

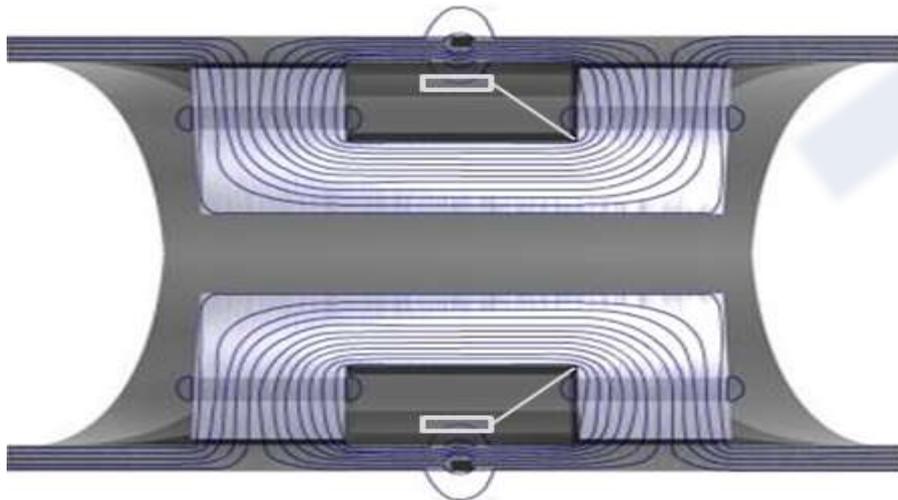
# Hard Spot and Mechanical Damage Characterization Using the Dual Magnetization Technology

UKOPA 2012 Technical Seminar  
Thomas Beuker  
29-May-2012

- Basic Principle
- Tool Design
- Hard Spot Characterization
- Mechanical Damage Characterization
- Combined Inspection Technologies
- Conclusion

## Basic Principle

Axial Magnetic Flux Leakage magnetic circuit consist of permanent magnets, backing iron and the pipeline wall



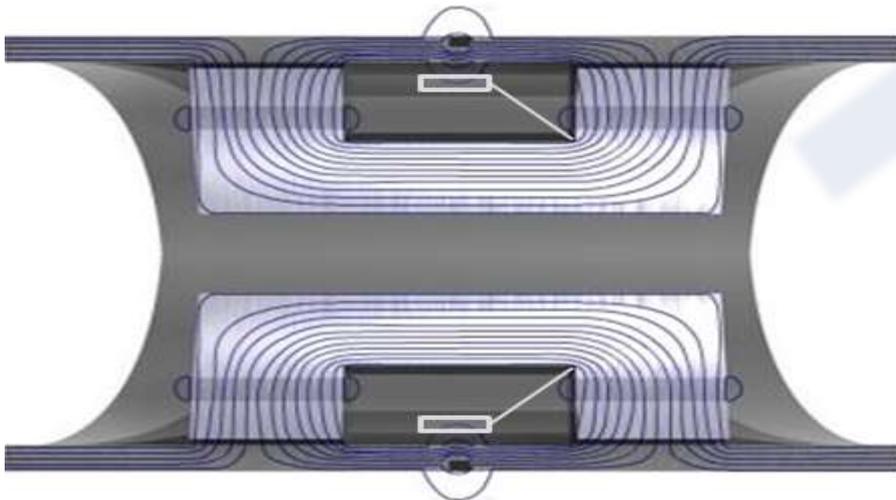
12" RoCorr-MFL

pipeline anomalies like corrosion or metal loss generate a disturbance of the magnetic flux in the pipe wall

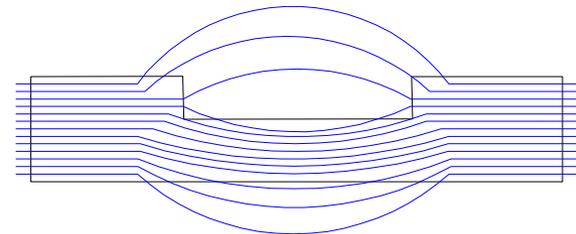
# Magnetic Flux Leakage (MFL) Tools

## Basic Principle

Axial Magnetic Flux Leakage magnetic circuit consist of permanent magnets, backing iron and the pipeline wall



