Detection & Sizing of Cracks in SCC Colonies using MWM-Array Eddy Current Testing

Neil Goldfine, Andrew Washabaugh, Todd Dunford, Shayan Haque

JENTEK Sensors, Inc., 110-1 Clematis Avenue, Waltham MA 02453
Tel: 781-373-9700; www.jenteksensors.com

June 3, 2015

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Technology Description

1. Sensors: MWM®-Arrays

- **Paradigm shift** in sensor design (first priority is predictable response based on physics-based modeling)
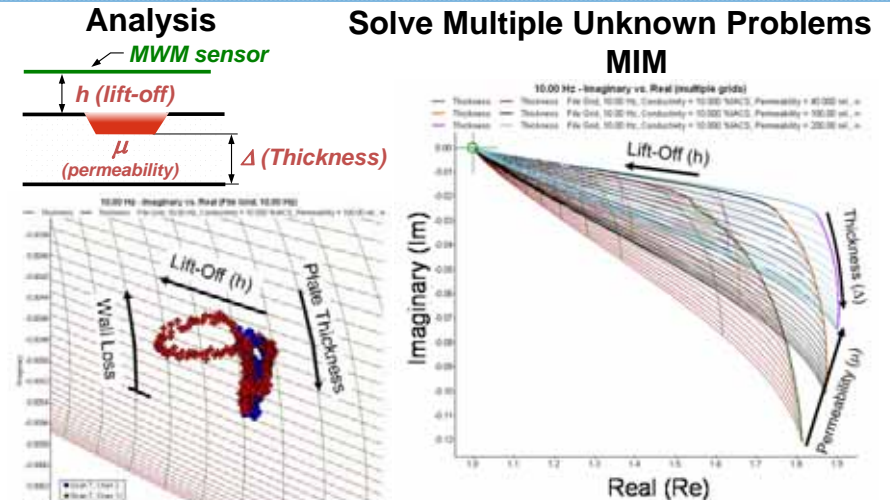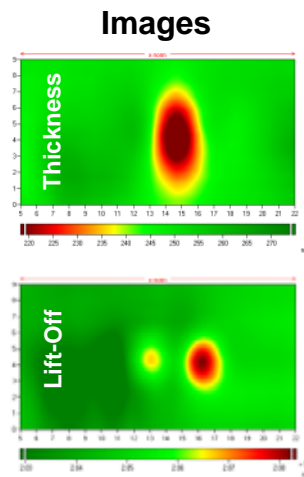

Scan Direction

$\lambda/4$

2. Next Generation 8200 GridStation® Electronics

- **10x signal-to-noise improvement**
- **Very low frequencies (deep penetration)**
- **Crack detection through up to 0.5 inches of material**
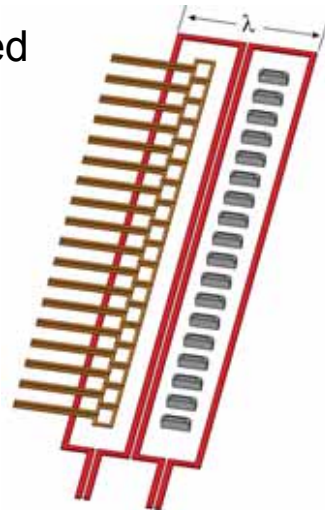- **Reduced drift**

3. GridStation Software using Hyperlattices®

- **Rapid, autonomous data analysis** Performs multivariate inverse method (MIM) using precomputed databases
  - Defect Images
  - Performance Diagnostics
  - Noise Suppression

Images

Thickness

Lift-Off

Analysis

MWM sensor

h (lift-off)

μ (permeability)

Δ (Thickness)

Lift-Off (h)

Plate Thickness

Wall Loss

Solve Multiple Unknown Problems MIM

Lift-Off (h)

Imaginary (Im)

Real (Re)

Sensor Selection

- Decay rate determined by skin depth at high frequency and sensor dimensions at low frequency

- Large dimensions needed for thick coatings/insulation

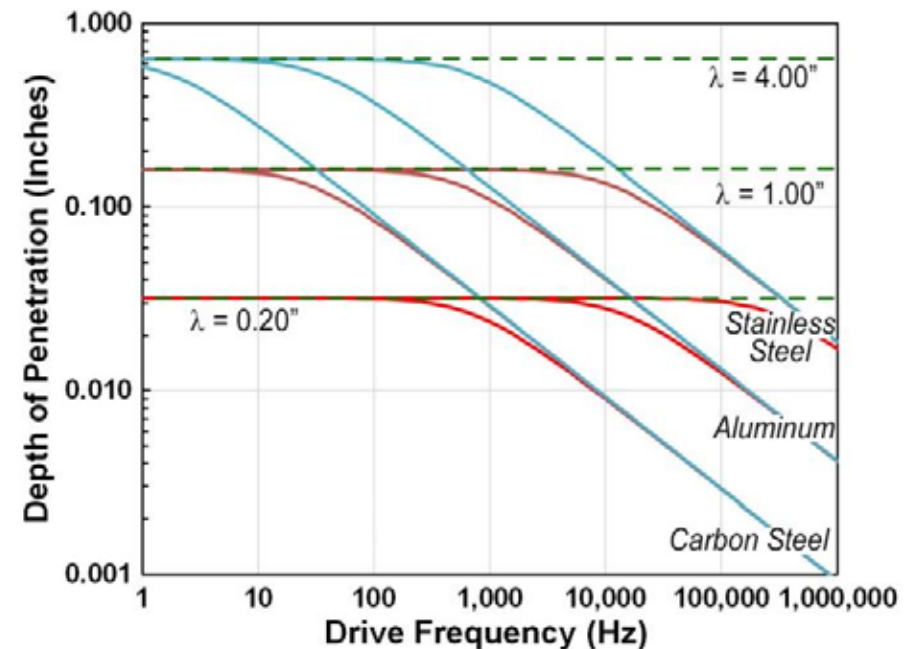- Low frequencies needed to penetrate through steel pipe wall

Depth of Penetration = $1/\text{Re}(\Gamma_n)$

Low Frequency Limit = $\dfrac{\lambda}{2\pi}$

$$\Gamma_n = \sqrt{(2\pi n/\lambda)^2 + j2/\delta^2}$$

Skin depth: $\delta = \sqrt{\dfrac{1}{\pi f \mu \sigma}}$

1 inch = 25.4 mm

MWM sensors and MWM-Arrays covered by issued and pending patents, including, but not limited to: 8,928,316, 8,803,515, 8,768,657, 8,494,810, 8,237,433, 8,222,897, 8,050,883, 7,994,781, 7,876,094, 7,812,601, 7,696,748, 7,589,526, 7,533,575, 7,528,598, 7,526,964, 7,518,360, 7,467,057, 7,451,657, 7,451,639, 7,411,390, 7,385,392, 7,348,771, 7,289,913, 7,280,940, 7,230,421, 7,188,532, 7,183,764, 7,161,351, 7,161,350, 7,106,055, 7,095,224, 7,049,811, 6,995,557, 6,992,482, 6,952,095, 6,798,198, 6,784,662, 6,781,387, 6,727,691, 6,657,429, 6,486,673, 6,433,542, 6,420,867, 6,380,747, 6,377,039, 6,351,120, 6,198,279, 6,188,218, 6,144,206, 5,966,011, 5,793,206, 5,629,621, 5,990,677 and RE39,206

