ADVANCE INSPECTION TECHNOLOGIES APPLIED TO THE GAS INDUSTRY

Mar del Plata – Octubre 2012

LEADING IN INSPECTION TECHNOLOGIES

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Rosen Europe BV

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)
- Absence of liquids require new **Ultrasonic Testing methods** to characterize crack related threats.

Content

- **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**

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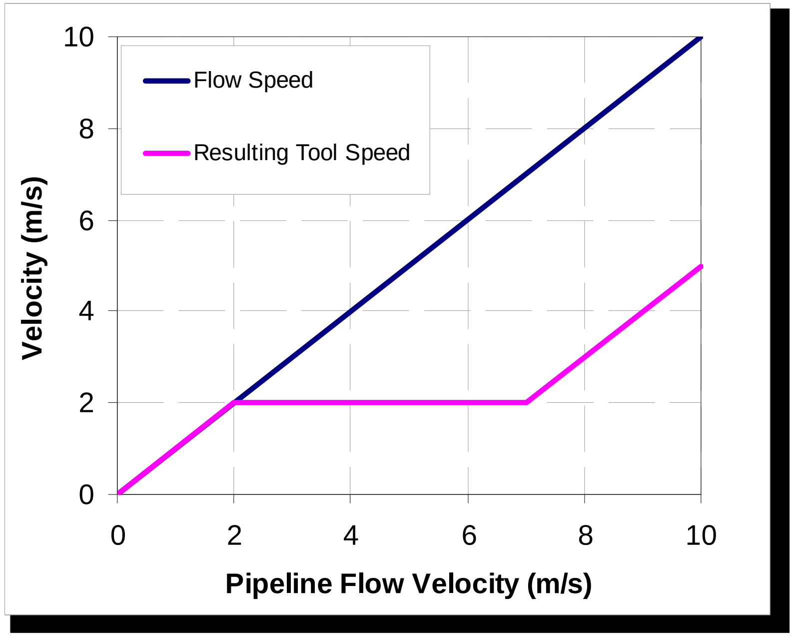
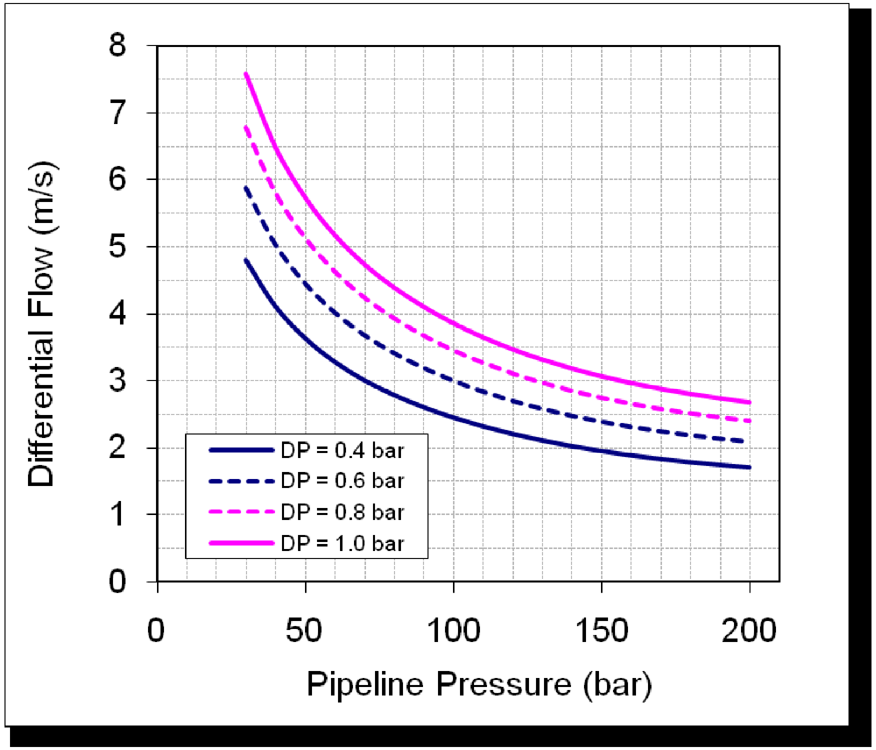
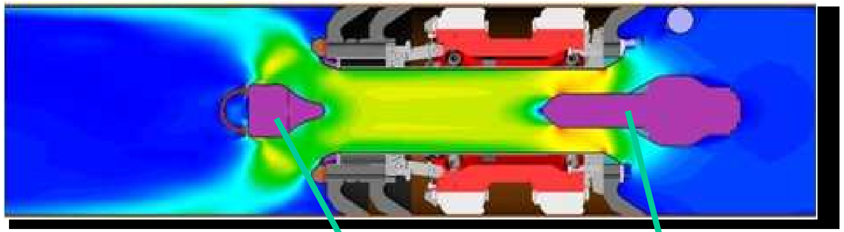
Controlling the Inspection Speed



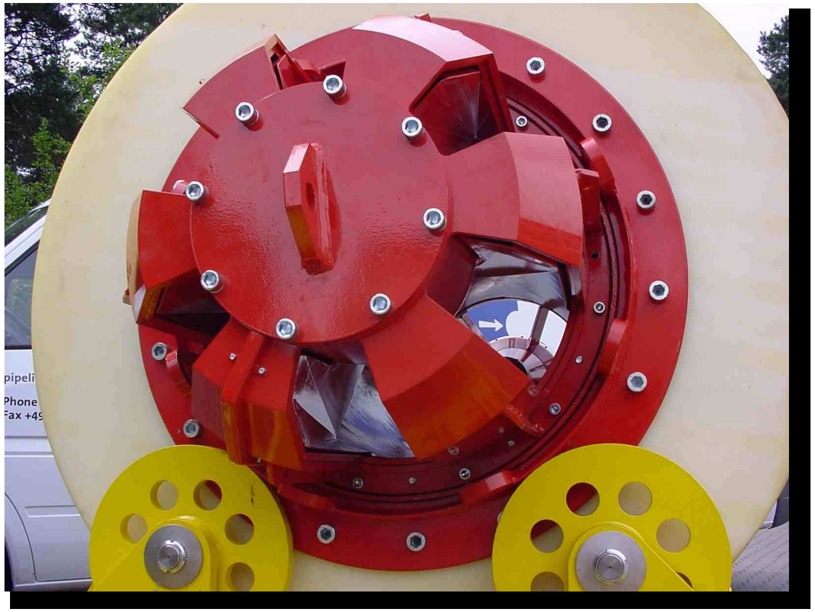
- Basic Principle of Speed Control Unit
- Pressure Dependency of Differential Flow thru valve for 26”/30” Tool in 30” Pipeline

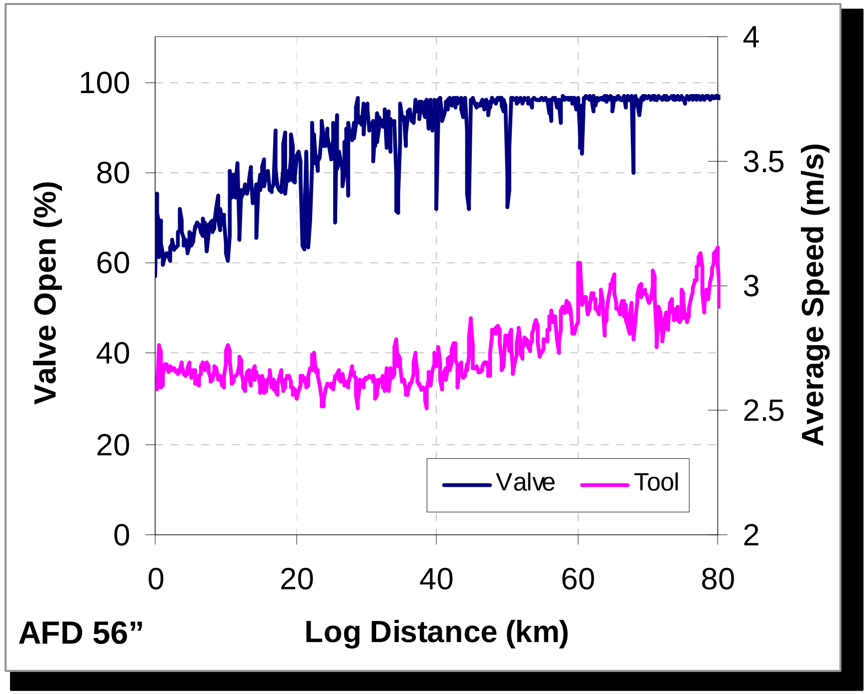


Controlling the Inspection Speed



CDP 40/42"

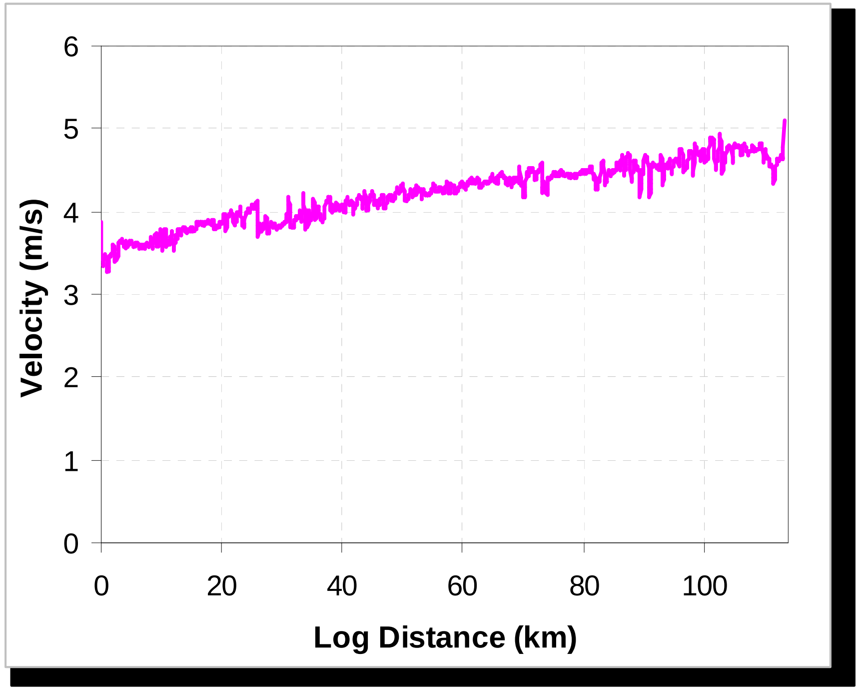




AFD 56"