12" RoCorr-MFL



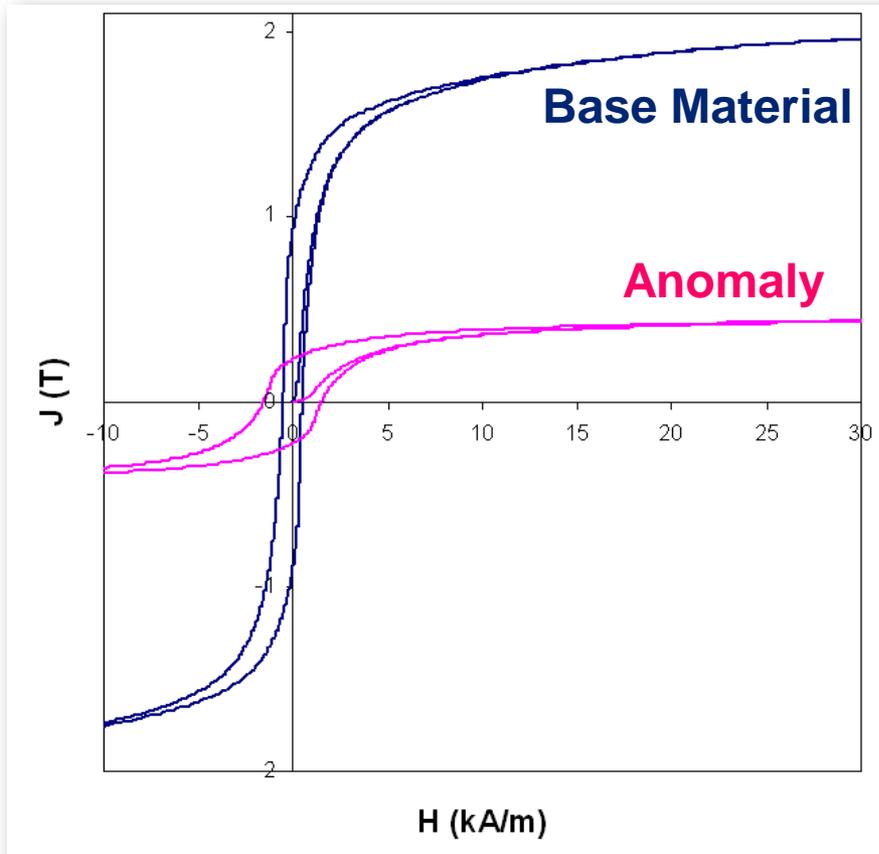
metal loss is a geometric change of the pipewall dimensions !



Microstructural Changes in the pipe material is generating different magnetic responses

Applies for various anomalies  
**hard spots, plastic deformation, cold working, overheating, arc burns ...**

