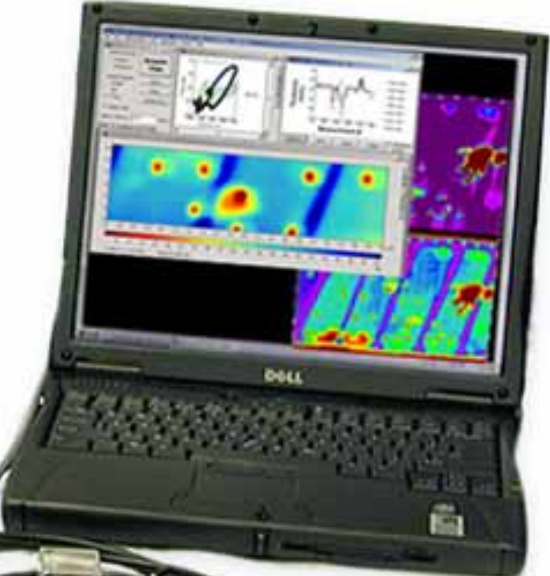
JENTEK Multi-Channel High-Speed Impedance Instrumentation

Up to 7 Channels



Up to 39 Channels

Laptop with JENTEK GridStation Software



MWM-Array Probe with Interchangeable Array Tips



MWM Probe with Interchangeable Sensor Tips



Overview of the JENTEK GridStation and Scanner Setup for the FSW inspection



JENTEK
GridStation
Software

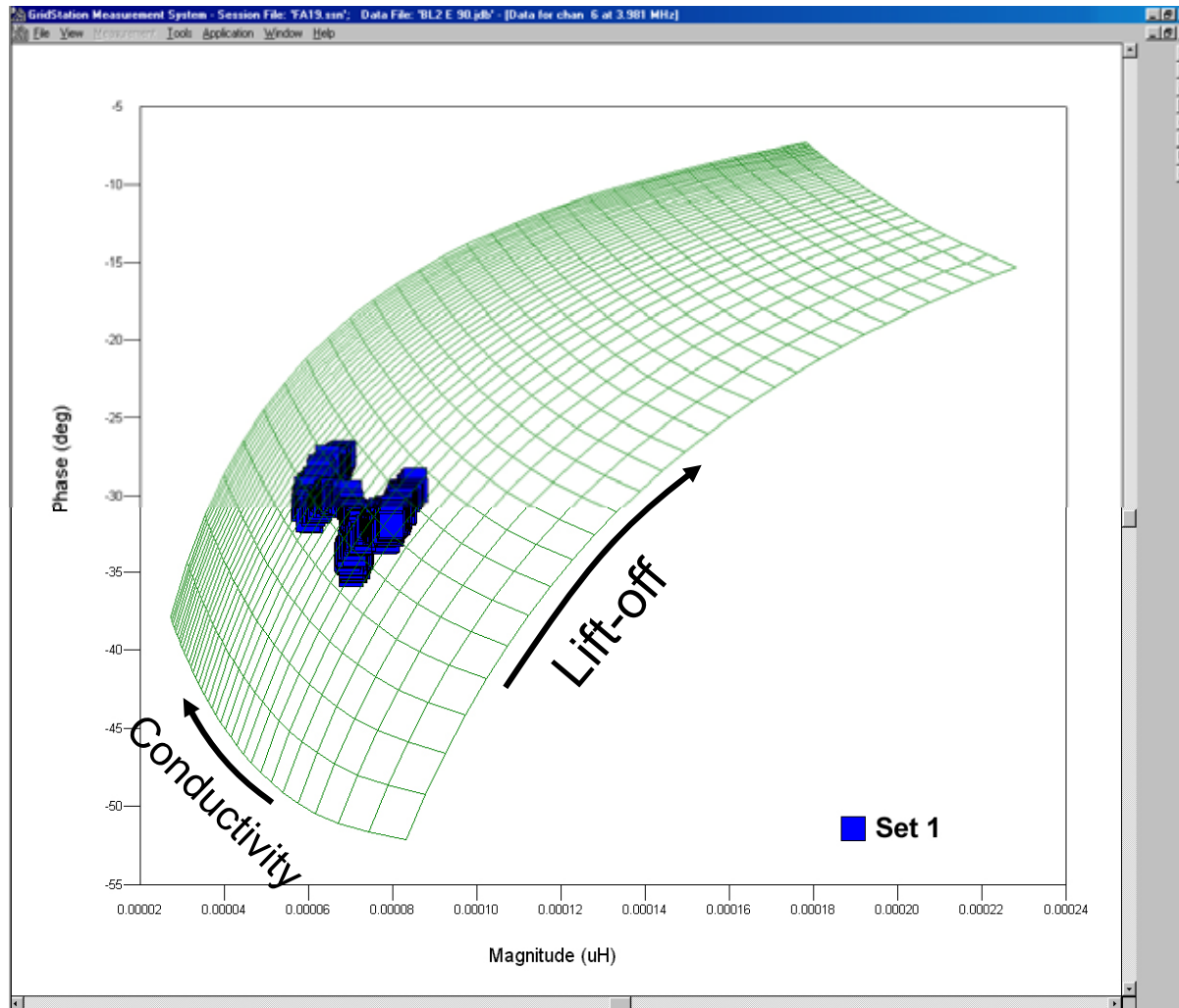
MWM-Array
37-Channel
Probe and
Sensor Tip

Scanner

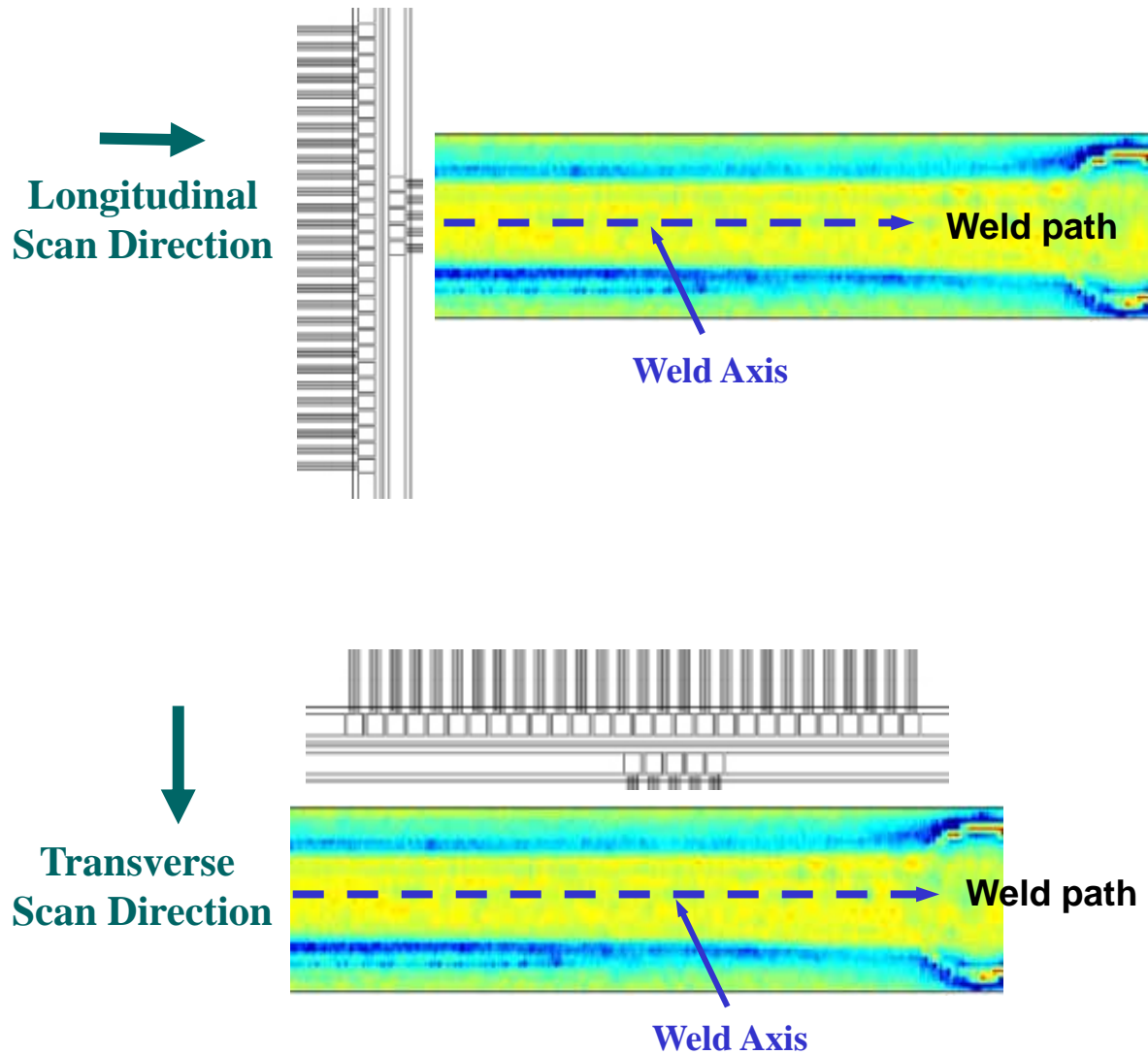
FSW Panel

JENTEK 39-Channel
Instrumentation

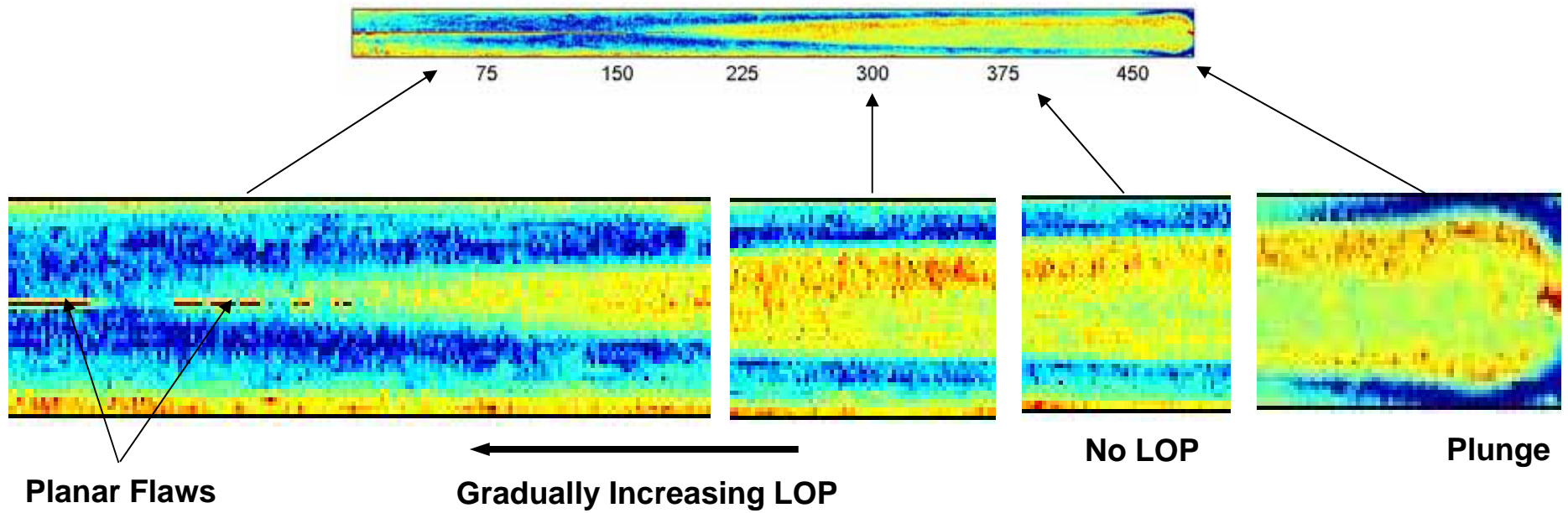
Conductivity/Lift-off Grid for Characterization of FSWs at 3.98 MHz



