Review of Advanced In-Line Inspection Solutions for Gas Pipelines

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Introduction

- In-Line Inspection of gas pipelines is more demanding, in particular for **extreme** (low/high) **flow and pressure** conditions
- Compressible nature of the medium gas requires special tool configuration i.e. **low friction sealing** elements or intelligent **bypass valves**
- Some threats are more frequent in gas than in liquid lines, e.g. **Stress Corrosion Cracking** (SCC) or **Top of the Line Corrosion** (TOL)
- Absence of liquids require new **Ultrasonic Testing methods** to characterize crack related threats.

Content

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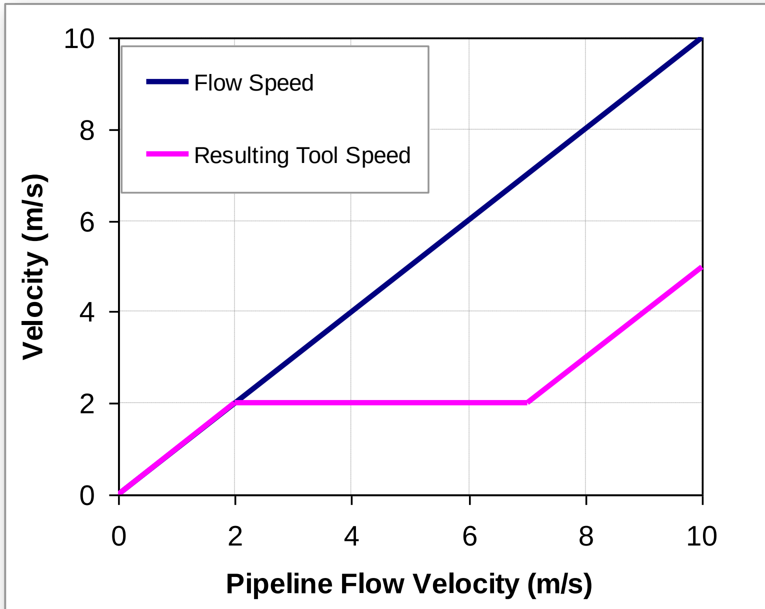
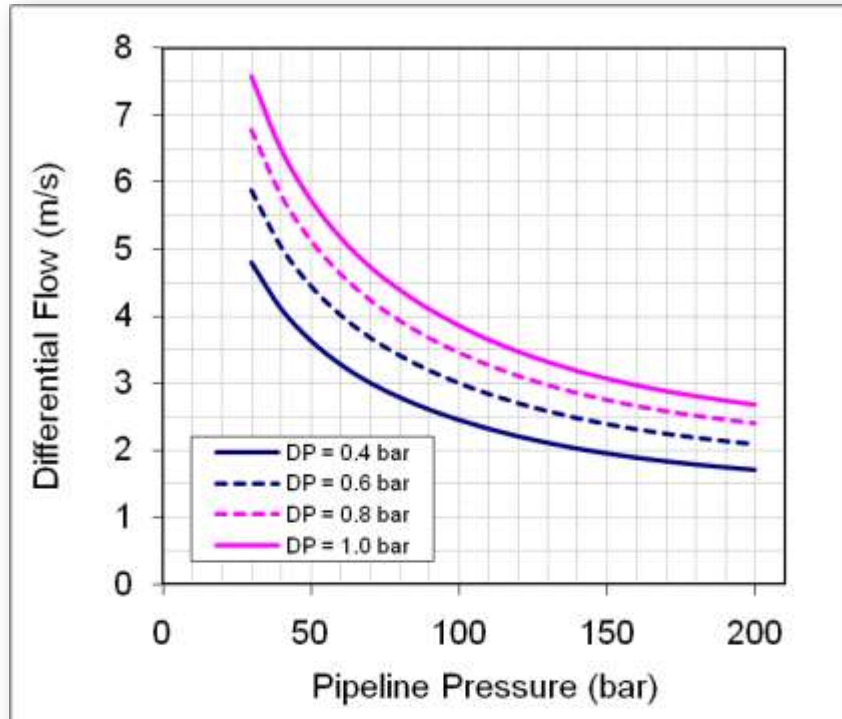
- **Introduction**
- **In-Line Inspection – Run Behavior**
  - Controlling the Inspection Speed
  - Controlling the Tool Dynamics
  - Reduced Pressure and Flow Conditions
- **In-Line Inspection – Pipe Anomalies**
  - Dents and Pipeline Geometry
  - Corrosion
  - Cracking
  - Coating Assessment
- **Conclusion**

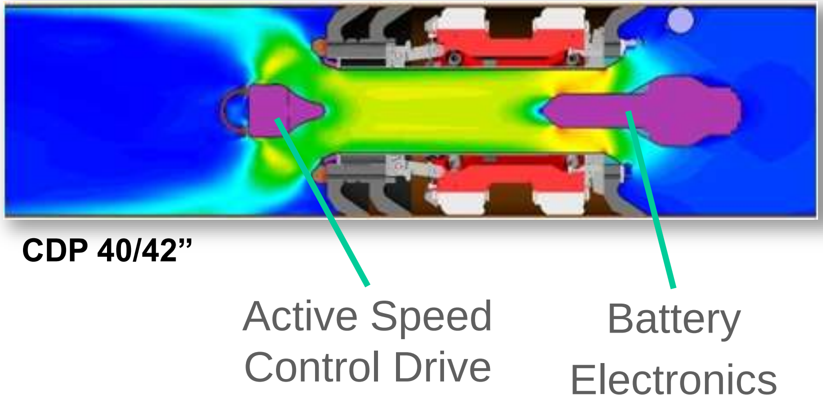
Controlling the Inspection Speed

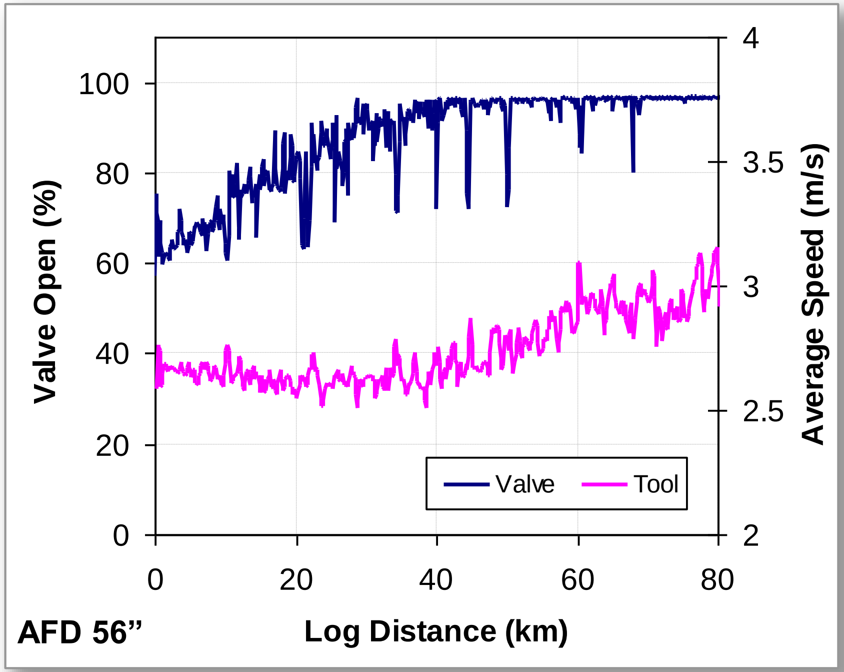


- Basic Principle of Speed Control Unit
- Pressure Dependency of Differential Flow thru valve for 26”/30” Tool in 30” Pipeline



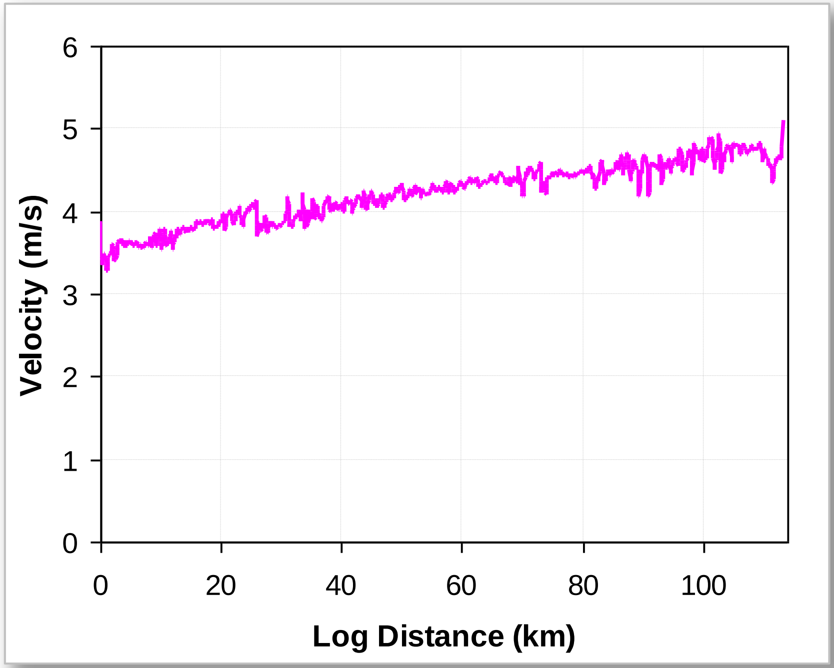
Controlling the Inspection Speed





	Launcher
Gas Velocity	8.4 m/s
Gas Flow	2,868,458 sm^3/h
Pressure	6.53 MPa
Temperature	40ºC

