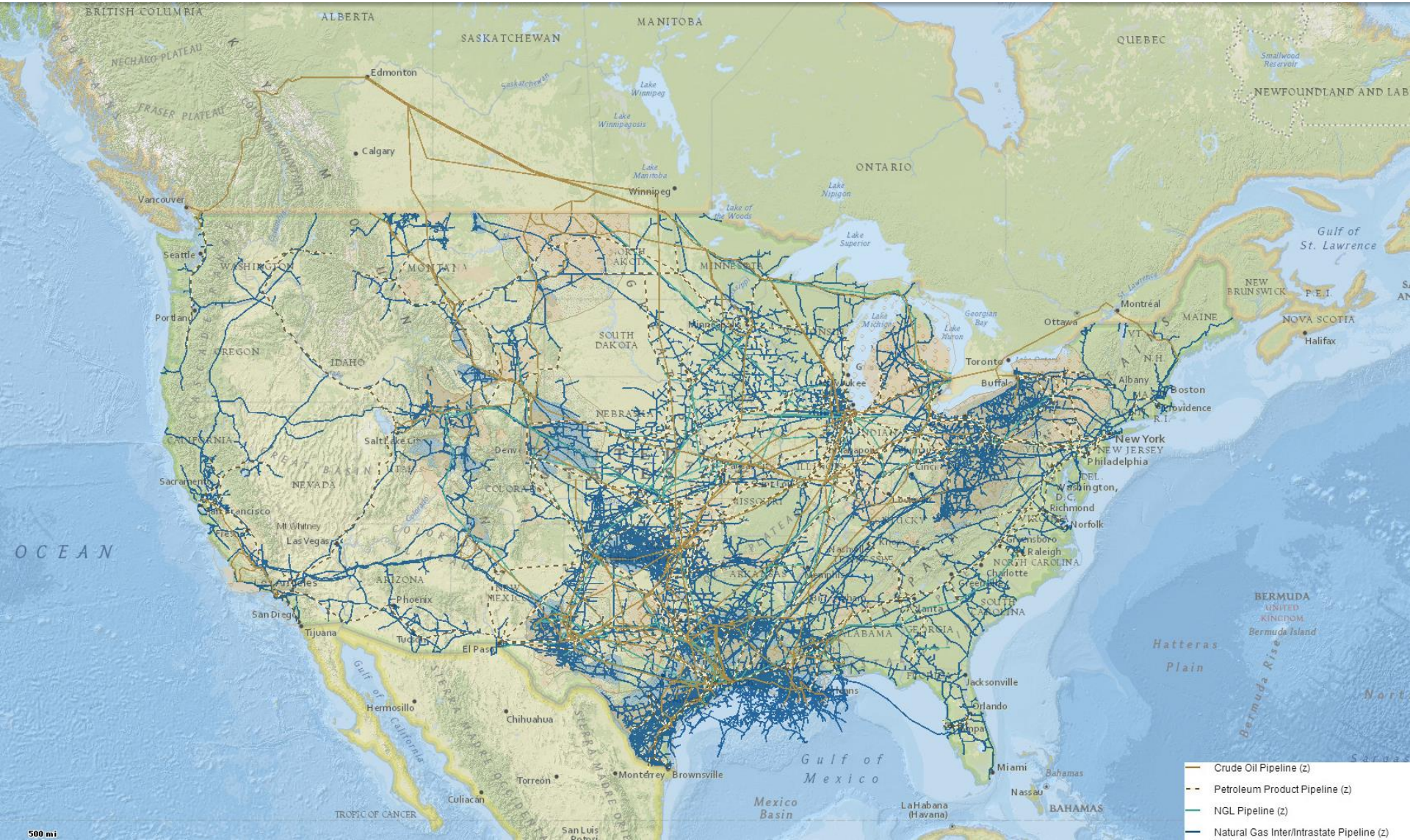
Pipeline Performance™

Smart Pigs

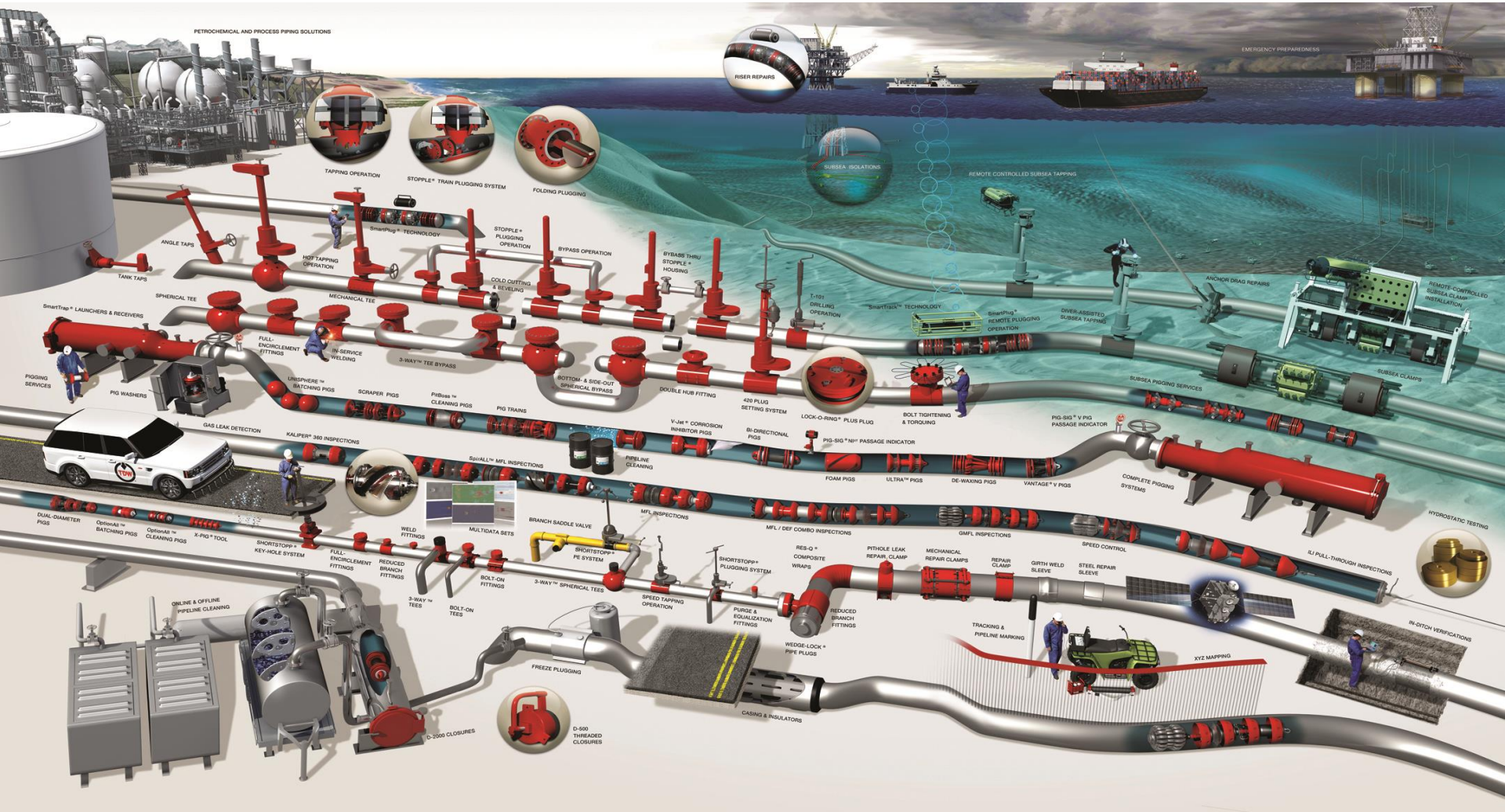
Adrian Belanger
March 7, 2017

www.tdwilliamson.com

Oil and Gas Pipeline Network



Pipeline Services



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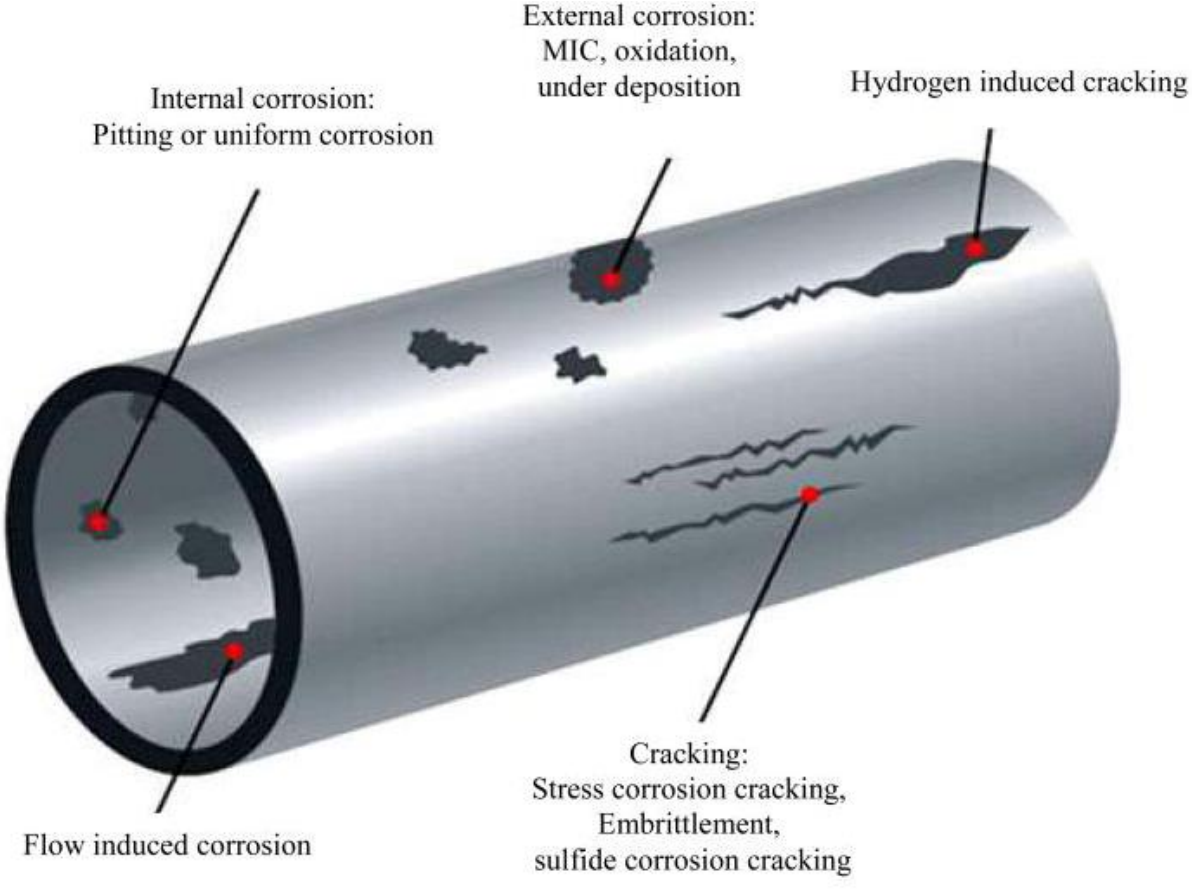
Why Pipeline Inspections?

Bellingham, WA - 1999

San Bruno, CA - 2010

What Are The Threats?

Threats - Overview



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Corrosion

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Selective Seam Corrosion

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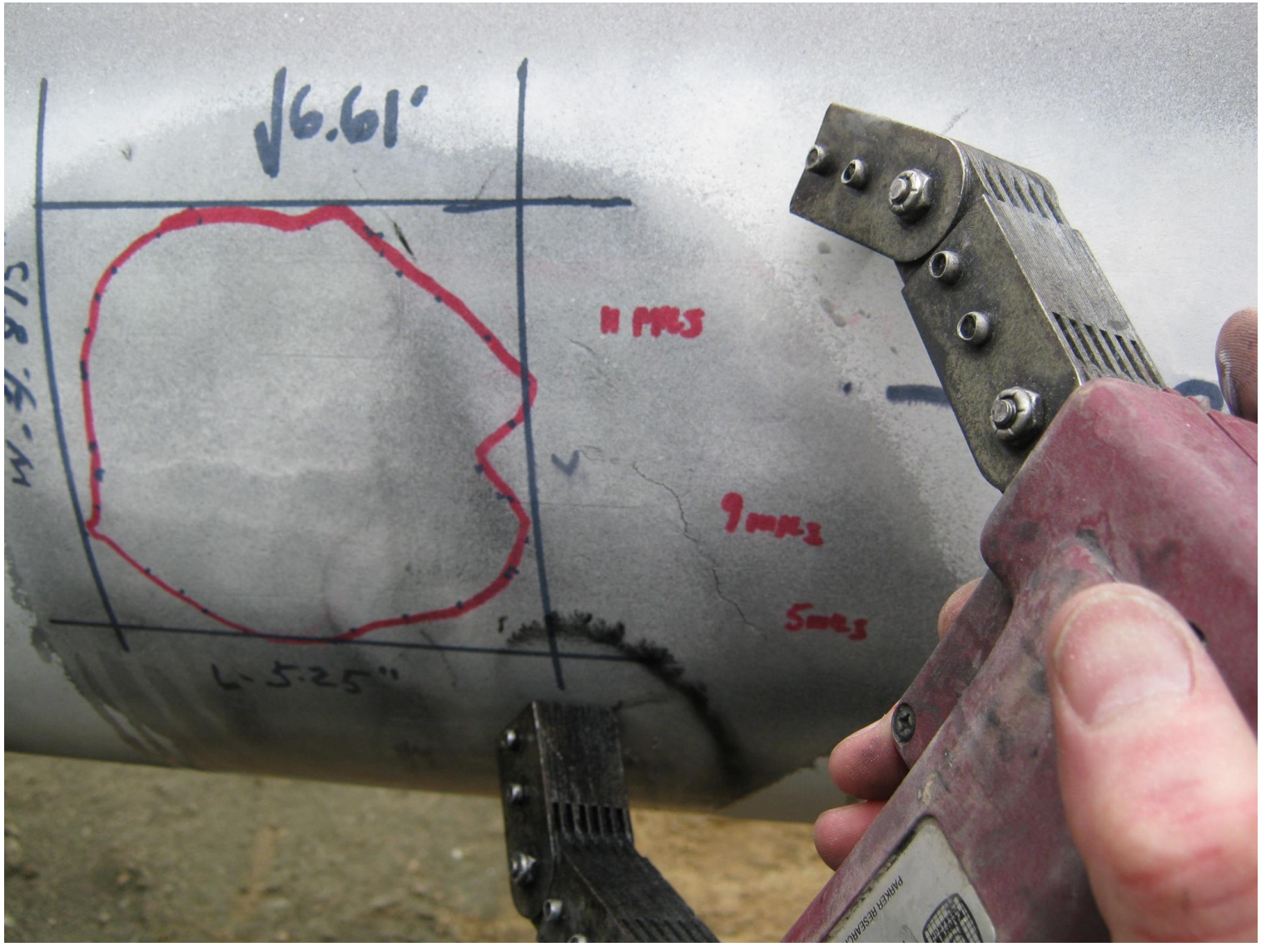
Cracking