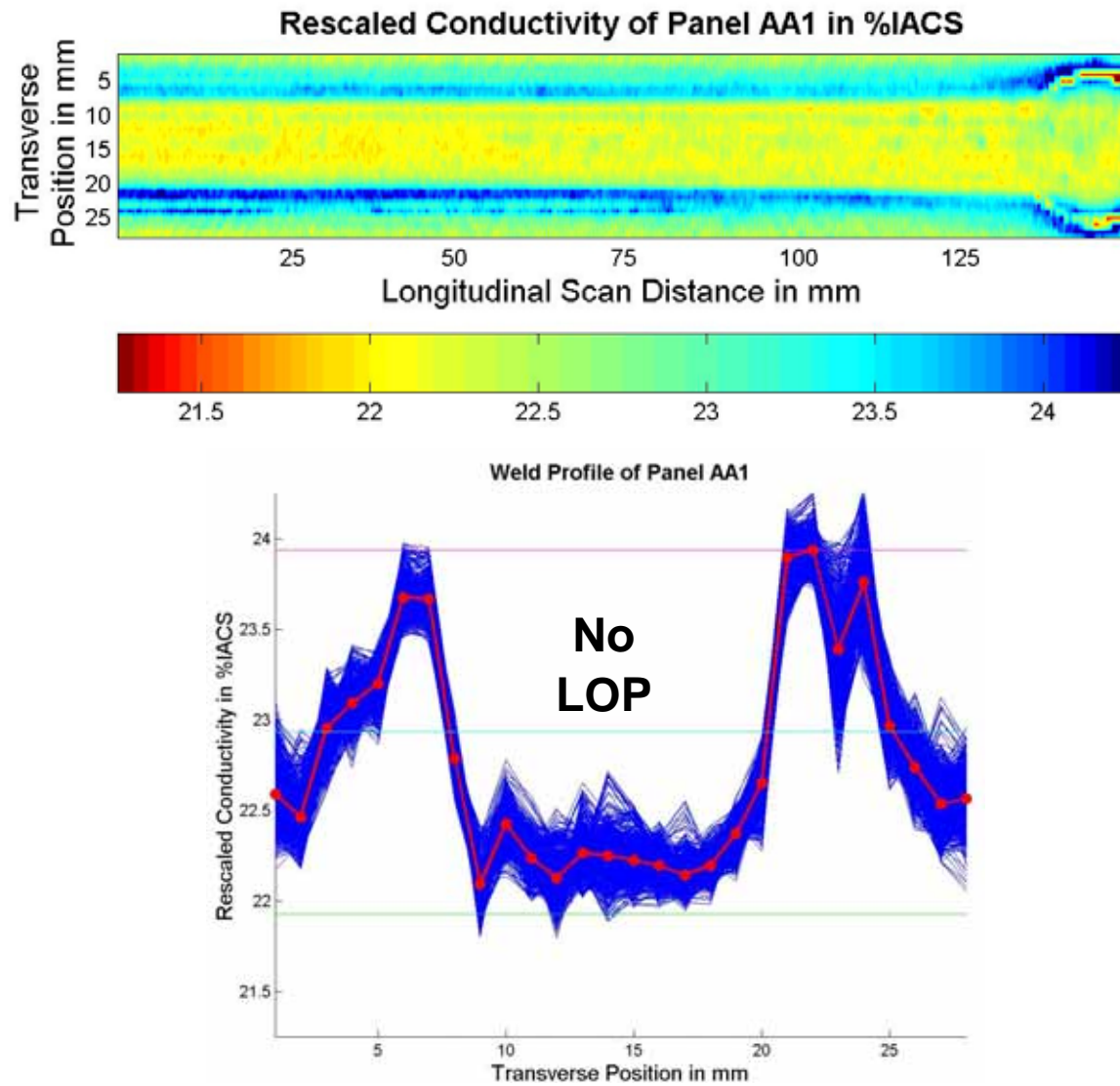
MWM-Array Orientations for Scanning of a Friction Stir Weld



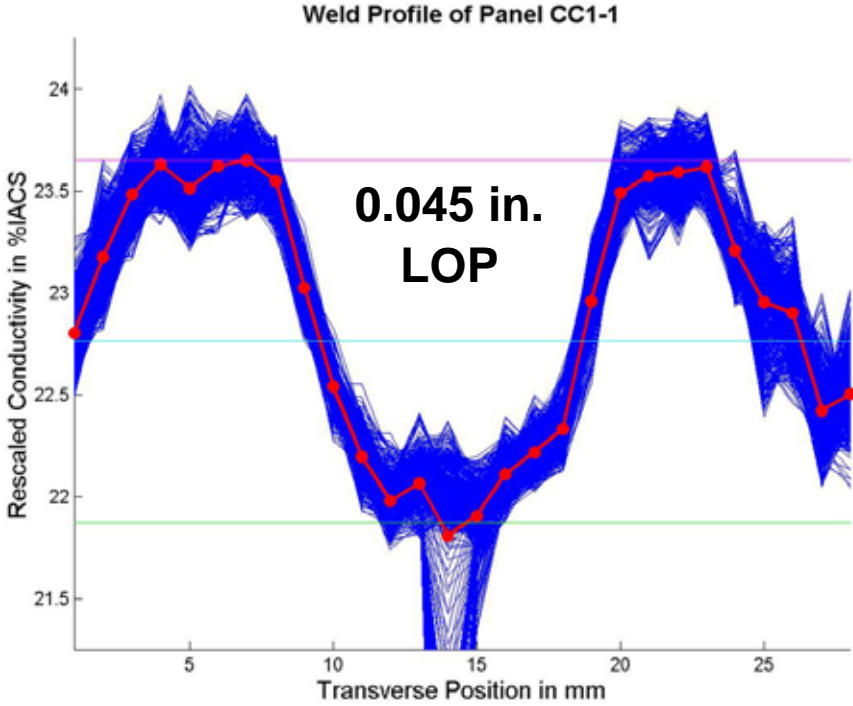
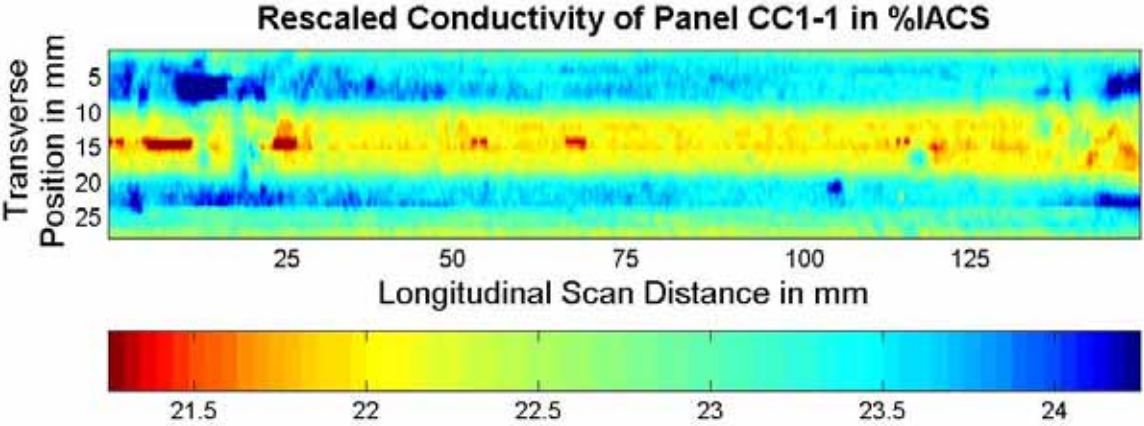
MWM-Array conductivity image of FSW in blind test panel B01A



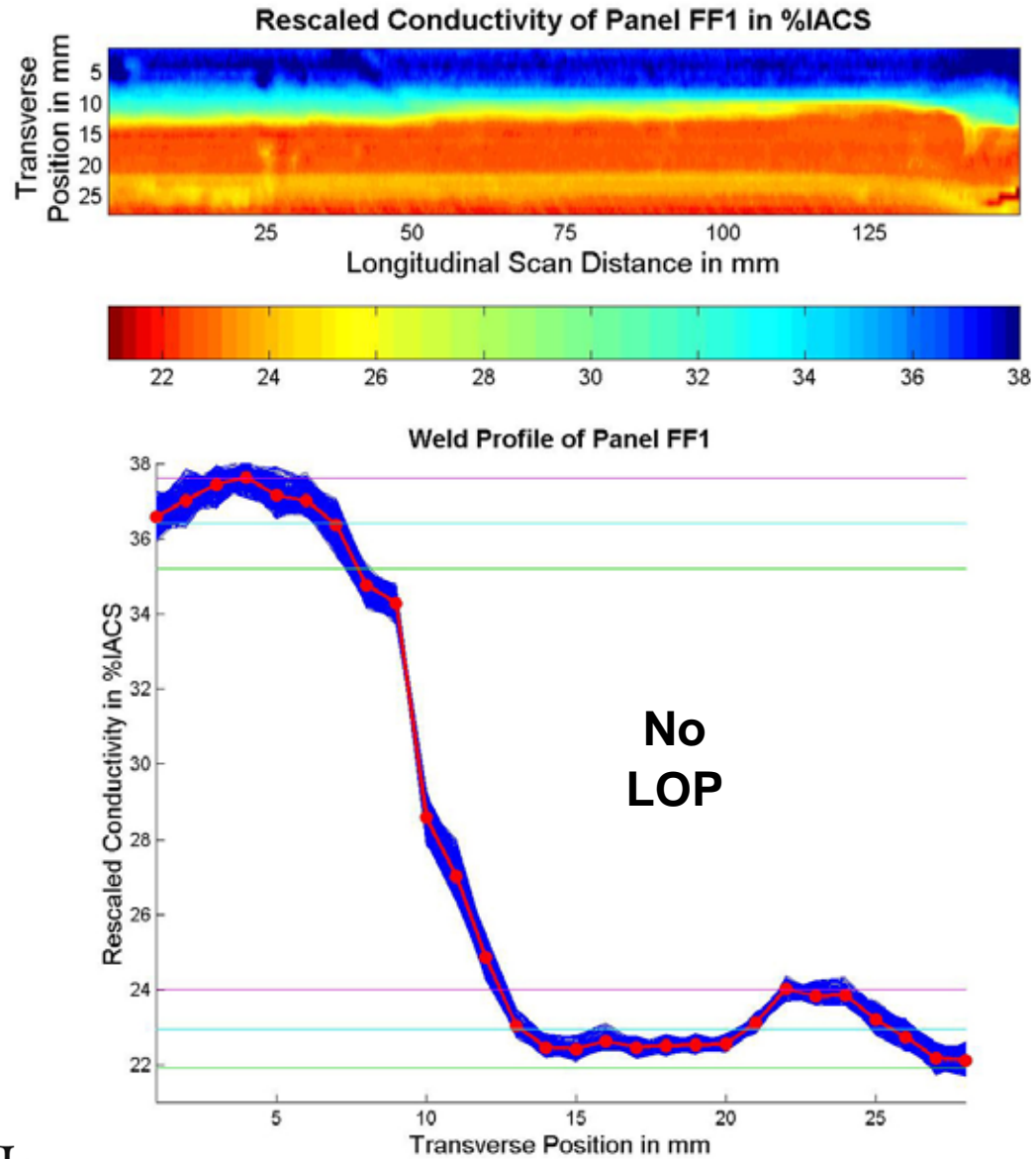
Conductivity image and profile for similar metal FSW



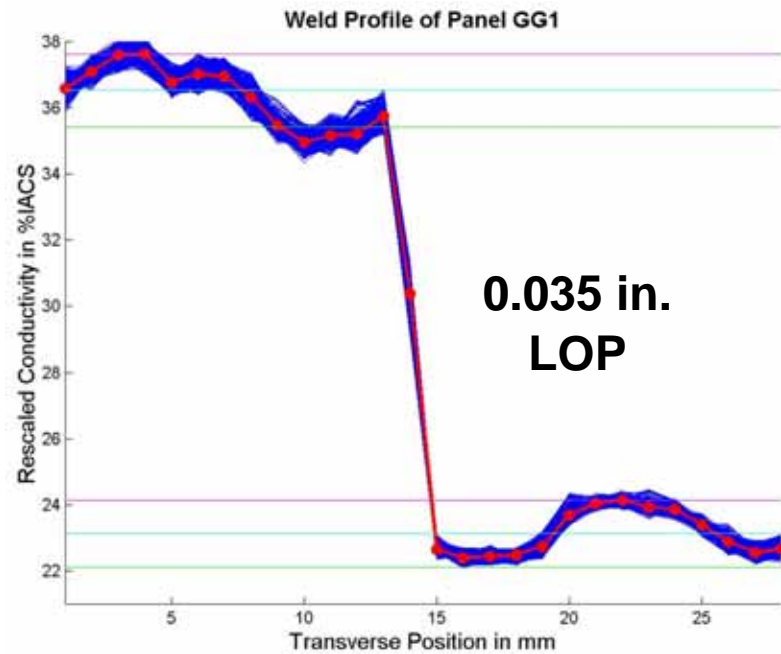
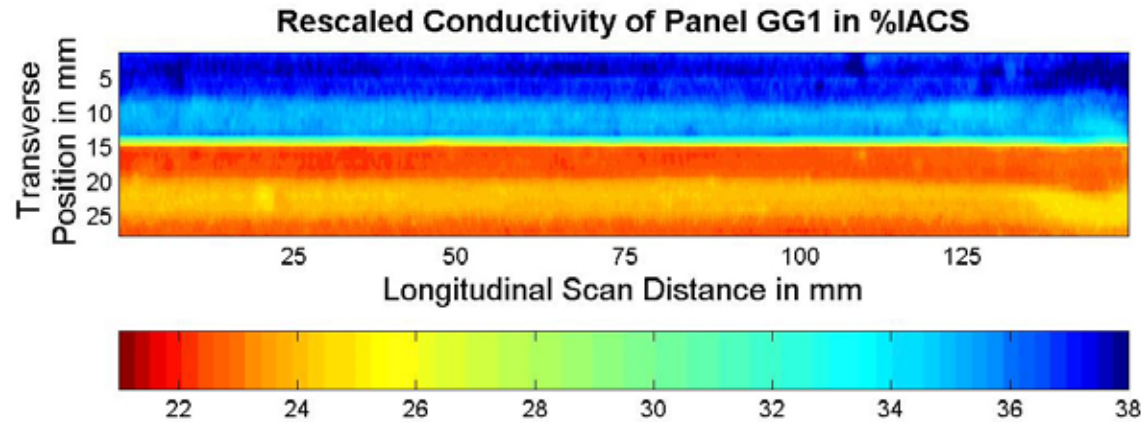
Conductivity image and profile for similar metal FSW