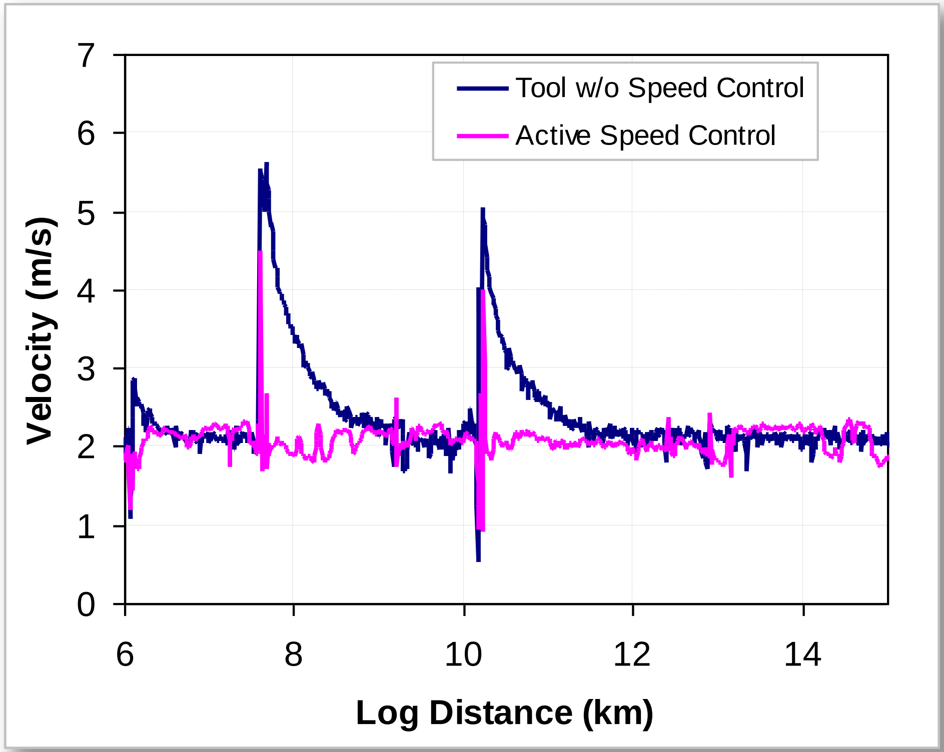
Controlling the Inspection Speed



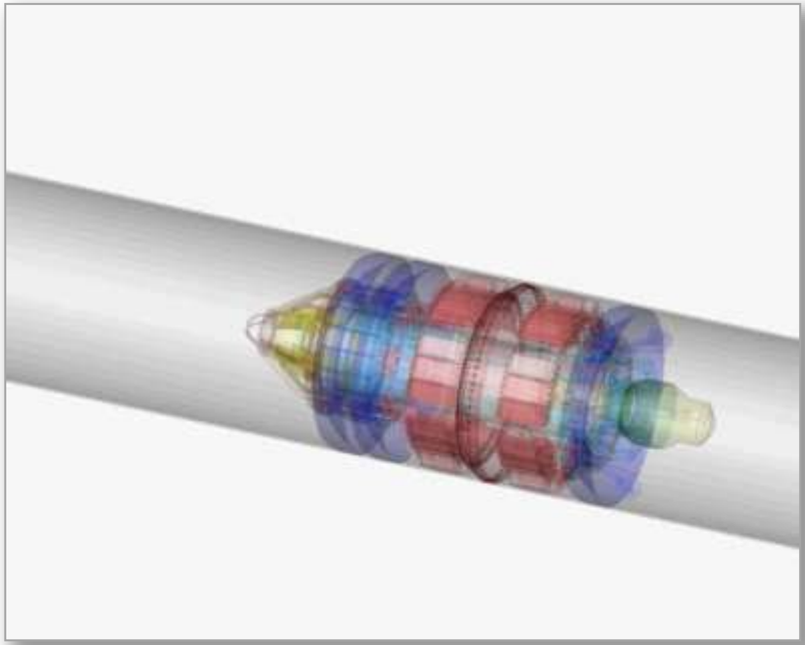
- ILI Inspection of a 56” Gas-Pipeline
- 1.5D; Mitered Bends
- High Resolution MFL
- Difference between Tool and Flow 5m/s

	Launcher	Receiver
Gas Velocity	8.8 m/s	10.1 m/s
Gas Flow	3,060,000 sm^3/h	3,060,000 sm^3/h
Pressure	6.68 MPa	5.52 MPa
Temperature	40ºC	27ºC

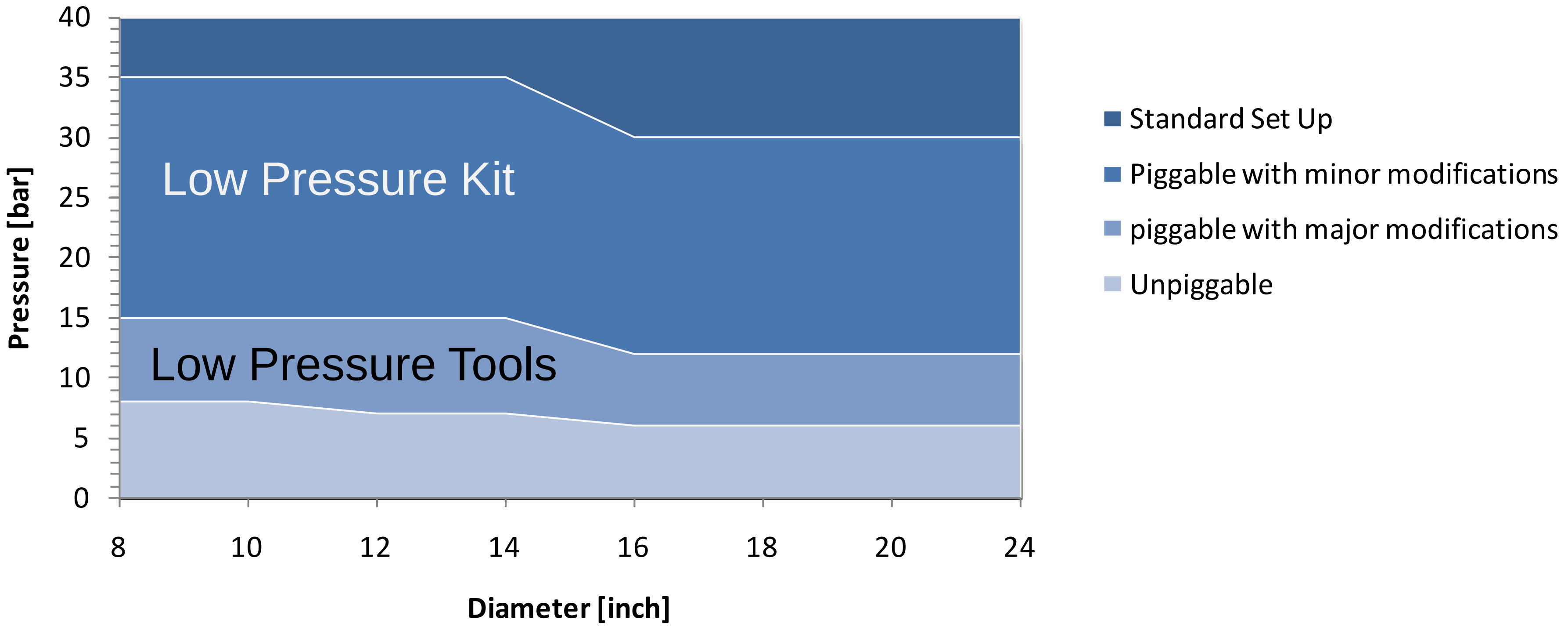
Controlling the Tool Dynamics



- ILI Inspection of a 26" Gas-Pipeline
- Two runs were performed
- Gas Equalization within 50m with Speed Control



Reduced Pressure and Flow Conditions



08” High-Res MFL ILI Tool – Low Pressure

Low Pressure Kit

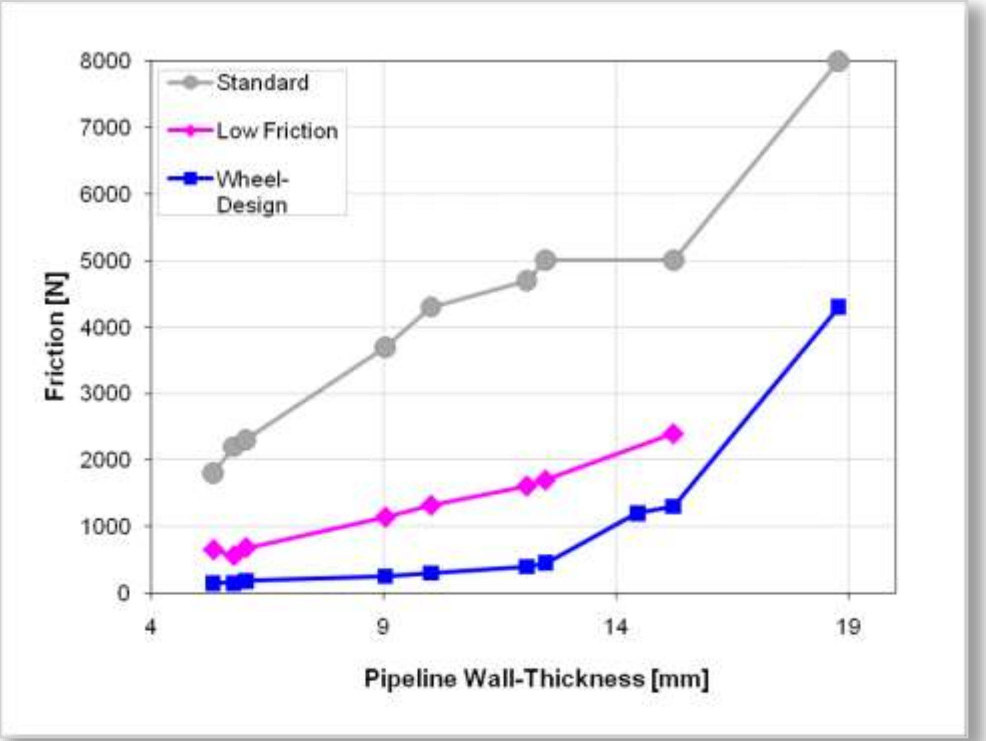
- Pull-Unit
- Low Friction Setup
- Wheel Design