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Dent

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Gouge

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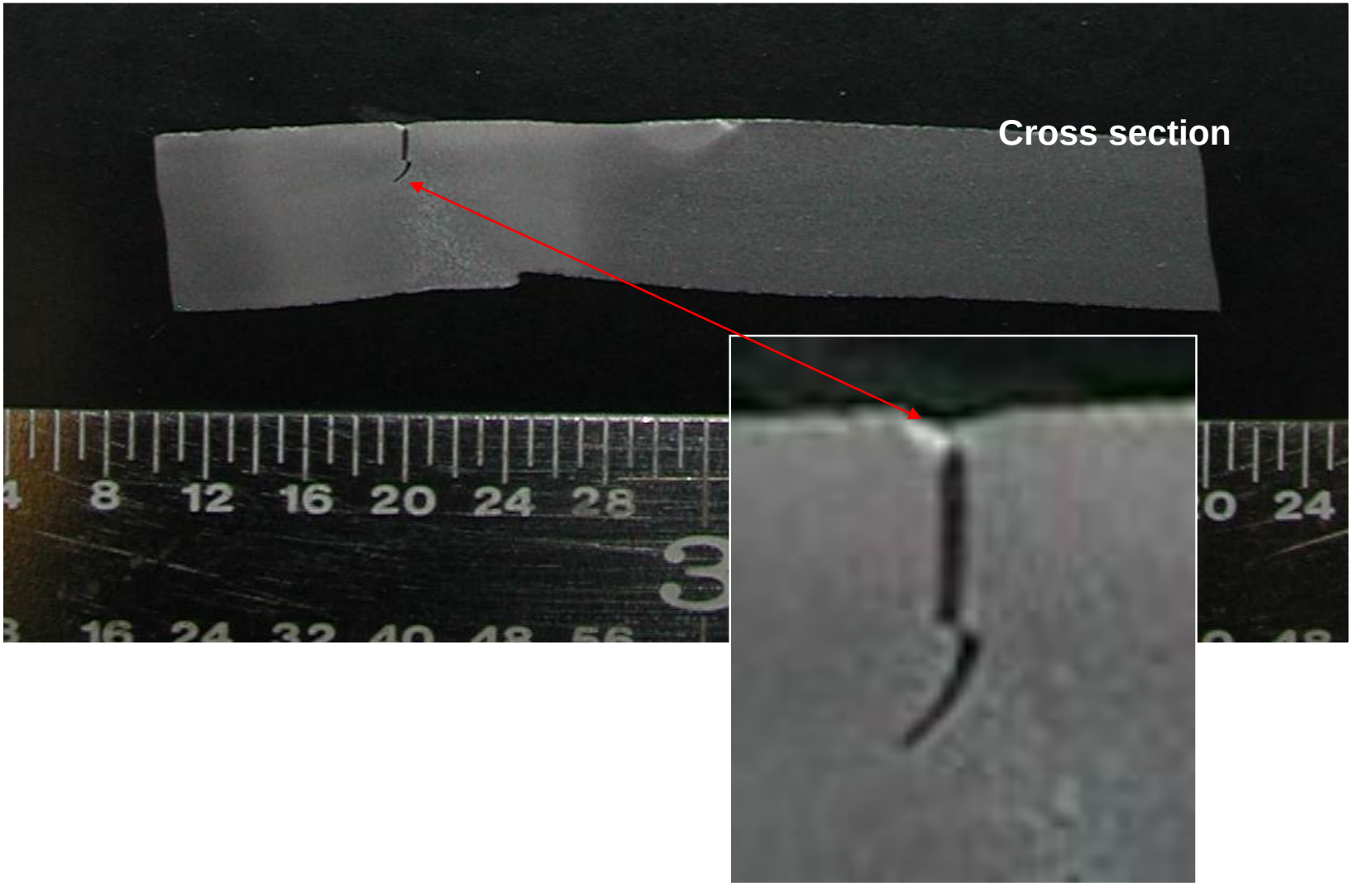
Hook Cracks



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Wrinkle Bend Failures

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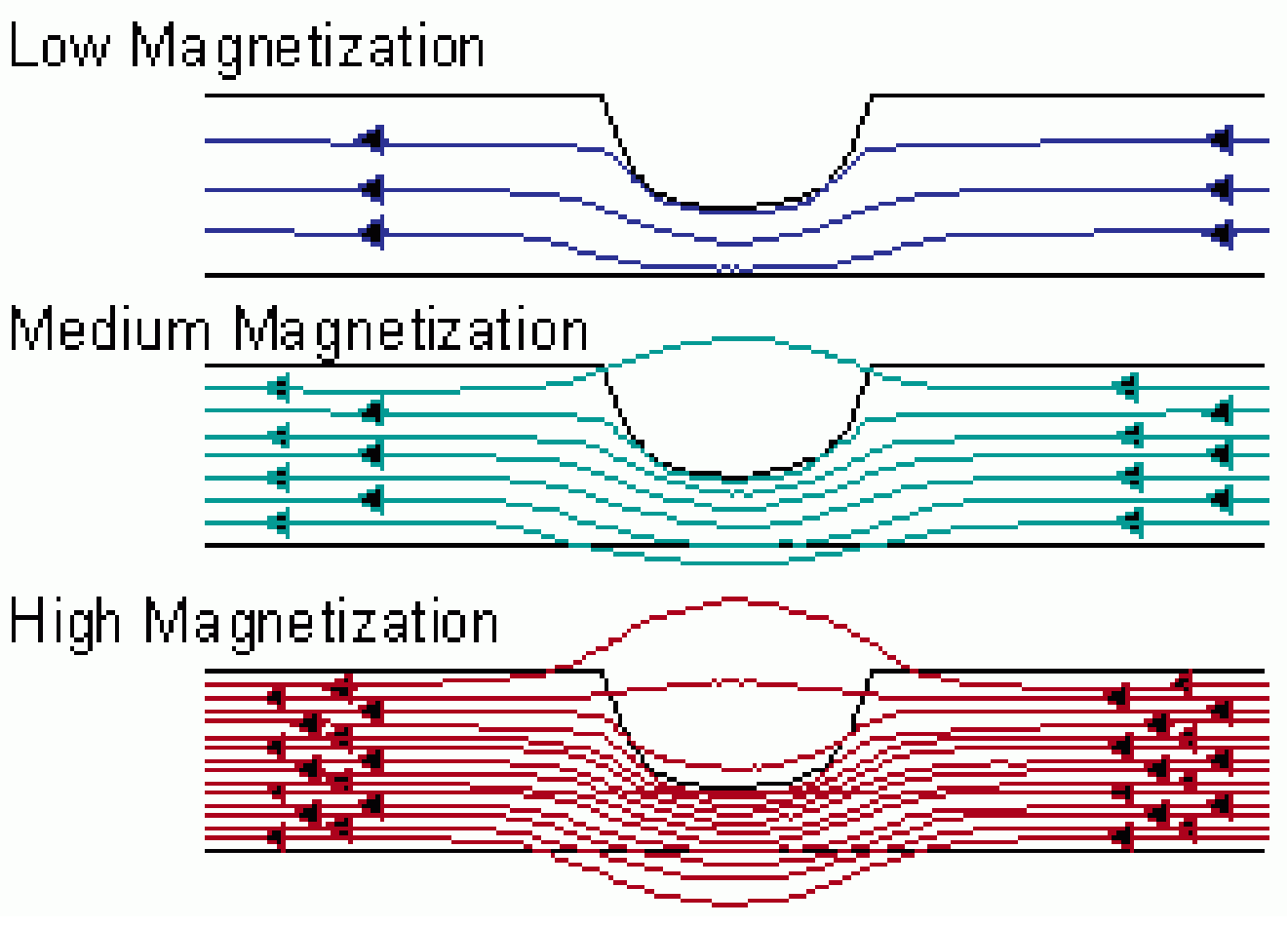
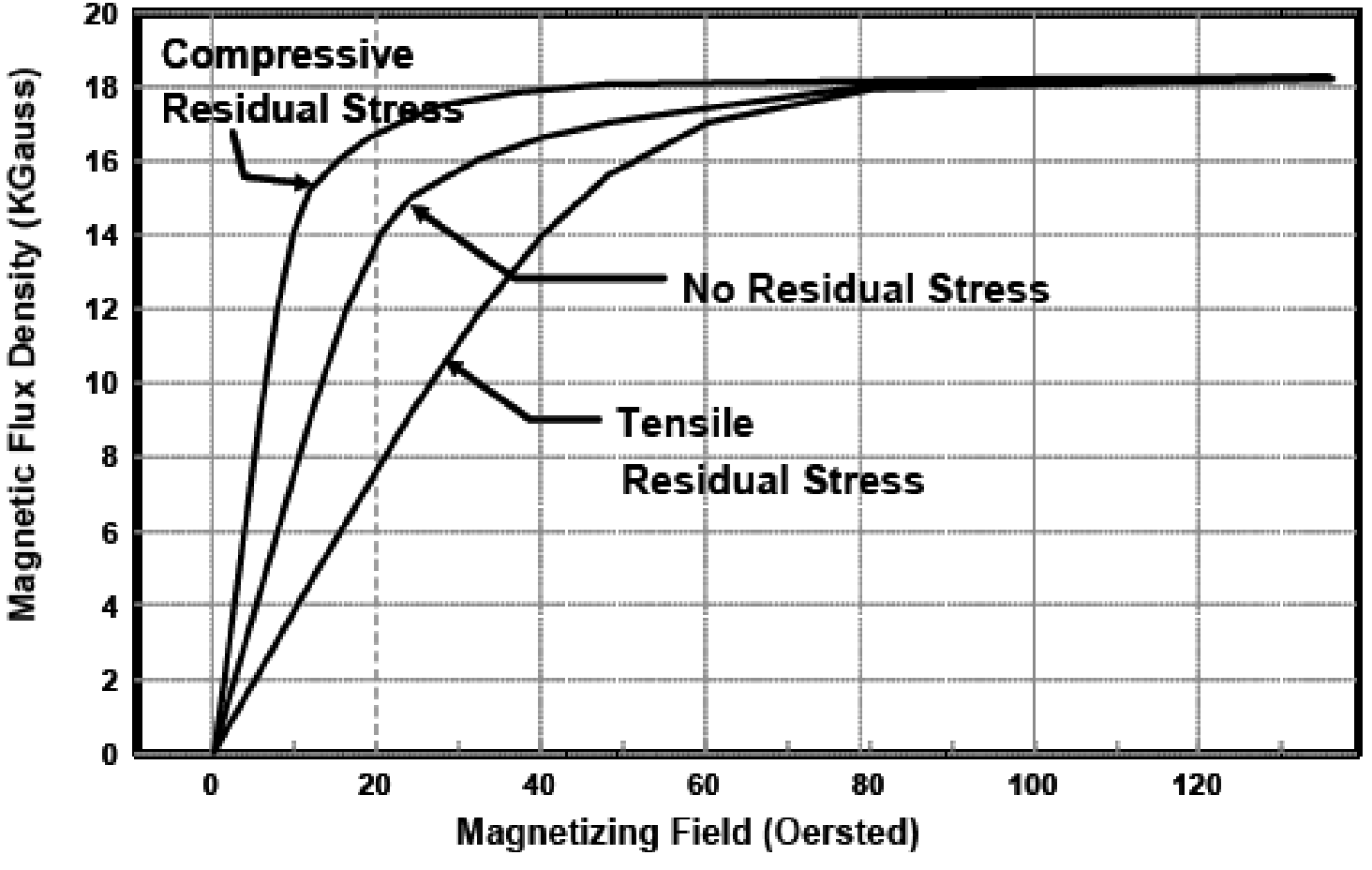
What Are The Solutions?

Magnetic Flux Leakage (MFL)



Changes in permeability cause magnetic lines of flux to “leak” outside of the specimen, which can be measured by a sensor.