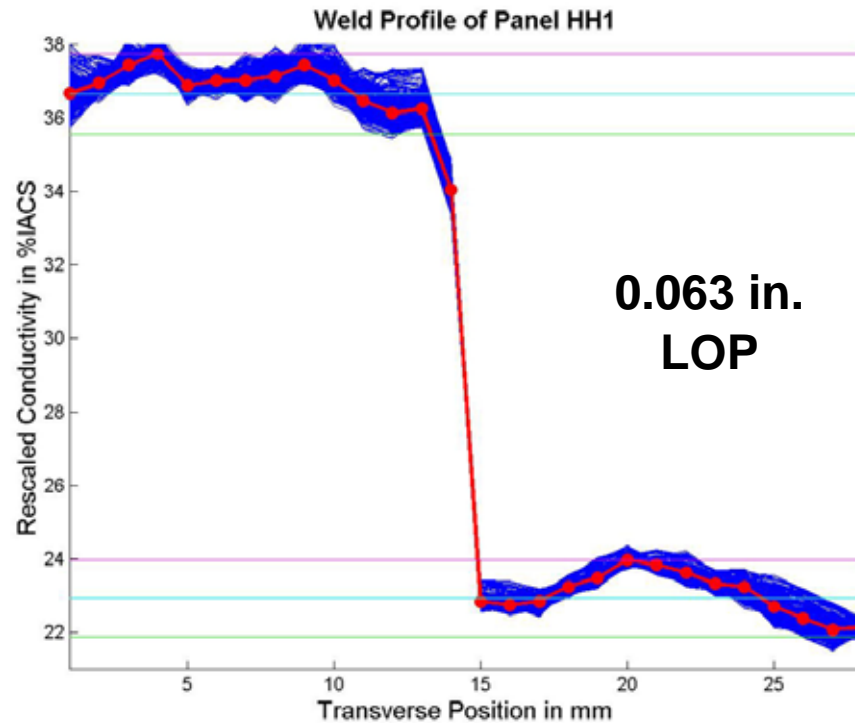
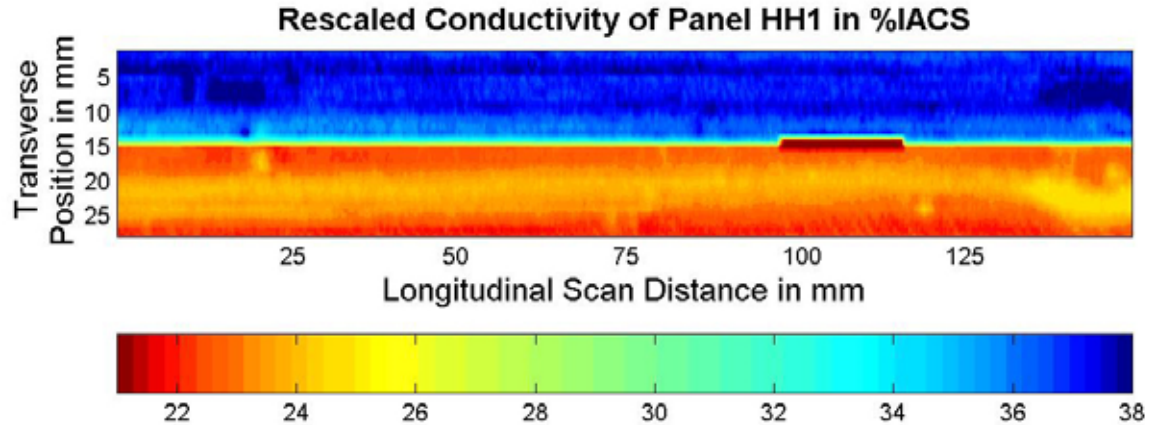
Conductivity image and profile for thin-plate dissimilar metal FSW



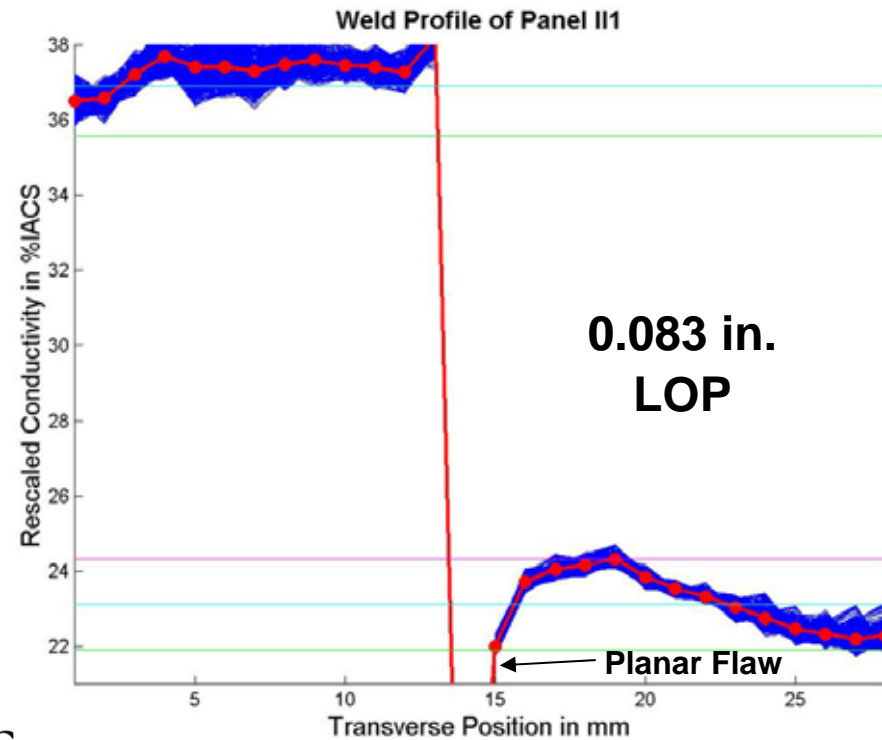
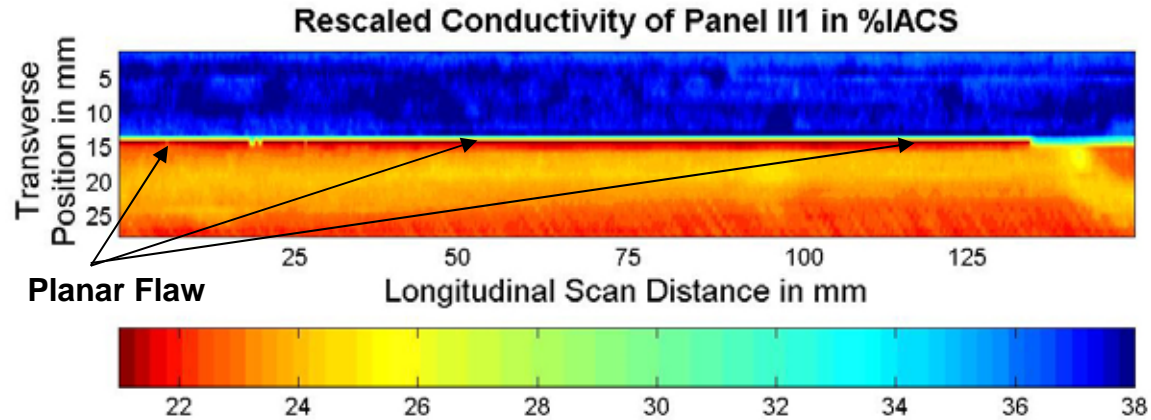
Conductivity image and profile for thin-plate dissimilar metal FSW



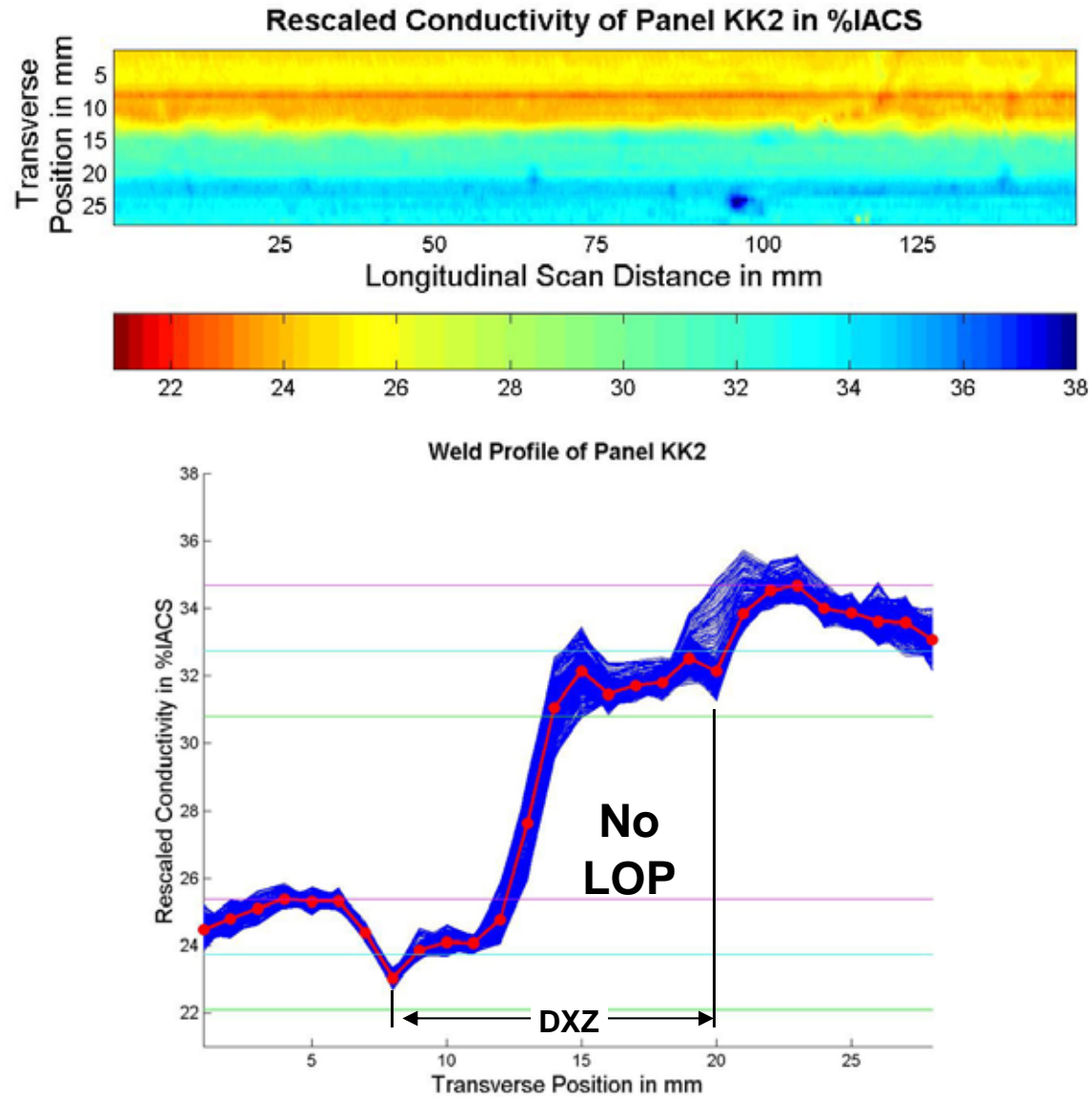
Conductivity image and profile for thin-plate dissimilar metal FSW