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Crack Imaging and Depth Sizing

- Representative FA24 data at 100 kHz on EDM notch pipe sample
- Notches clearly indicated as increase in permeability
- Pairs of notches show resolution capability
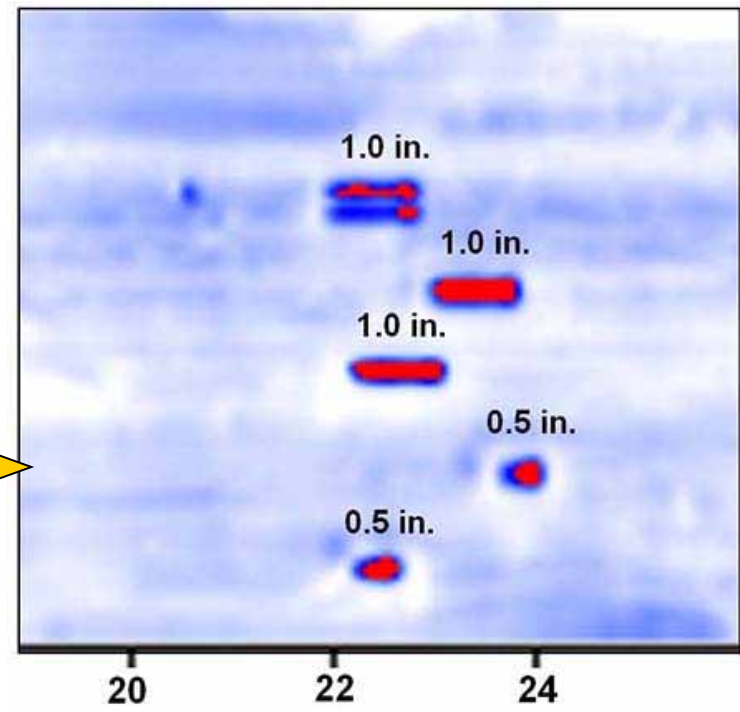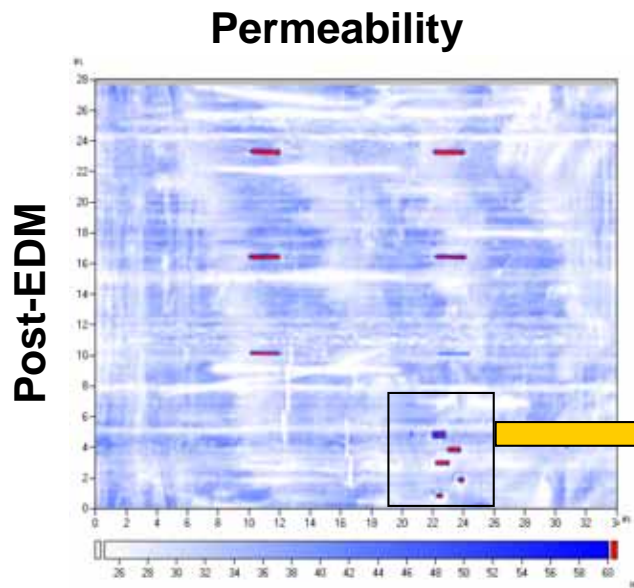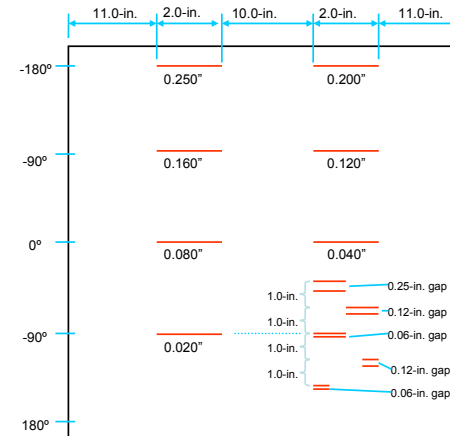

Permeability

Crack Imaging and Depth Sizing

- Reasonable measurement correlation between depth and effective permeability change