Low Field Magnetization



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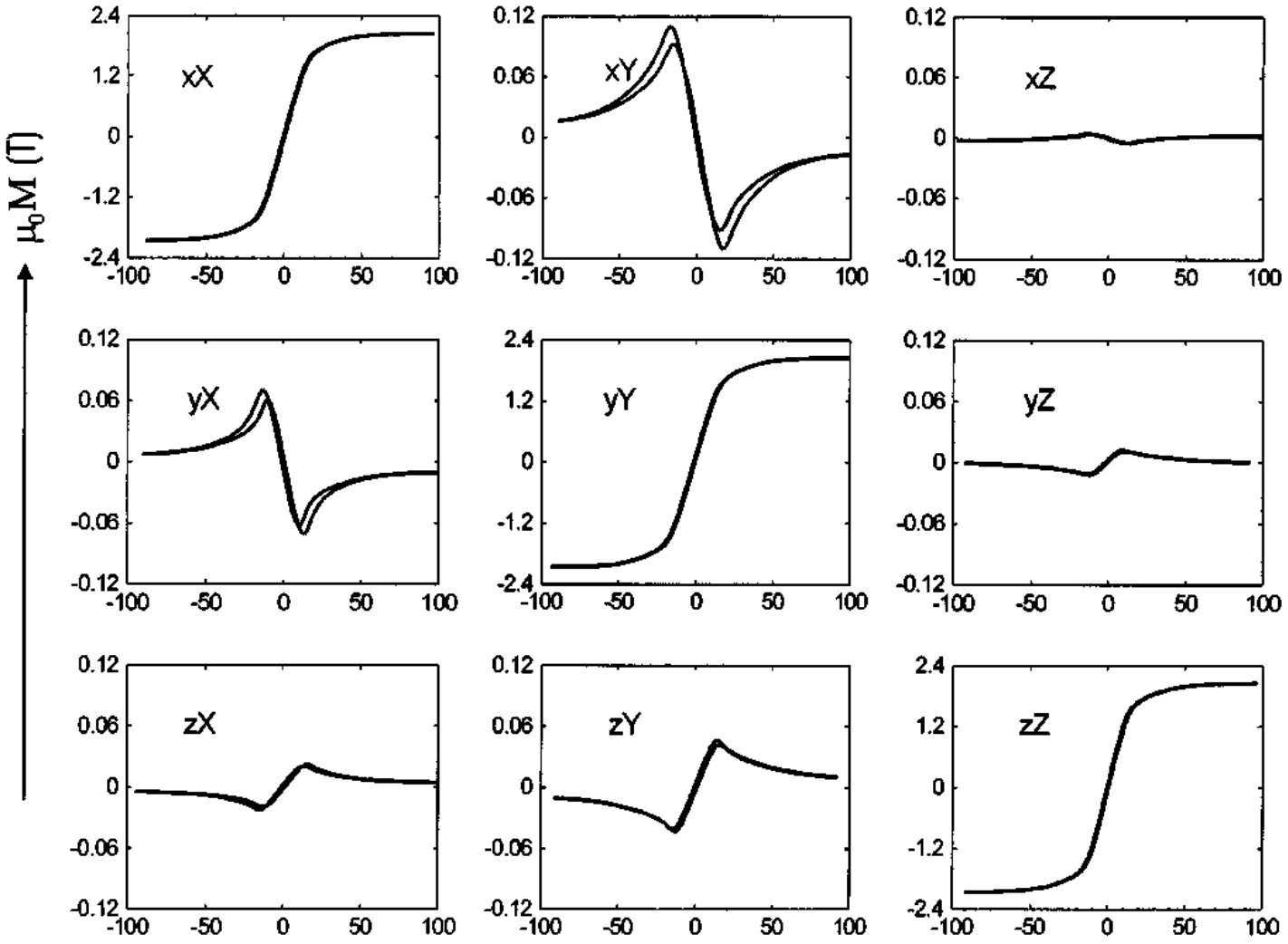
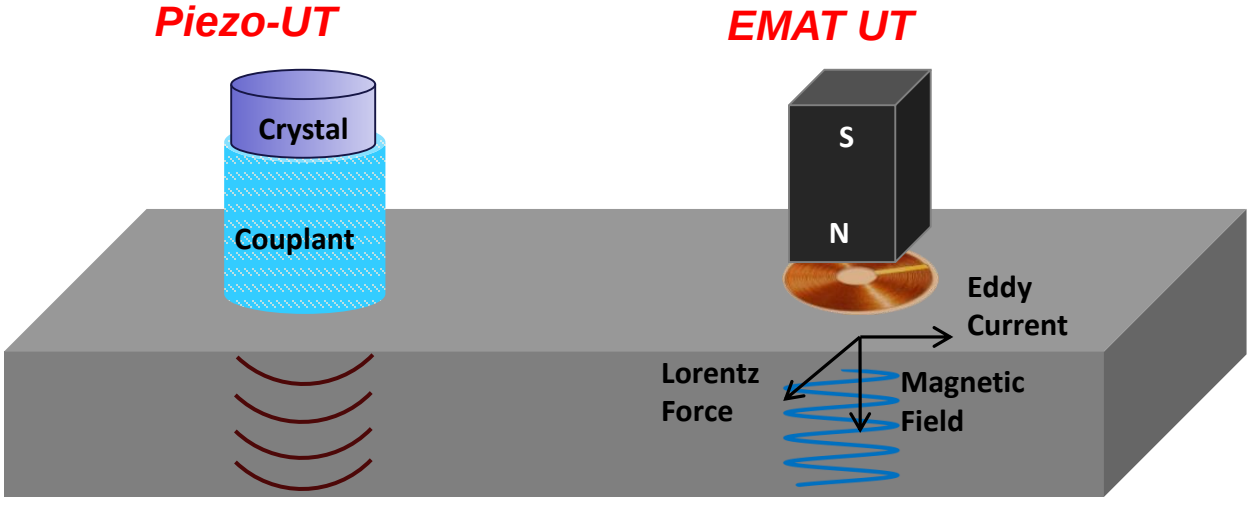
Permeability Tensor



Wall Thickness (UT and EMAT)



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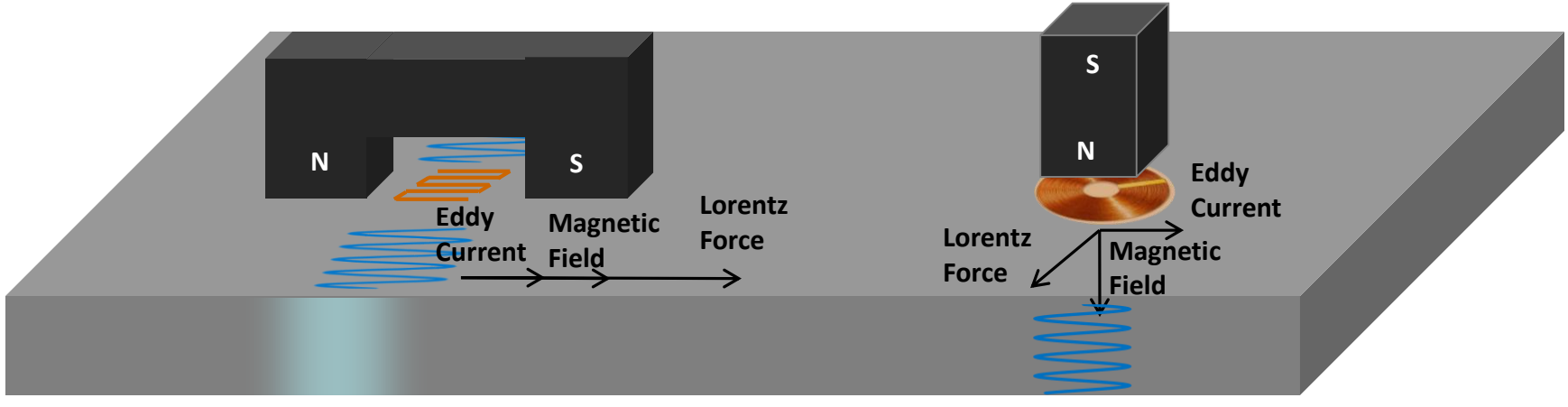
EMAT – Magnetostrictive vs. Lorentz



Magnetostrictive

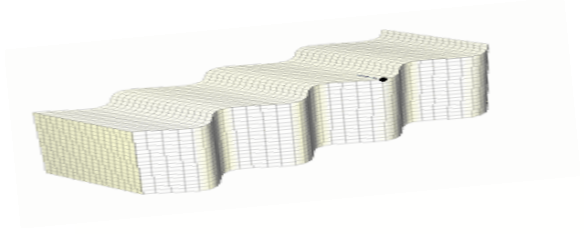
- Applied magnetic field is parallel to the current in the coil
- Alternating current generates a magnetic field perpendicular to the biasing field. This causes magnetostriction
- The oscillating magnetostriction generates a shear wave that propagates in the direction of the current

Lorentz

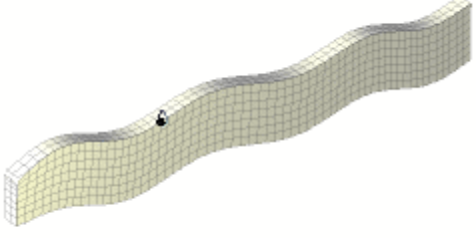
Uses a magnetic biasing field and pancake coil to create an acoustic wave. When a pulsed high frequency electric current is applied to the transmitting coil, a time varying magnetic field is induced into the material. This field in turn generates a pulse of elastic waves into the pipe via the magnetostrictive or Joule effect.