Magnet Unit

- Reduction of Friction by **65 %**
- Improved **Start/Stop**

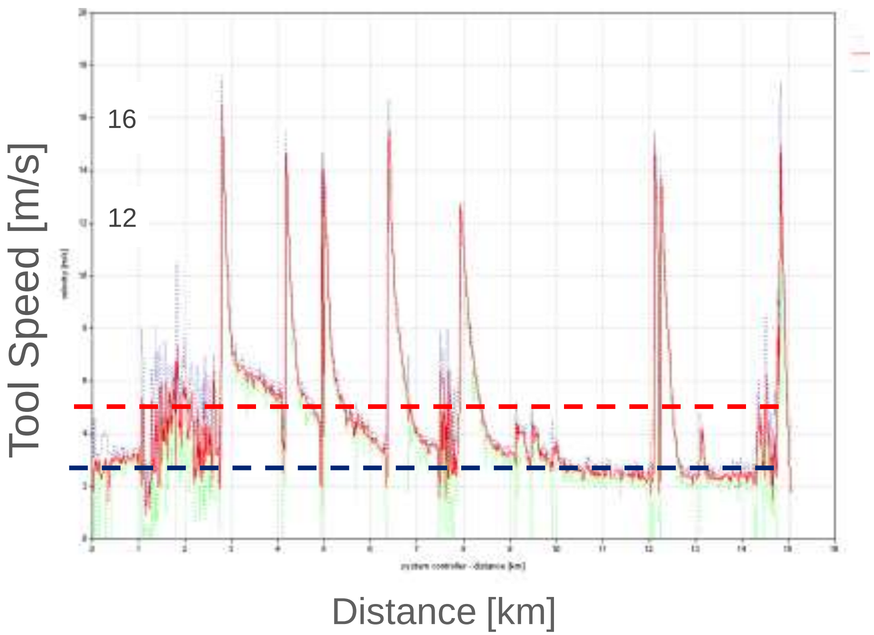
Low Pressure Tool

- Magnet Unit on Wheels
- E-Box Design
- U-Joint Design

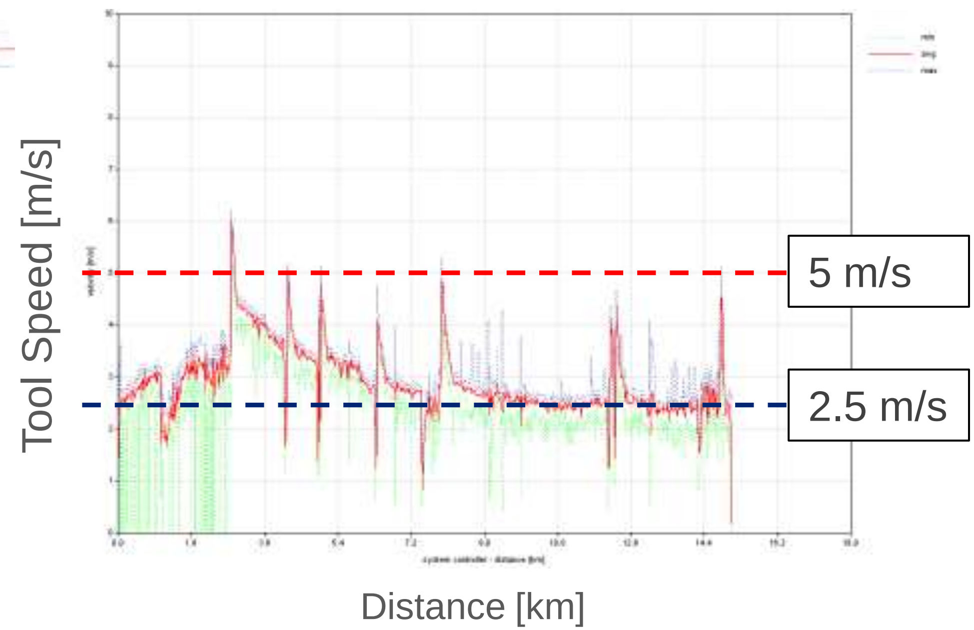


Low Pressure Example

Geometry Tool – Standard Setup



Low Pressure Tool – MFL



OD nom.	10” (273.1mm)
Pressure:	16 - 18 bar
Wall Thickness:	6.35mm – 12.7 mm
Length:	15km

Low Flow Condition

Special Drive Unit

Just Seal Principle

- Minimum Bypass
- Minimum Friction
- Optimized Centralization
- Optimized Load Capacity

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Combined ILI-Technologies

- **high resolution geometry** inspection (Geo)
- pipeline route mapping (XYZ)
- **corrosion mapping** with magnetic flux leakage (MFL)
- mapping of **shallow internal corrosion (SIC)** using eddy current technology

XYZ

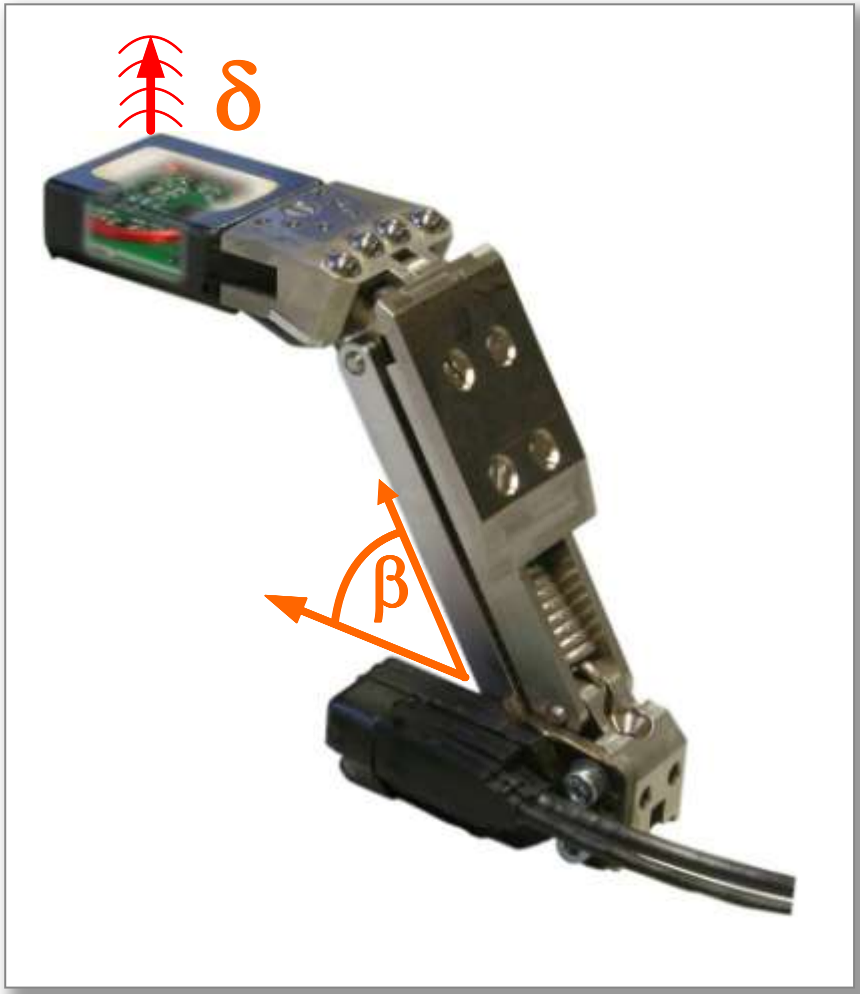
Geo

MFL

SIC

ROSEN Contour Following Proximity Sensor

(Compensated Deflection)