	Launcher
Gas Velocity	8.4 m/s
Gas Flow	2,868,458 sm³/h
Pressure	6.53 MPa
Temperature	40ºC

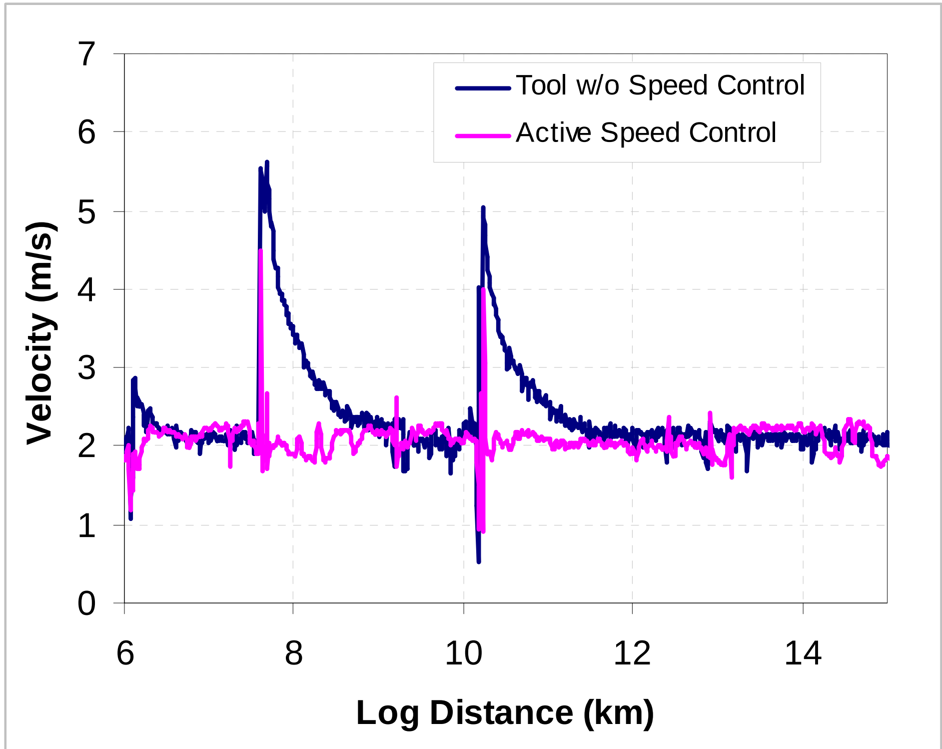
Controlling the Inspection Speed



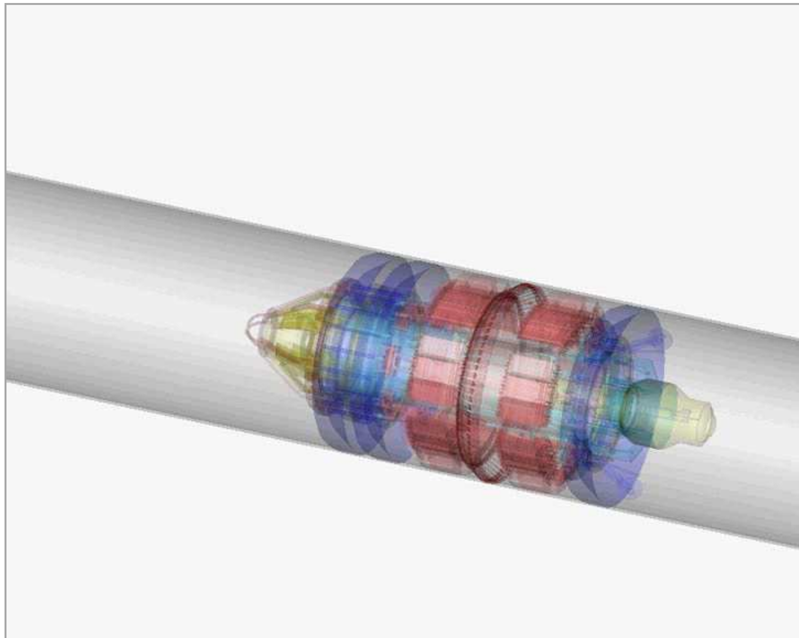
- ILI Inspection of a 56" Gas-Pipeline
- 1.5D; Mitered Bends
- High Resolution MFL
- Difference between Tool and Flow 5m/s

	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

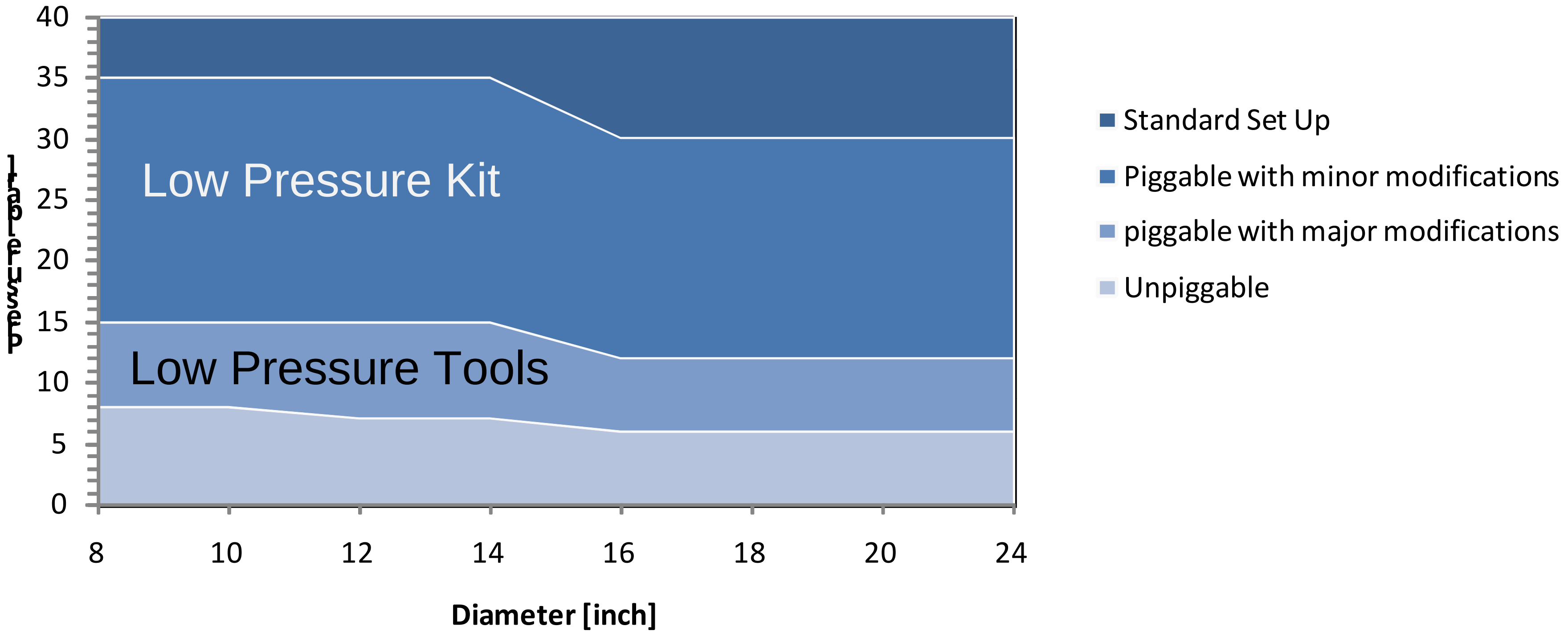
Controlling the Tool Dynamics



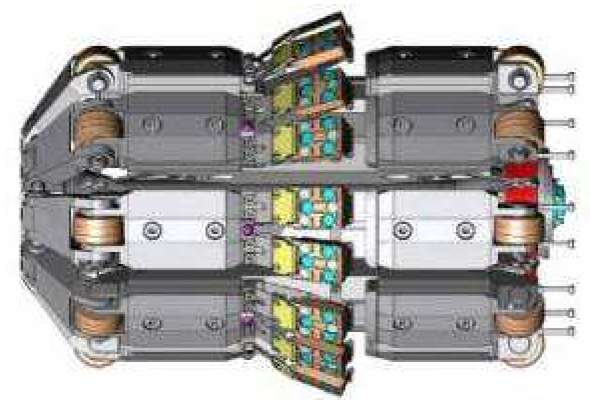
- ILI Inspection of a 26" Gas-Pipeline
- Two runs were performed
- Gas Equalization within 50m with Speed Control



Reduced Pressure and Flow Conditions



MFL Tools for Gas Pipelines



3D Concept of a 12” Low Flow / Low Pressure MFL Magnetizer

Reduce the Drag !