- Sensitive to notch depth over this range

Single Crack

Crack Pairs
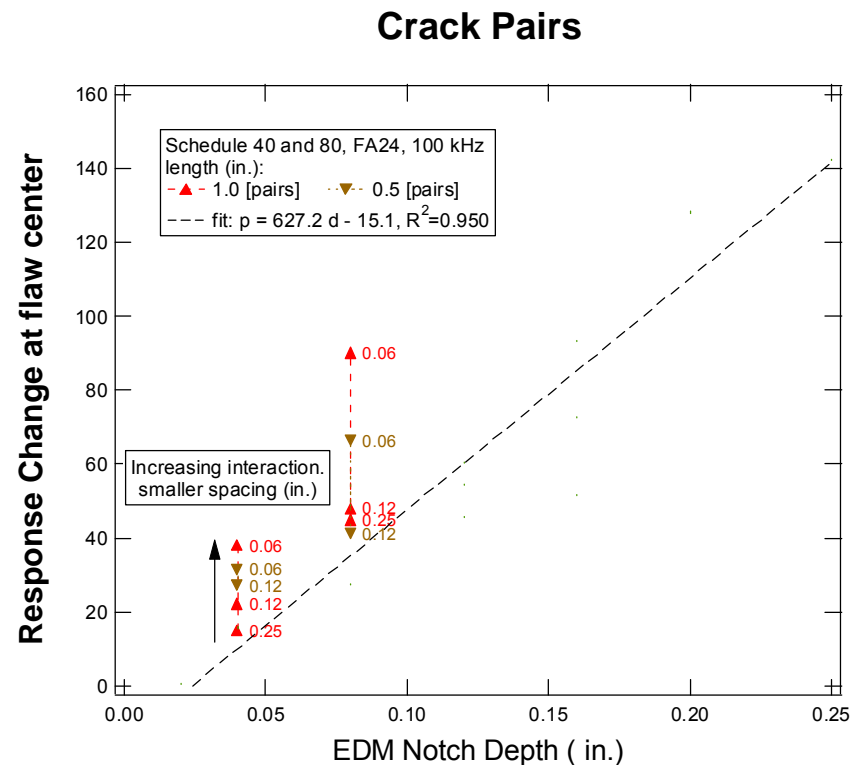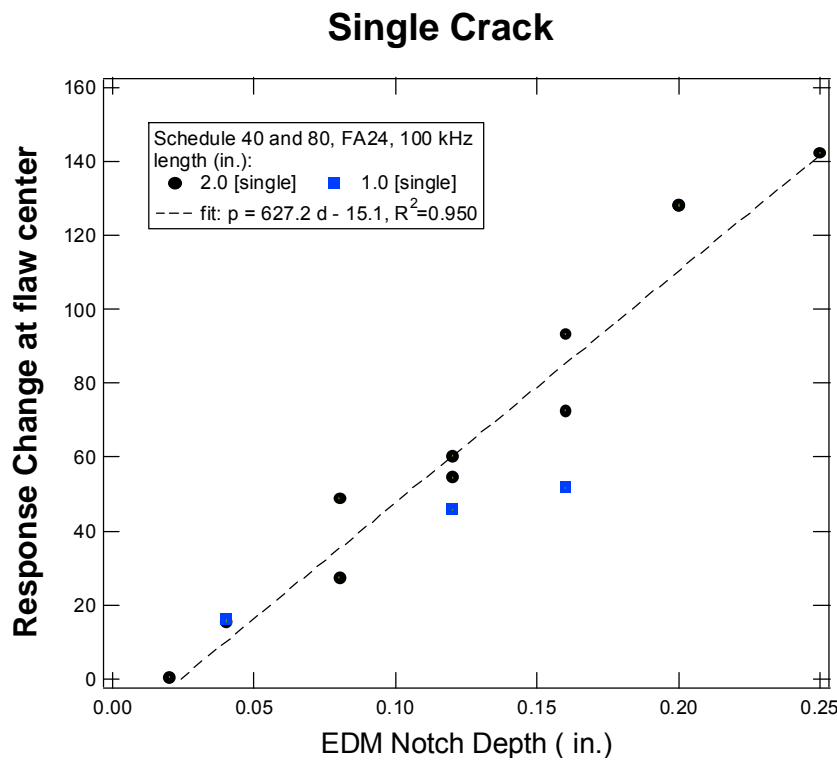
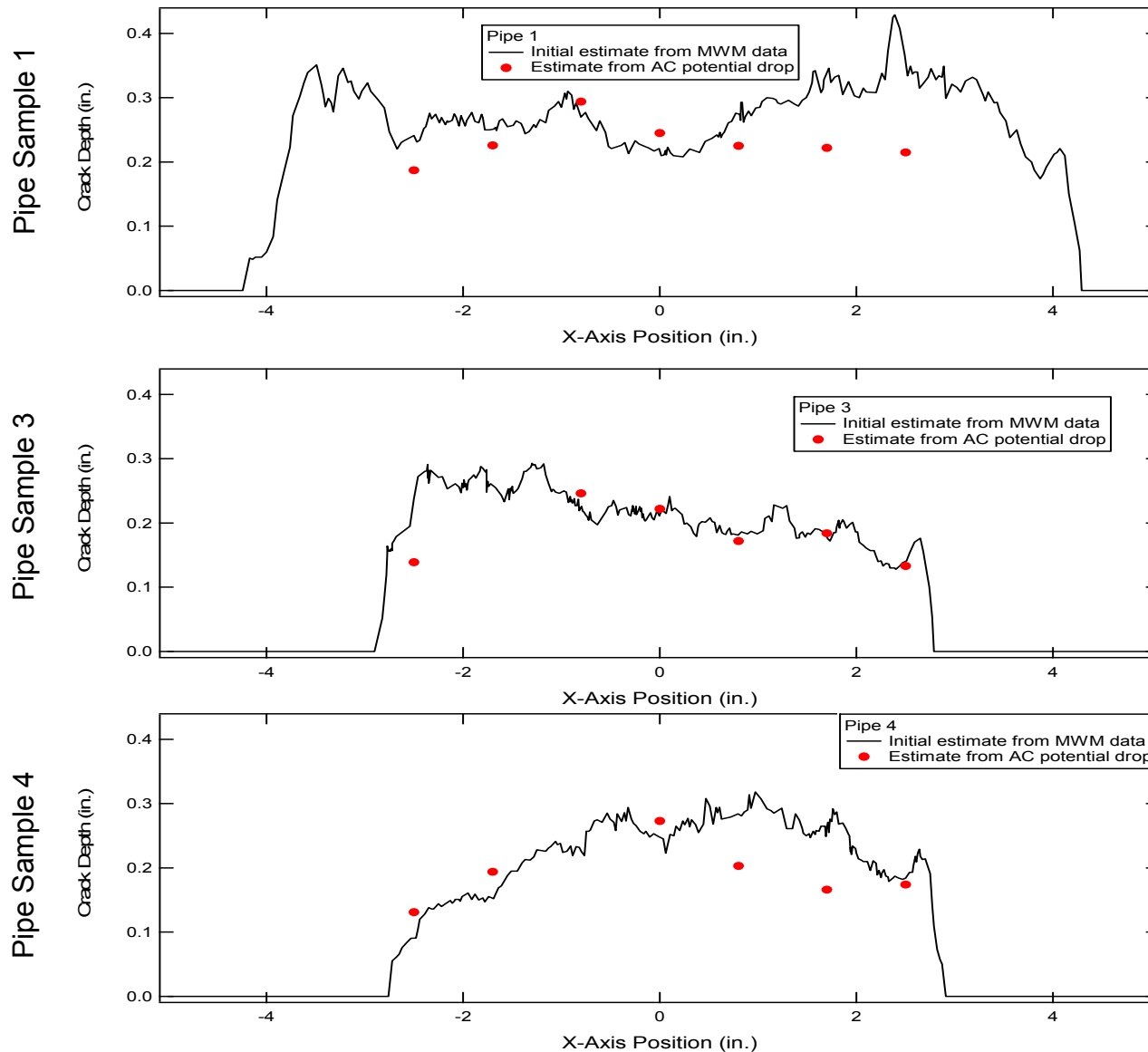# Crack Imaging & Depth Measurement Capability
Testing at DNV (Columbus)