Guided Wave Modes

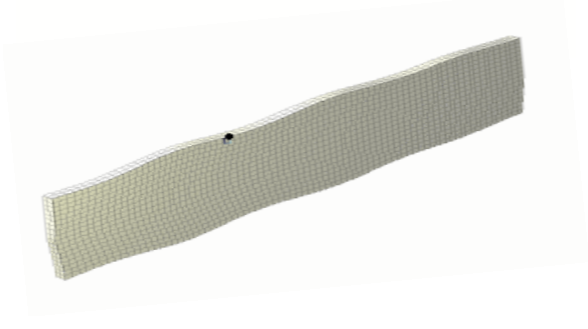
- Shear Horizontal



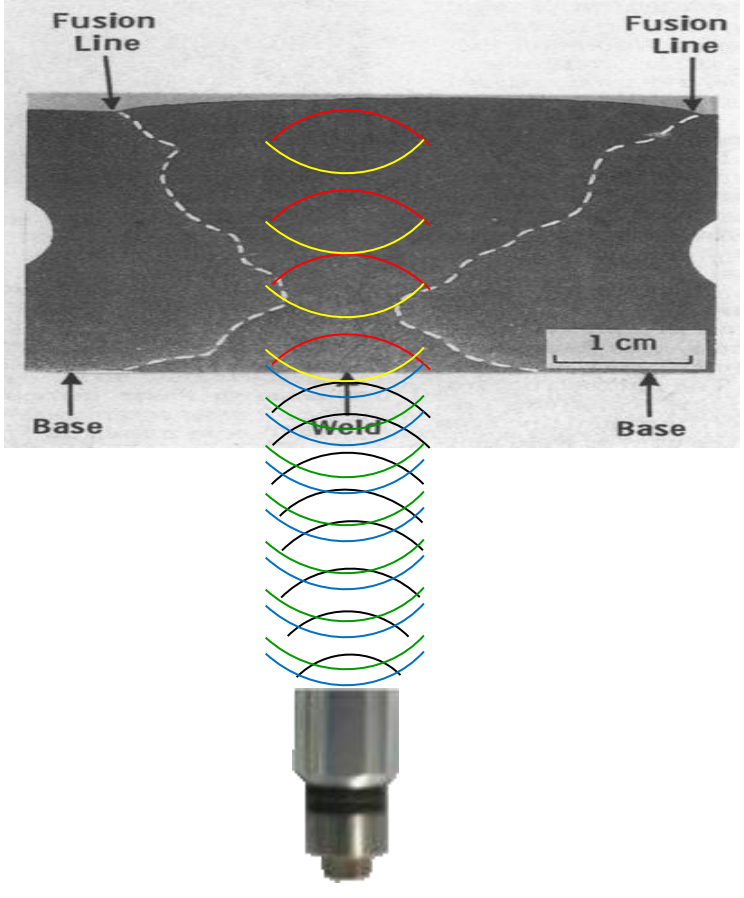
- Symmetric



- Anti-Symmetric

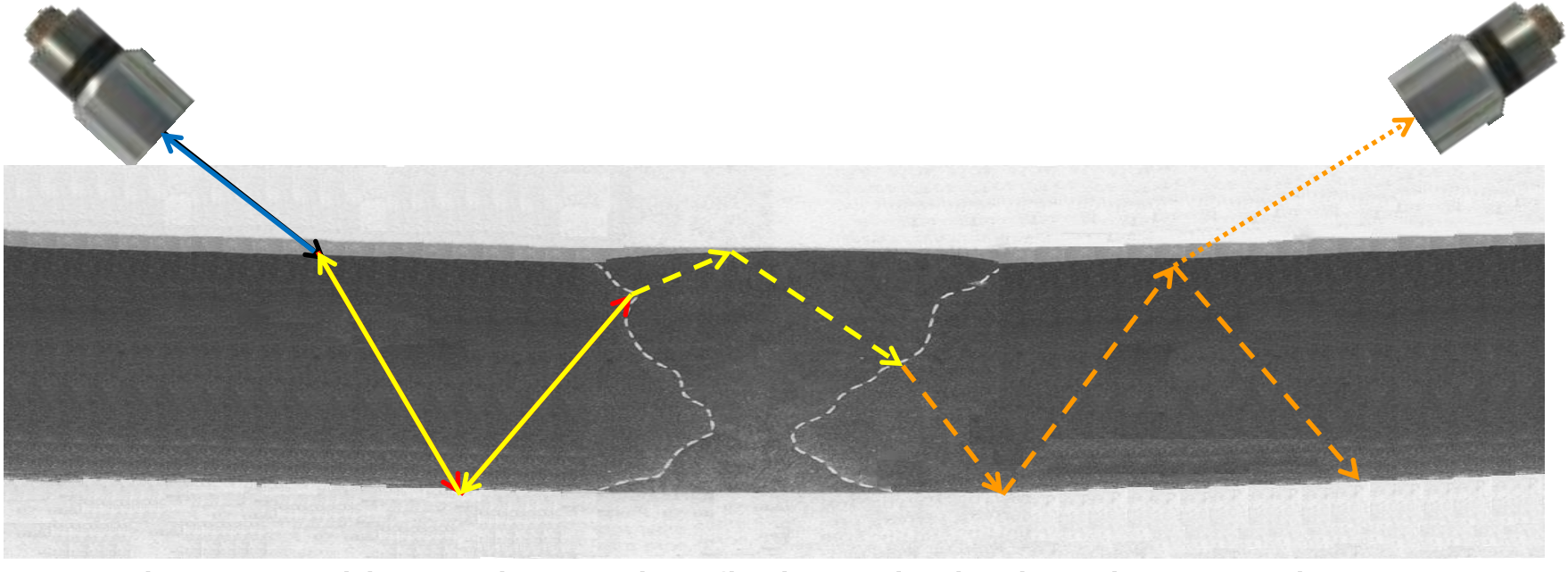


Pulse Echo Ultrasonic Inspection



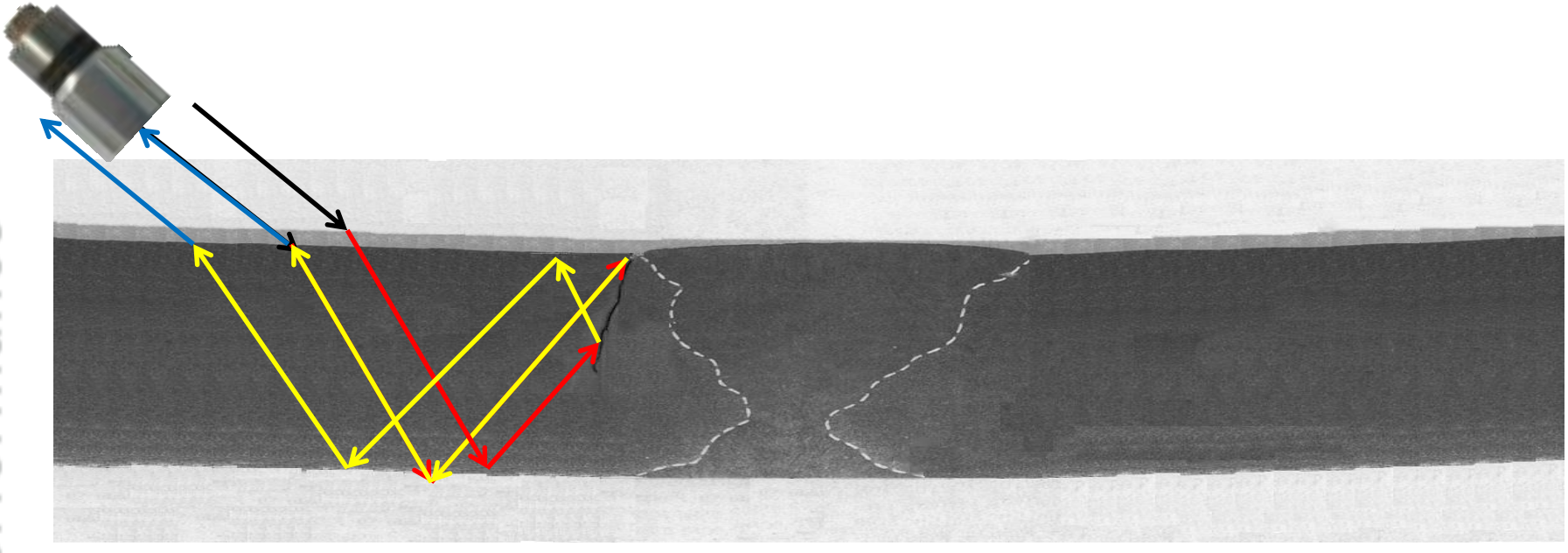
- Transverse ultrasonic beams are oriented 90° to the surface of the pipe.
- They detect the reflection from the front surface and the back wall.
- This measurement is a direct measurement of wall thickness, though in welds there is a lot of scatter.

Angled Beam Probe – Pitch-Catch



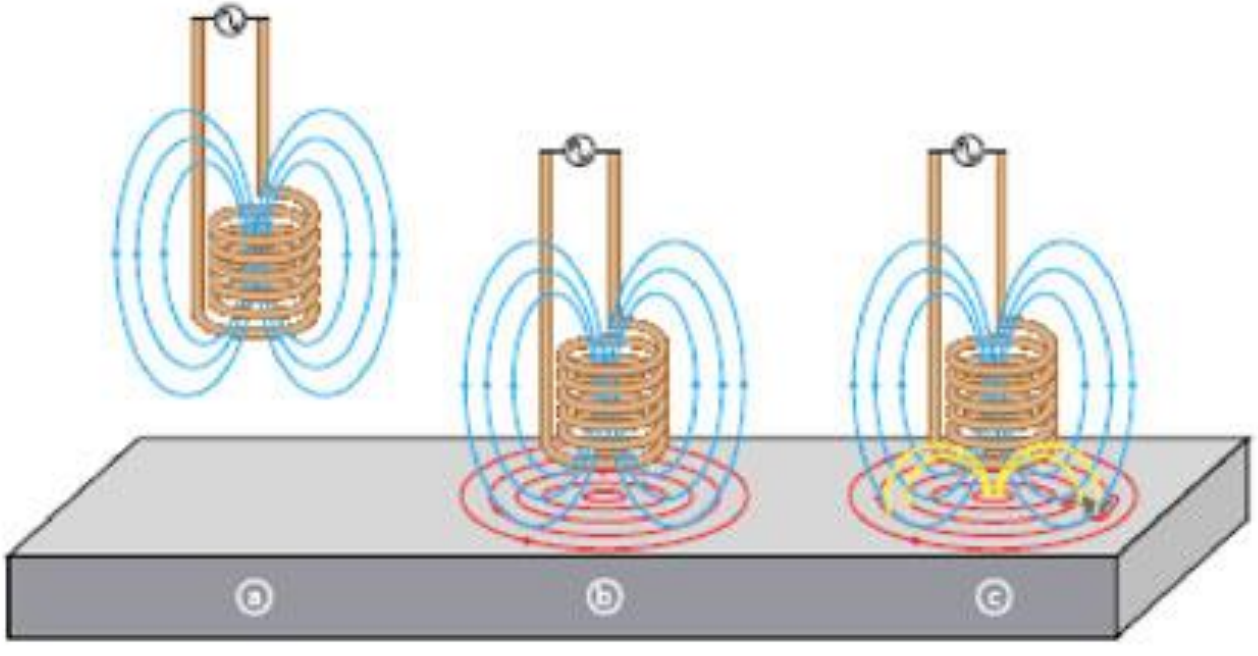
- The angled beam is used to find cracks in the pipe wall that are perpendicular to the direction of the beam.
- The weld reflects a portion of the sound beam dependent on fusion, porosity, slag and other heterogeneities.
- Beams must be oriented in both clockwise and counter-clockwise directions in order to get full coverage.

Angled Beam Probe – Pulse Echo



- The maximum reflection is when a discontinuity is perpendicular to the sound beam
- For a crack the maximum amount of signal is reflected by its corner where it meets the surfaces
- Because the long seam can refract the UT signal, the sensor on the crack side of the long seam has the best chance of detection

Eddy Current Testing

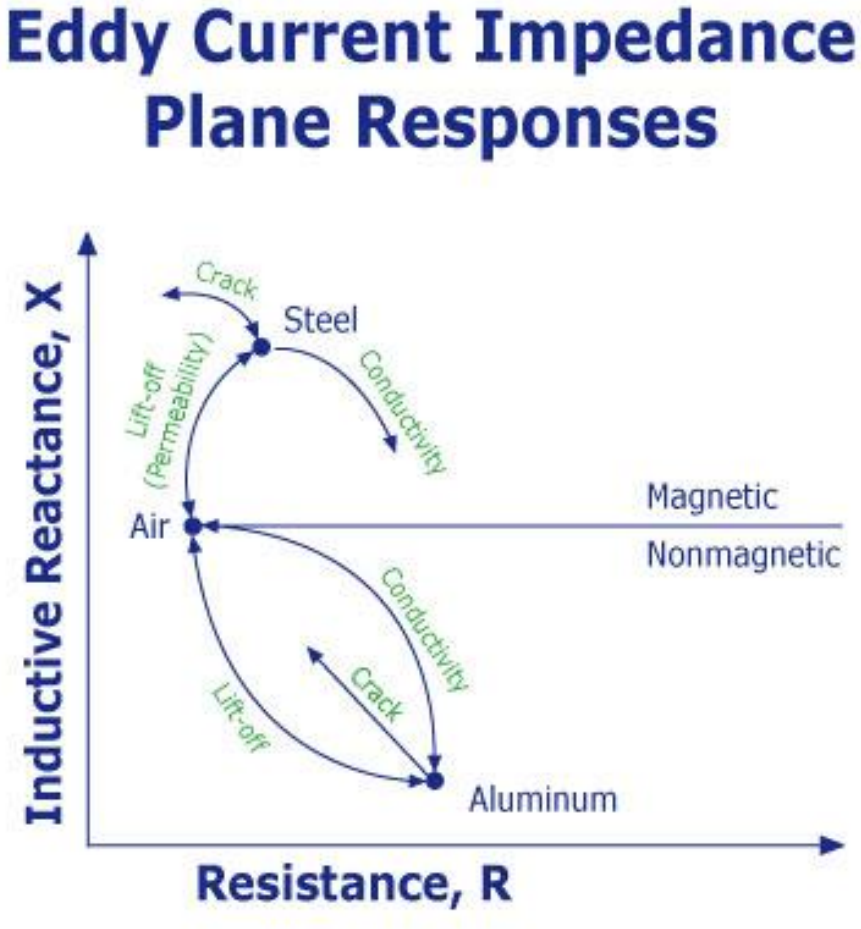


a—The alternating current flowing through the coil at a chosen frequency generates a magnetic field around the coil.

b—When the coil is placed close to an electrically conductive material, eddy current is induced in the material.

c—If a flaw in the conductive material disturbs the eddy current circulation, the magnetic coupling with the probe is changed and a defect signal can be read by measuring the coil impedance variation.

Impedance Plane



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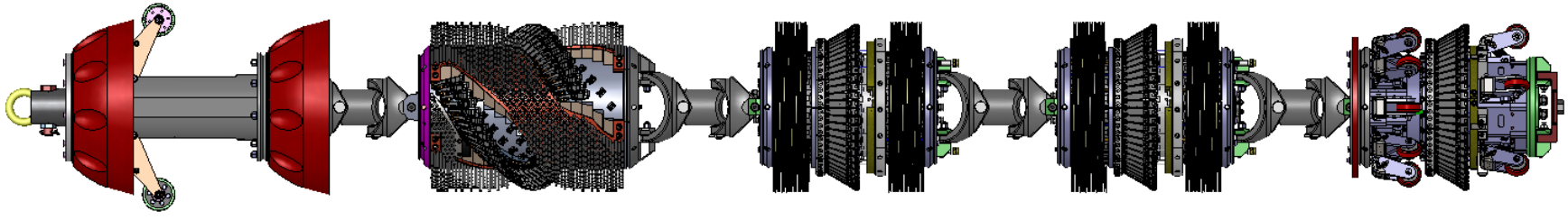
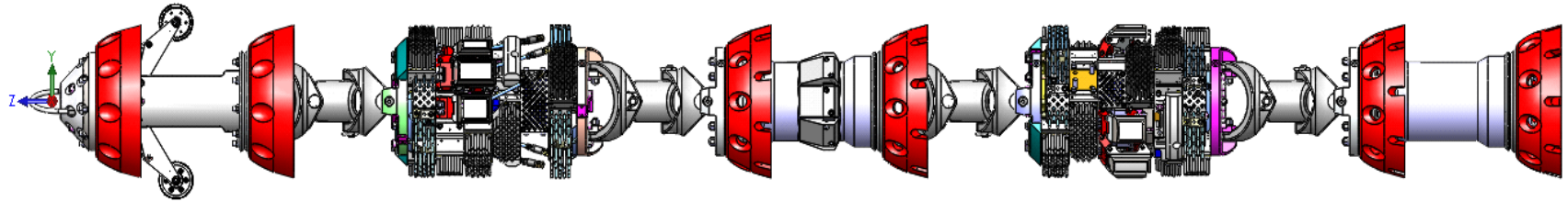
Inline Inspection Tools (Smart Pigs)