12” Low Flow / Low Pressure MFL Tool

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 %**

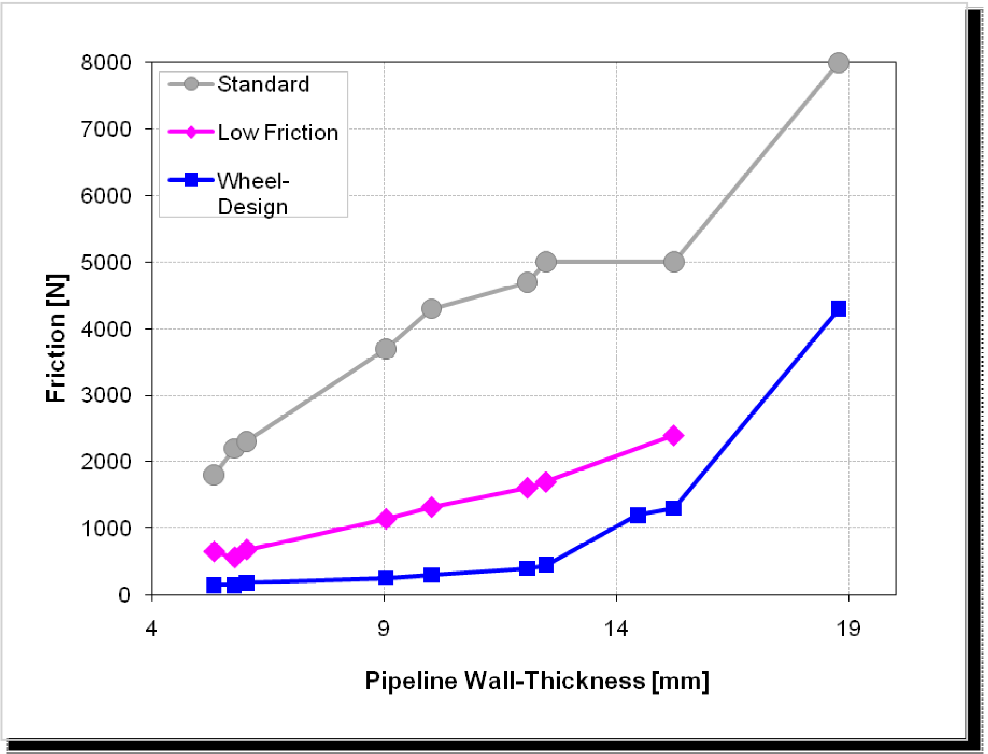
•Improved **Start/Stop**

Low Pressure Tool

•Magnet Unit on Wheels

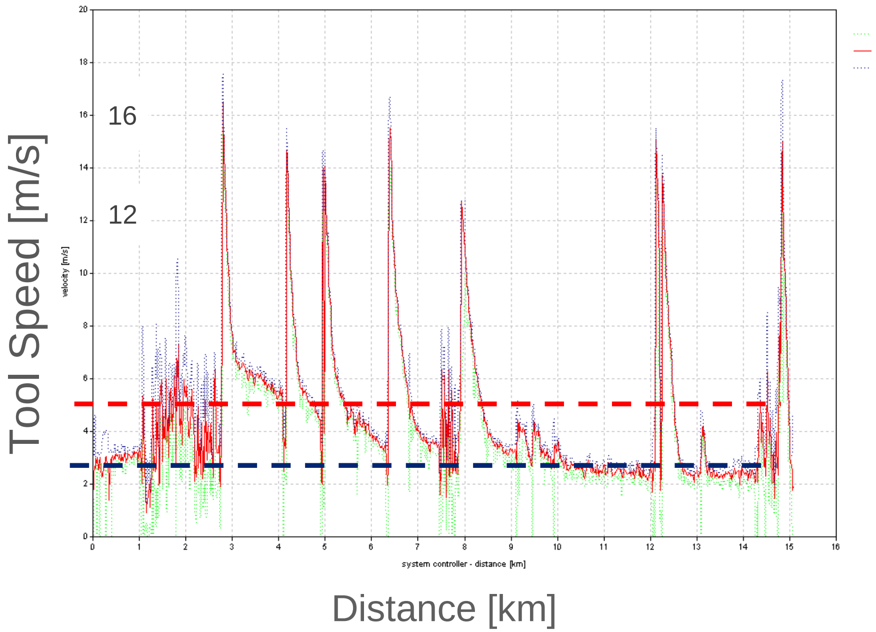
•E-Box Design

•U-Joint Design

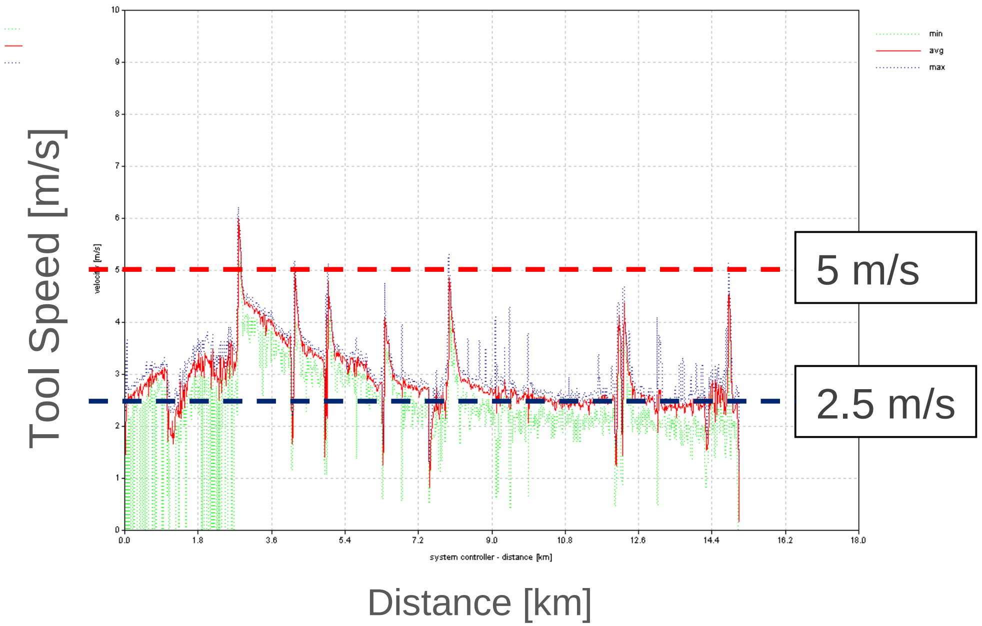


Low Pressure Example

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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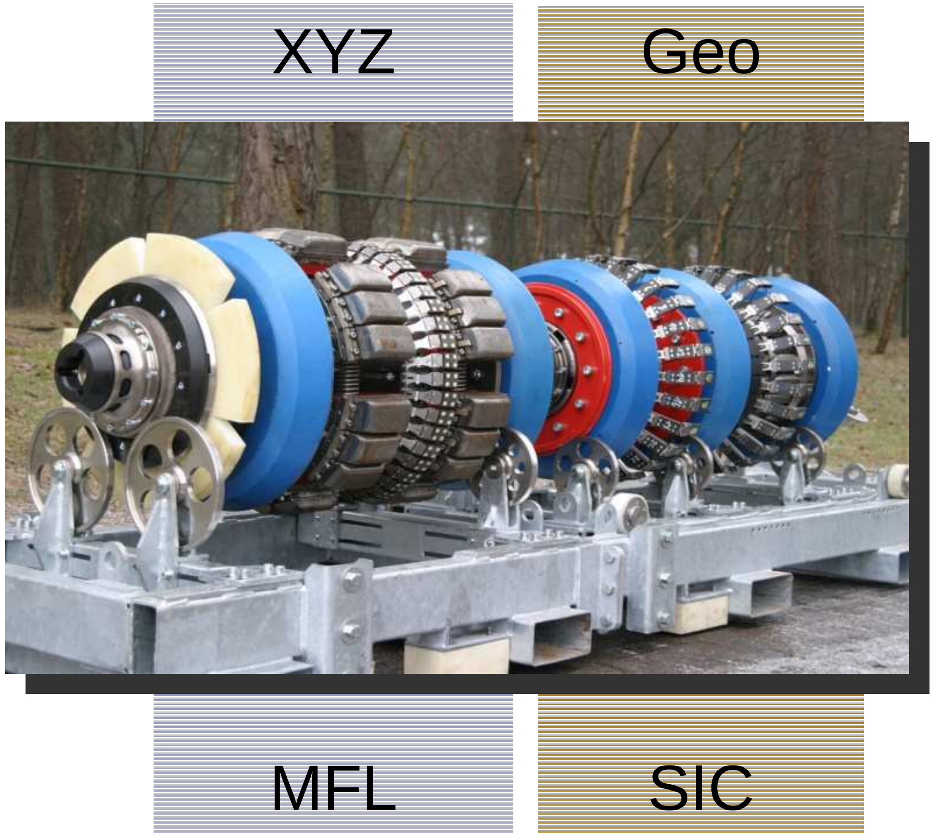
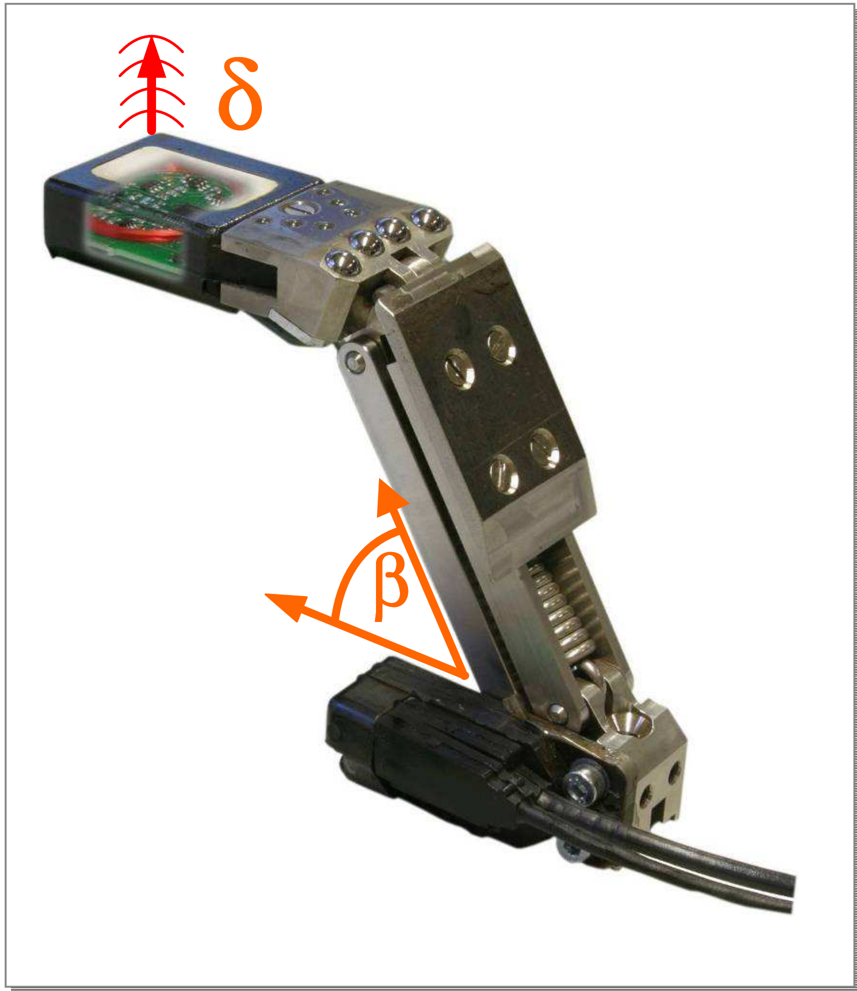
Combined ILI-Technologies

- **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



ROSEN Contour Following Proximity Sensor

(Compensated Deflection)