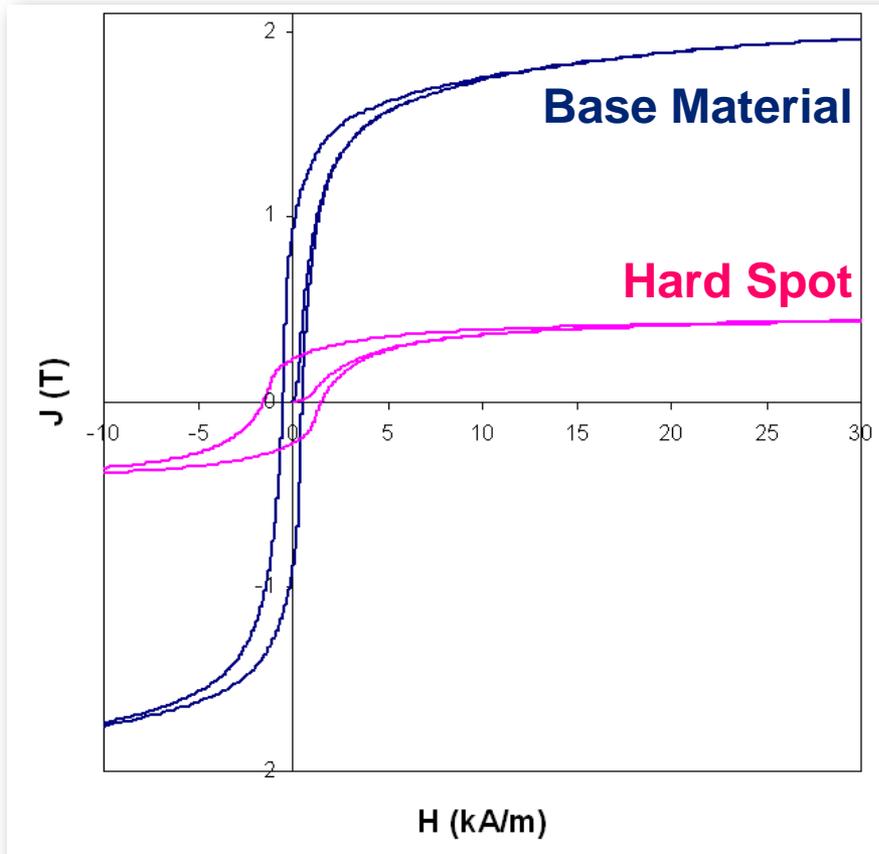
Such anomalies are not changing the geometry of the pipewall



Microstructural Changes in the pipe material is generating different magnetic responses

Applies for various anomalies  
hard spots, plastic deformation, cold working, overheating, arc burns ...

## Detection of Hard Spots by using Different Magnetic Responses



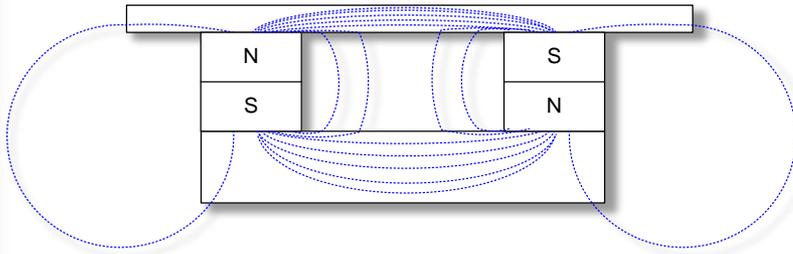
Differences in

- Saturation  $J_s$ ,
- Coercive Force  $H_c$ ,
- Remanent Magnetization  $J_r$   
**(but cannot be used !)**