MDS and EMAT



MDS
SMFL+MFL+LFM+DEF



EMAT

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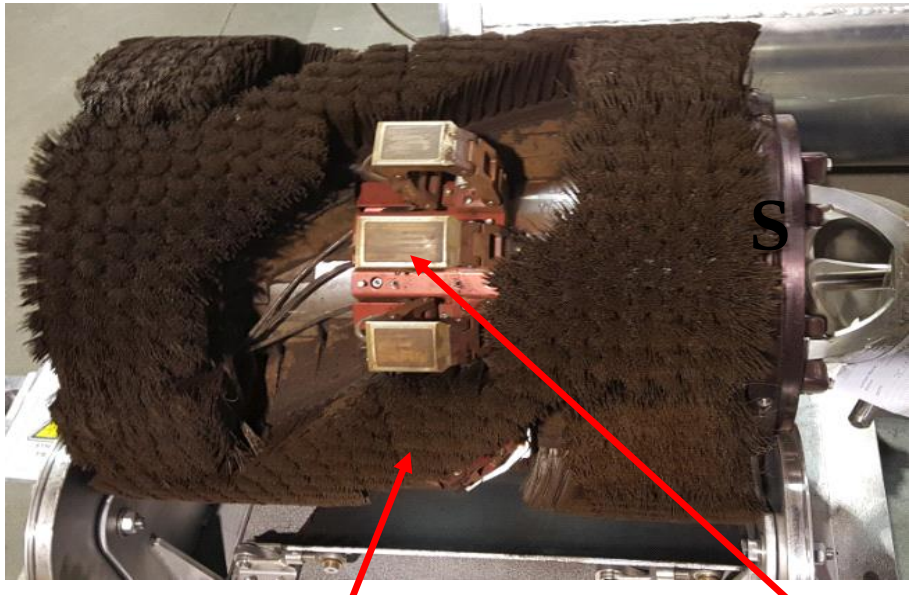
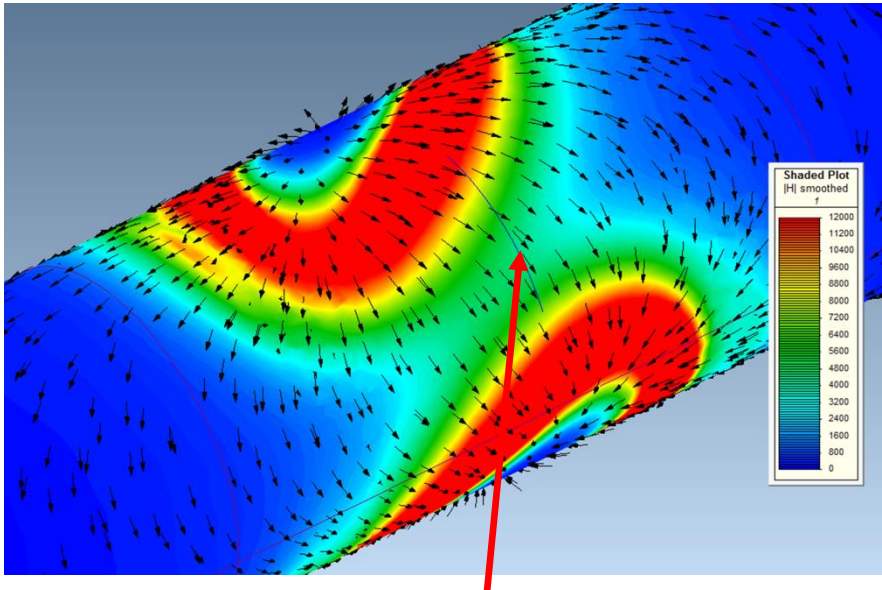
Magnetostrictive with Oblique Field





Helical Magnetizer **Meander Coils** **Oblique Magnetic field**

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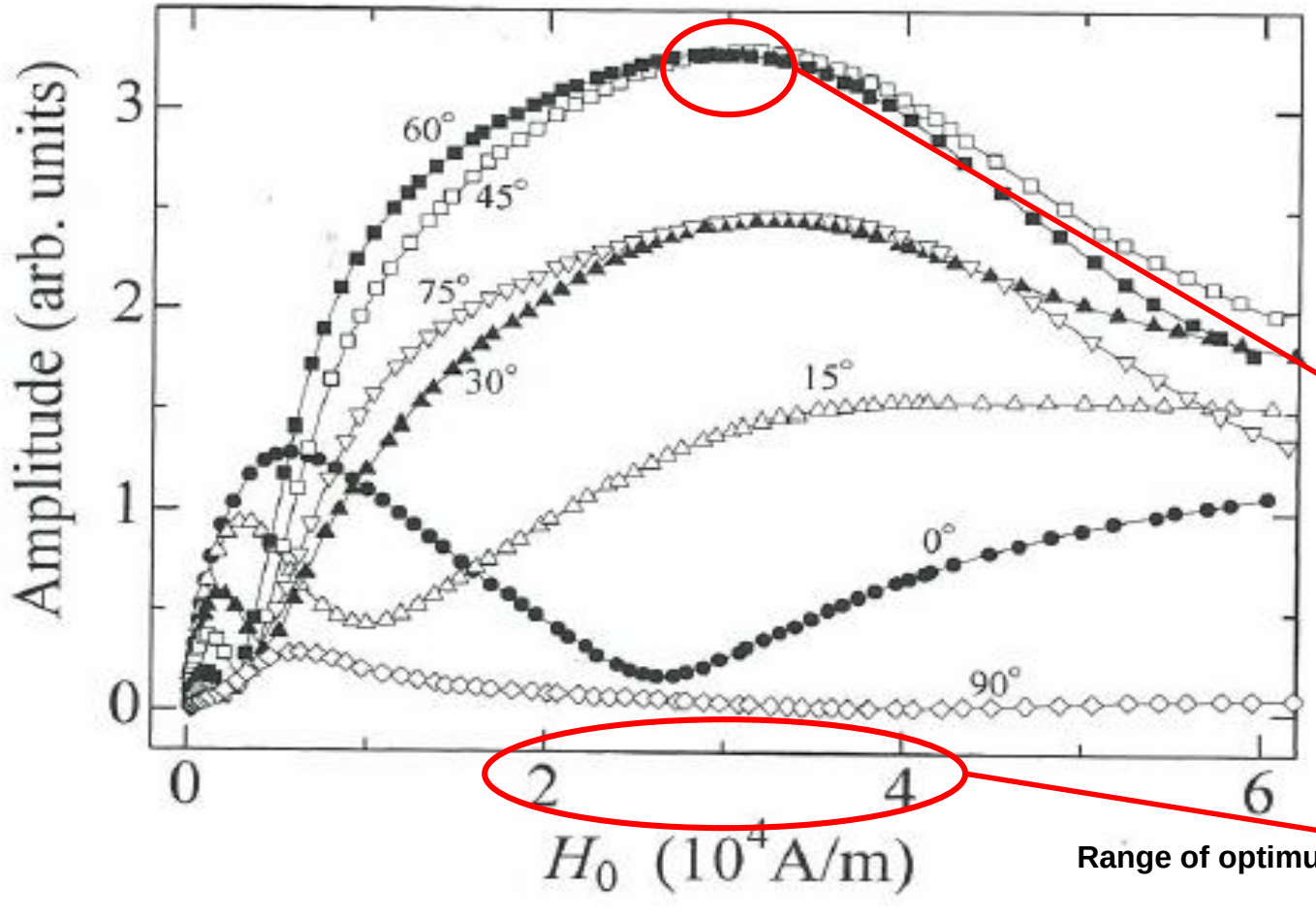
How Spiral Field Works



45° to 60° - Magic Angle

Range of optimum magnetization

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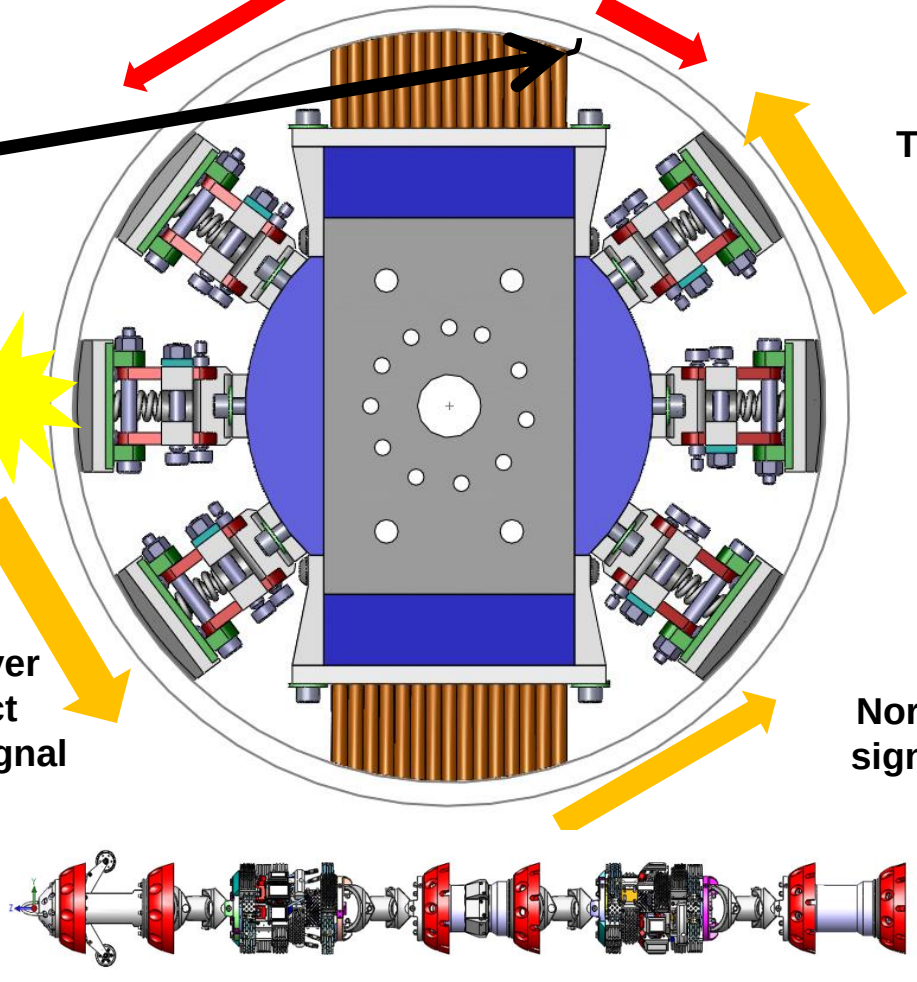
EMAT Sensor Function



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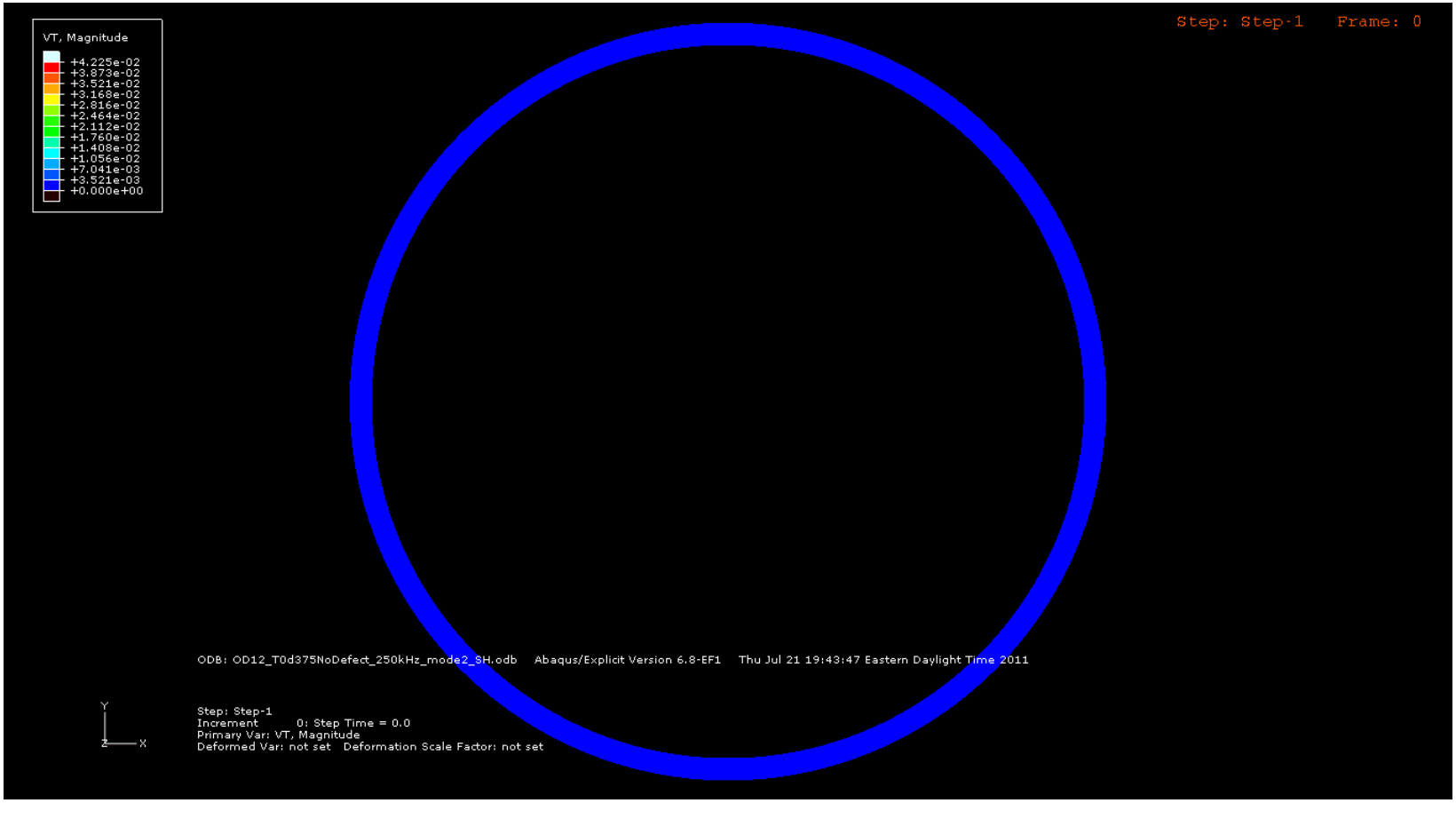
Propagation of Shear Horizontal Wave