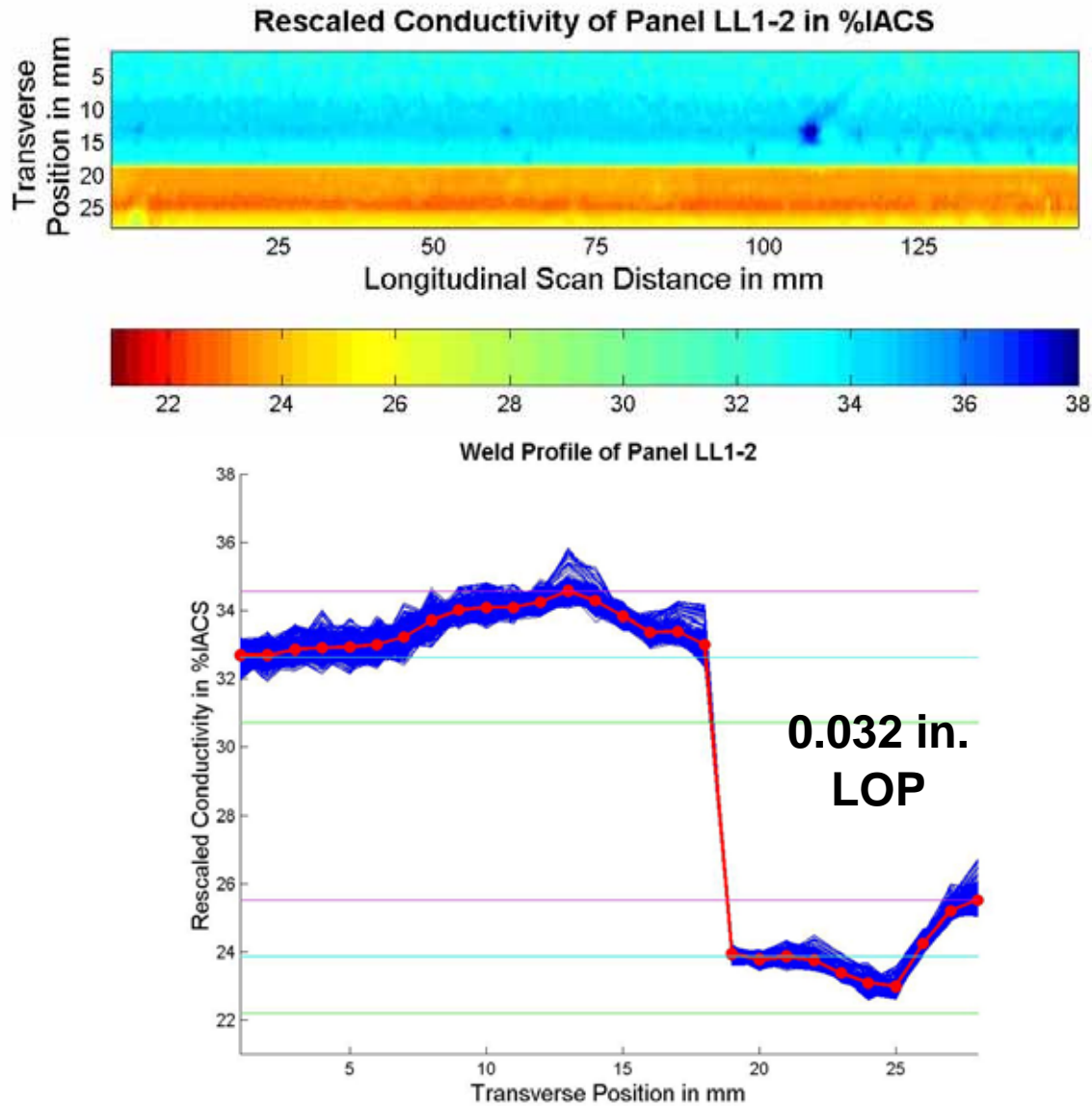
Conductivity image and profile for thin-plate dissimilar metal FSW



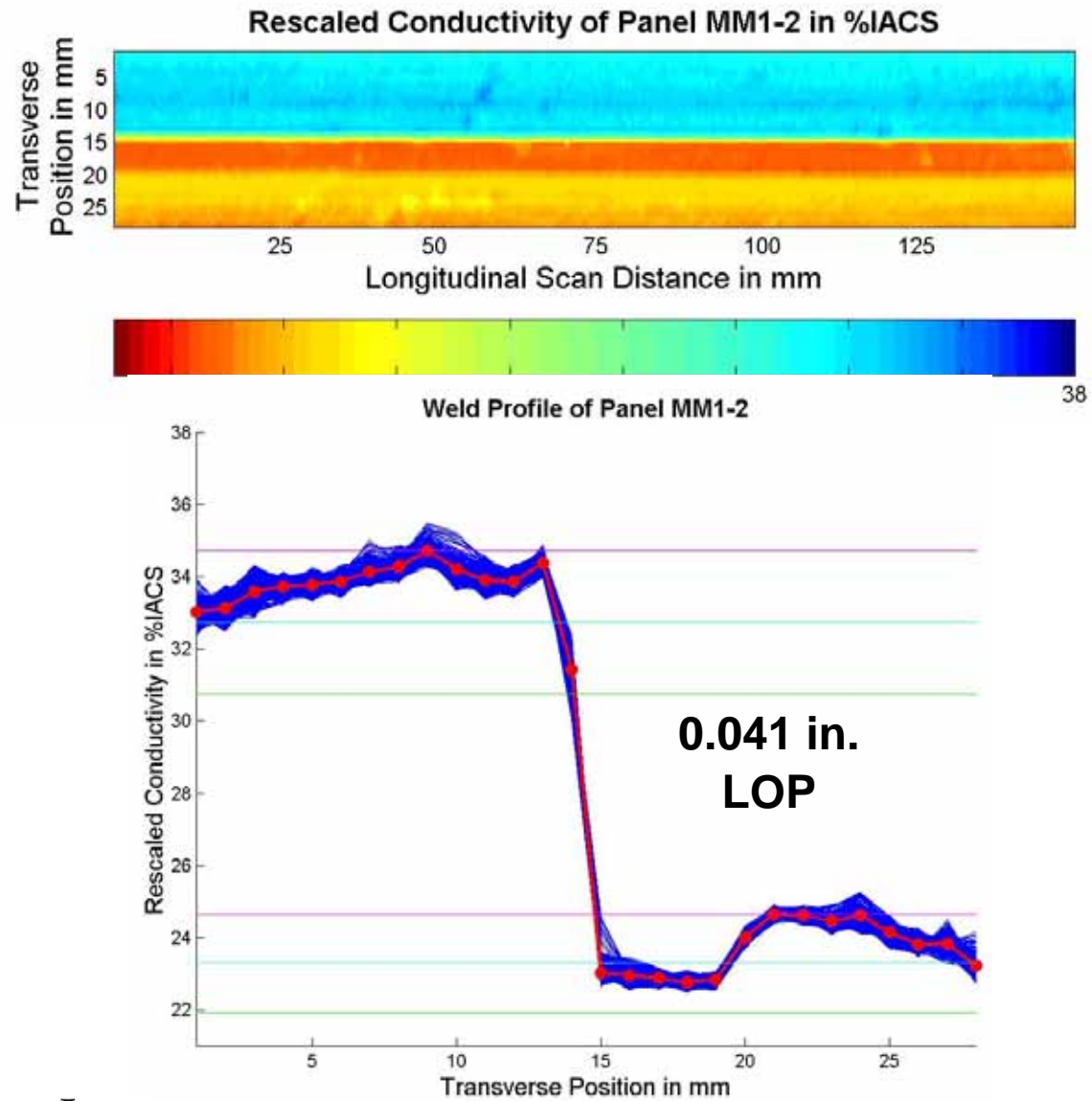
Conductivity image and profile for thick-plate dissimilar metal FSW



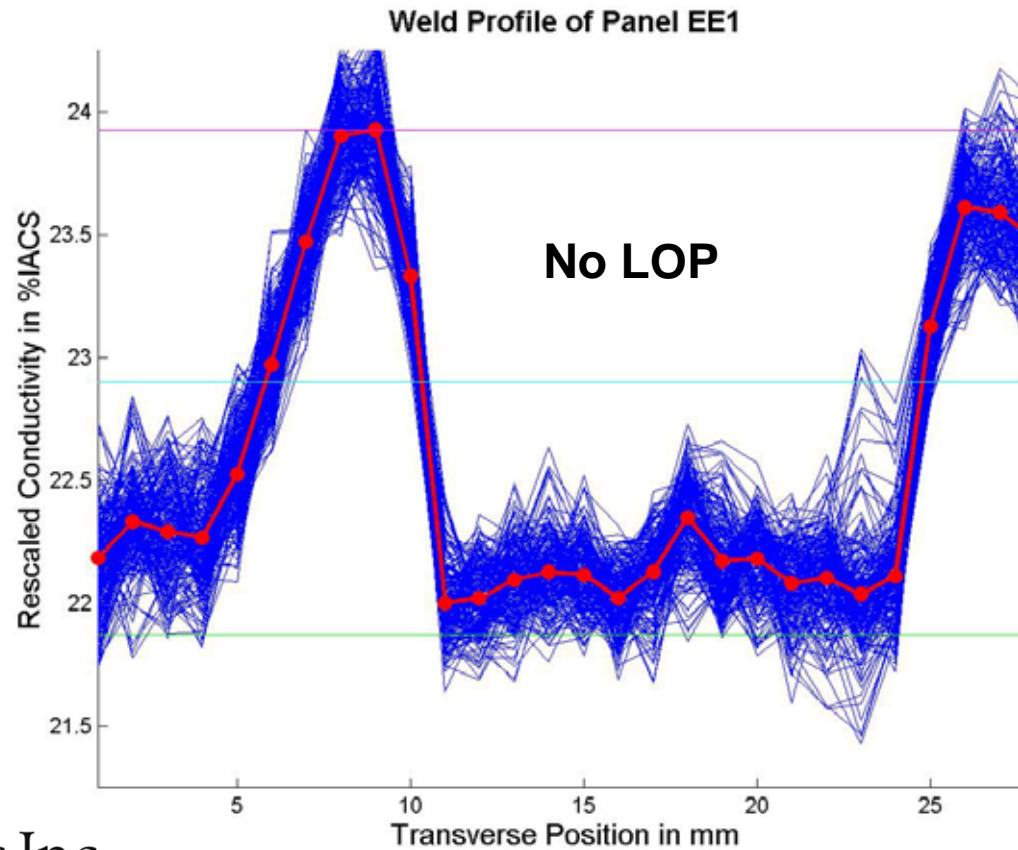
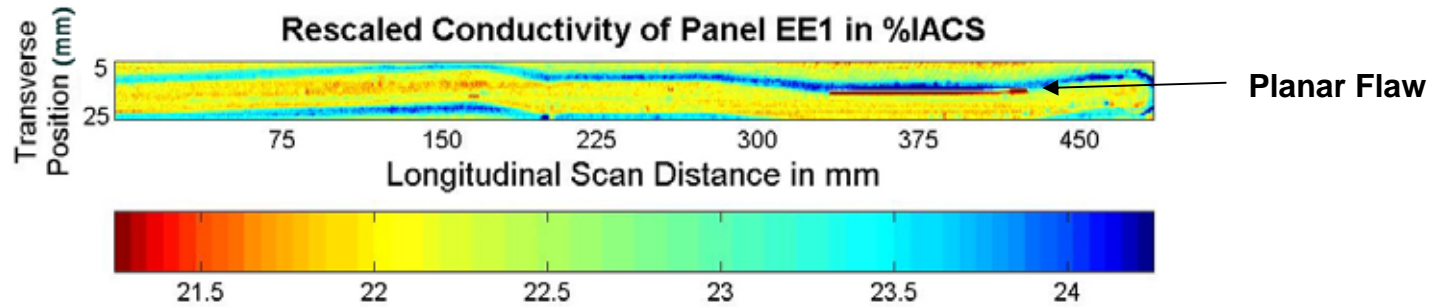
Conductivity image and profile for thick-plate dissimilar metal FSW