- FA24 on DNV grinding test samples
- Baseline responses for 5-in. EDM notches with subsequent fatigue cracks
- Analysis and comparison to discrete potential drop data ongoing
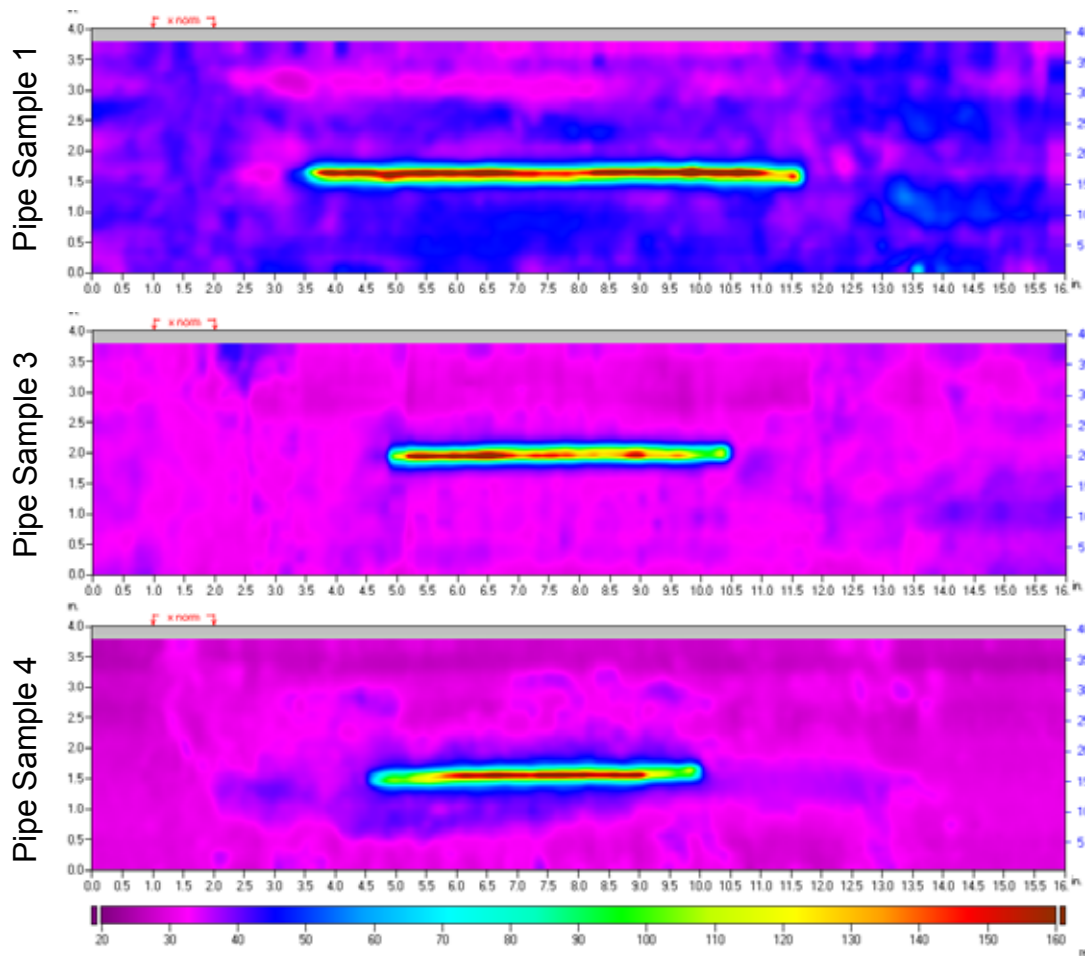
Crack Imaging & Depth Measurement Capability
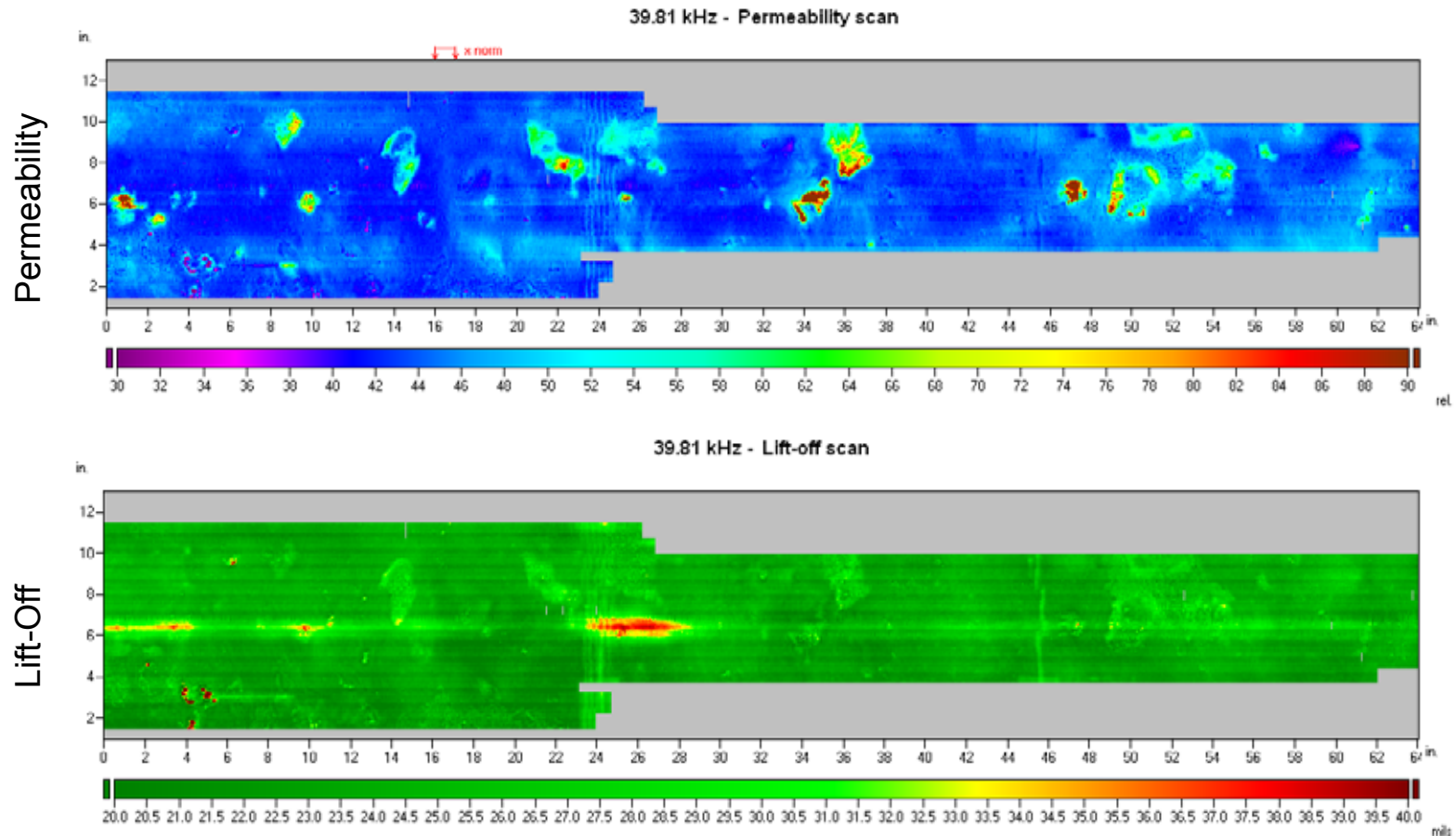## Testing at DNV (Columbus)