Radius Measurement

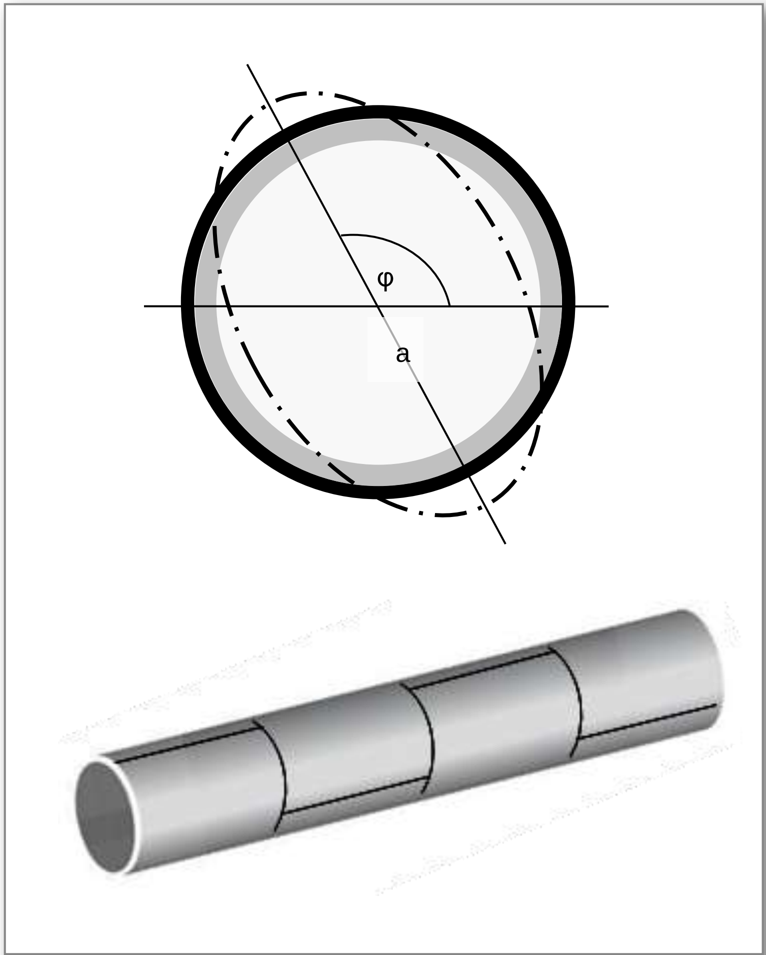
=

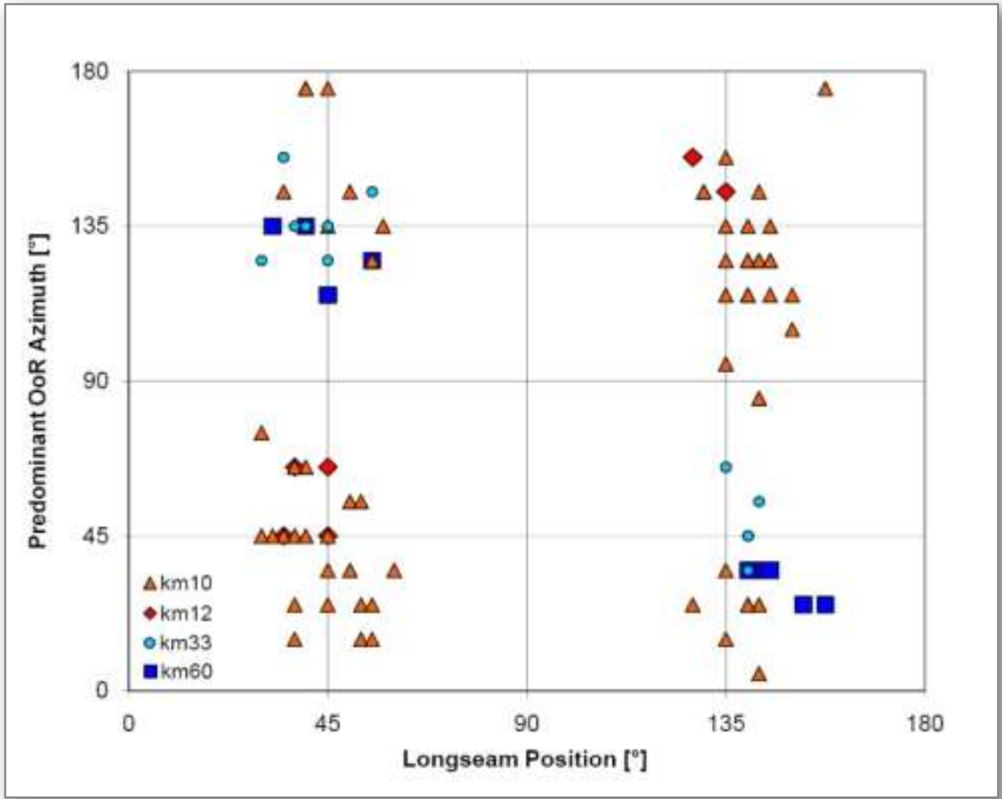
δ Touchless Proximity Sensor

+

β Electronic Angle Sensor

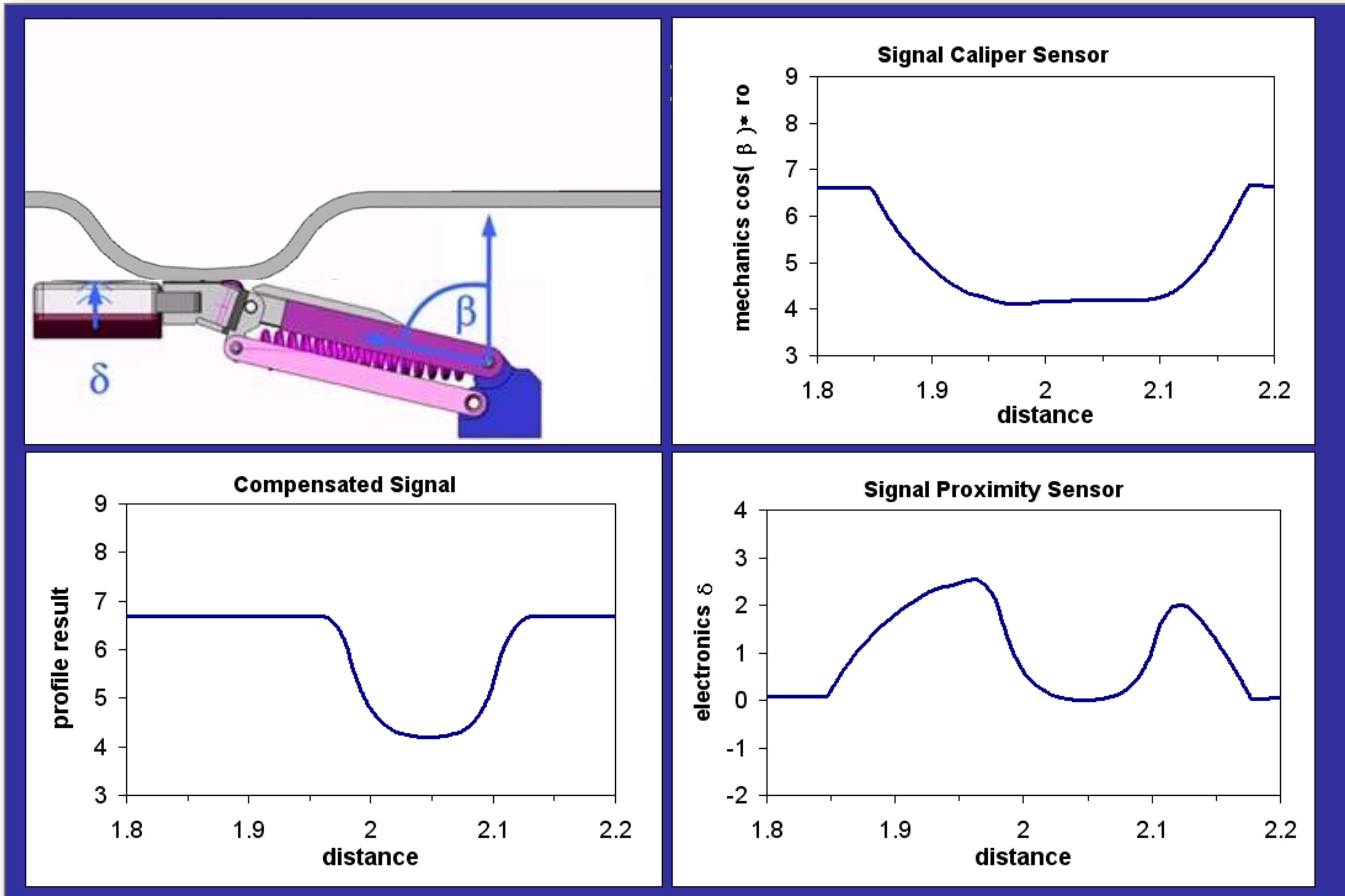
Out of Roundness Correlates with Longseam Position





OoR between 0.6mm to 1mm detected

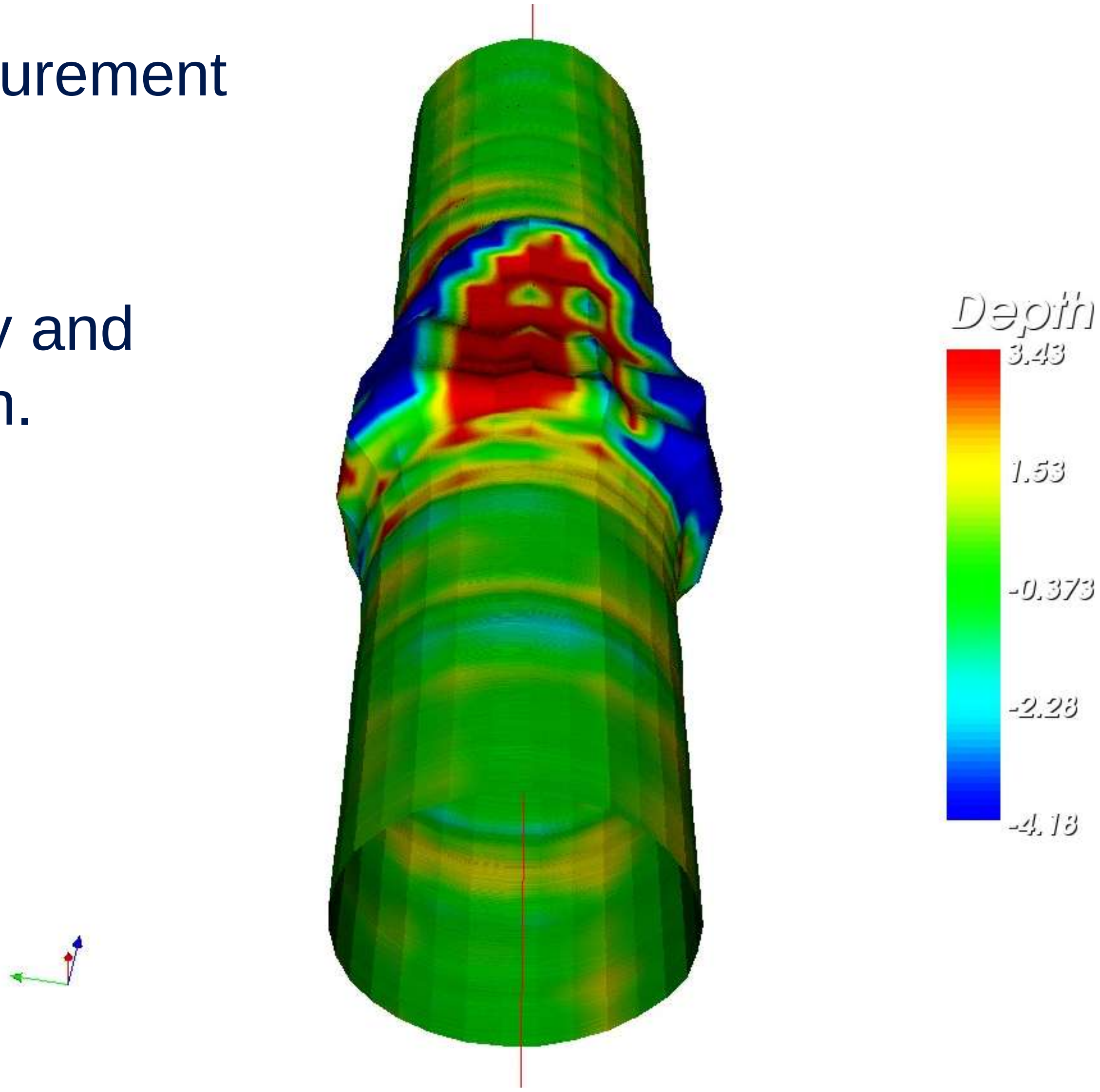
Accurate Dent Characterization - Combined Technology



Dents and Pipe Geometry

Geometry Tool measurement of check valve.

Checked immediately and approved for MFL run.



(03)

NONMANDATORY APPENDIX R
ESTIMATING STRAIN IN DENTS

R1 STRAIN

Strain in dents may be estimated using data from deformation in-line inspection (ILI) tools or from direct measurement of the deformation contour. Direct measurement techniques may consist of any method capable of describing the depth and shape terms needed to estimate strain. The strain estimating techniques may differ depending on the type of data available. Interpolation or other mathematical techniques may be used to develop surface contour information from ILI or direct measurement data. Although a method for estimating strain is described herein, it is not intended to preclude the use of other strain estimating techniques. See also Fig. R1.