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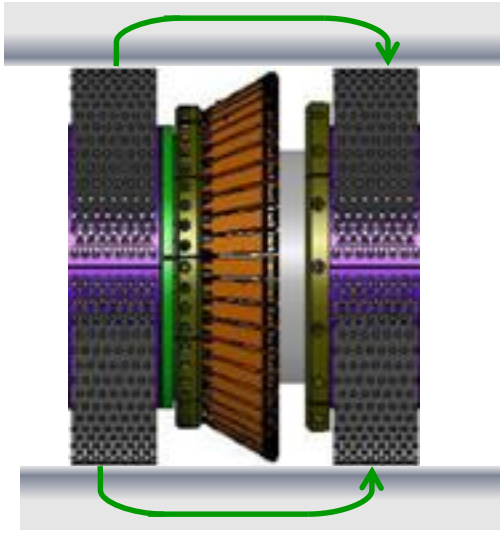
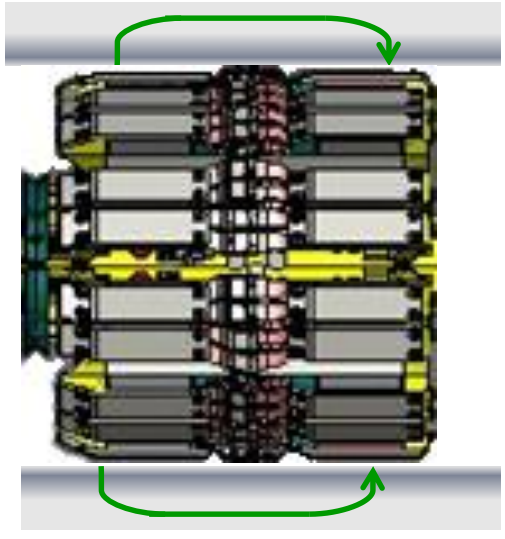
Axial Magnetization



Axial Direction



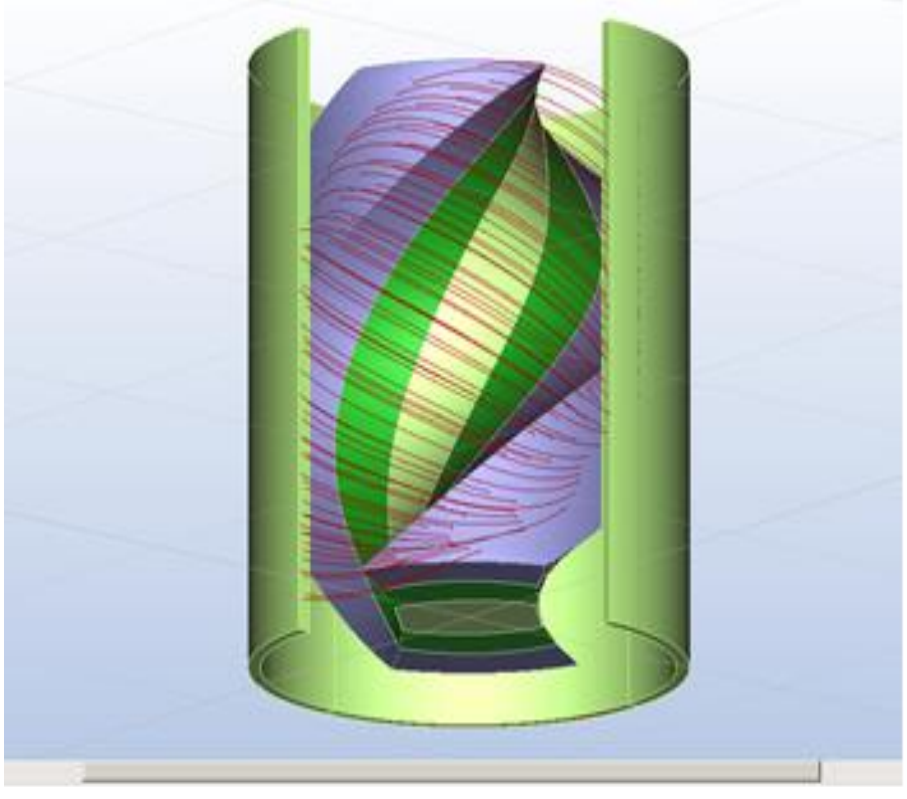
Solid Body – uses brushes to introduce flux into the pipe wall.

Sled – Places magnetic bars in close proximity to the pipe.

- The traditional method of magnetization is in the axial direction as it is the easiest to design.
- North magnetic poles are placed at one end and South at the other

Spiral Magnetization

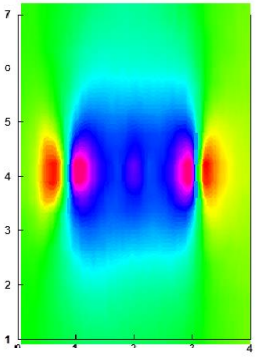
- Full circumferential coverage with all sensors in the sweet spot of the magnetic field
- Magnetization at ~45° which can size axial planar, circumferential planar and pitting.
- Less dependent on tool velocity.



MFL – Anomaly Orientation

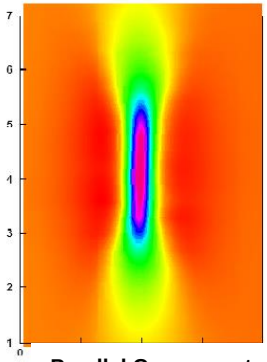
Parallel | **Perpendicular** | **Oblique**

(a)



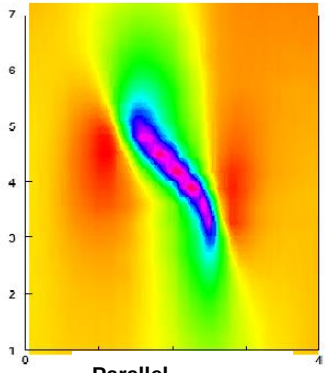
Parallel Component

(a)

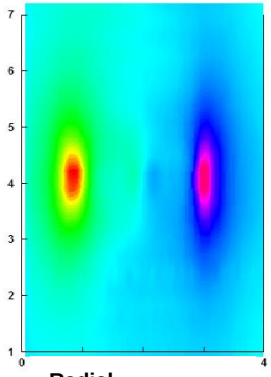


Parallel Component

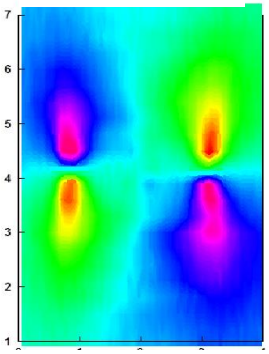
(a)