Radius Measurement

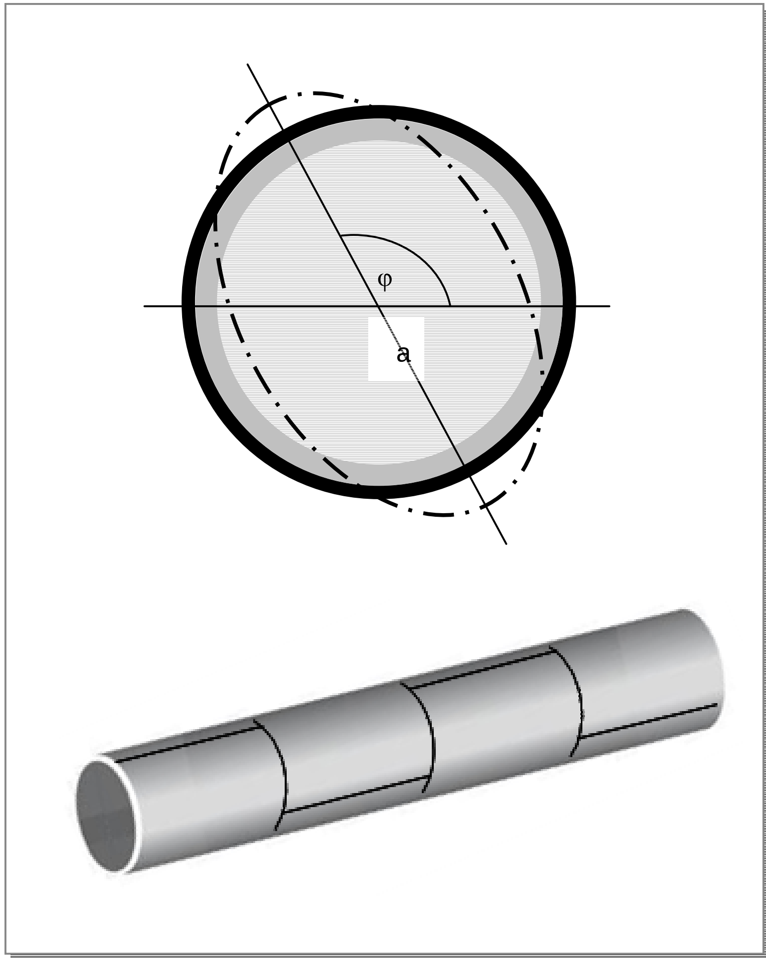
=

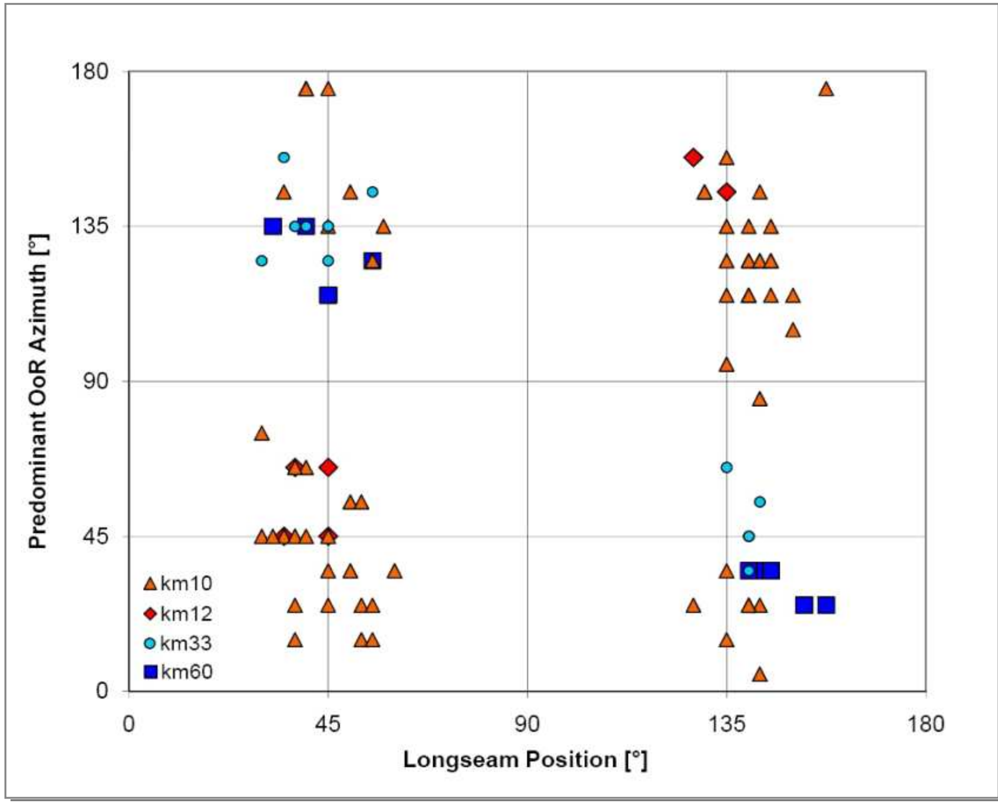
δ **Touchless Proximity Sensor**

\+

β **Electronic Angle Sensor**

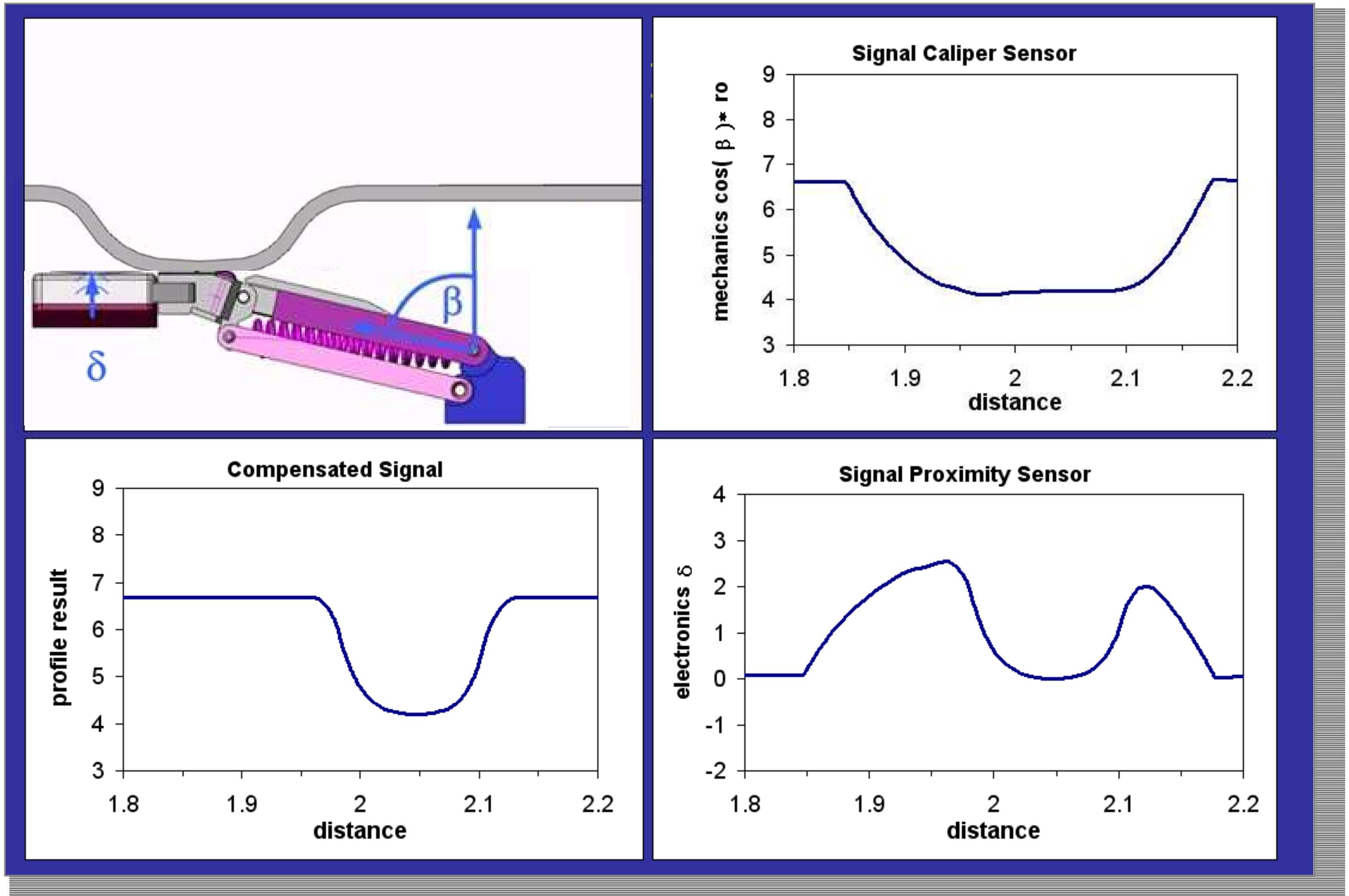
Out of Roundness Correlates with Longseam Position





OoR between 0.6mm to 1mm detected

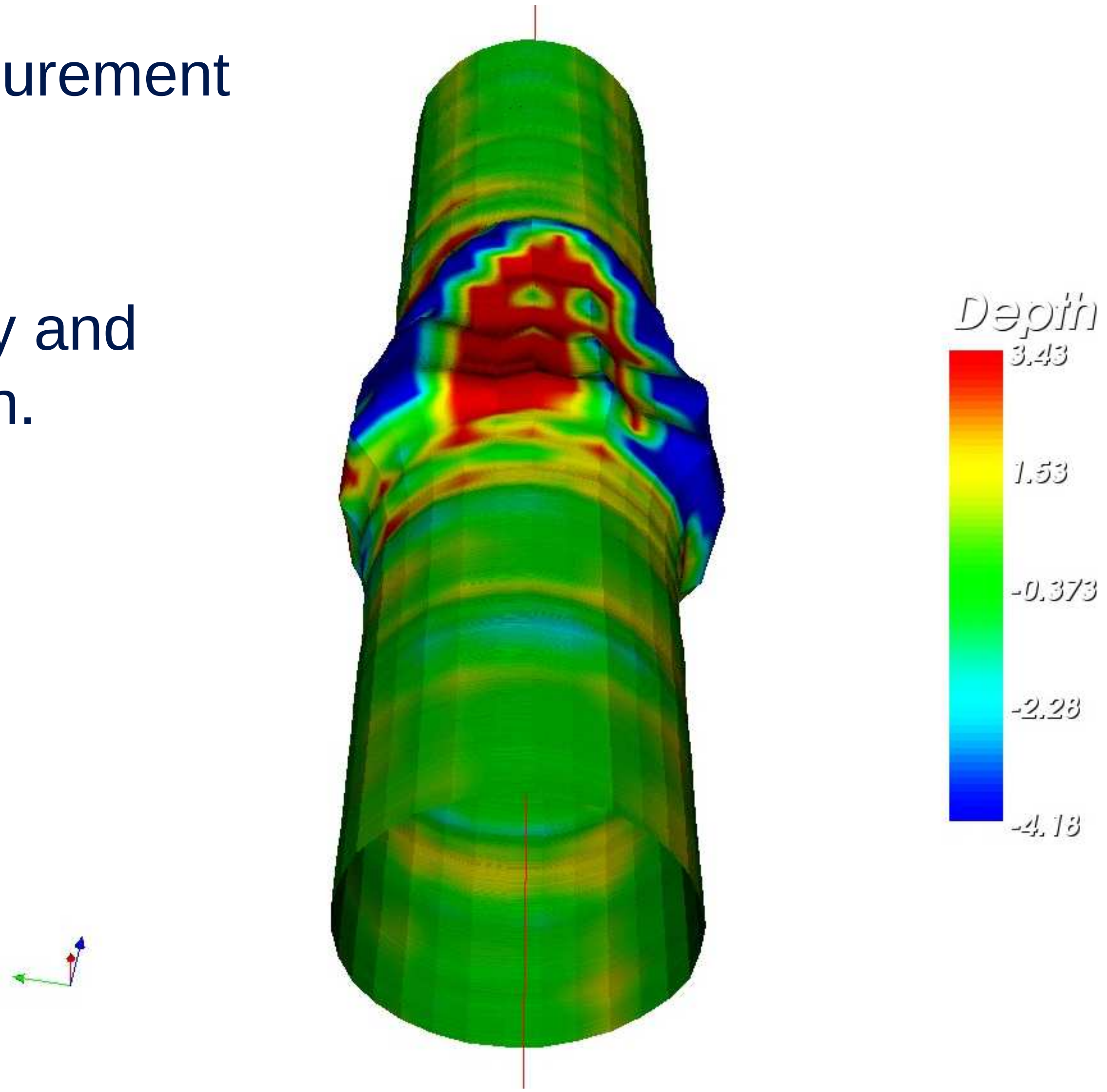
Accurate Dent Characterization - Combined Technology