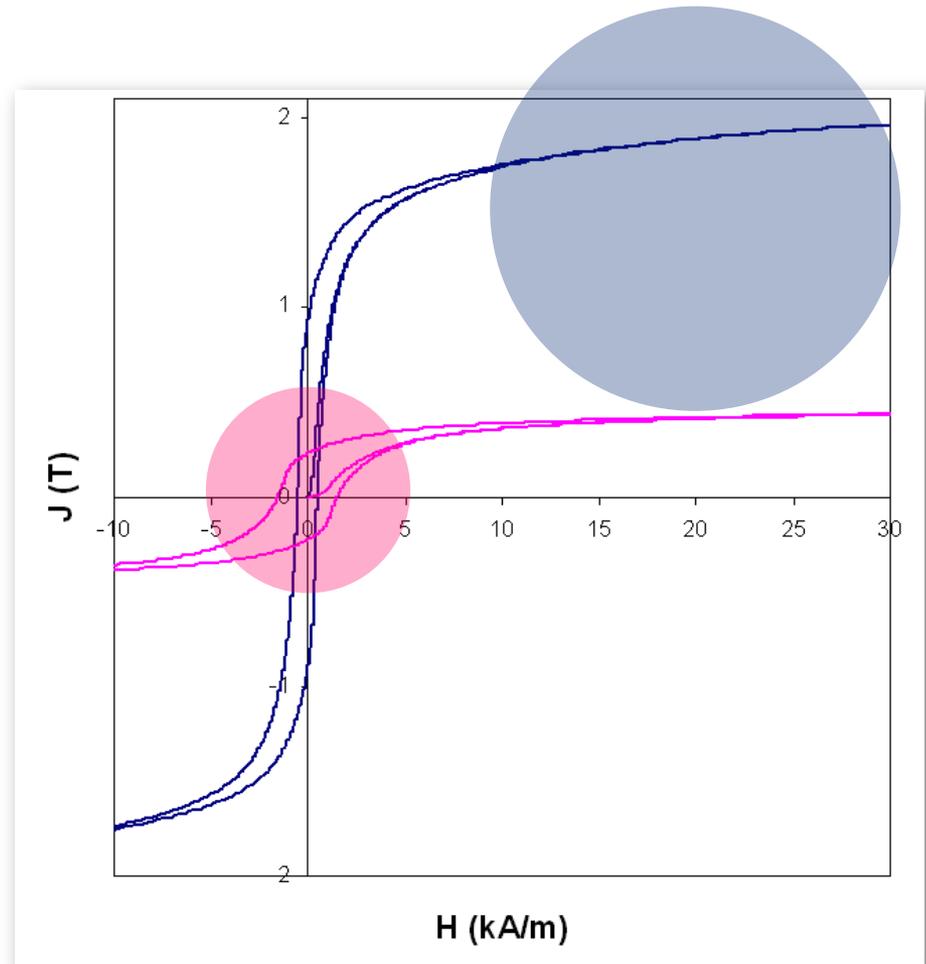
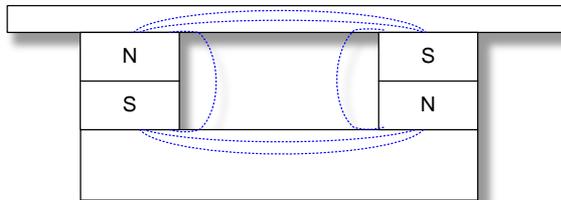
# Basic Principle