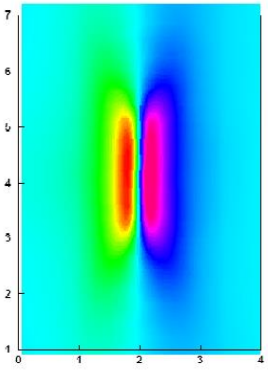
Parallel Component



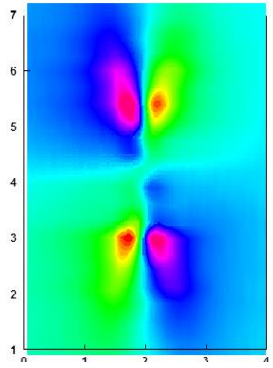
Radial Component



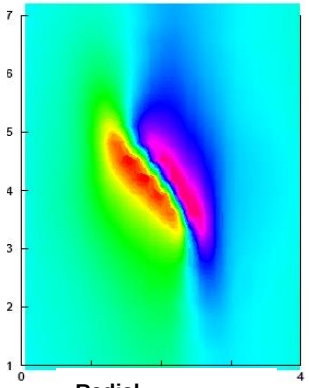
Perpendicular Component



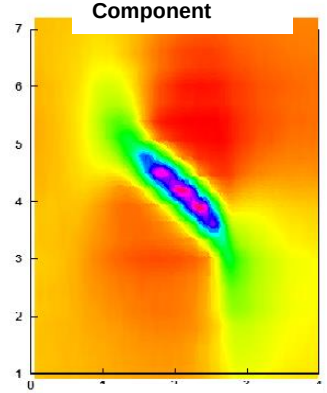
Radial Component



Perpendicular Component

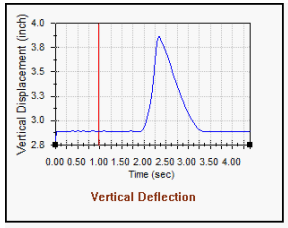


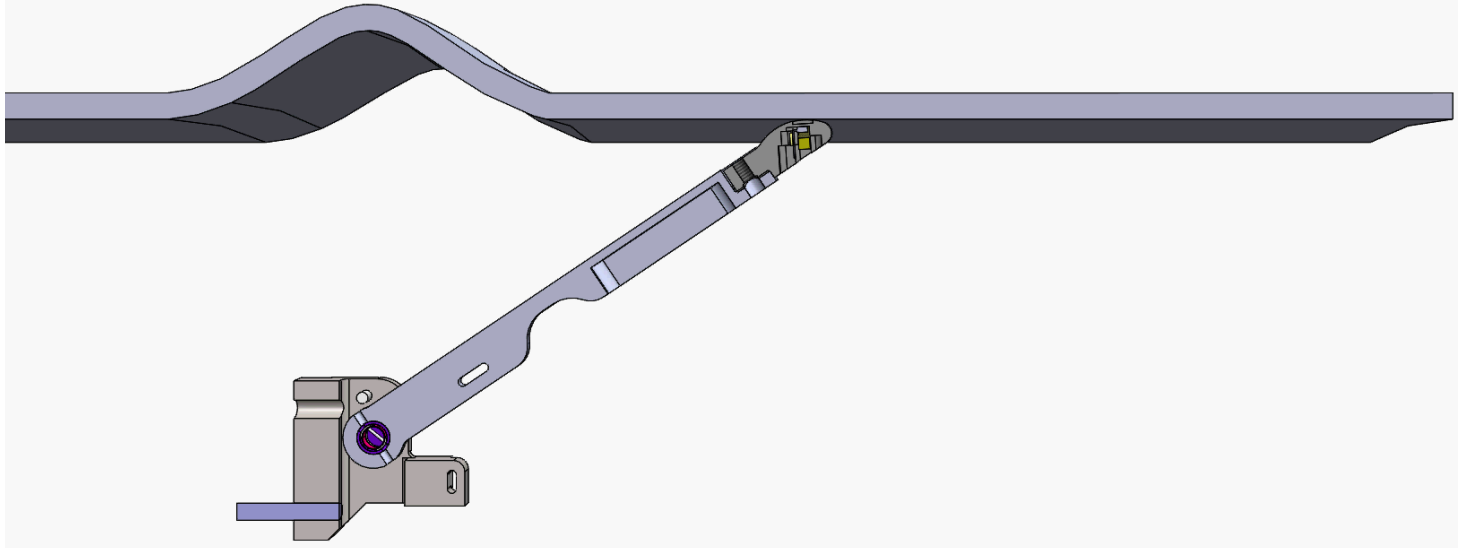
Radial Component



Perpendicular Component

Profilometry





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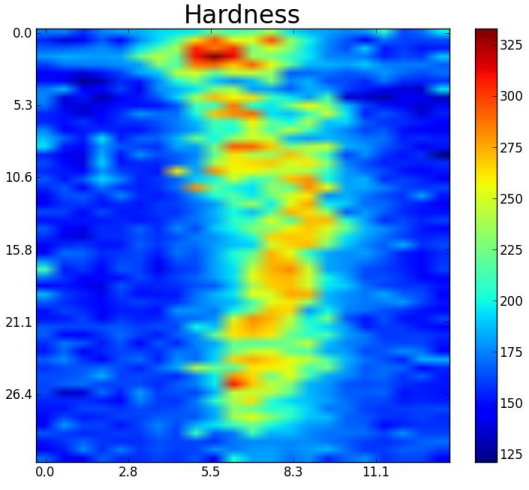
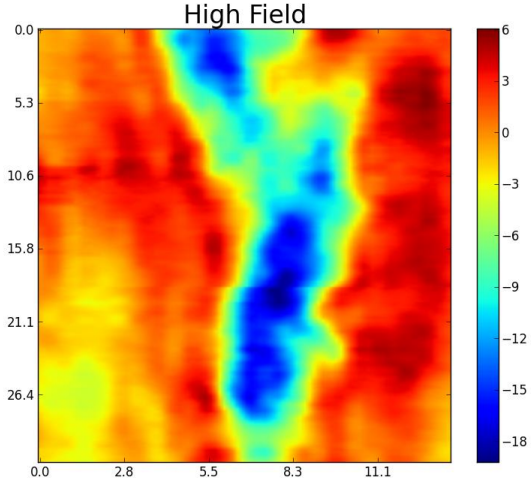
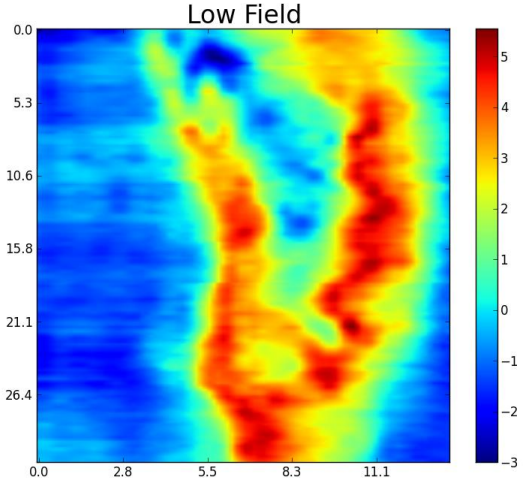
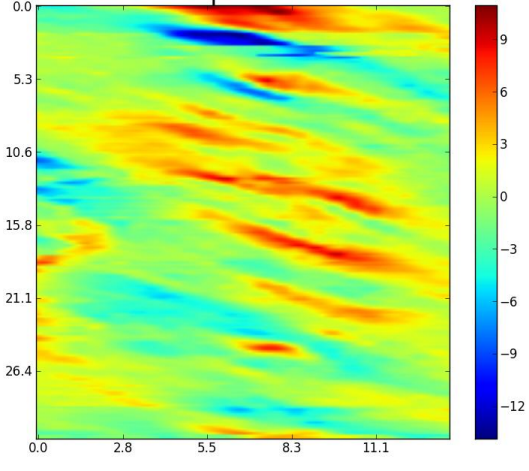
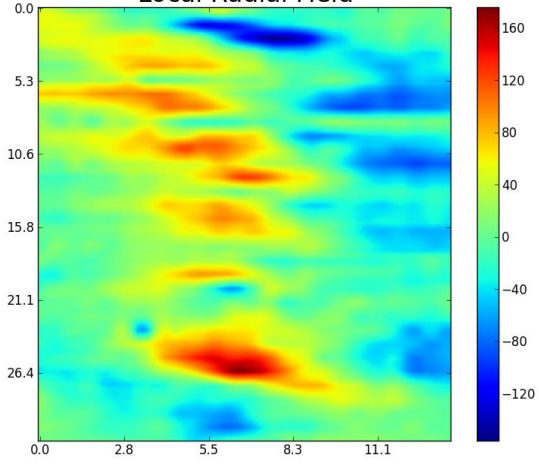
MDS Data Results for HS - Overview

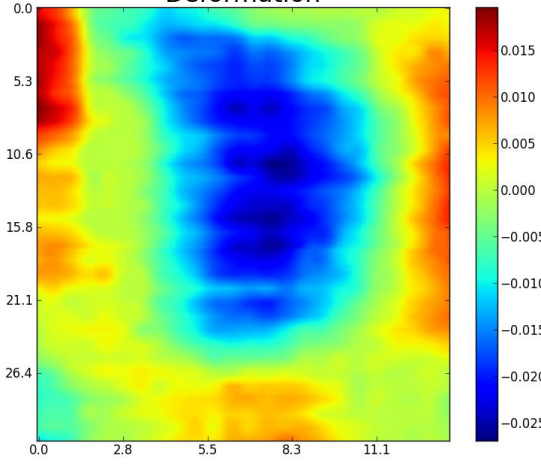












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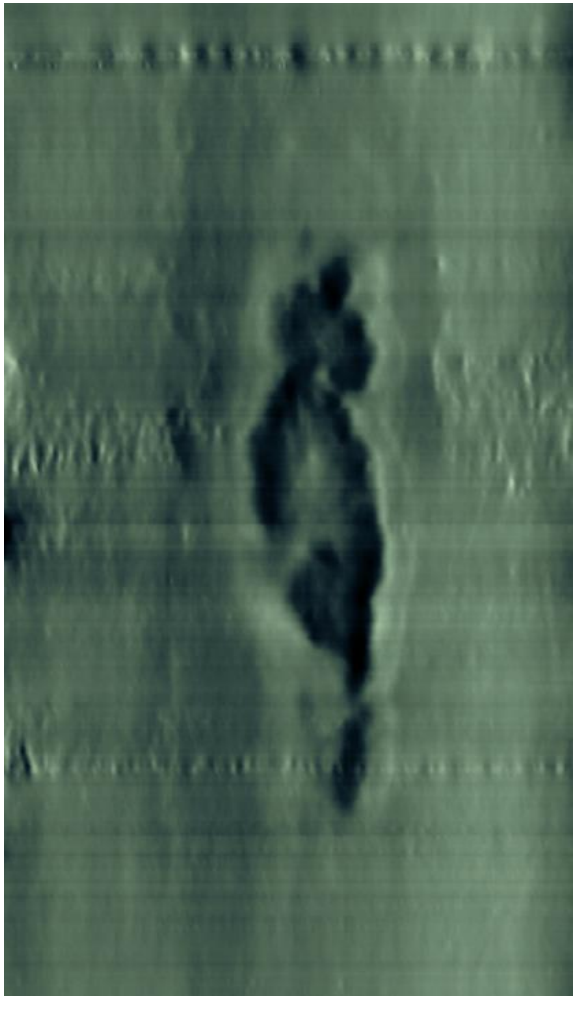
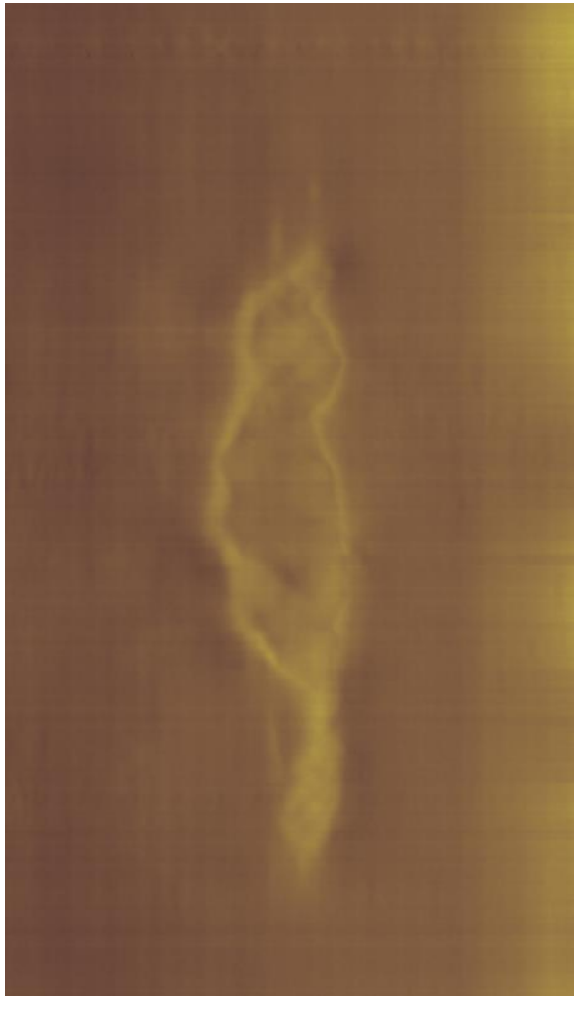
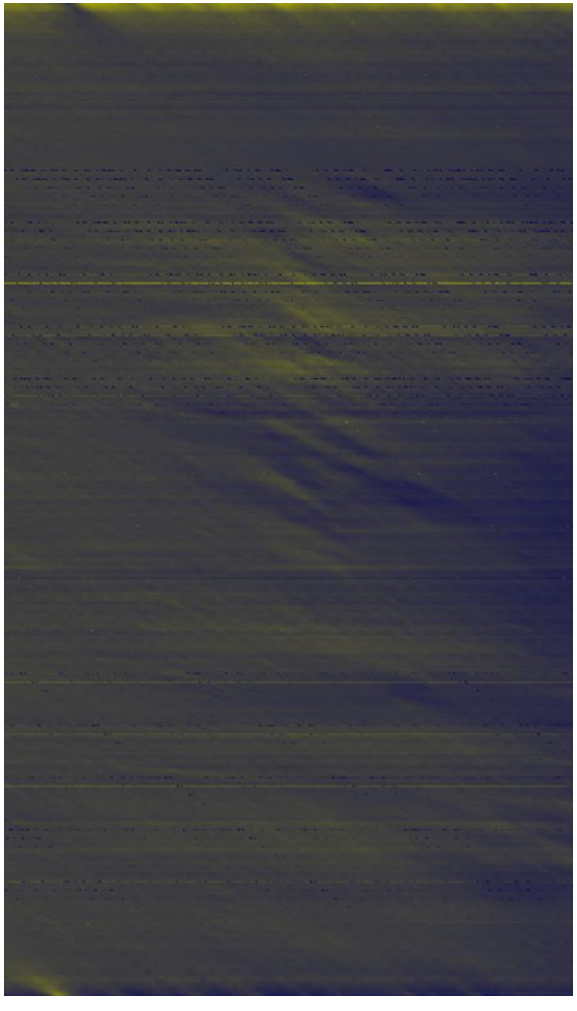
Hard Spot







High Field

Low Field

Spiral Field

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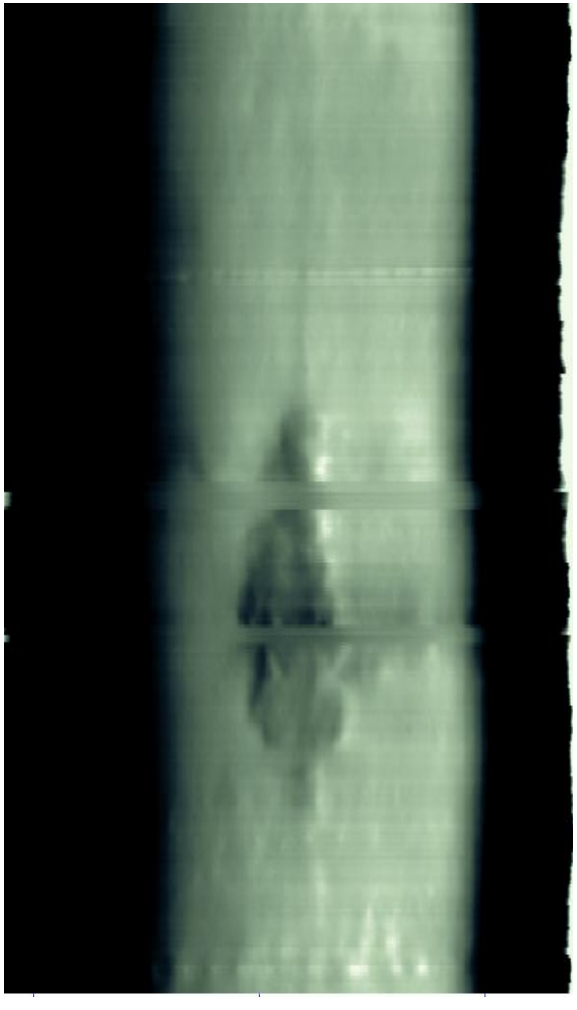
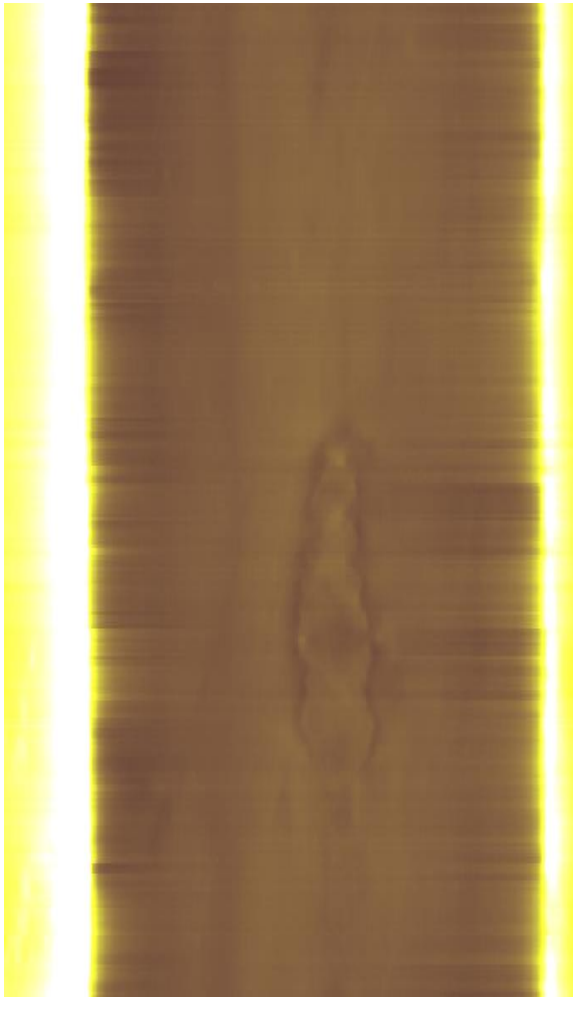
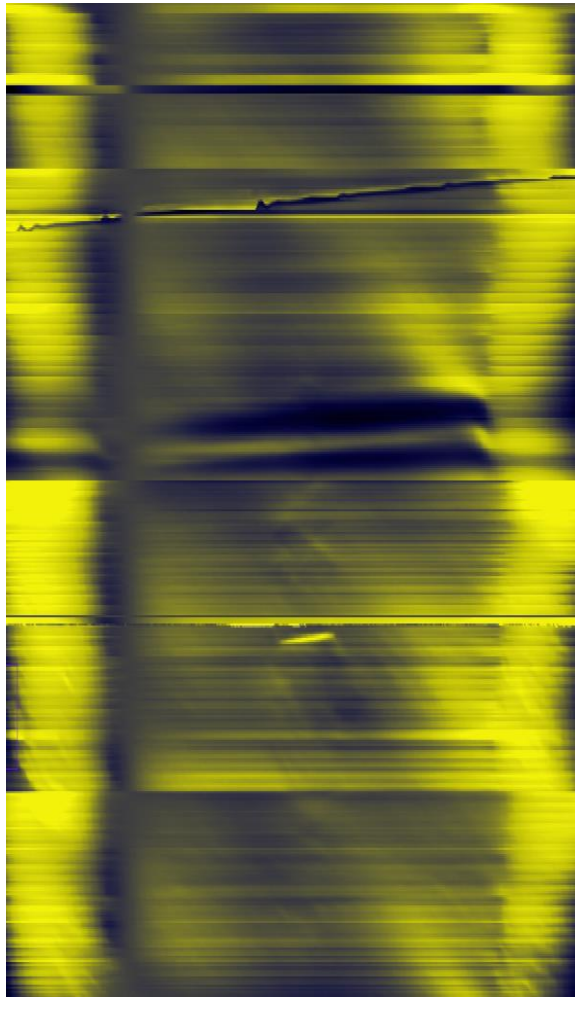
Sleeved Hard Spot with Crack