Dents and Pipe Geometry

Geometry Tool measurement of check valve.

Checked immediately and approved for MFL run.



ROSEN

(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 i… 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

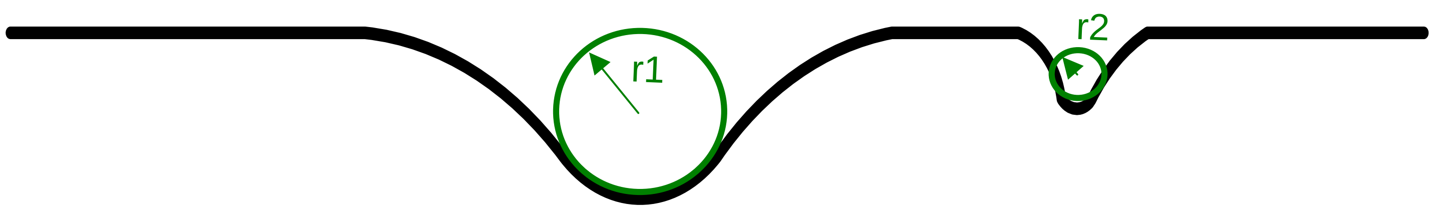
… the outside pipe surface as

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

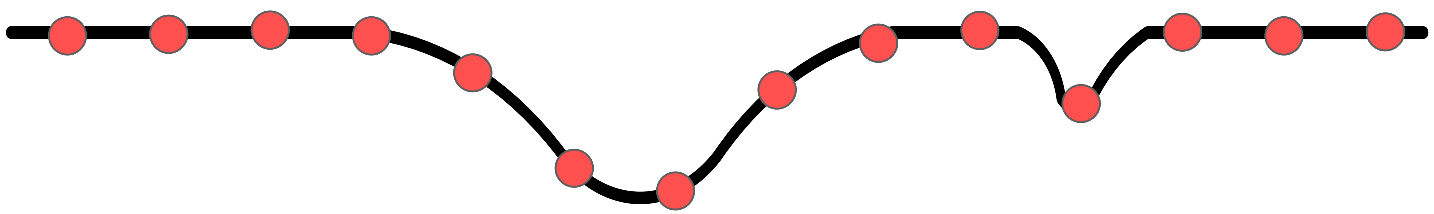
ASME Code, B31.8-2003, Appendix R, page 158

ε = Strain = displacement

r = radius = curvature

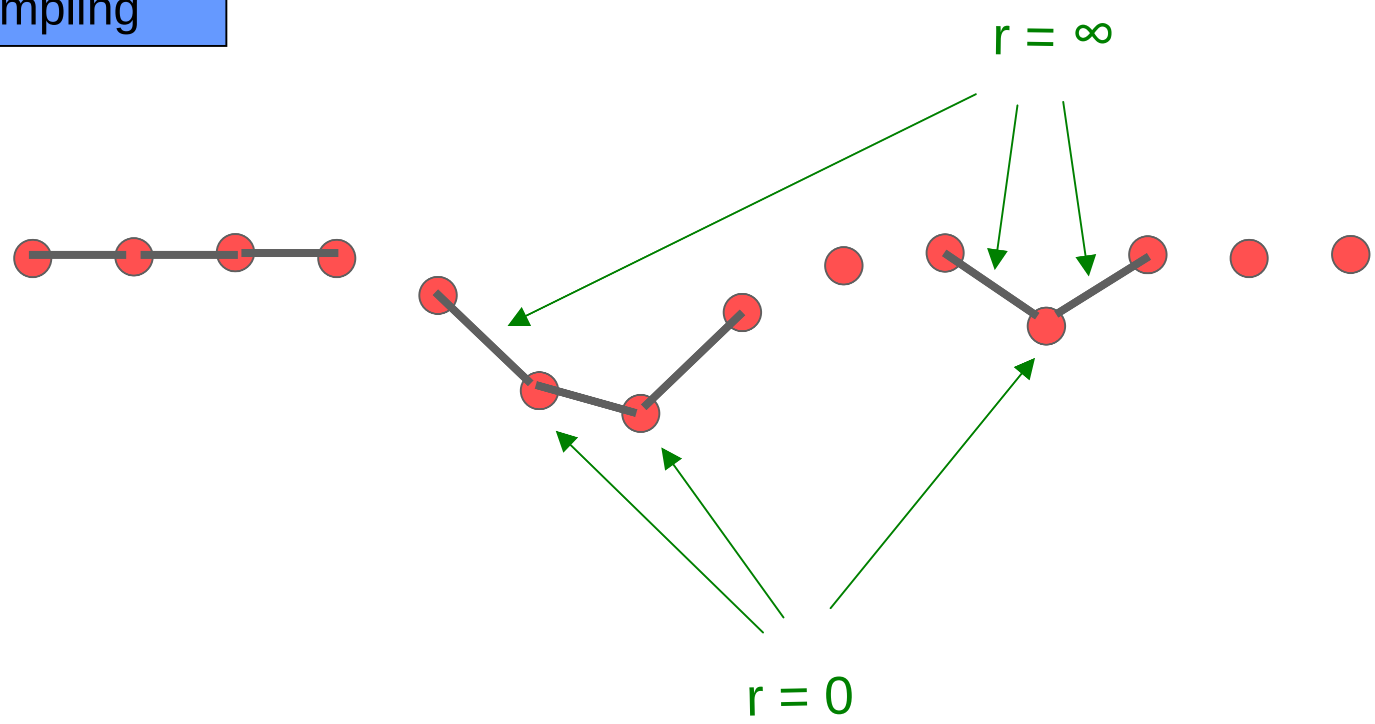


ILI Geometry Measurement and Analysis



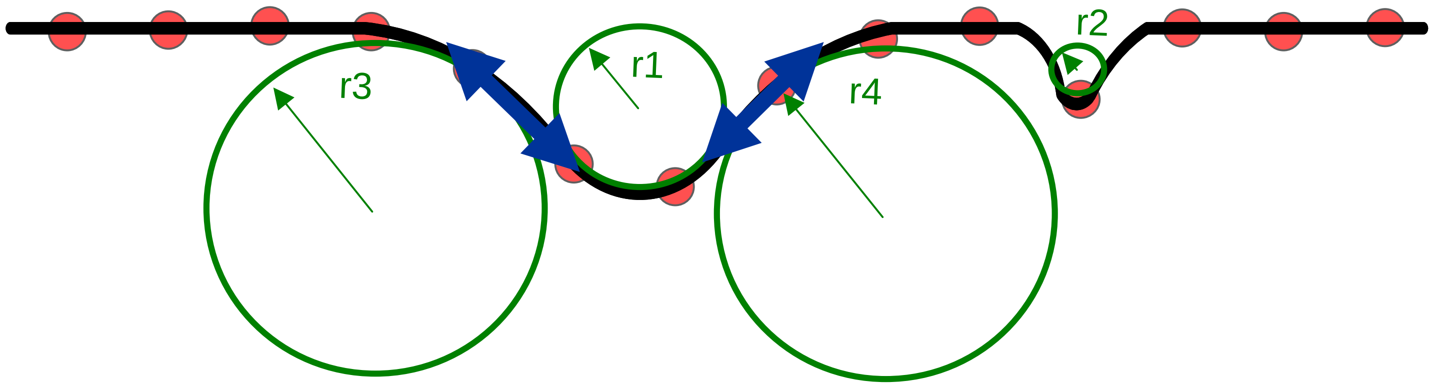
ILI Geometry Measurement and Analysis

Accurate Sampling



ILI Geometry Measurement and Analysis

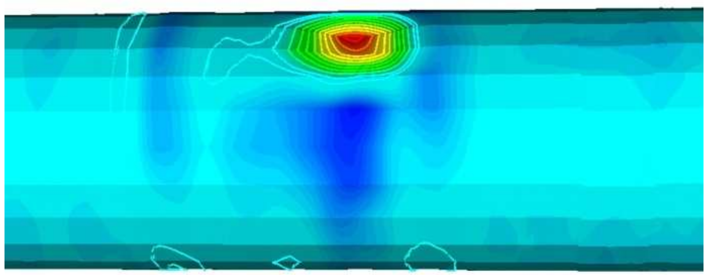
Accurate Sampling	Spline Approximation	Curvature Detemination	Membrane[1] Dent