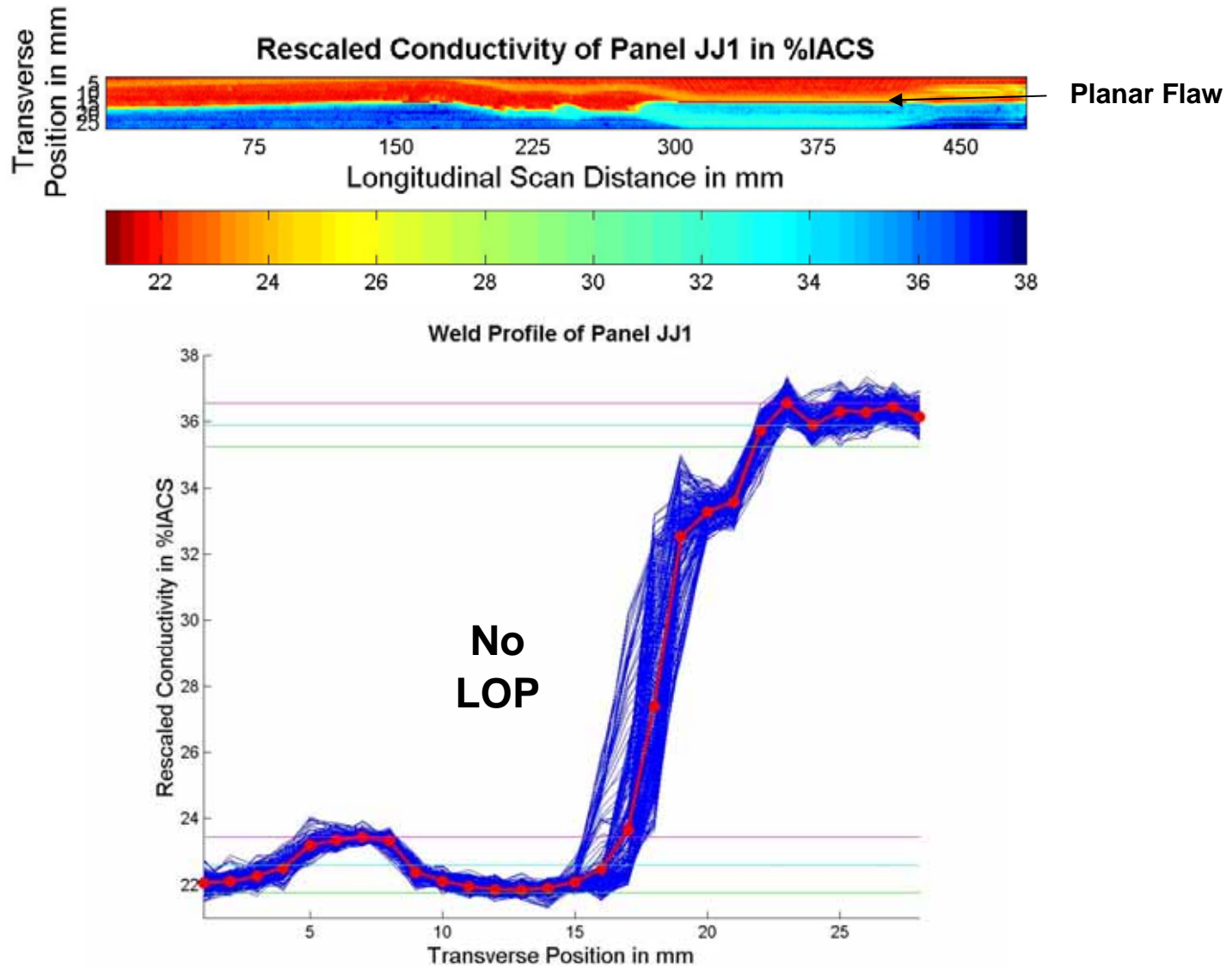
Conductivity image and profile for thick-plate dissimilar metal FSW



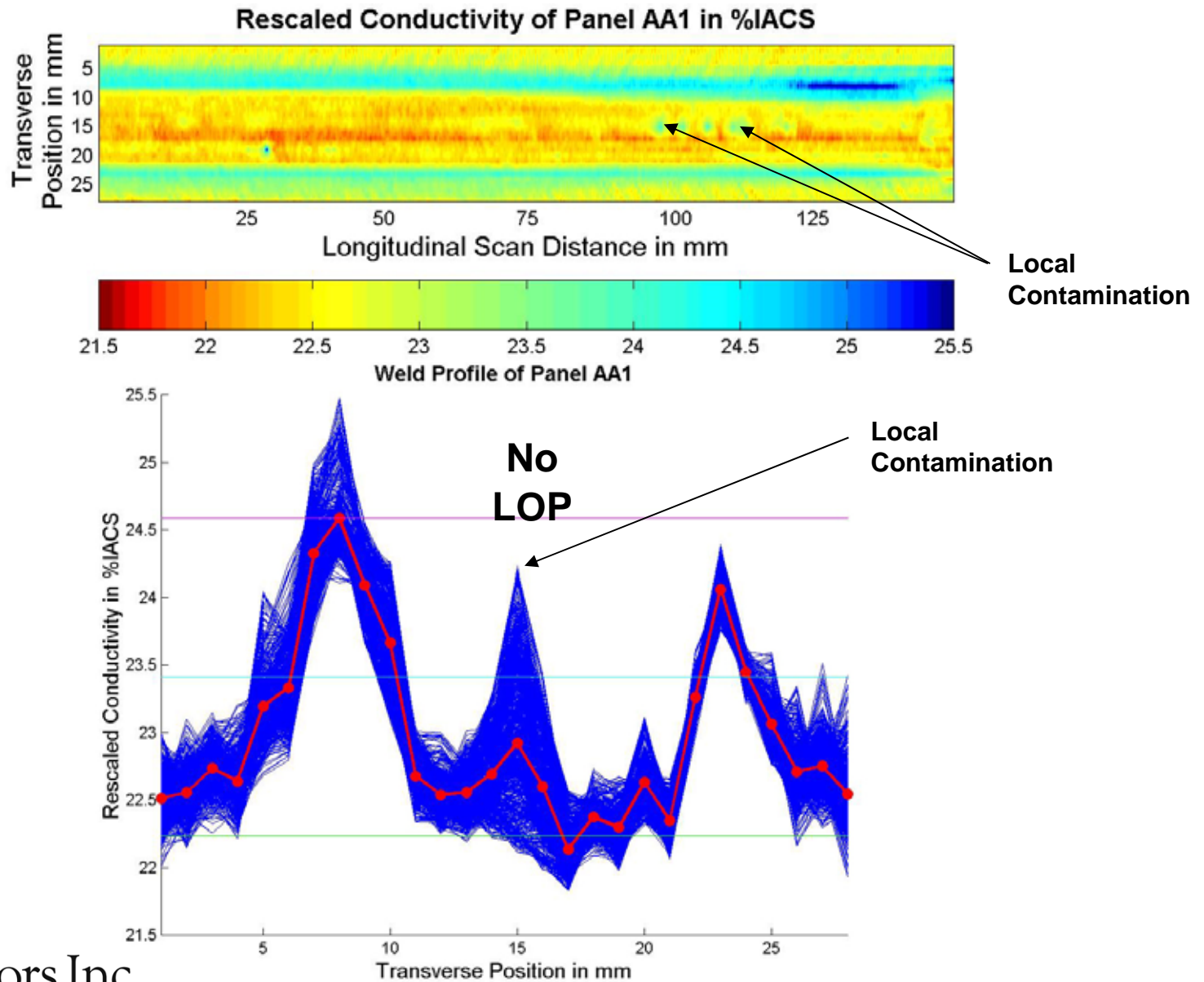
Conductivity image and profile for similar metal FSW with an offset section



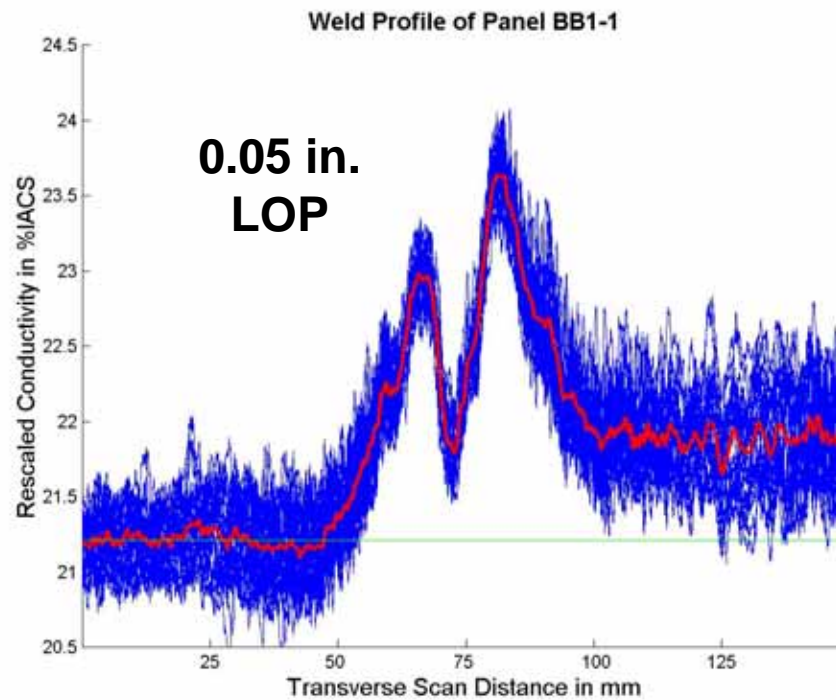
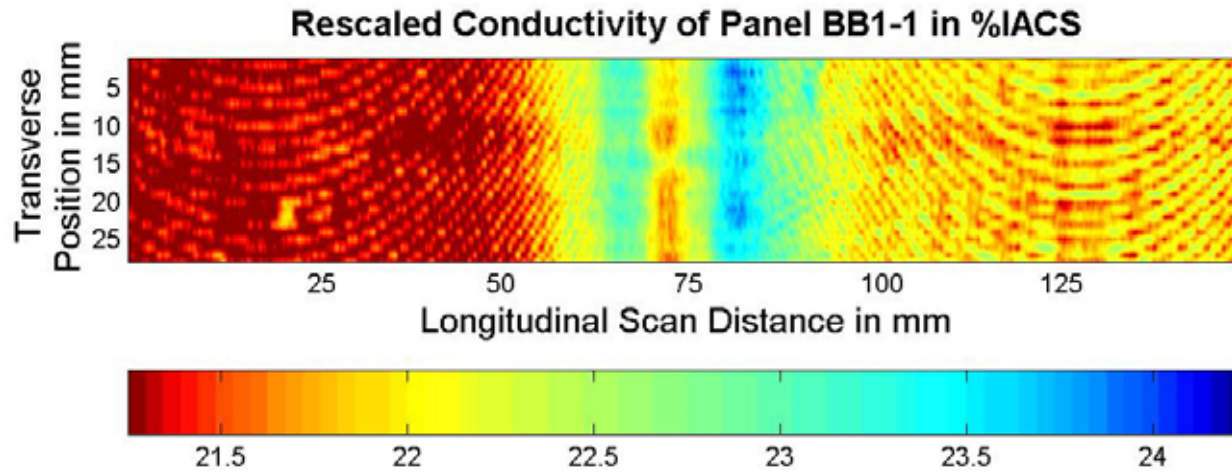
Conductivity image and profile for dissimilar metal FSW with an offset section