SCC Testing at GDF-Suez

- Coordinated with DOT and related efforts
- Scans performed with FA26 & FA24 MWM-Arrays at three (3) stages of cyclic fatiguing
- FA28 scans performed to show higher resolution imaging of crack clusters
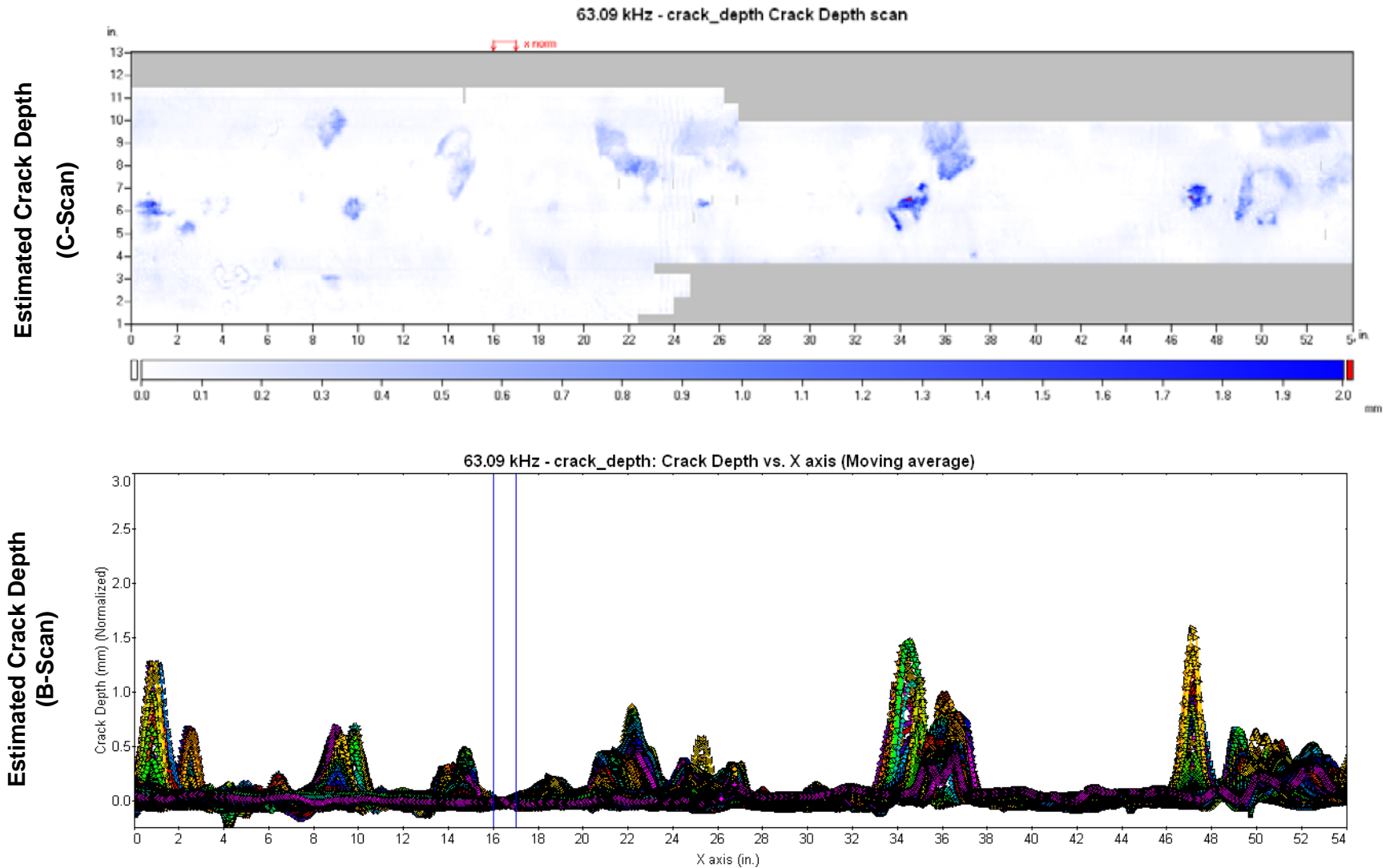- Analysis of results on-going

SCC Testing at GDF-Suez (Preliminary Results - Baseline)
FA26 Scans at 6bar Pressure
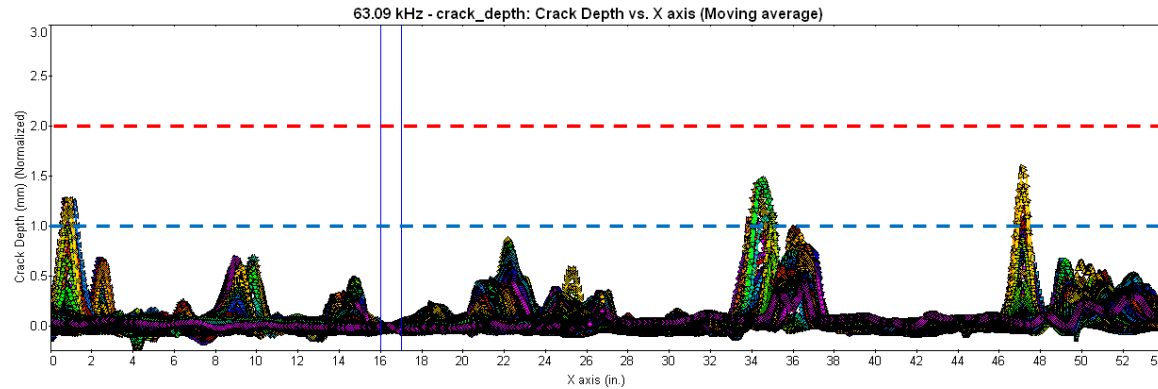
SCC Testing at GDF-Suez (Preliminary Results - Baseline)
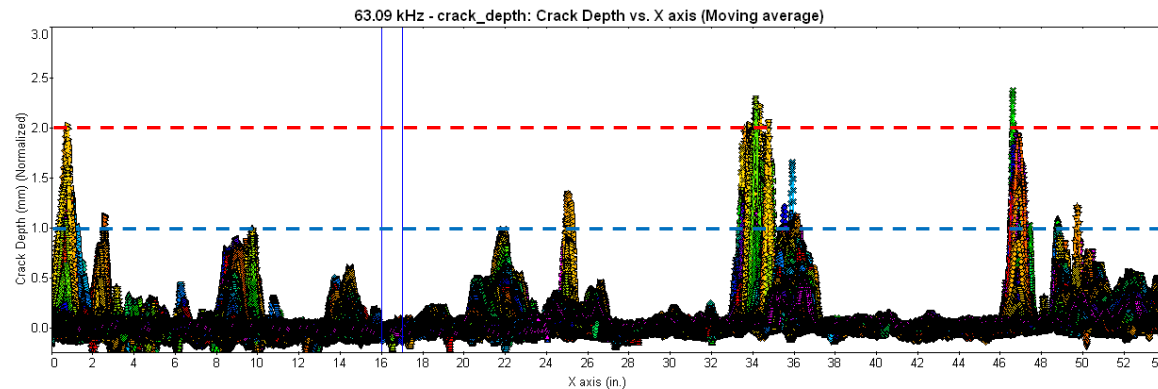## FA26 Scans at 6bar Pressure