## Detection of Hard Spots by using Different Magnetic Responses

**HIGH Field 10-30 kA/m**

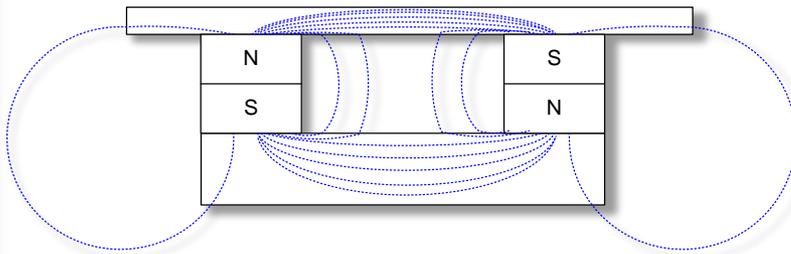


**LOW Field 2-5kA/m**

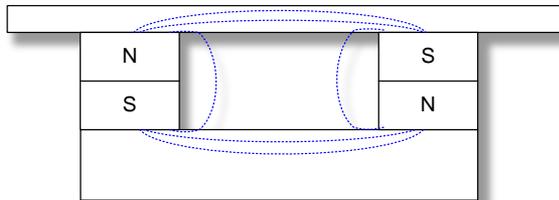


## Detection of Hard Spots by using Different Magnetic Responses

**HIGH Field 10-30 kA/m**



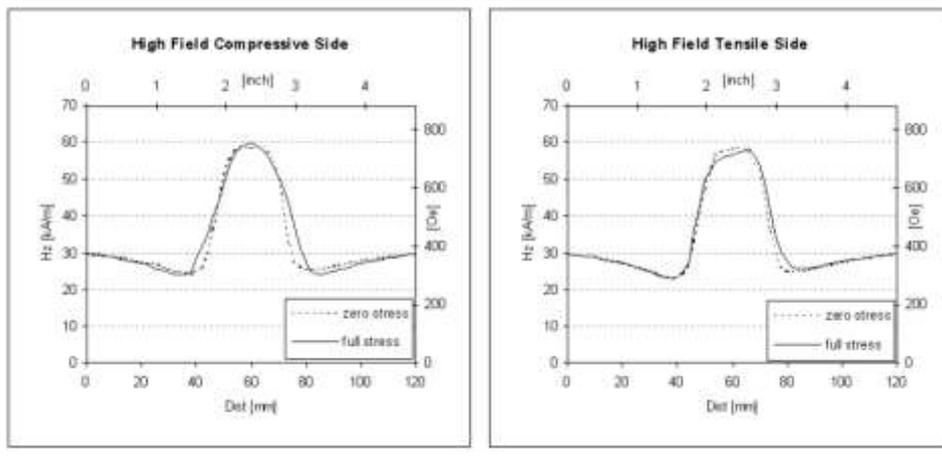
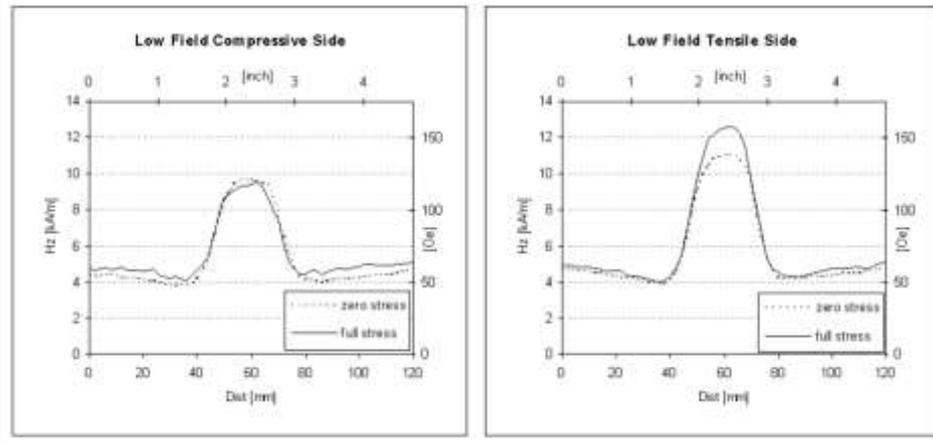
**LOW Field 2-5kA/m**



High/Low Field Principle applicable for

- hard spots
- plastic deformation (e.g. dents, re-rounding)
- residual and applied stress, bending

## Detection of Hard Spots by using Different Magnetic Responses

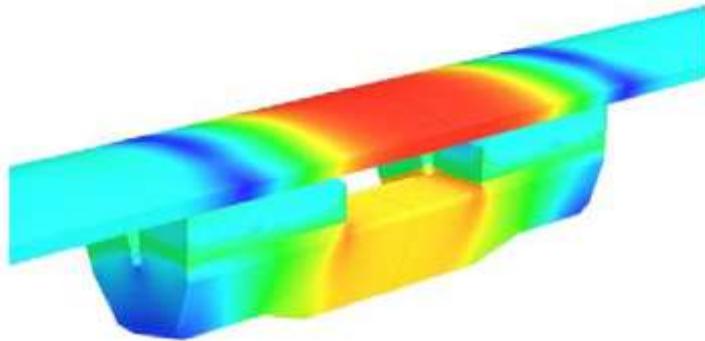


High/Low Field Principle applicable for

- hard spots
- plastic deformation (e.g. dents, re-rounding)
- residual and applied stress, bending