[1] local membrane strain in dent

Results and Reporting

Strain
Data Visualization



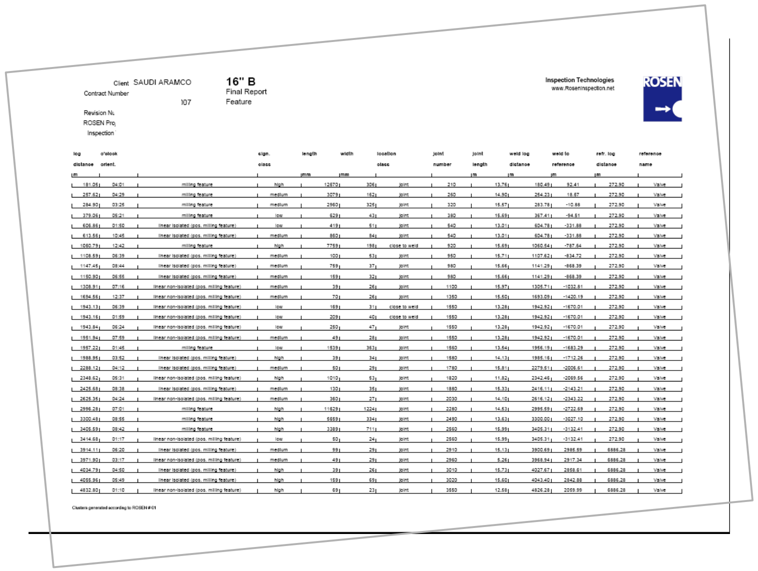
List of Significnaces

Data Arrays

- Strain
- Curvature
- Geometry

Dent Parameter

- Length
- Width
- Depth
- max Strain



Client SAUDI ARAMCO
Contract Number
07
Revision Nu
ROSEN Pro
Inspection

16" B
Final Report
Feature

Inspection Technologies
www.RosenInspection.net

ROSEN

log distance	o'clock orient.		sign. class	length	width	location class	joint number	joint length	weld log distance	weld to reference	refr. log distance	reference name
m				mm	mm			m	m	m	m	
181.05	04:01	milling feature	high	12670	306	joint	210	13.76	180.49	92.41	272.90	Valve
257.62	04:29	milling feature	medium	3079	162	joint	260	14.90	254.23	18.67	272.90	Valve
284.90	03:25	milling feature	medium	2960	325	joint	320	15.57	283.78	-10.88	272.90	Valve
379.06	05:21	milling feature	low	629	43	joint	380	15.69	367.41	-94.51	272.90	Valve
606.86	01:50	linear isolated (pos. milling feature)	low	419	51	joint	540	13.01	604.78	-331.88	272.90	Valve
613.56	10:45	linear isolated (pos. milling feature)	medium	860	84	joint	540	13.01	604.78	-331.88	272.90	Valve
1060.79	12:42	milling feature	high	7759	198	close to weld	920	15.69	1060.54	-787.64	272.90	Valve
1108.59	06:39	linear isolated (pos. milling feature)	medium	100	53	joint	950	15.71	1107.62	-834.72	272.90	Valve
1147.45	08:44	linear isolated (pos. milling feature)	medium	759	37	joint	980	15.66	1141.29	-868.39	272.90	Valve
1150.90	06:55	linear isolated (pos. milling feature)	medium	159	32	joint	980	15.66	1141.29	-868.39	272.90	Valve
1308.91	07:16	linear non-isolated (pos. milling feature)	medium	39	26	joint	1100	15.97	1305.71	-1032.81	272.90	Valve
1694.56	12:37	linear non-isolated (pos. milling feature)	medium	70	26	joint	1350	15.50	1693.09	-1420.19	272.90	Valve
1943.13	06:39	linear non-isolated (pos. milling feature)	low	169	31	close to weld	1550	13.28	1942.92	-1670.01	272.90	Valve
1943.16	01:59	linear non-isolated (pos. milling feature)	low	209	40	close to weld	1550	13.28	1942.92	-1670.01	272.90	Valve
1943.84	06:24	linear non-isolated (pos. milling feature)	low	250	47	joint	1550	13.28	1942.92	-1670.01	272.90	Valve
1951.94	07:59	linear non-isolated (pos. milling feature)	medium	49	28	joint	1550	13.28	1942.92	-1670.01	272.90	Valve
1957.22	01:45	milling feature	low	1539	363	joint	1560	13.54	1956.19	-1683.29	272.90	Valve
1988.95	03:52	linear isolated (pos. milling feature)	high	39	34	joint	1580	14.13	1985.16	-1712.26	272.90	Valve
2288.12	04:12	linear isolated (pos. milling feature)	medium	50	29	joint	1780	15.81	2279.51	-2006.61	272.90	Valve
2348.62	05:31	linear non-isolated (pos. milling feature)	high	1010	53	joint	1820	11.82	2342.46	-2069.56	272.90	Valve
2425.68	08:38	linear isolated (pos. milling feature)	medium	130	35	joint	1880	15.33	2416.11	-2143.21	272.90	Valve
2625.35	04:24	linear non-isolated (pos. milling feature)	medium	360	27	joint	2030	14.10	2616.12	-2343.22	272.90	Valve
2996.28	07:01	milling feature	high	11629	1224	joint	2280	14.53	2995.59	-2722.69	272.90	Valve
3300.48	08:55	milling feature	high	5659	334	joint	2490	13.63	3300.00	-3027.10	272.90	Valve
3405.59	08:42	milling feature	high	3389	711	joint	2560	15.99	3405.31	-3132.41	272.90	Valve
3414.68	01:17	linear non-isolated (pos. milling feature)	low	50	24	joint	2560	15.99	3405.31	-3132.41	272.90	Valve
3914.11	06:20	linear isolated (pos. milling feature)	medium	99	29	joint	2910	15.13	3900.69	2985.59	6886.28	Valve
3971.90	03:17	linear non-isolated (pos. milling feature)	medium	49	29	joint	2960	5.26	3968.94	2917.34	6886.28	Valve
4034.79	04:50	linear isolated (pos. milling feature)	high	39	26	joint	3010	15.73	4027.67	2858.61	6886.28	Valve
4055.96	05:49	linear isolated (pos. milling feature)	high	159	69	joint	3020	15.60	4043.40	2842.88	6886.28	Valve
4832.80	01:10	linear non-isolated (pos. milling feature)	high	69	23	joint	3550	12.58	4826.28	2059.99	6886.28	Valve

Clusters generated according to ROSEN # 01

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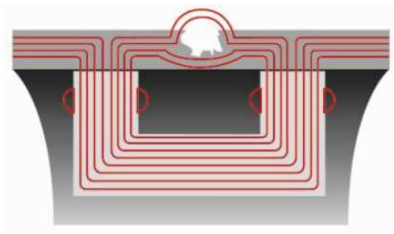
Corrosion Mapping

XYZ

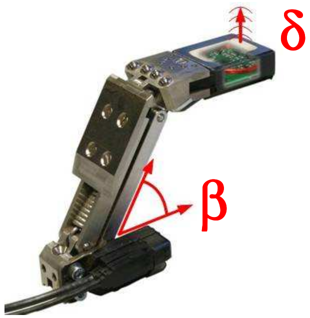
Geo

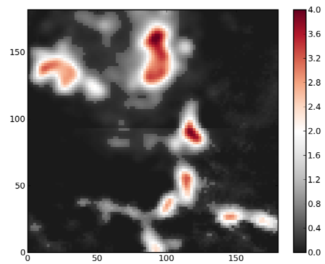
MFL

SIC



Corrosion Mapping with MFL



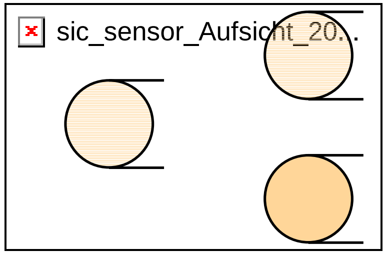


Corrosion Mapping with
Shallow Internal Corrosion Sensor

Measurement Principle

SIC Sensor

SIC Sensor (schematic)



sic_sensor_Seitenriss_2...