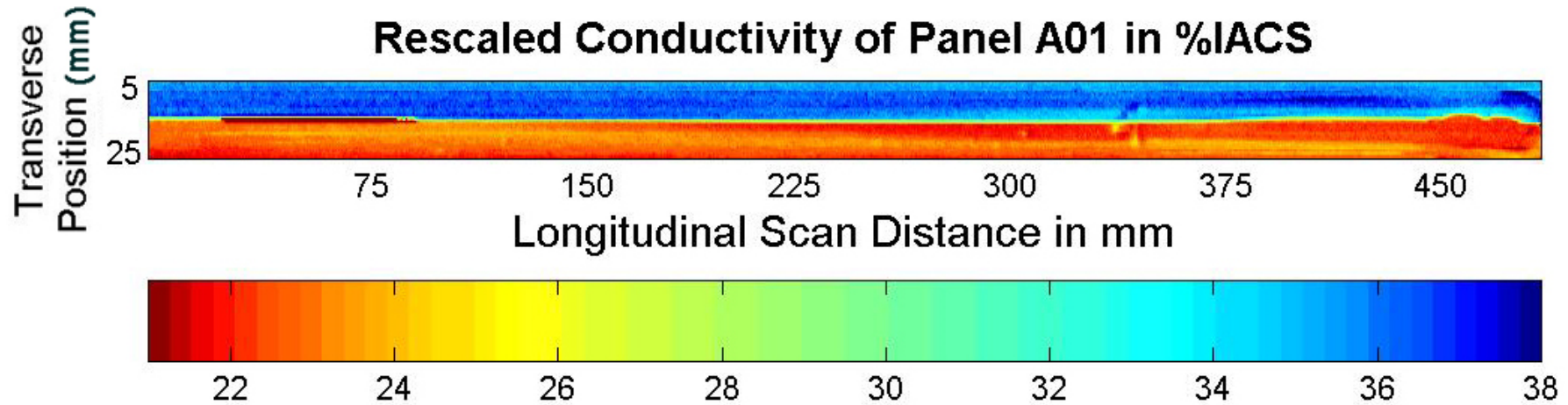
Conductivity image and profile for a similar metal FSW contaminated by the anvil



Conductivity image and profile for *nominally* similar FSW

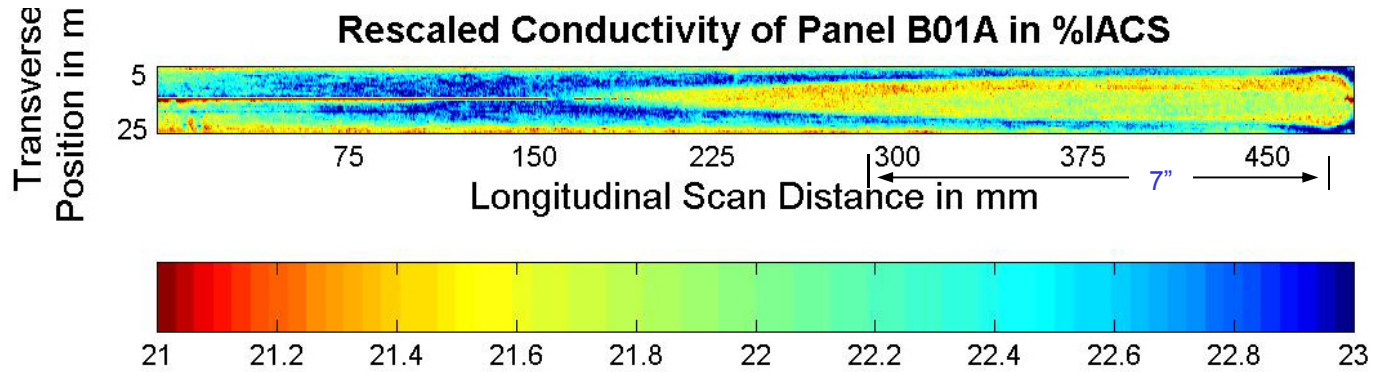


Conductivity image for the FSW in blind test panel A01

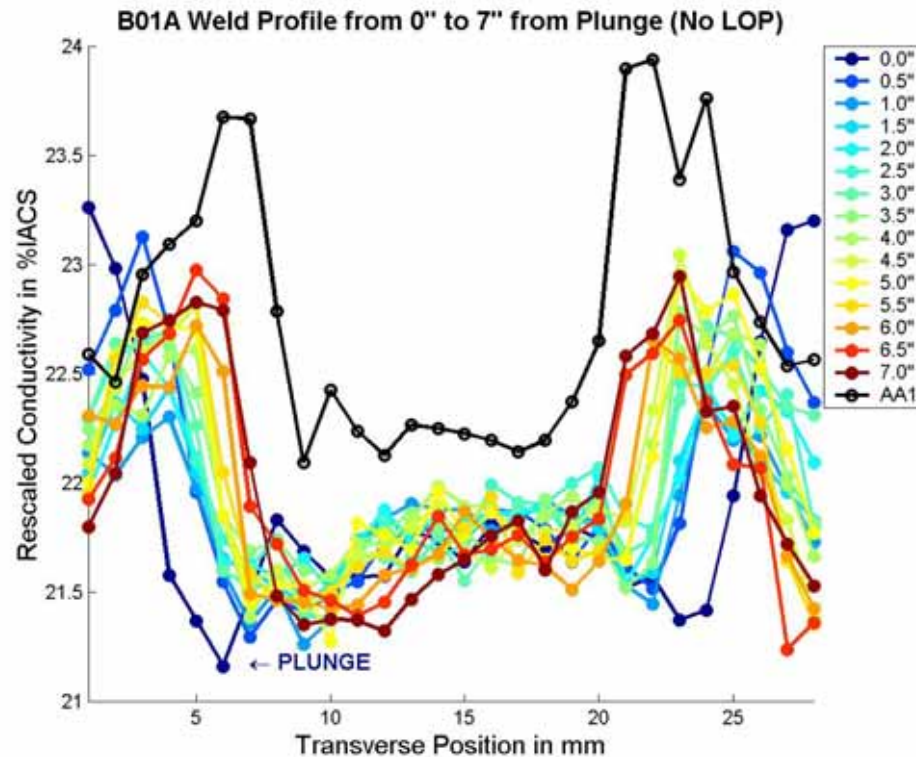


Conductivity profile was not generated for this panel scanned at the Marshall Space Flight Center due to lack of baseline data for rescaling. This is not expected in the future application when the required baseline data are not likely to be missing.

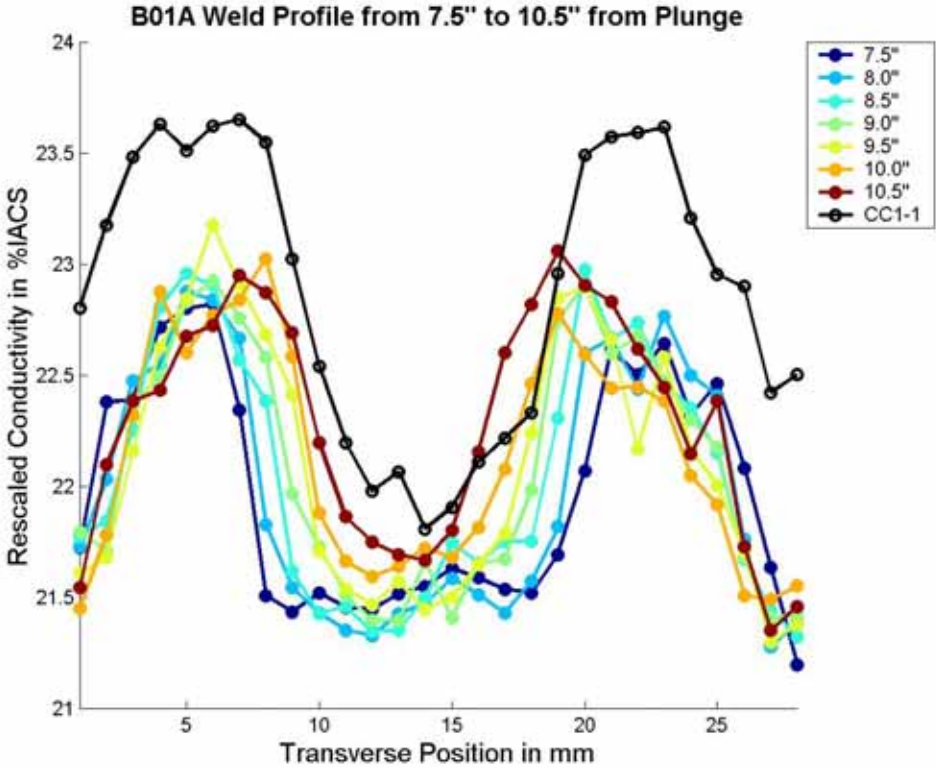
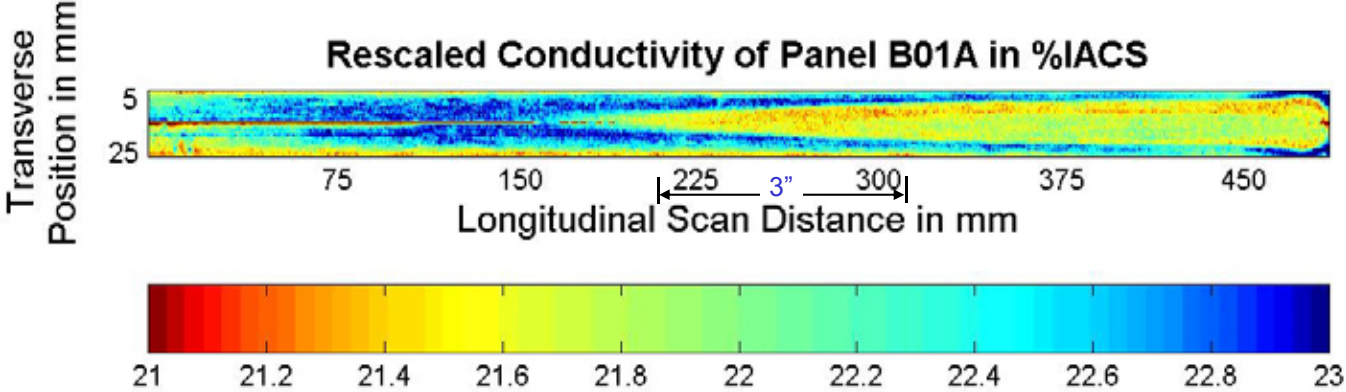
Conductivity image and profile for a 7-in. long section of the FSW in blind test panel B01A



The superimposed profile from no-LOP training set panel AA1 shows that the entire 7-in. long section in the blind test panel has no LOP

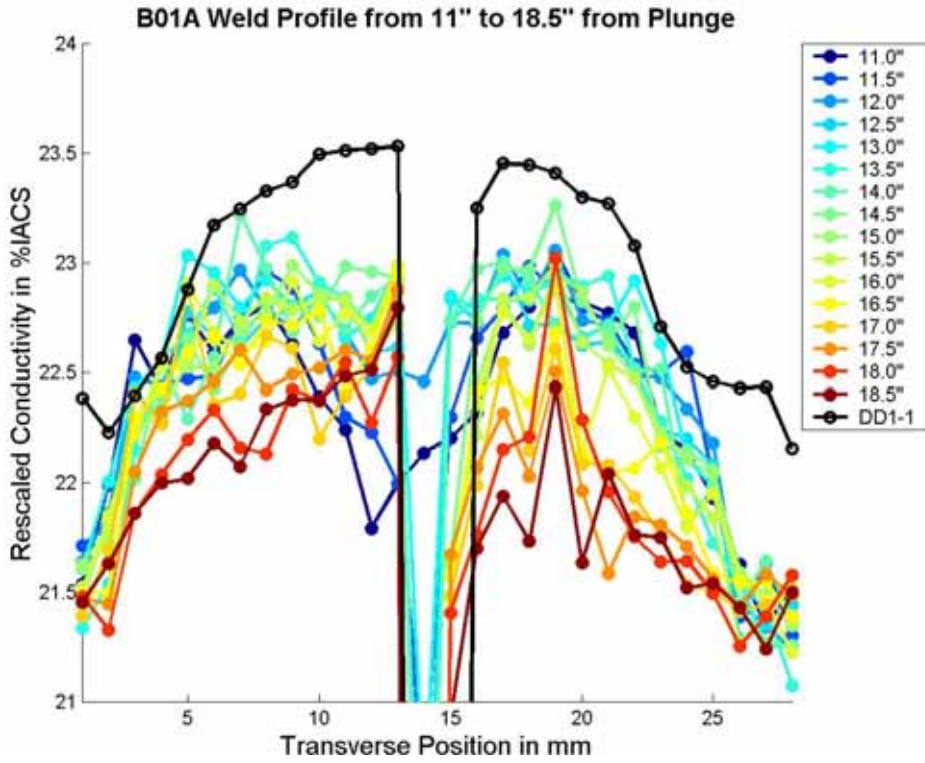
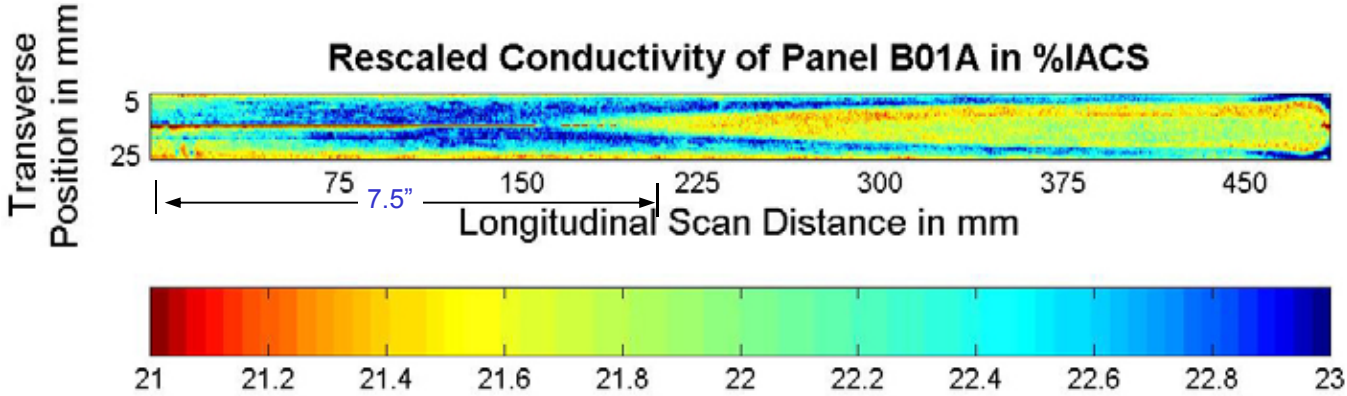