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Crack Propagation
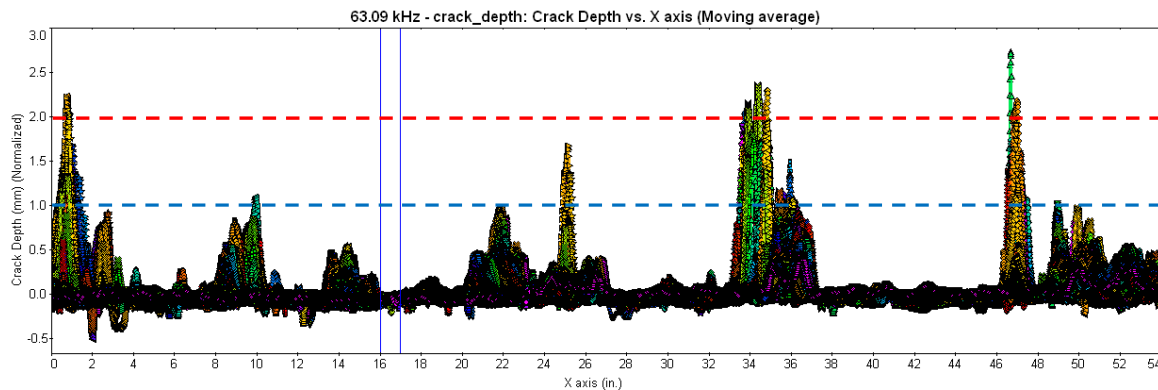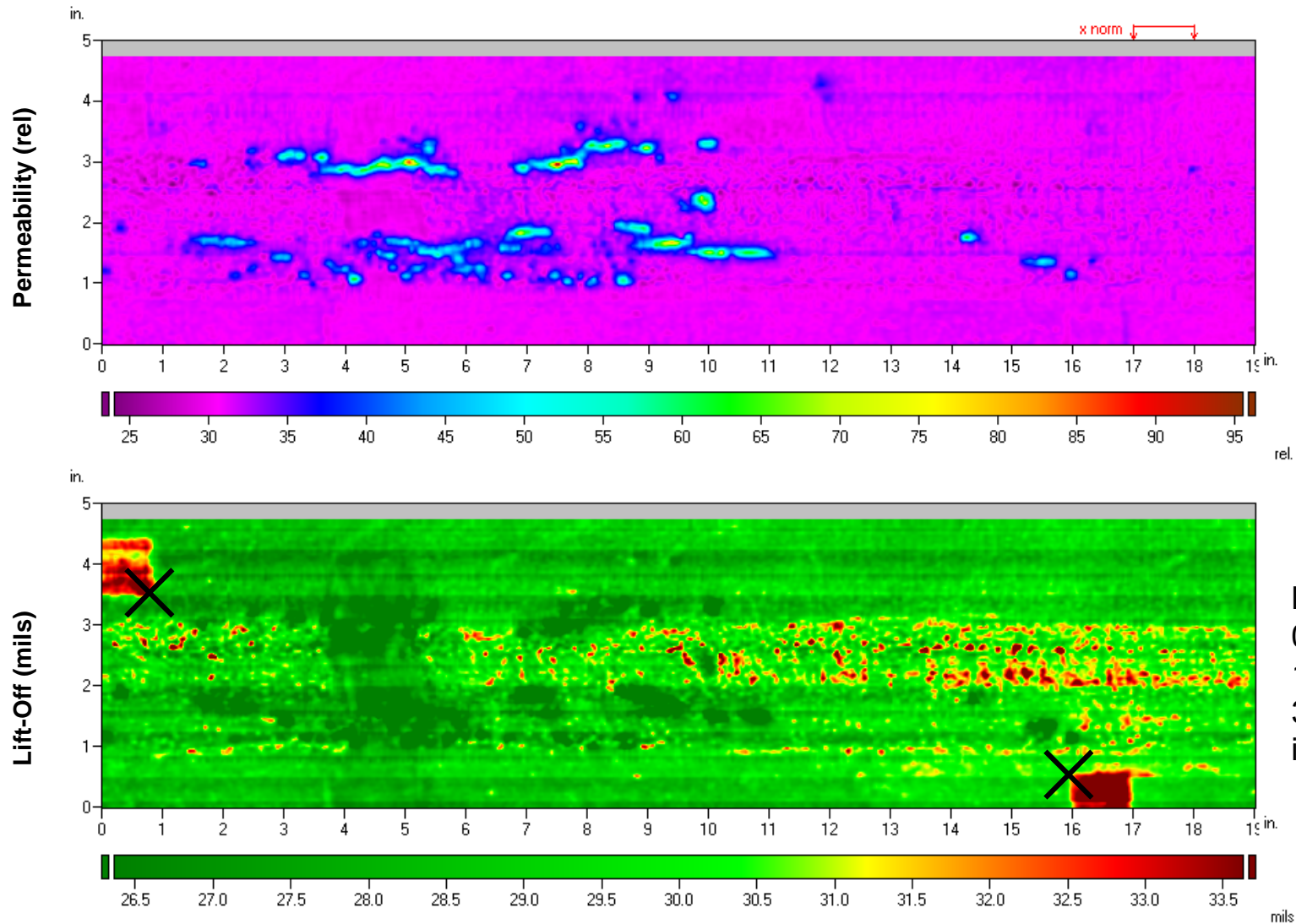## FA26 Scans at 6bar Pressure – Baseline, Intermediate & Final Stage