Sensor over full pipewall

sic_coil_1_200807.jpg

Pipe wall

Sensor over metal loss

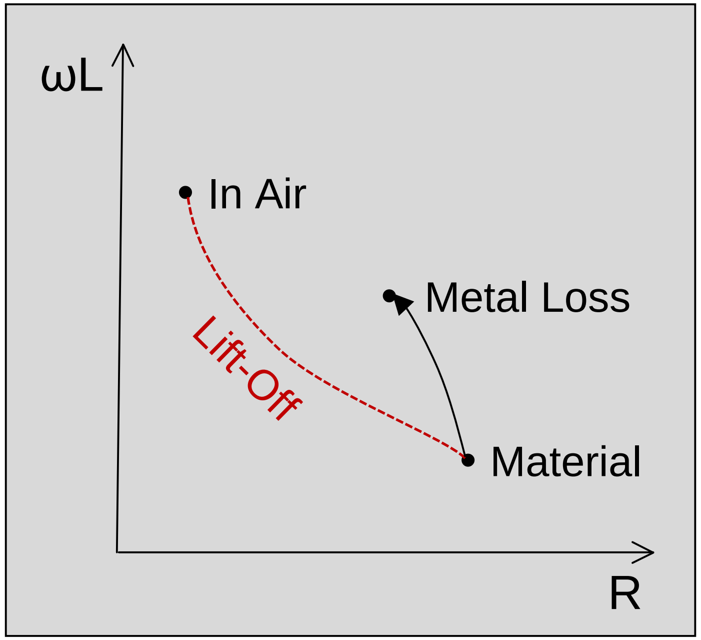
sic_coil_2_200807.jpg

Amplitude change

Phase movement

Measurement Principle

SIC Sensor



Sensor over full pipewall

sic_coil_1_200807.jpg

Pipe wall

Sensor over metal loss

sic_coil_2_200807.jpg

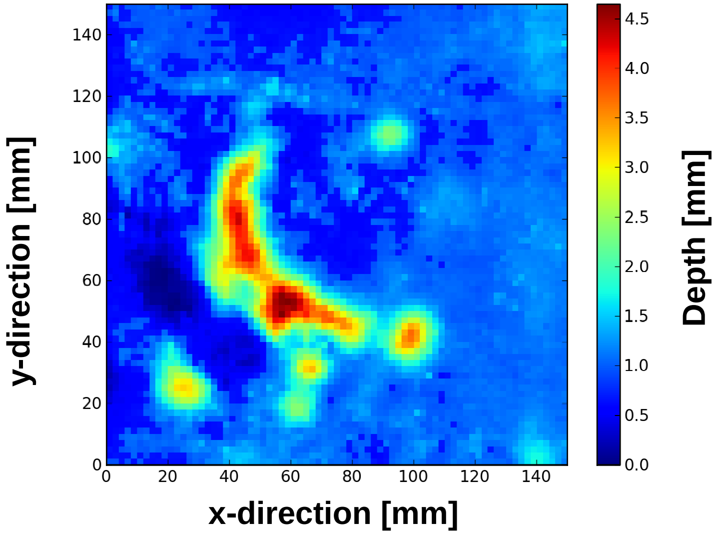
Amplitude change

Phase movement

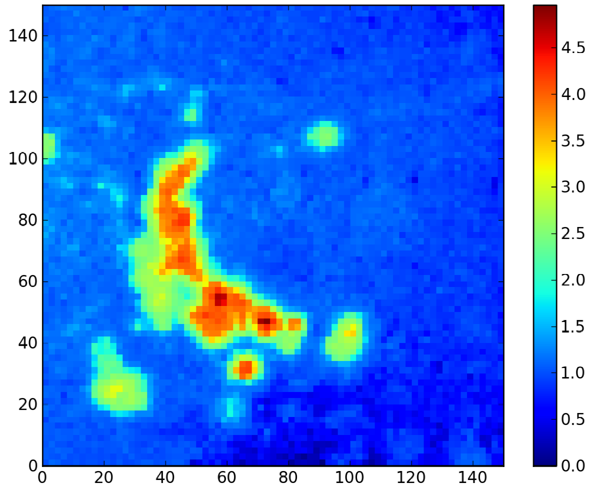
SIC Scan of TOL cut-out

Photograph

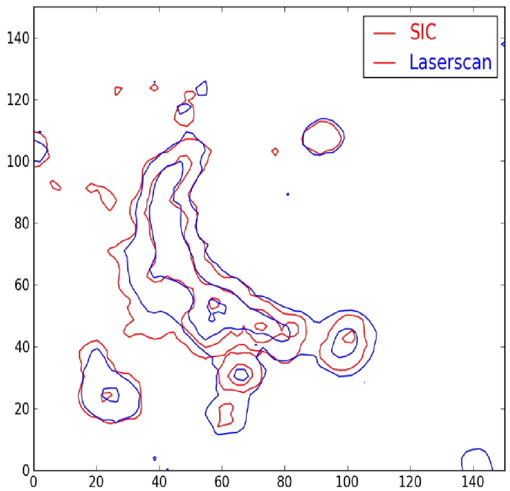
SIC Data



Laserscan



Contour plot



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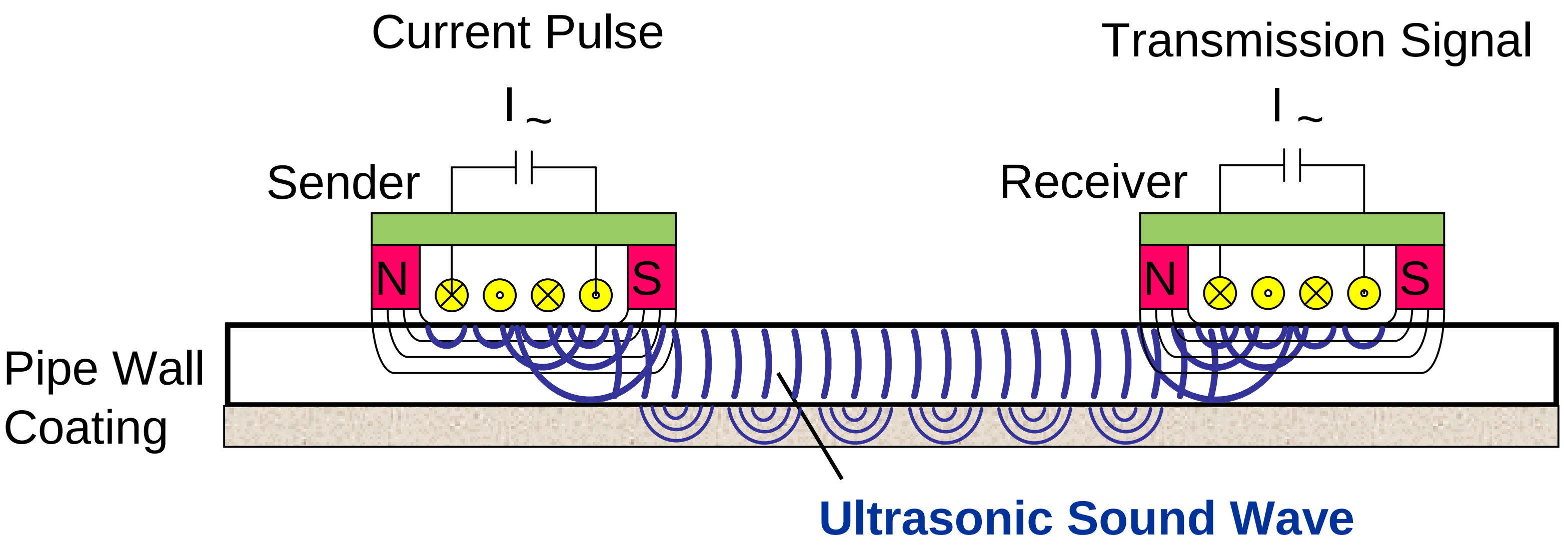
Measurement Principle

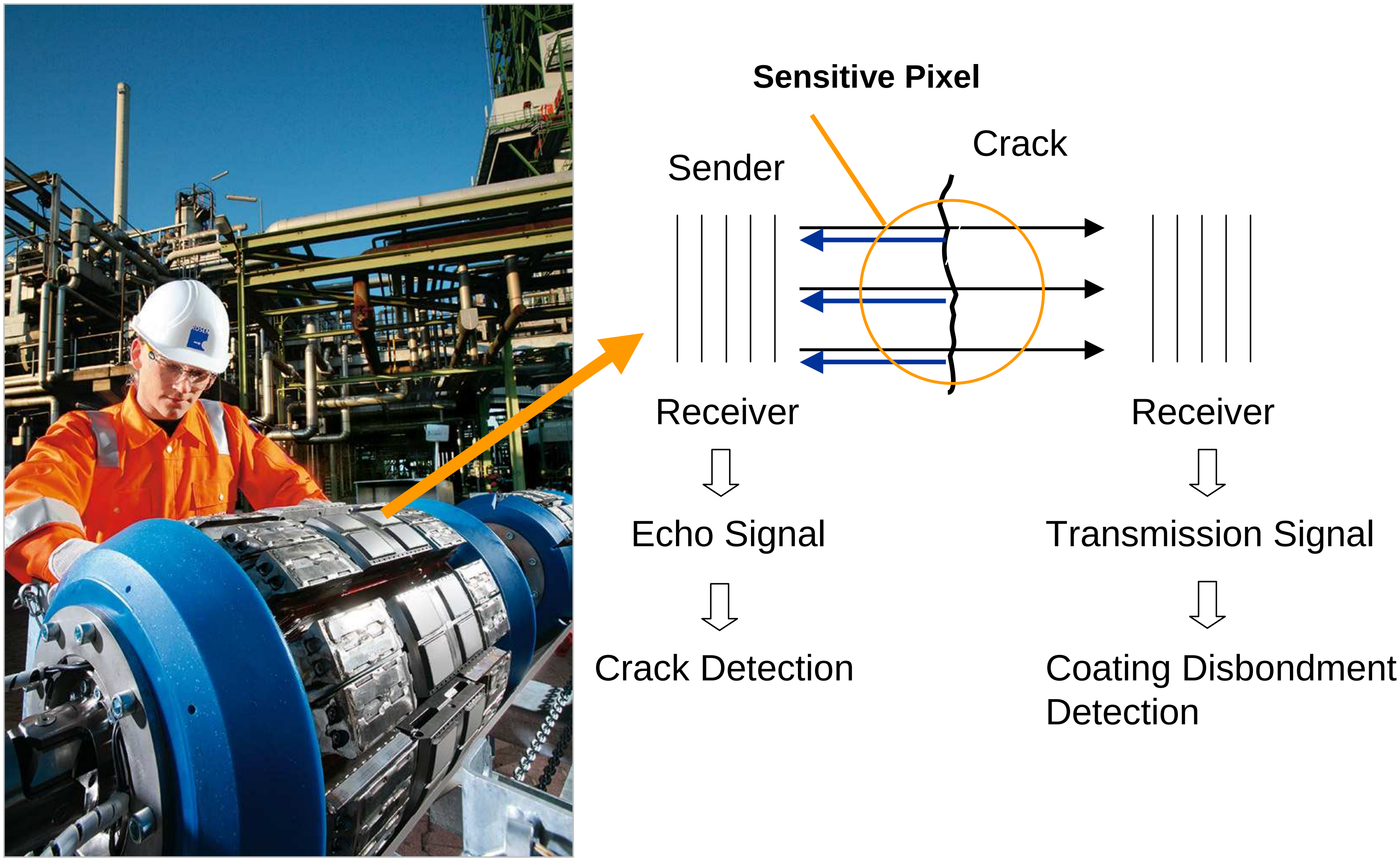
EMAT = Electro-Magnetic Acoustic Transducer



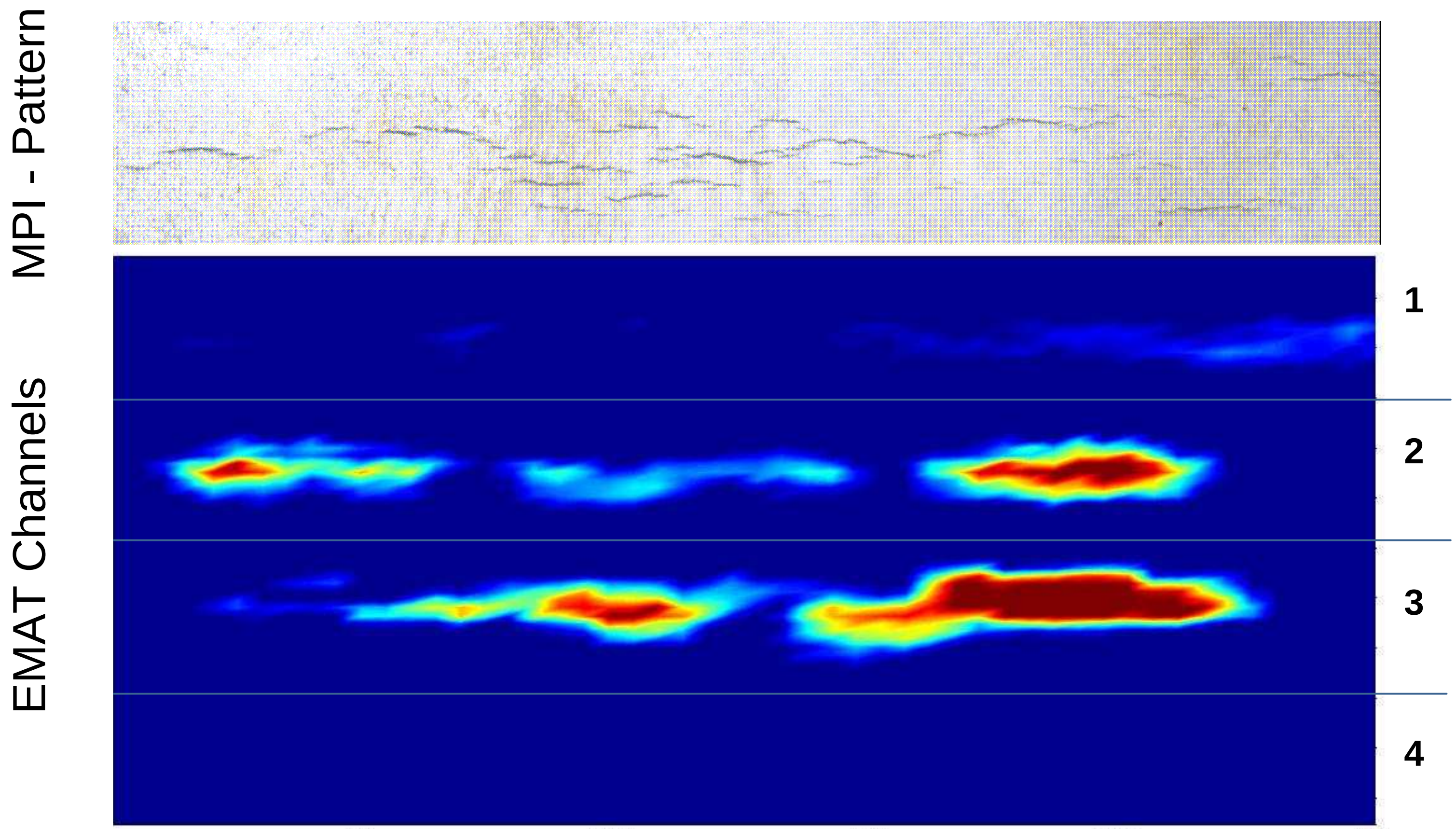
Ultrasound is generated inside the pipeline itself