Conductivity image and profile for a 3-in. long section of FSW in blind test panel B01A



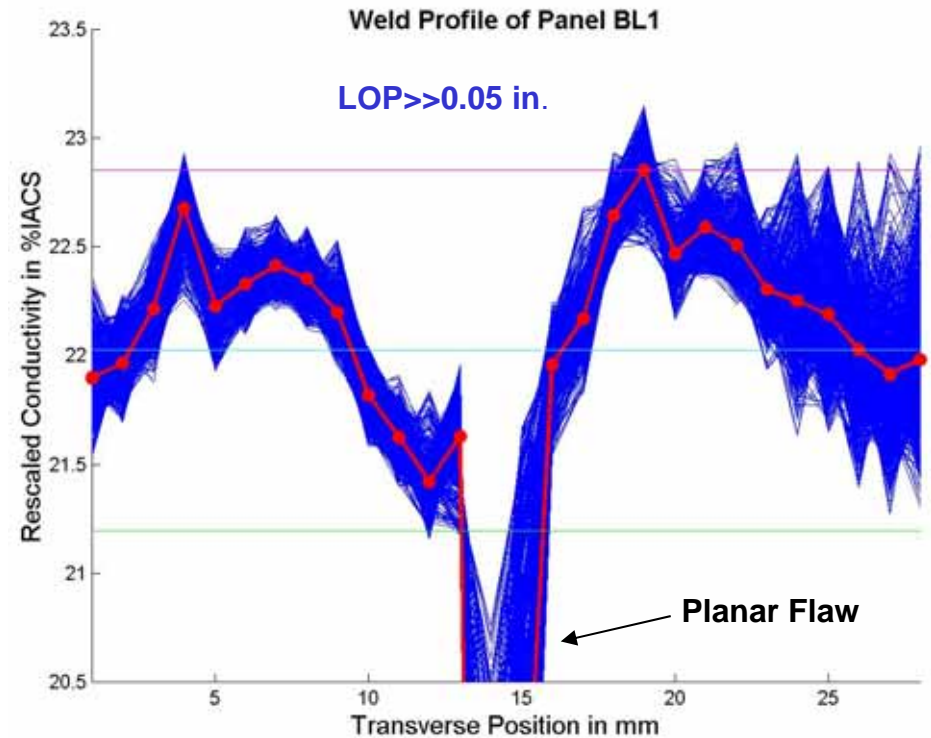
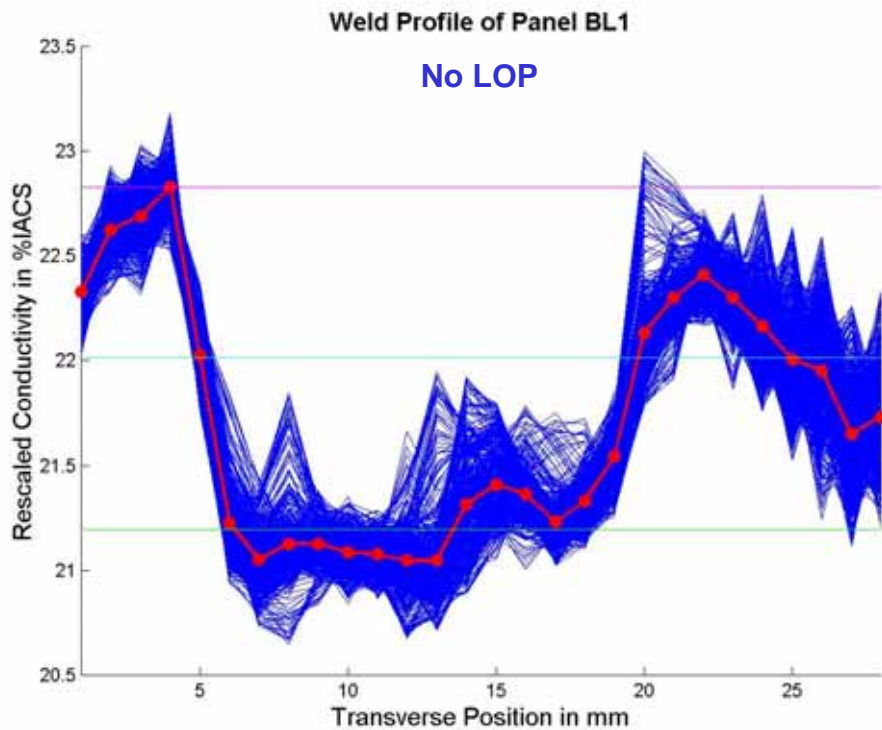
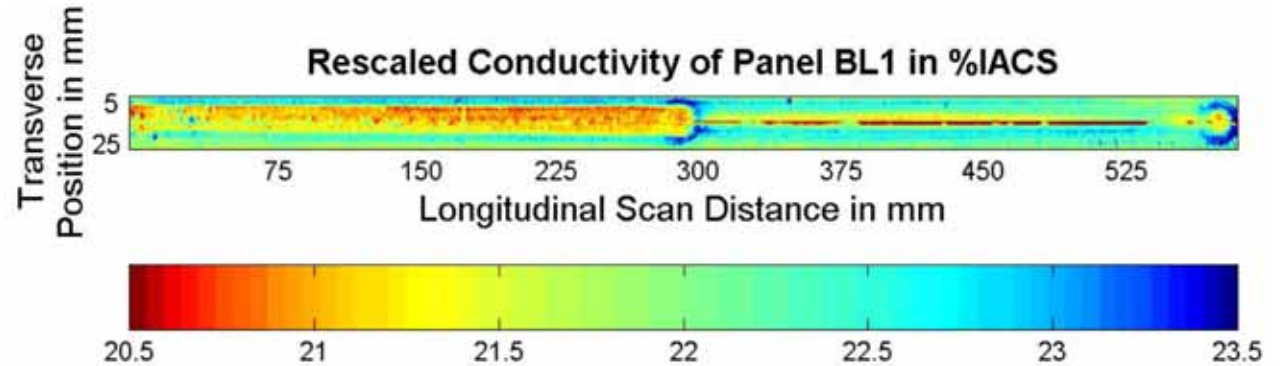
The superimposed profile from training set panel CC1-1 (with 0.045-in. LOP) shows that a major part of the 3-in. long section has LOP gradually increasing from well under 0.03 in. to ≥ 0.05 in.

Conductivity image and profile for a 7 1/2-in. long section of FSW in blind test panel B01A



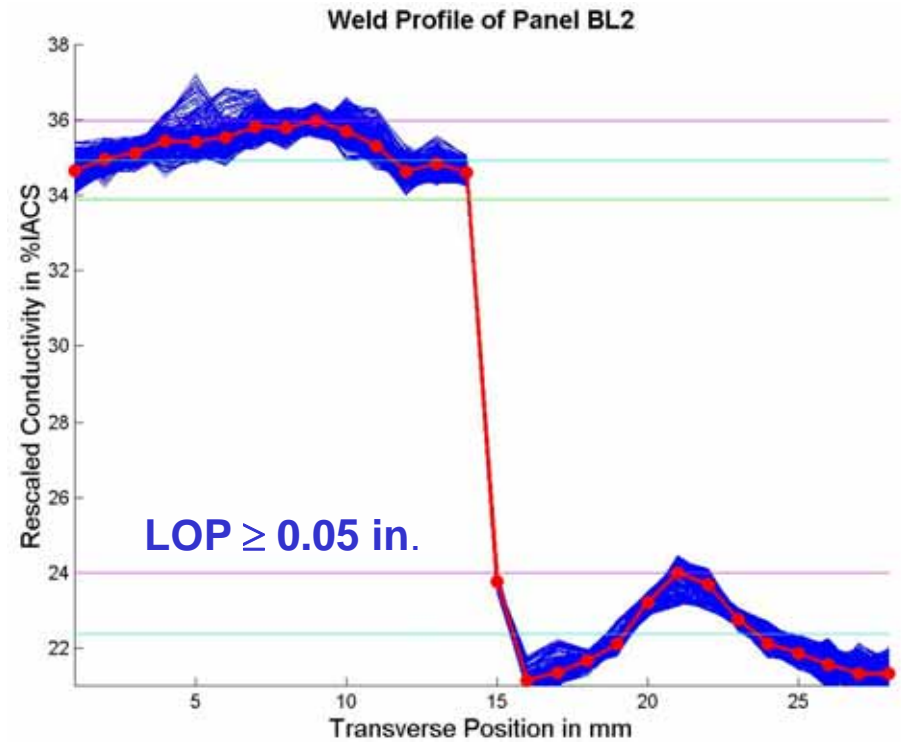
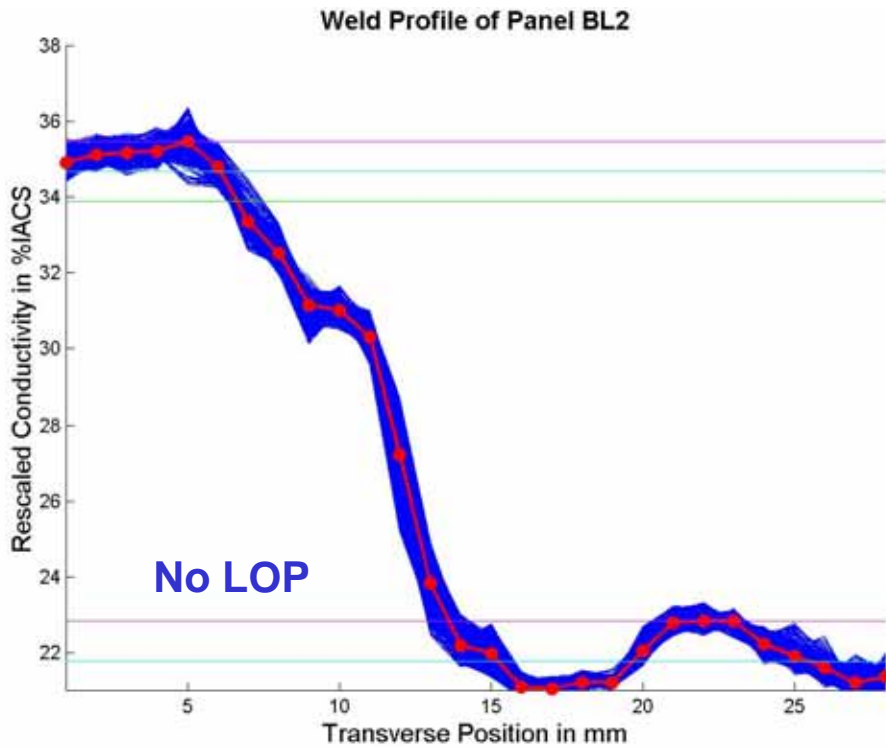
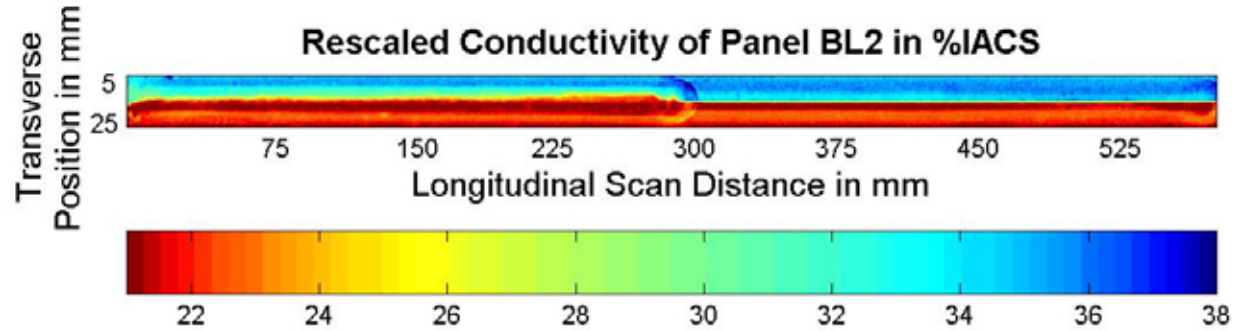
Conductivity image and profile for blind test panel BL1

The presence of **two plunges** suggests the presence of **two aligned FSWs** in this **similar** metal panel.