MFL



LFM



SMFL

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Mechanical Damage

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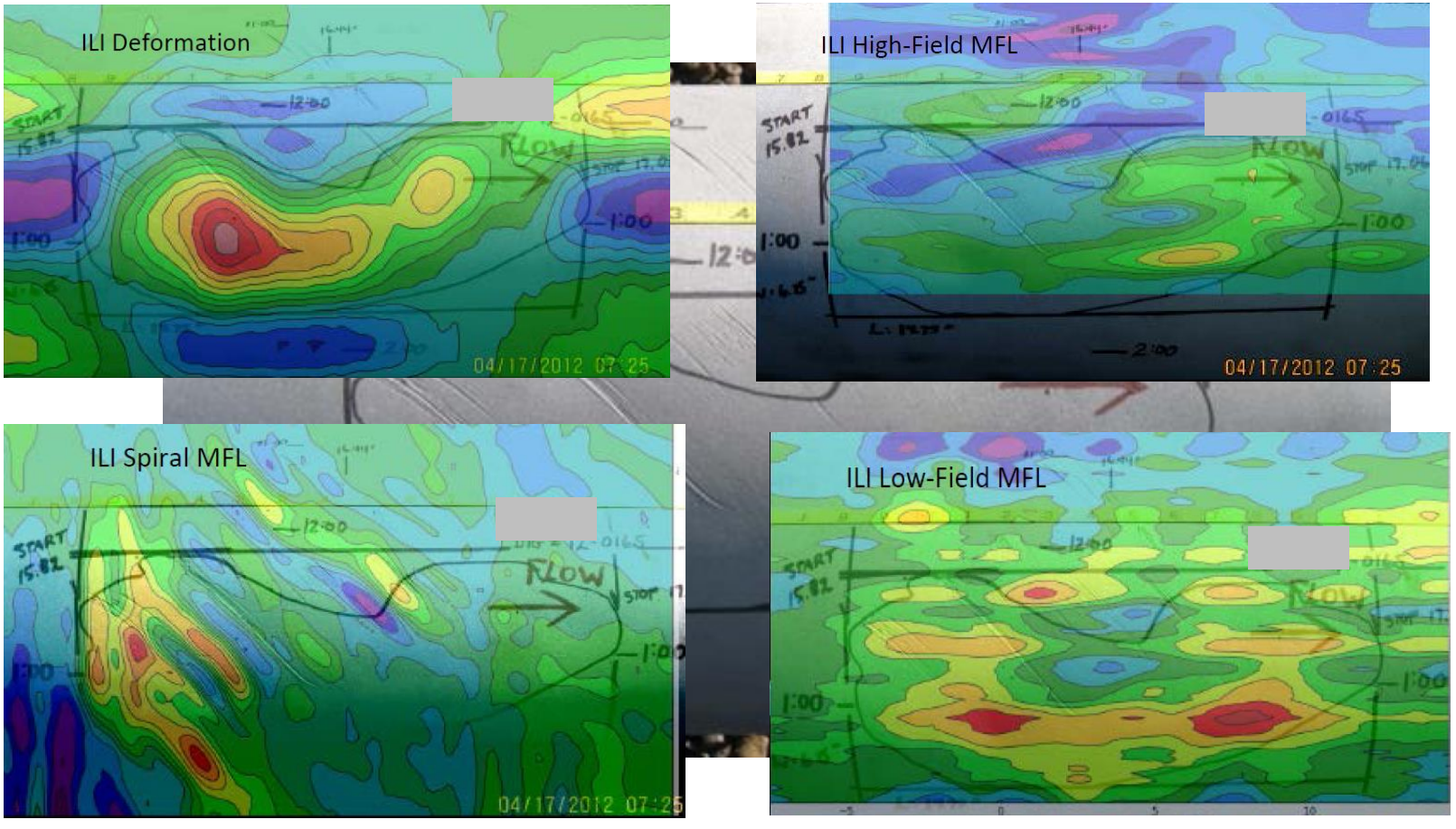
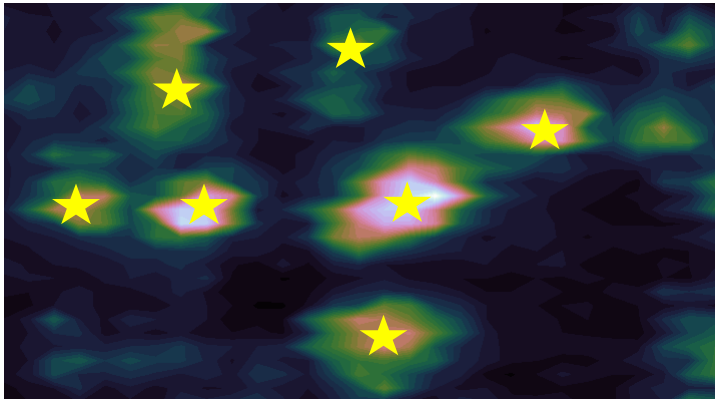
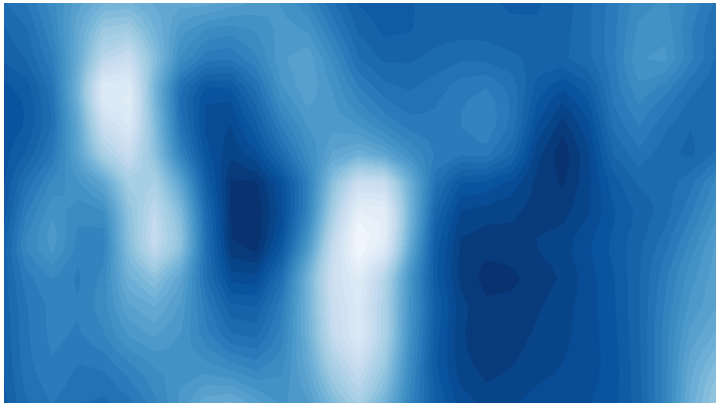


Future Work

Aligning Data Sets

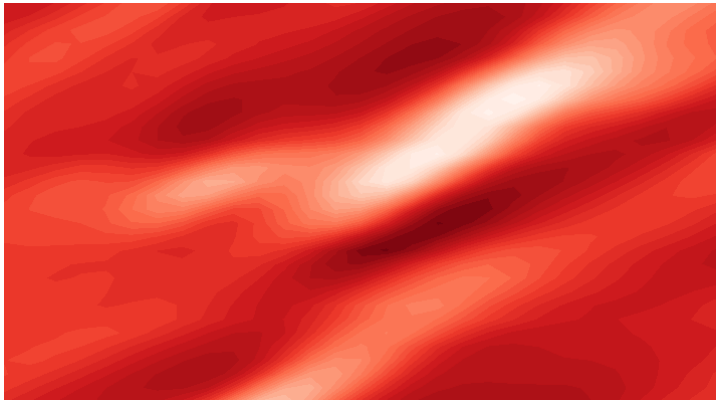


Laser Profilometry



Axial High Field

Axial Low Field



Spiral Field

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Strain

- Current standard sets a critical strain of 6%. This standard is an empirical standard carried over from ship manufacturing.
- Strain equations used by the industry use realistic assumptions to make the calculations solvable and repeatable.
- The greatest missing factor is the history of stress application that caused the straining process.

Toughness

- Liquid lines are failing at pressures as low as 20% specified minimum yield strength (SMYS)
- At present there are no inline solutions for measuring toughness and the nondestructive evaluation (NDE) techniques being used are still being validated.

Crack Propagation

- Crack Propagation depends strongly on material properties like toughness that are hard to measure nondestructively.
- Crack models make many assumptions and in light of recent failures many of them are under review
- Data and algorithms for calculating failure are in most part proprietary.
- A calculation that has a safety factor of 10 can definitely use refinement.

Pipe Properties

- Because of all the mergers, acquisitions and lay-offs over the last few decades, there are many lines with missing or incomplete records.
- Operators have been operating under a grandfather clause but new regulations from PHMSA are requiring traceable, verifiable and complete documentation for every joint of pipe.
- There are solutions being proposed for NDE and ILI.

NDE Techniques

Automatic Indenter

Spectroscopy

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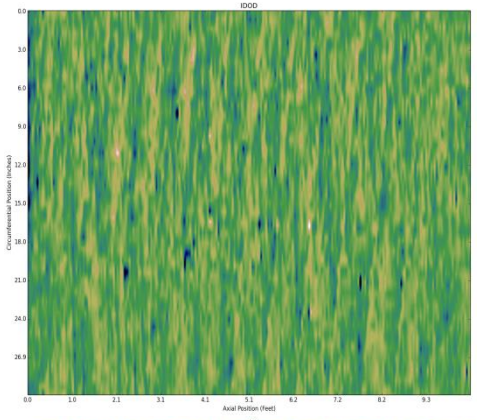
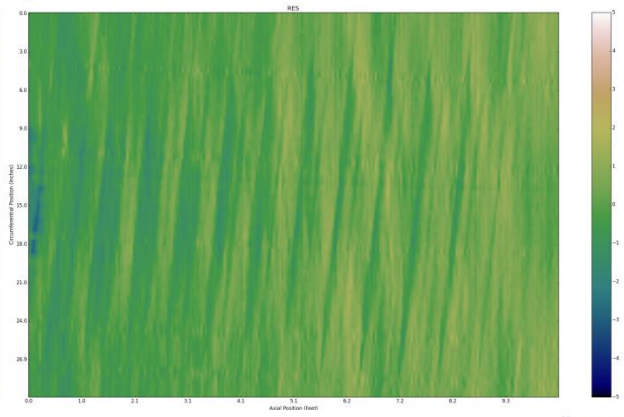
Pipe Joint Classification

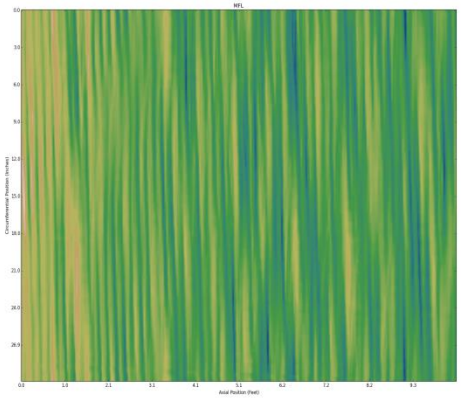
IDOD



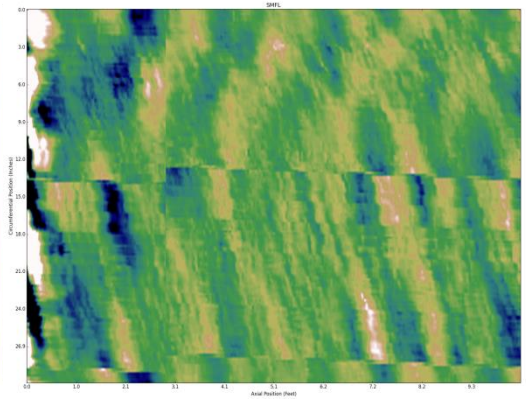
LFM



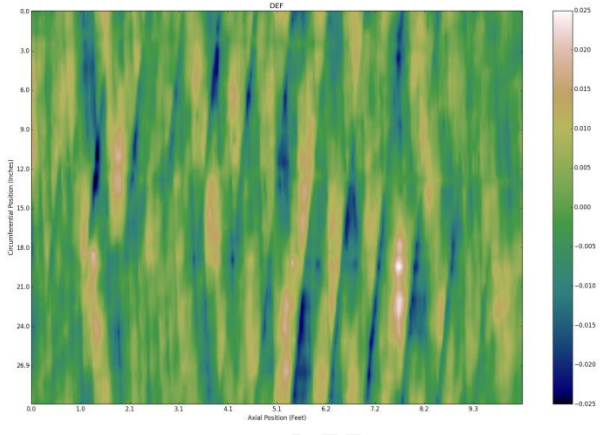
Every data set collected by the multiple dataset tool (MDS) can be used to identify the manufacture of that joint



MFL



SMFL



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Conclusion