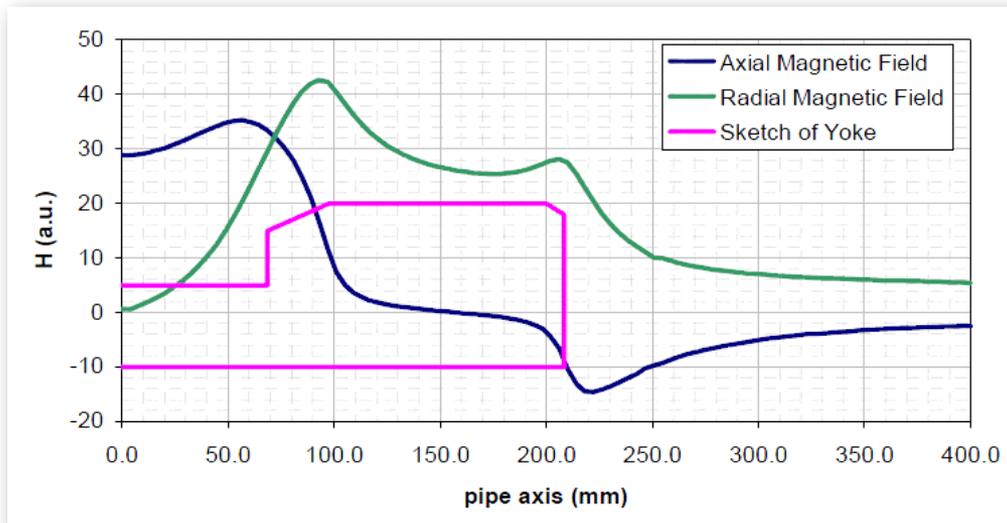
- Basic Principle
- **Tool Design**
- Hard Spot Characterization
- Mechanical Damage Characterization
- Combined Inspection Technologies
- Conclusion

## to Achieve LOW/HIGH Field Different Tool Concepts are Possible



### Single Unit Tool

- position of low field sensor crucial
- avoid measurement in remanent magnetization ( $H=0$ )! **unpredictable results**



## to Achieve LOW/HIGH Field Different Tool Concepts are Possible



06" Dual Magnetization MFL Tool

alternative design is utilizing two magnet units for high and low field magnetization