R2 ESTIMATING STRAIN

R_0 is the initial pipe surface radius, equal to ½ the nominal pipe OD. Determine the indented OD surface radius of curvature, R_1 in a transverse plane through the dent. The dent may only partially flatten the pipe such that the curvature of the pipe surface in the transverse plane is in the same direction as the original surface curvature, in which case R_1 is a positive quantity. If the dent is re-entrant, meaning the curvature of the pipe surface in the transverse plane is actually reversed, R_1 is a negative quantity. Determine the radius of curvature, R_2 in a longitudinal plane through the dent. The term R_2 as used herein will generally always be a negative quantity. Other dimensional terms are: the wall thickness, t; the dent depth, d; and the dent length, L.

(a) Calculate the bending strain in the circumferential direction as

$$\varepsilon_1 = t\,(1/R_0 - 1/R_1)$$

Strain

e the bending strain in the longitudinal

$$\varepsilon_1 = -t/R_2$$

Radius

(c) Calculate the extensional strain in direction as

$$\varepsilon_1 = (^1/_2)(d/L)^2$$

(d) Calculate the strain on the inside pipe surface as

$$\varepsilon_i = [\varepsilon_1{}^2 - \varepsilon_1\,(\varepsilon_2 + \varepsilon_3) + (\varepsilon_2 + \varepsilon_3)^2]^{1/2}$$

REMARK: Formula not correct

the outside pipe surface as

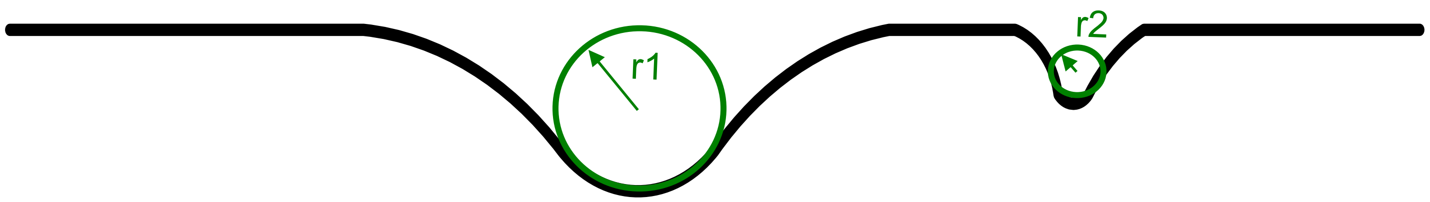
$$\varepsilon_o = [\varepsilon_1 \ldots \varepsilon_3)^2]^{1/2}$$

ASME Code, B31.8-2003, Appendix R, page 158

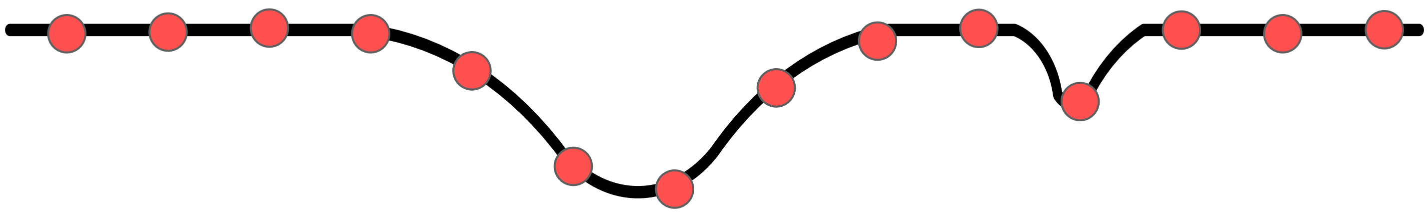
Strain and Stress

ε = Strain = displacement

r = radius = curvature

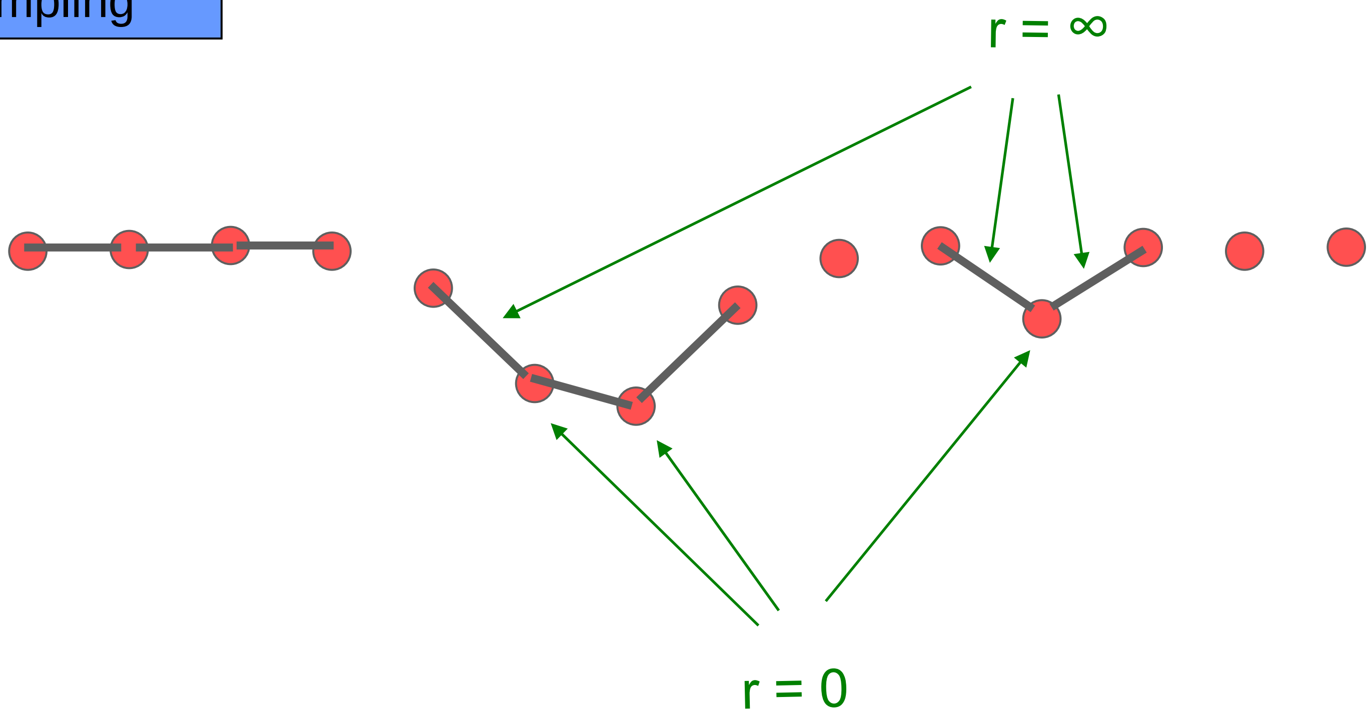


ILI Geometry Measurement and Analysis



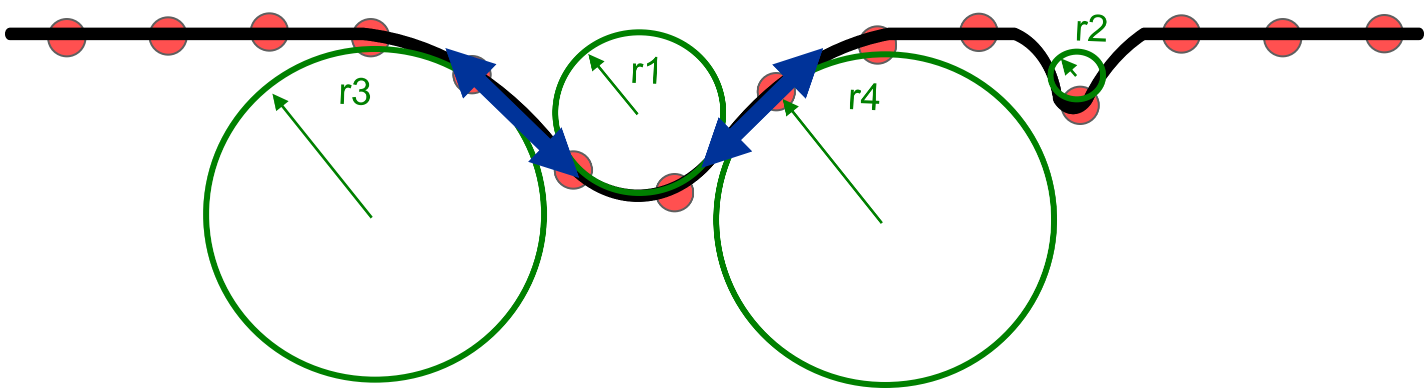
ILI Geometry Measurement and Analysis

Accurate Sampling



ILI Geometry Measurement and Analysis

Accurate Sampling	Spline Approximation	Curvature Detemination	Membrane[1] Dent



[1] local membrane strain in dent

ILI Geometry Measurement and Analysis

Accurate Sampling

Spline Approximation

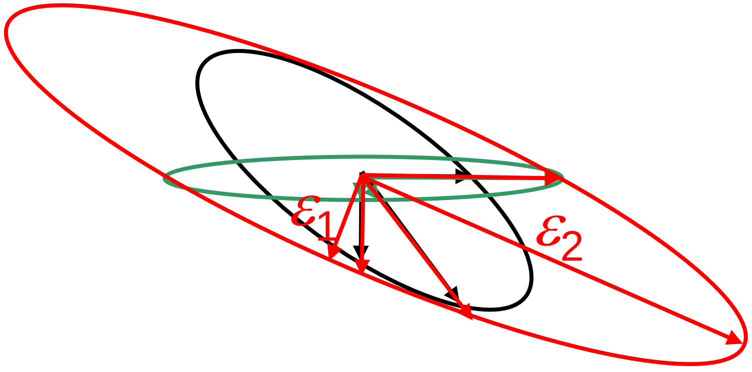
Curvature Detemination

Membrane[1] Dent

Strain Calculation

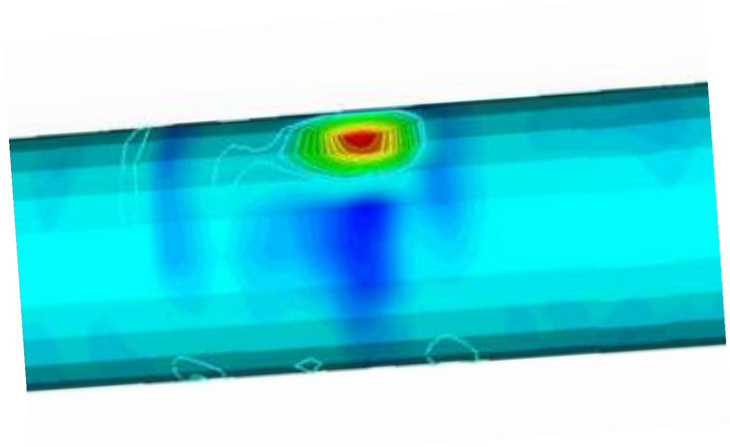
$$\varepsilon_{total} = \sqrt{\varepsilon_1^2 - \varepsilon_1\varepsilon_2 + \varepsilon_2^2}$$