Testing at PRCI Repository

- Sample provided by PRCI, containing five (5) recorded SCC colonies
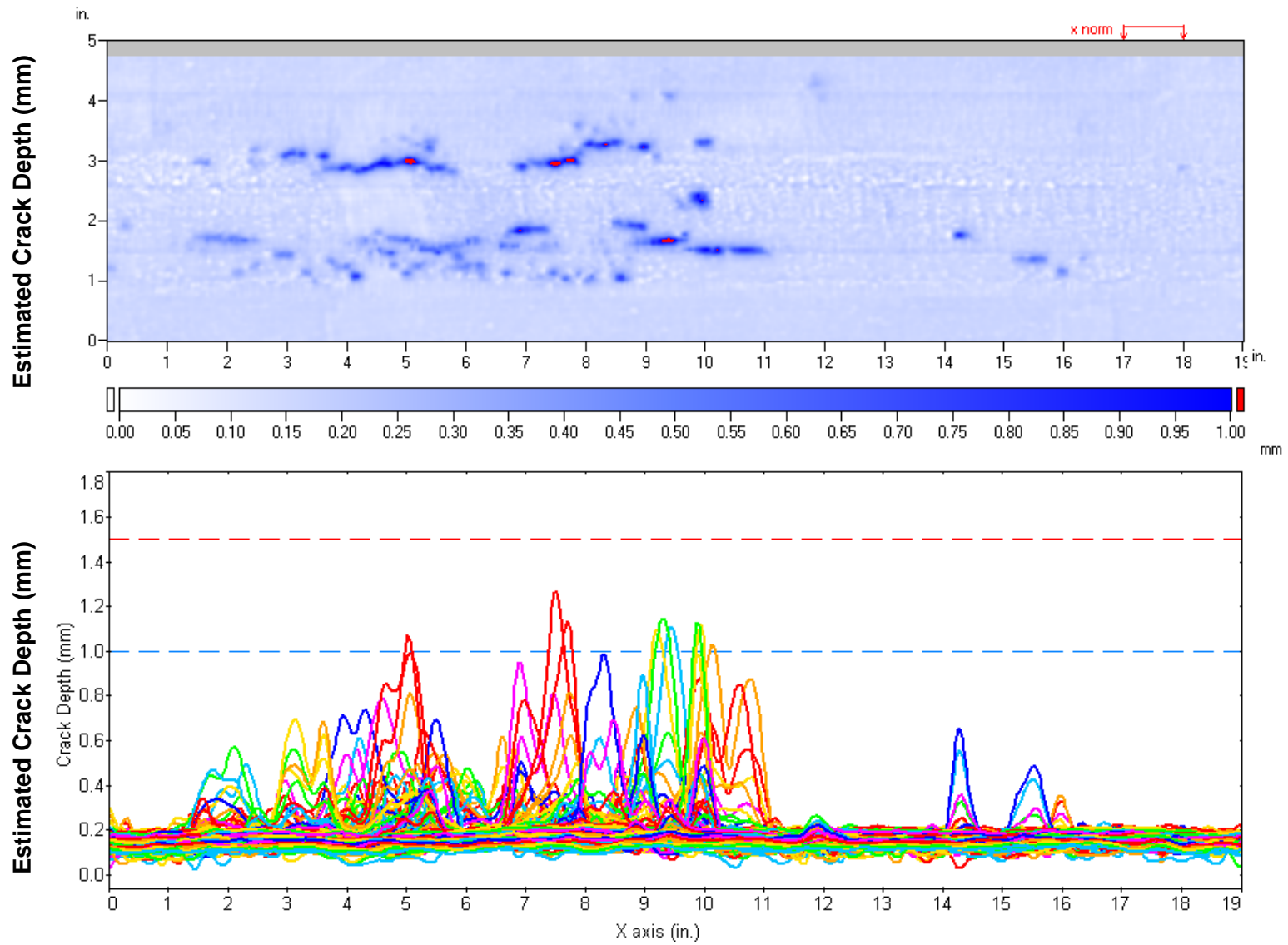- Scans performed with GS-D8000β impedance instrument and FA26 MWM-Array

SCC Imaging – Results
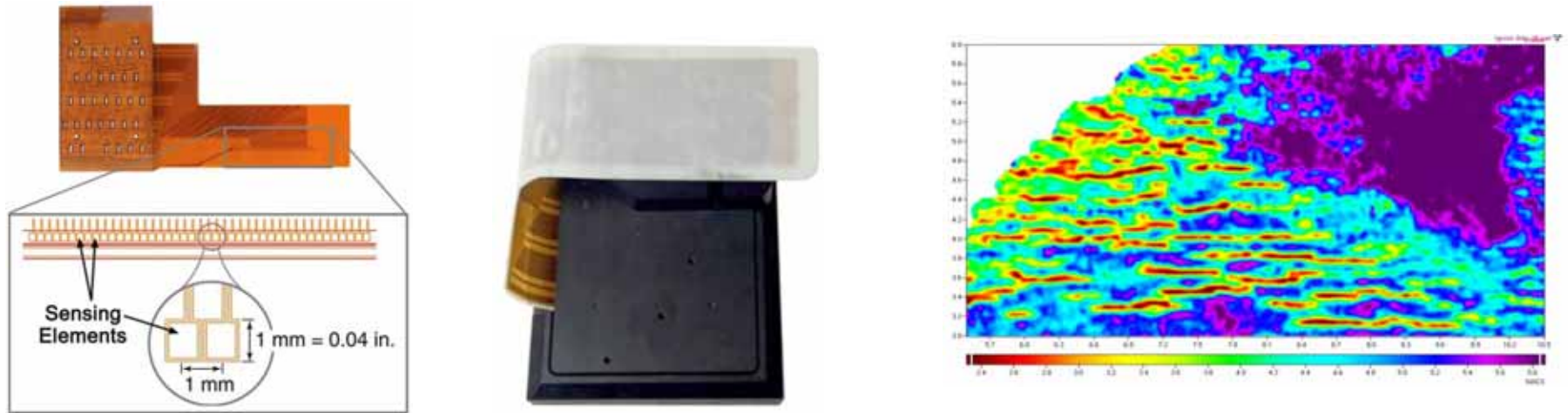## Permeability & Lift-Off C-Scans

Marks at 0,0 and 15.50, 3.00 inches

SCC Imaging – Results
Estimated Crack Depth C-Scan Image and B-Scan Plot

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Crack Imaging and Depth Sizing: Sensors

**FA28 MWM-Array for Very High Resolution Imaging**

**FA214 MWM-Array for High Resolution Depth Sizing**

Crack Imaging and Depth Sizing: Software

## MWM-Array Mapping of SCC Crack Depth:

- Crack detection through coatings (screening capability)
- Mapping of crack location with digital record (MPI replacement)
- Crack depth estimation (single cracks or SCC colonies)
- Not affected by coatings, surface prep, moisture, or dirt