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

Key Advantages of High Resolution EMAT Tool

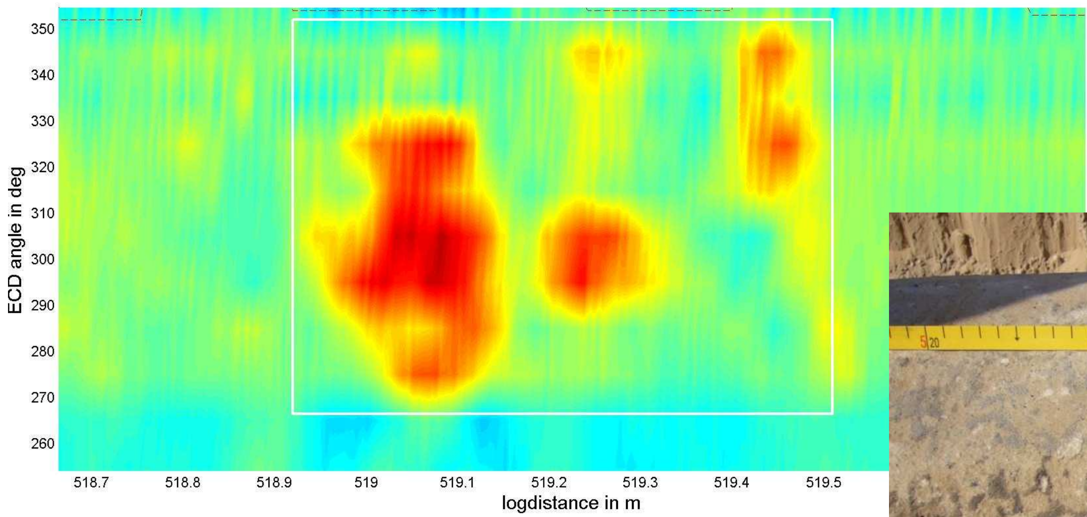


Crack Detection



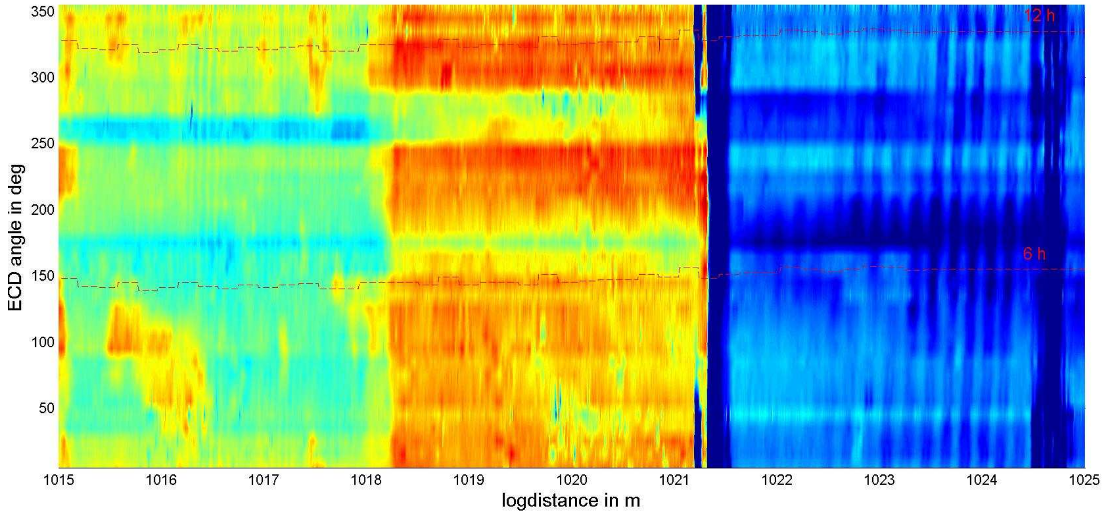
Coating Feature in Gas Line:
Localized coating disbondment

Integral of Transmission Signal



Correct identification of coating disbondment

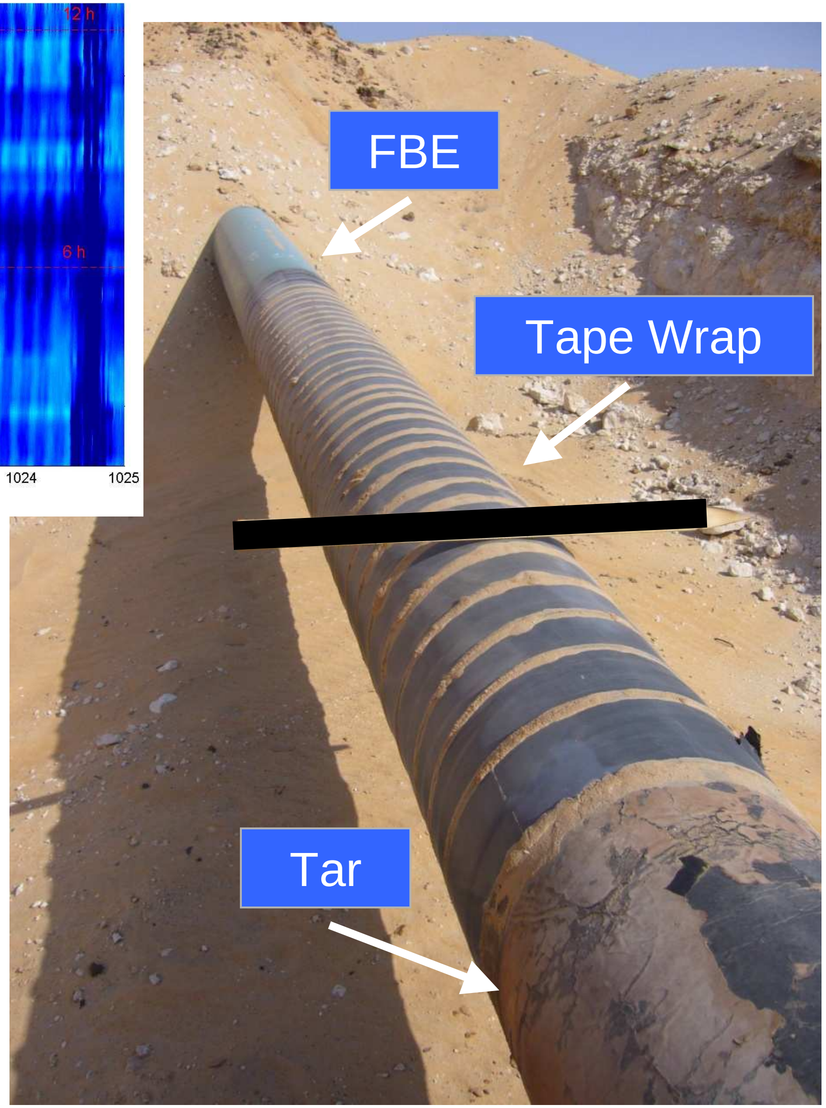
Correct identification of different types of coating



Integral of Transmission Signal

Sequence of coating types:

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



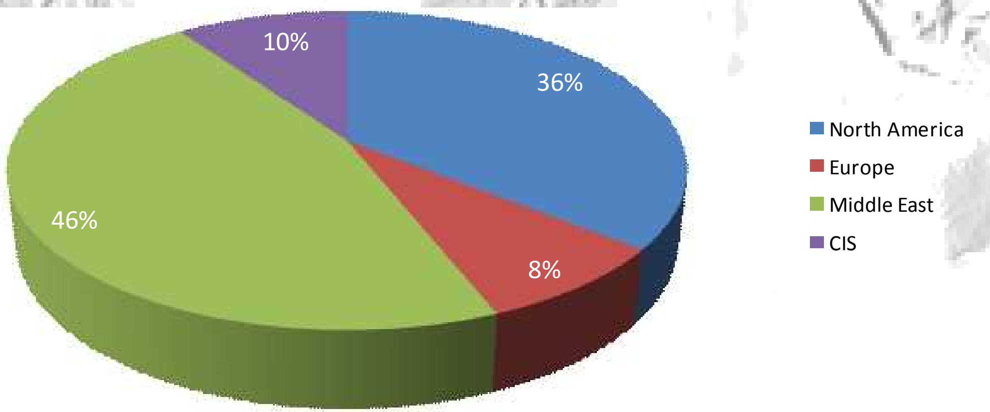
EMAT – Track Record (1)

Europe	
Number of P/l	8
Inspected P/l length [km]	663

CIS	
Number of P/l	9
Inspected P/l length [km]	791

North America	
Number of P/l	24
Inspected P/l length [km]	2892

Middle East	
Number of P/l	74
Inspected P/l length [km]	3,741



Status: 01-June-11

Total (RoCD²) inspected P/l length = 8,086 km

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…

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