Bending strain + membrane strain = total strain



Results and Reporting

Strain
Data Visualization



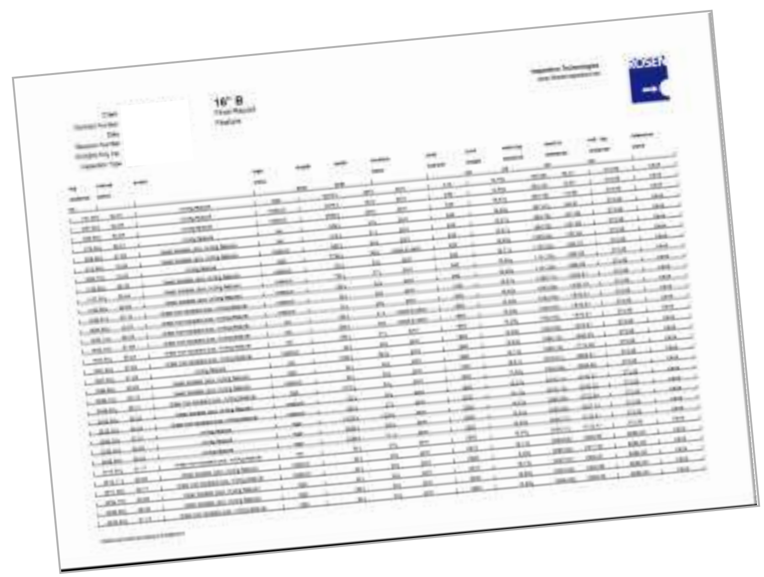
List of Significnaces

Data Arrays

- Strain
- Curvature
- Geometry

Dent Parameter

- Length
- Width
- Depth
- max Strain



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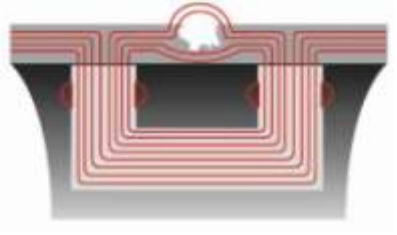
Corrosion Mapping

XYZ

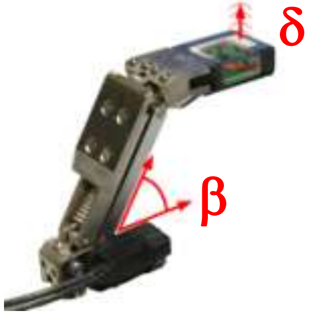
Geo

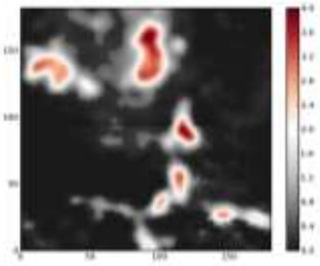
MFL

SIC



Corrosion Mapping with MFL



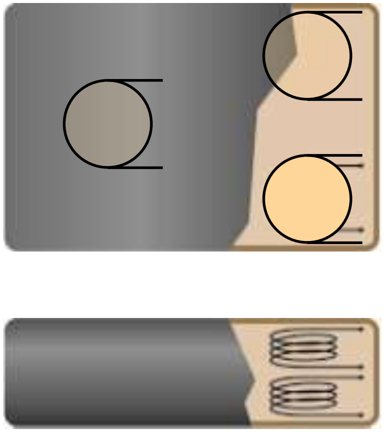


Corrosion Mapping with
Shallow Internal Corrosion Sensor

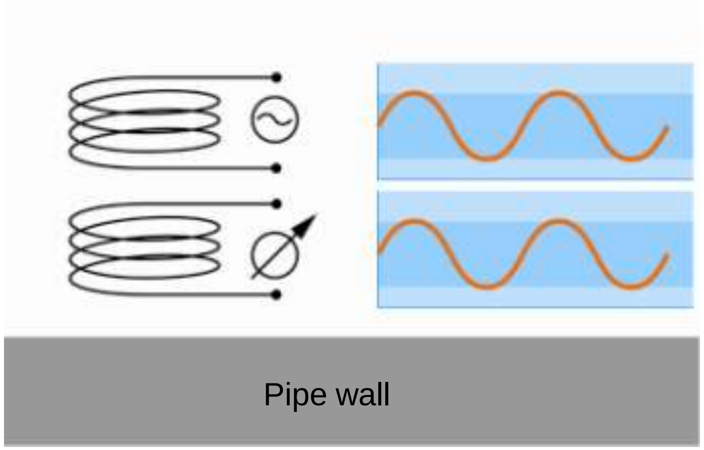
Measurement Principle

SIC Sensor

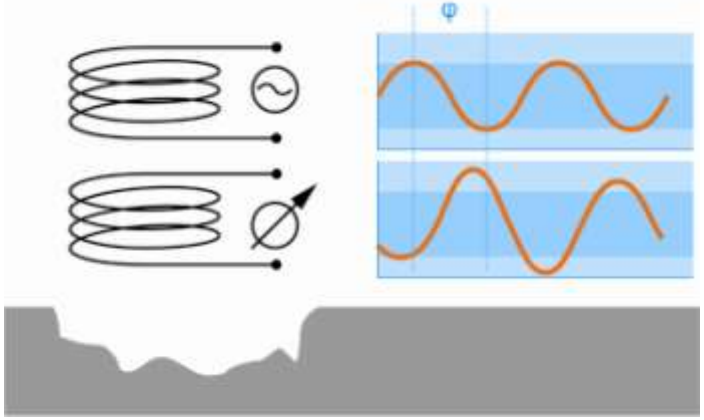
SIC Sensor (schematic)