mandatory for smaller diameter to achieve controlled magnetization condition

## Tool Availability 6" – 60"

tool can be combined from existing tools

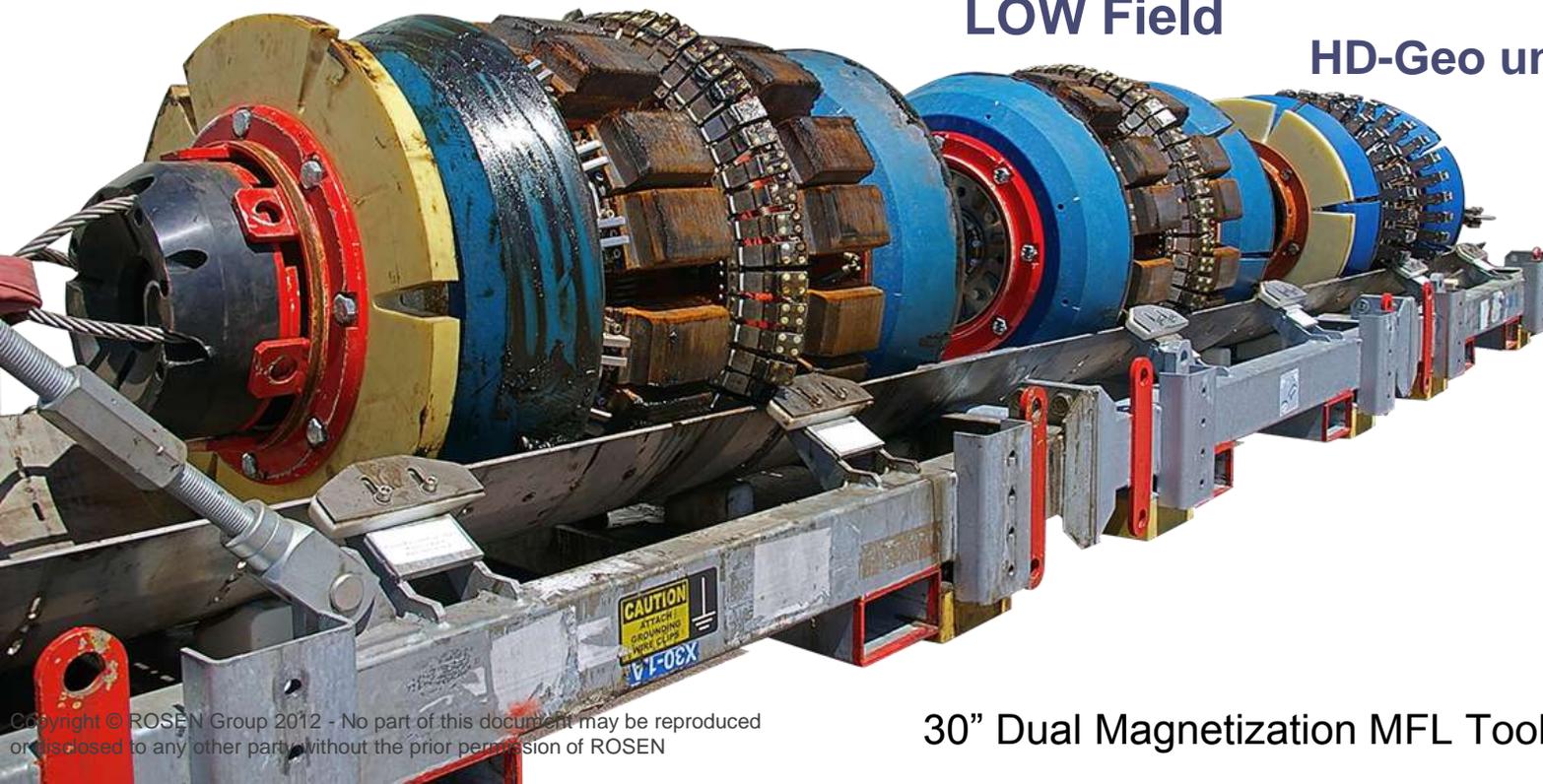
## Operational Performance

drag of second MFL unit significant lower due to low field.

**HIGH Field**

**LOW Field**

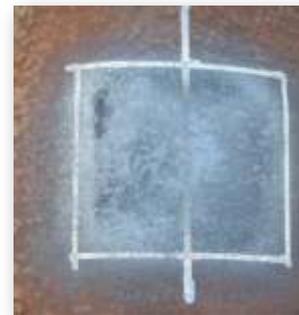
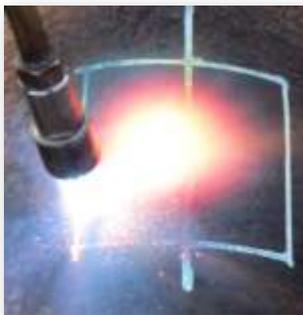
**HD-Geo unit**



30" Dual Magnetization MFL Tool

- Basic Principle
- Tool Design
- **Hard Spot Characterization**
- Mechanical Damage Characterization
- Combined Inspection Technologies
- Conclusion

- Hard Spots and Quenching are **Mill Related** Anomalies
- **Rejection Criteria** for mill related anomalies exist in API 5L
- Overheating in the HAZ, cold working, handling marks or arc burns are **Construction Related** Anomalies
- Construction Related Anomalies can cause **Delayed Failures**



hard spot experiment for pulltest calibration

## Criteria stated in API 5L

### 9.10.6 Hard spots

Any hard spot larger than 50 mm (2.0 in) in any direction shall be classified as a defect if its hardness exceeds 35 HRC, 345 HV10 or 327 HBW, based upon individual indentations. Pipes that contain such defects shall be treated in accordance with C.3 b) or C.3 c).