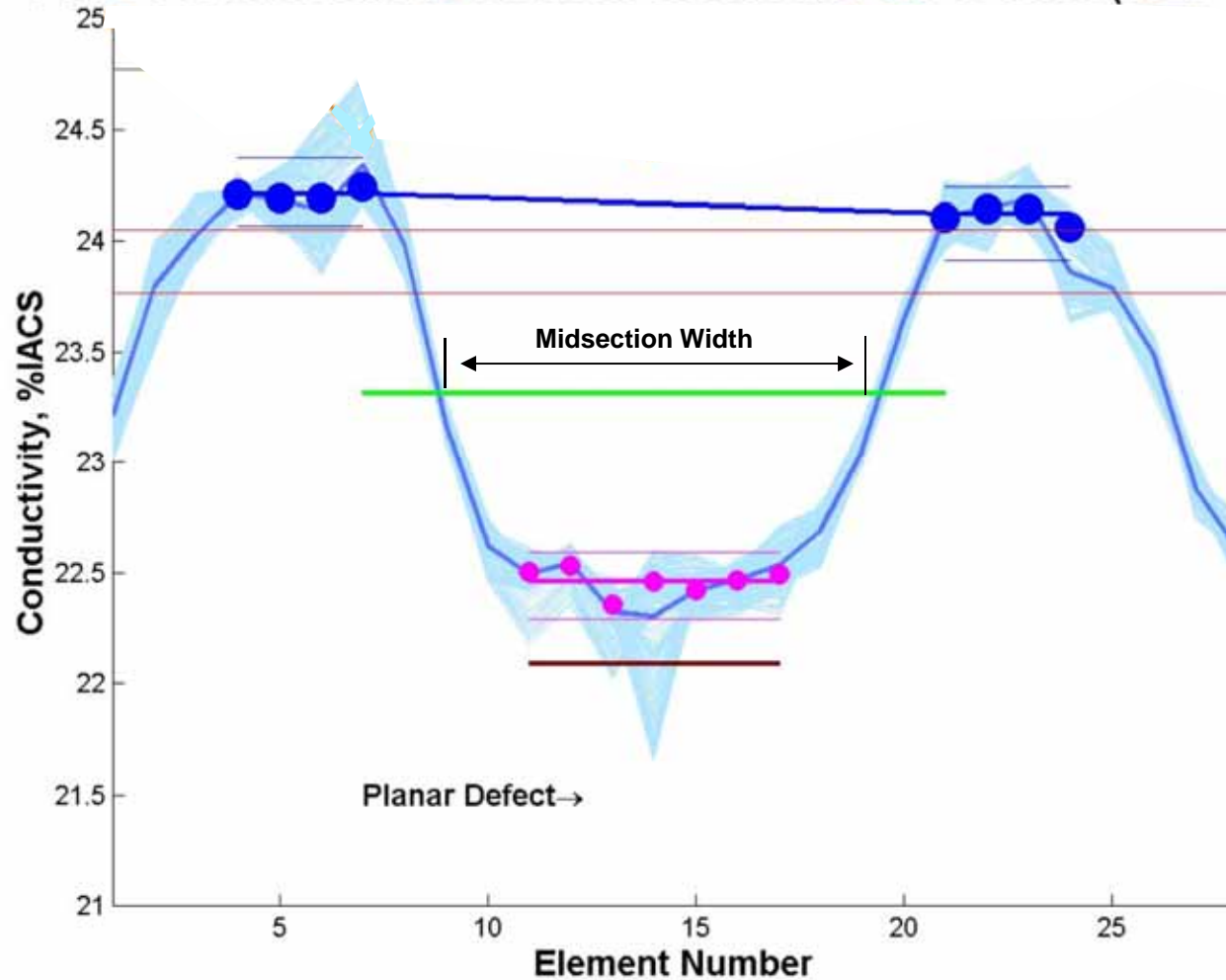
Conductivity image and profile for blind test panel BL2

The presence of **two plunges** suggests the presence of **two aligned FSWs** in this **similar** metal panel.

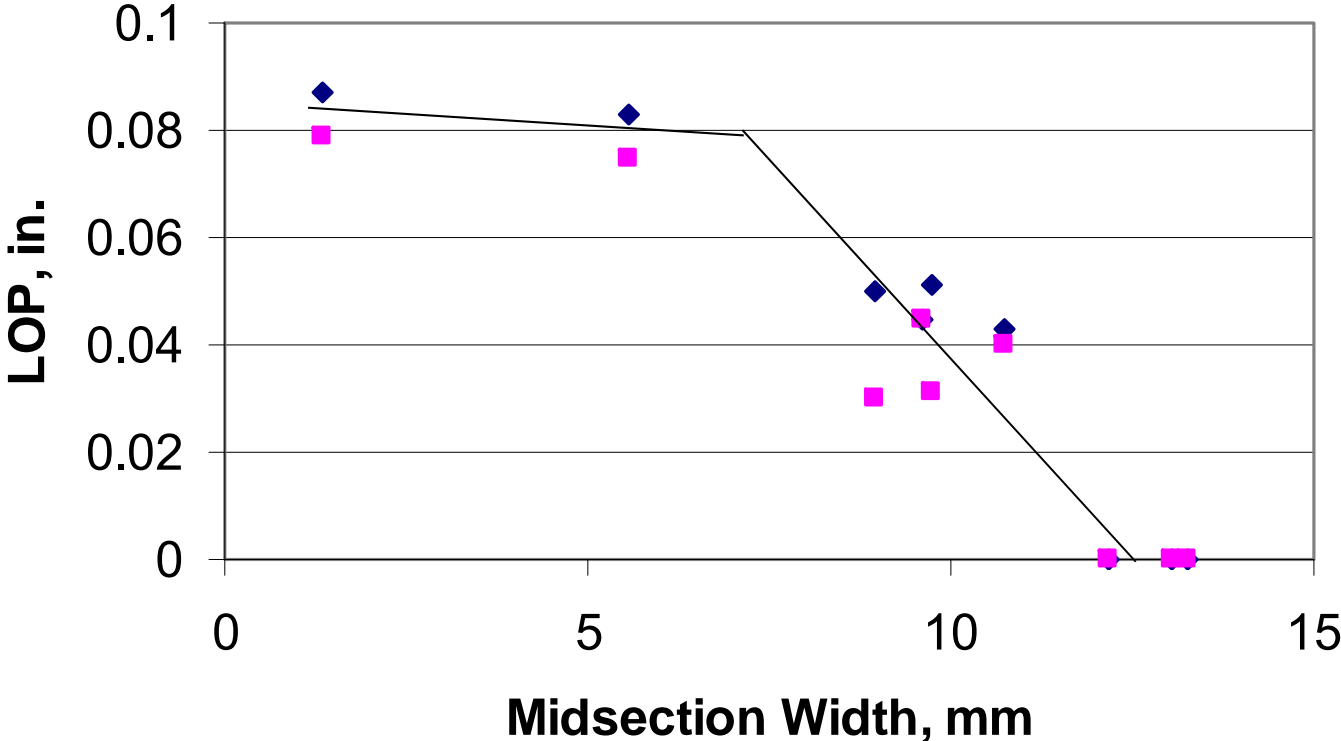


Conductivity profile schematically showing the midsection width definition for a similar metal FSW

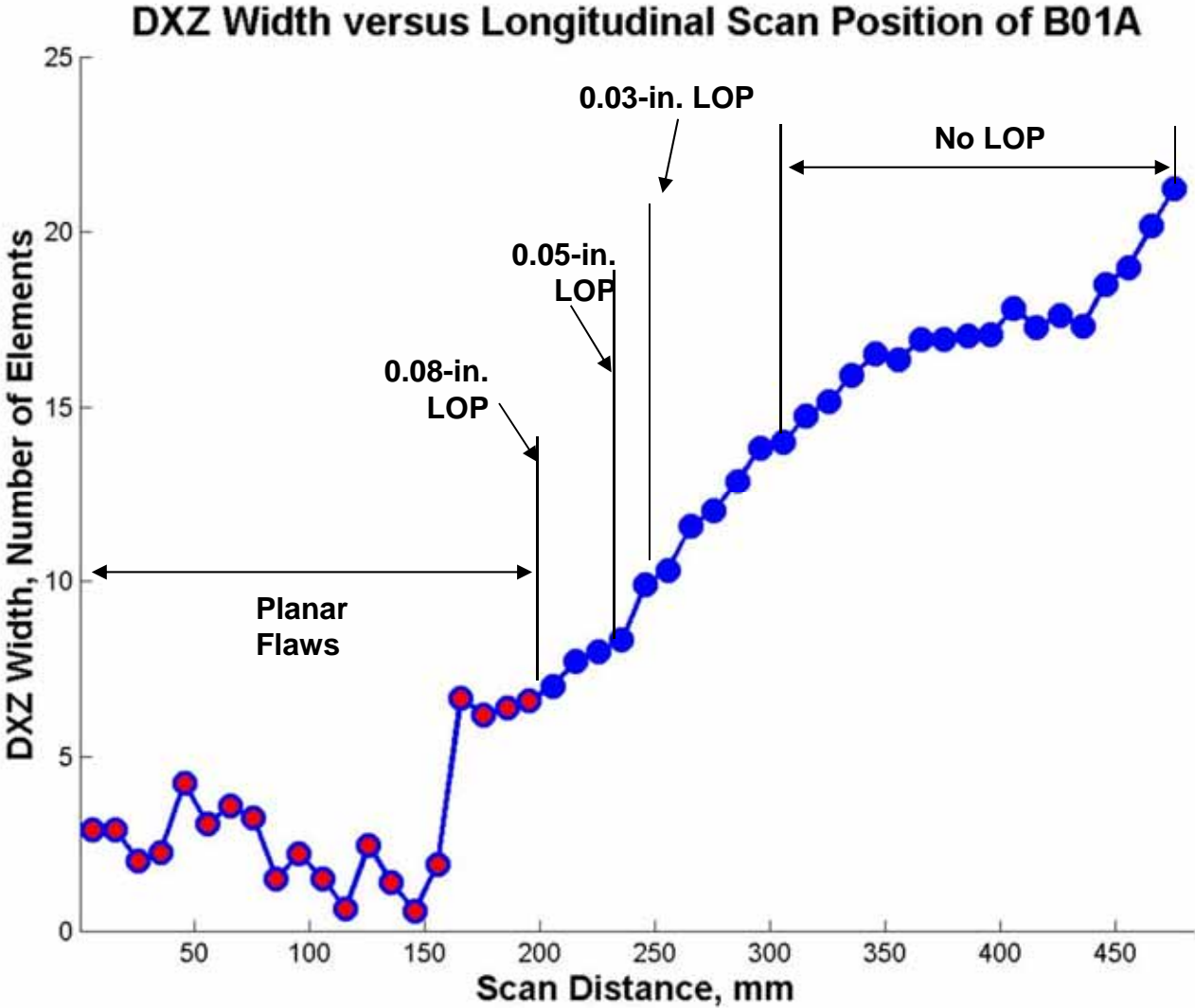
CC1-2 0 Weld Profile #5 between 40.7558 and 50.7191 mm (1022-1276)



Correlation between the midsection width and LOP for similar metal FSWs



Midsection width along the similar metal “tapered” FSW



Conclusions

JENTEK has demonstrated that **MWM-Array** (Meandering Winding Magnetometer Array) technology can provide an **effective tool** for **inspection of FSWs**, particularly for **detection and sizing of LOP** defects.

For similar aluminum alloy welds, a consistent relationship between estimated backside midsection widths and LOP depth has been demonstrated.

For dissimilar aluminum alloy welds, detection of LOP above 0.03-in. in depth appears likely.