Sensor over full pipewall



Sensor over metal loss

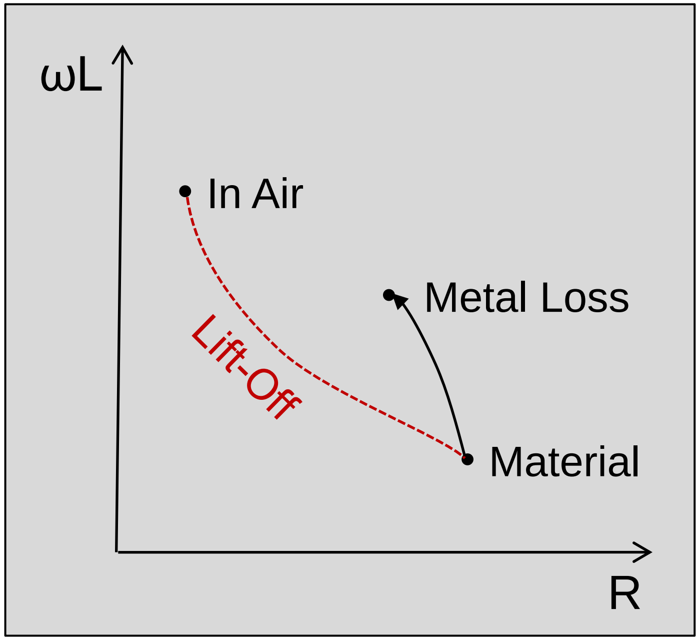


Amplitude change

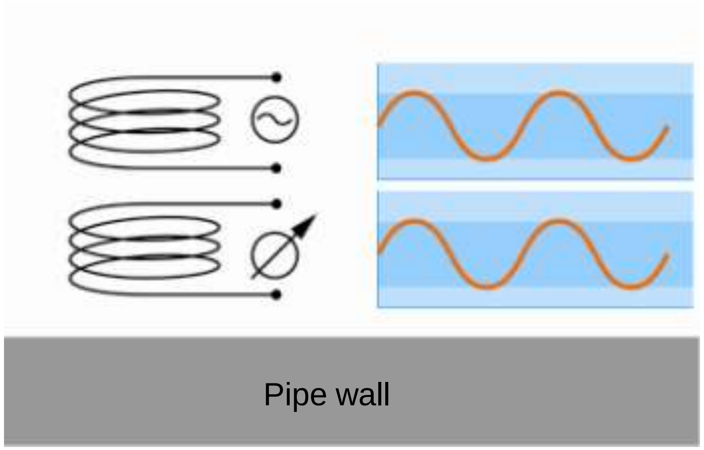
Phase movement

Measurement Principle

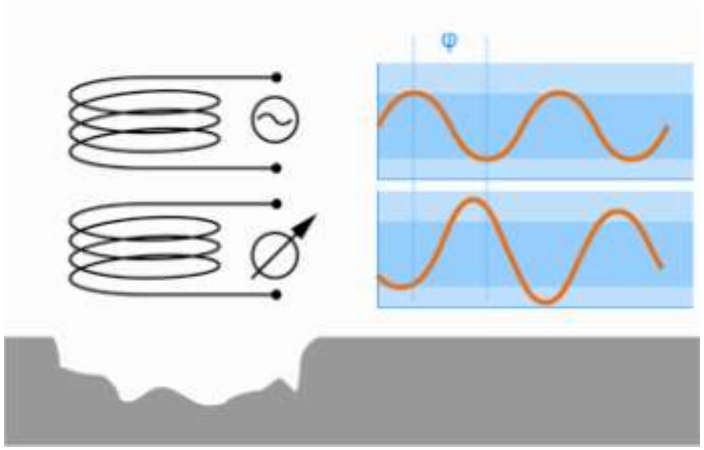
SIC Sensor



Sensor over full pipewall



Sensor over metal loss



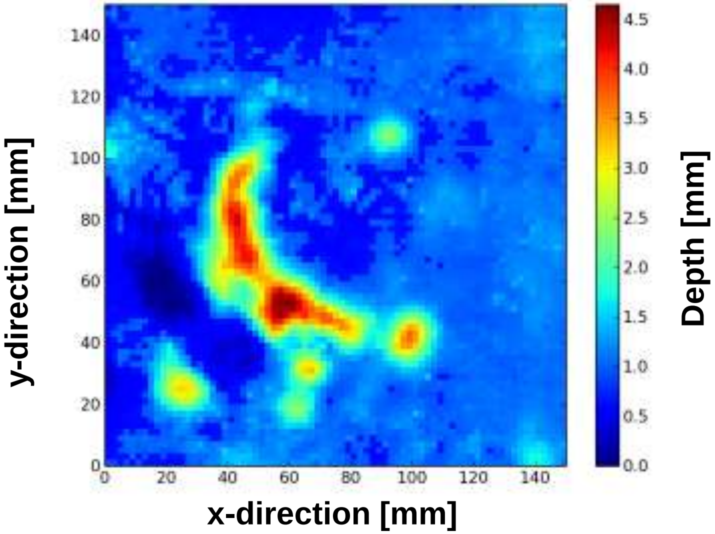
Amplitude change

Phase movement

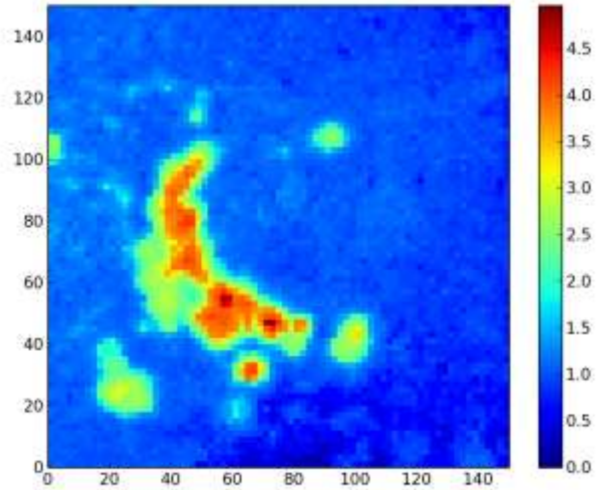
SIC Scan of TOL cut-out

Photograph

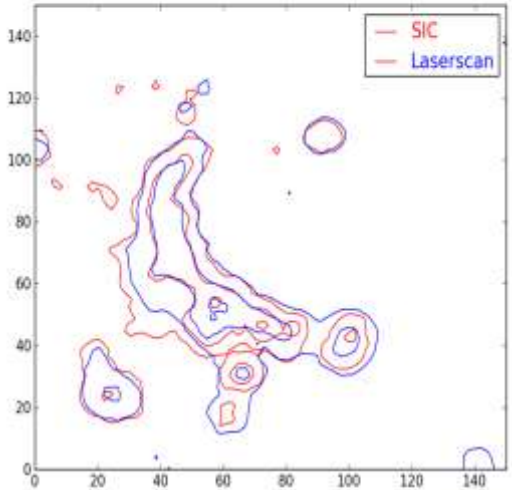
SIC Data



Laserscan



Contour plot



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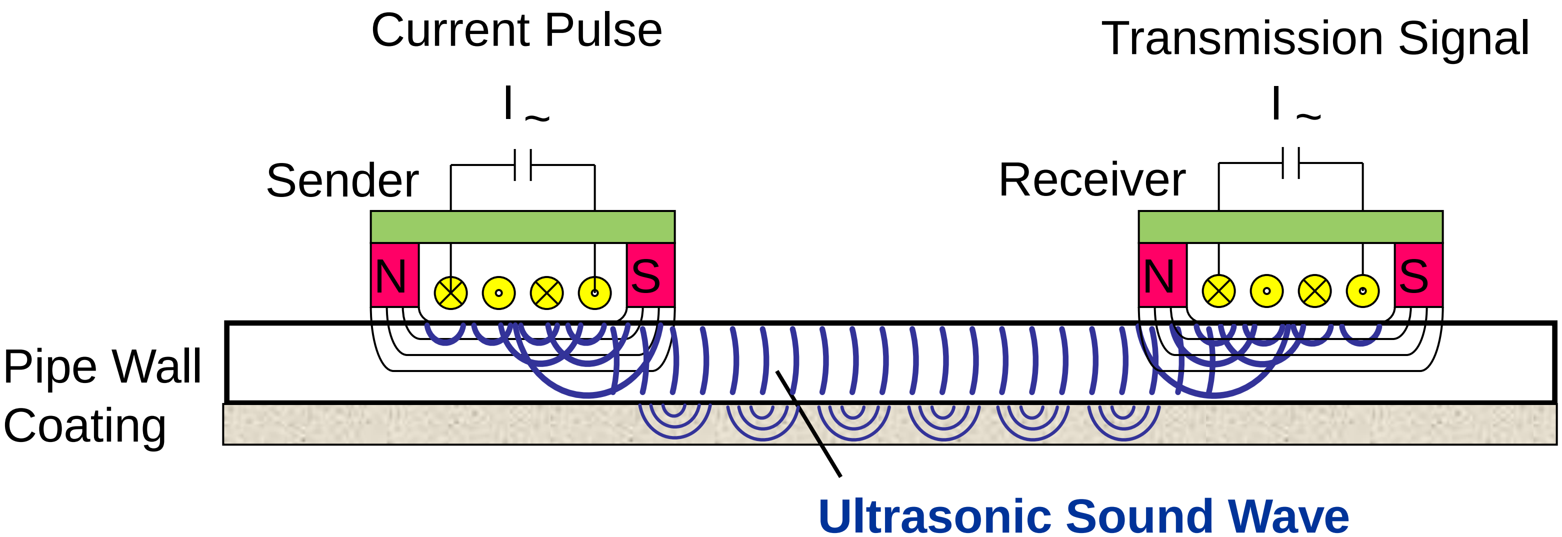
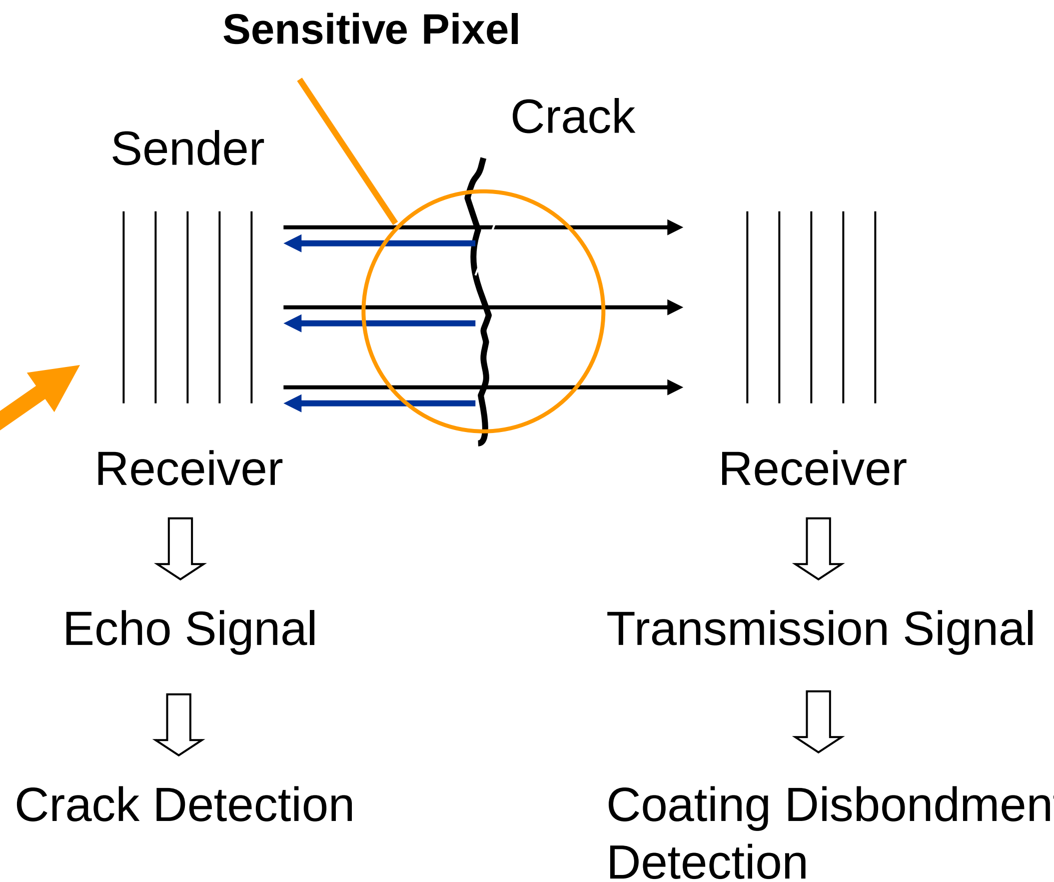
EMAT = Electro-Magnetic Acoustic Transducer