Crack Depth Algorithm Manager

Crack Depth C-Scan

Crack Depth B-Scan

Permeability C-Scan

Lift-Off C-Scan

Scan Notes
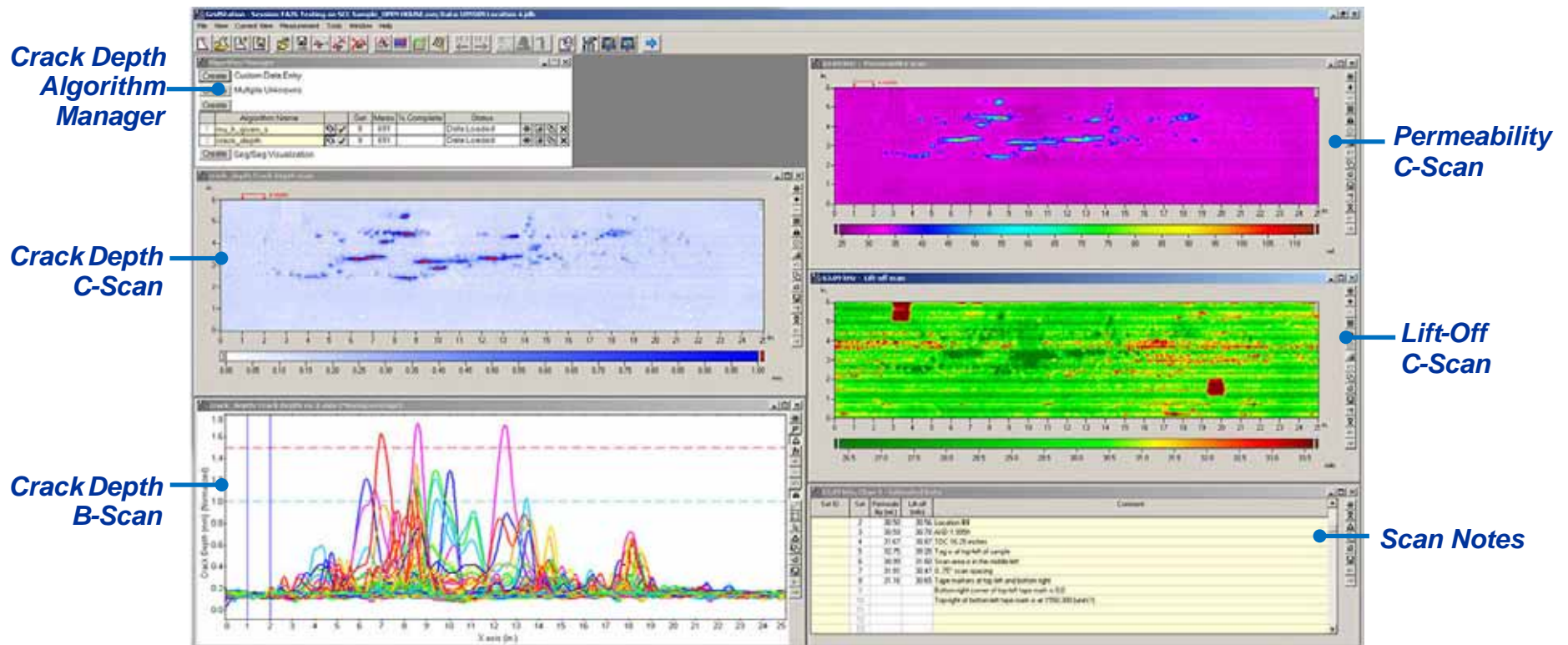
Crack Imaging and Depth Sizing: Scanners
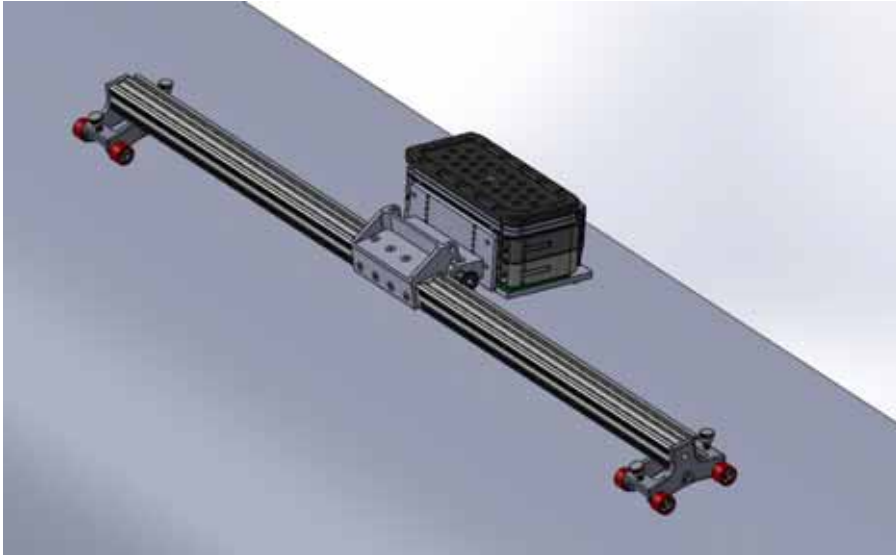
- Able to operate in hand-held and rail-mounted mode (as shown)
- Able to perform axial scans with varying sensor orientations
- Light-weight, improved reliability and operator ease-of-use
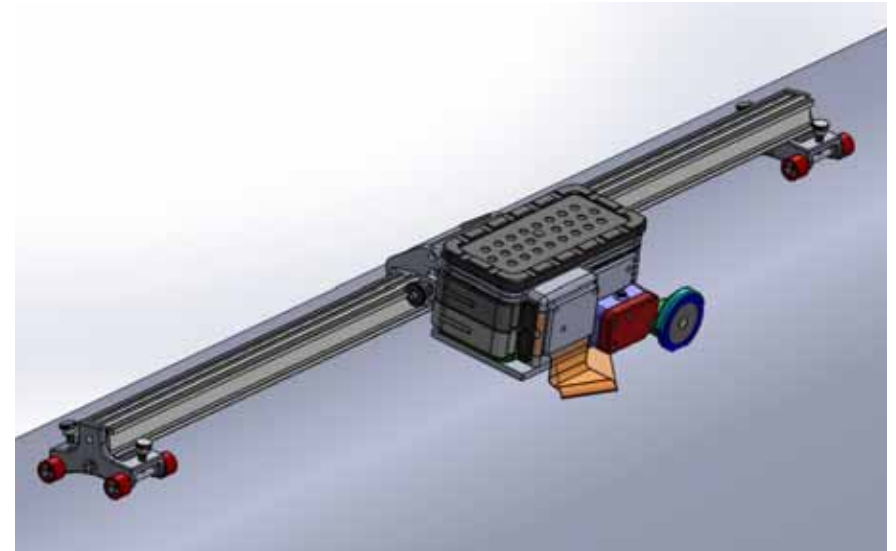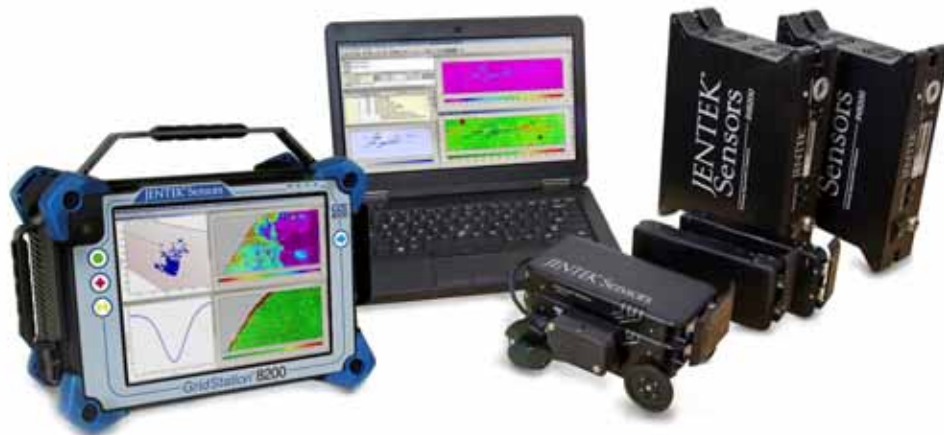
Summary

SCC Detection through Coatings

- Wide-area scanning arrays for preliminary screening of SCC through coatings (coal tar wrap, epoxy, etc.)

- Scan rates over 20 sq. ft./min (1.86 m^2) using JENTEK's GridStation 8200 instrumentation and SCC Scanner

High-Resolution SCC Crack Mapping & Sizing

- High-throughput C-Scan imaging of discrete cracks and/or SCC colonies available

- Conformable eddy current sensors configurable for wide range of pipe diameters

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