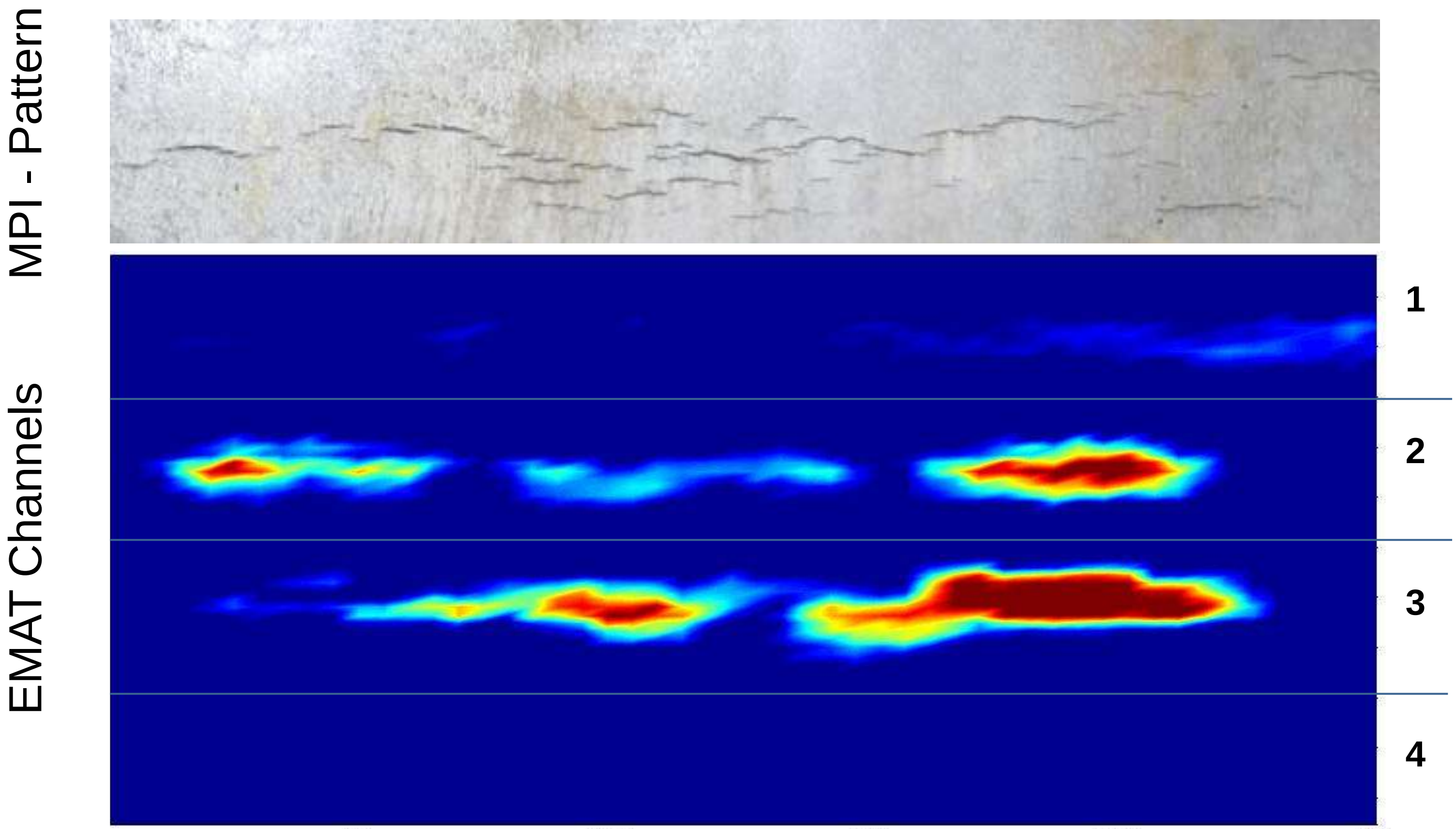
Ultrasound is generated inside the pipeline itself

No liquid coupling - **applicable in gas-pipeline**

Key Advantages of High Resolution EMAT Tool

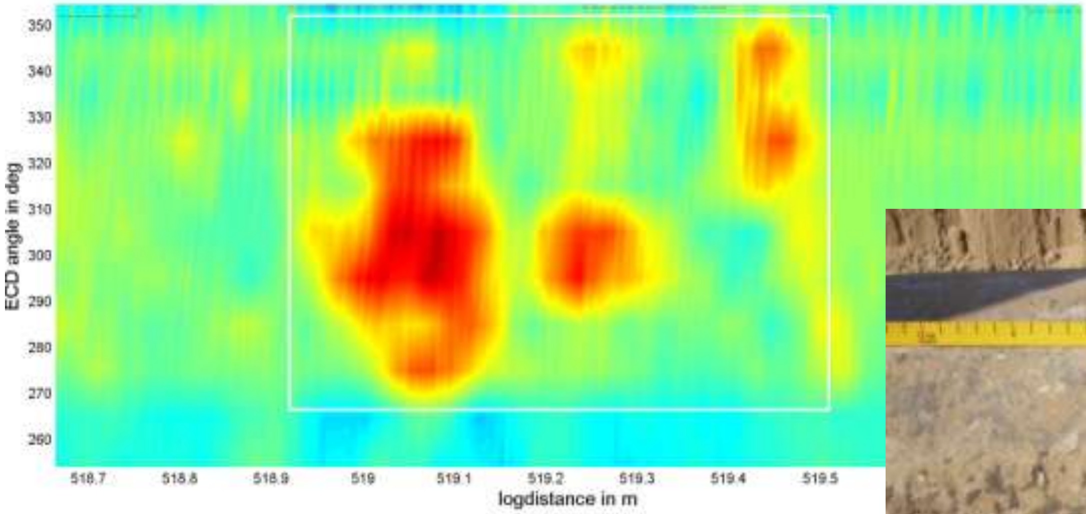


Crack Detection



Coating Feature in Gas Line: Localized coating disbondment

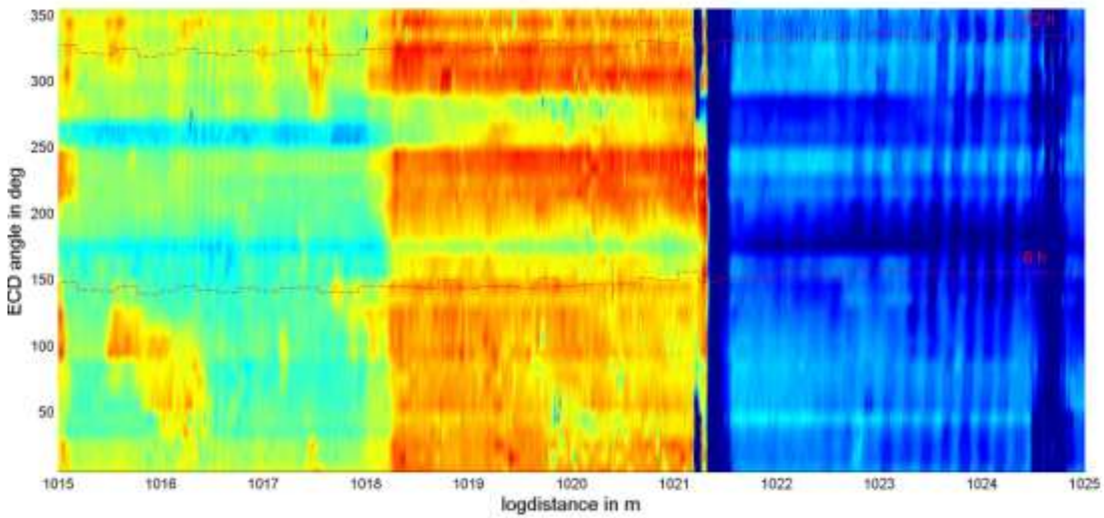
Integral of Transmission Signal



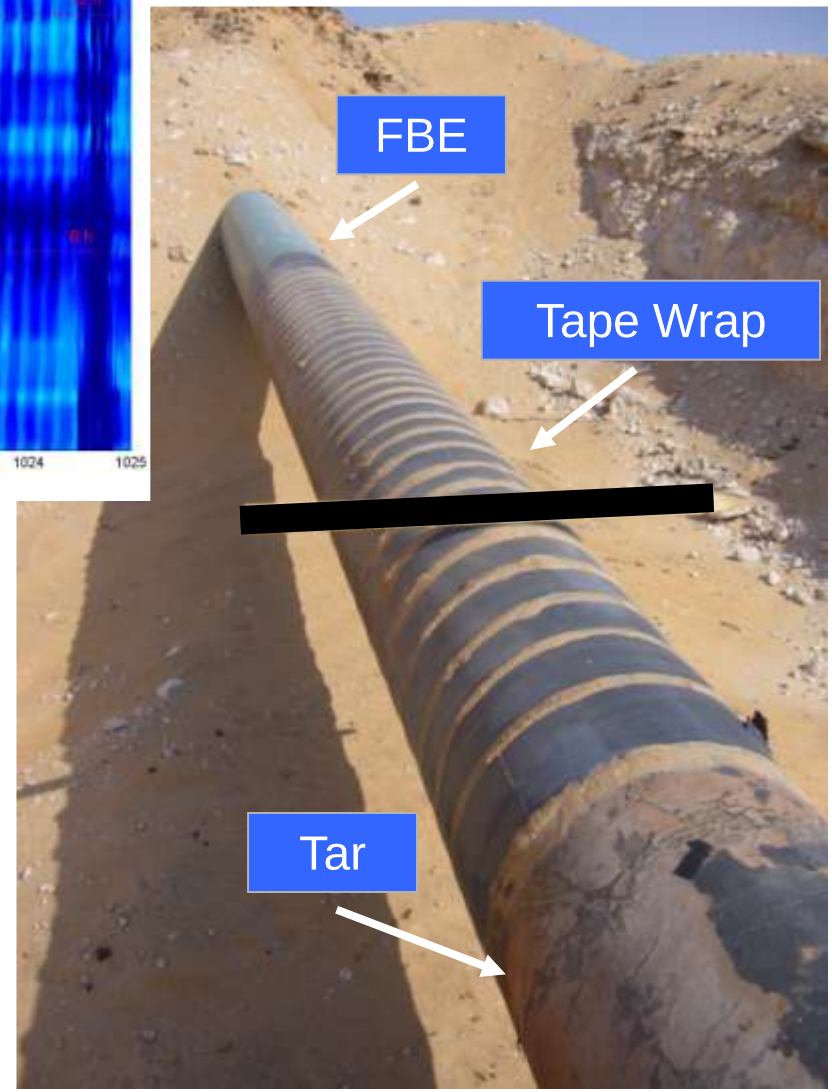
Correct identification of coating disbondment

Field Data

Correct identification of different types of coating



Integral of Transmission Signal



Sequence of coating types:

- epoxy coating
- field applied tape wrap
- factory applied tar coating

Conclusion

- Today, basically all **critical anomalies** can be identified and **characterized** by the various inspection technologies also for gas pipelines
- The **combination** of different inspection technologies allows a more throughout assessment of the pipeline integrity
- The operational requirements of an individual pipeline can be addressed to a wide extend. Nowadays former **non-piggable pipelines can be inspected**
- However, **design of vehicles** providing an acceptable environment for the measurement under real operational condition is still posing a **challenge for the future**

Thank You for joining the presentation…

ROSEN

EMPOWERED BY TECHNOLOGY