- nominal hardness of pipe **140 – 200 HV**
- industry-wide accepted accuracy **+/- 50HV**
- rejection of pipe at **345 HV**

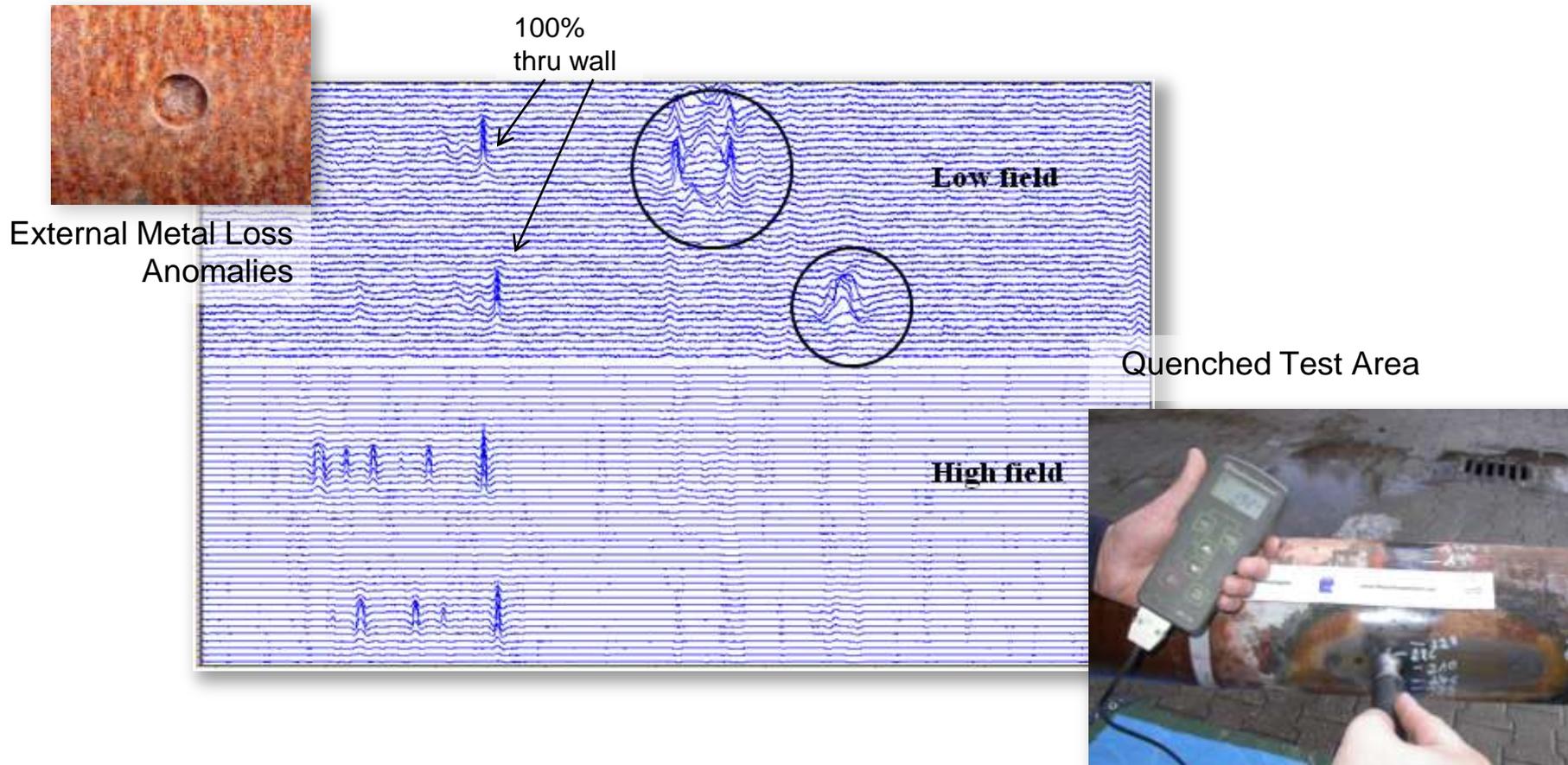
### C.3 Treatment of non-dressable surface defects

Pipes that contain non-dressable surface defects shall be given one or more of the following dispositions.

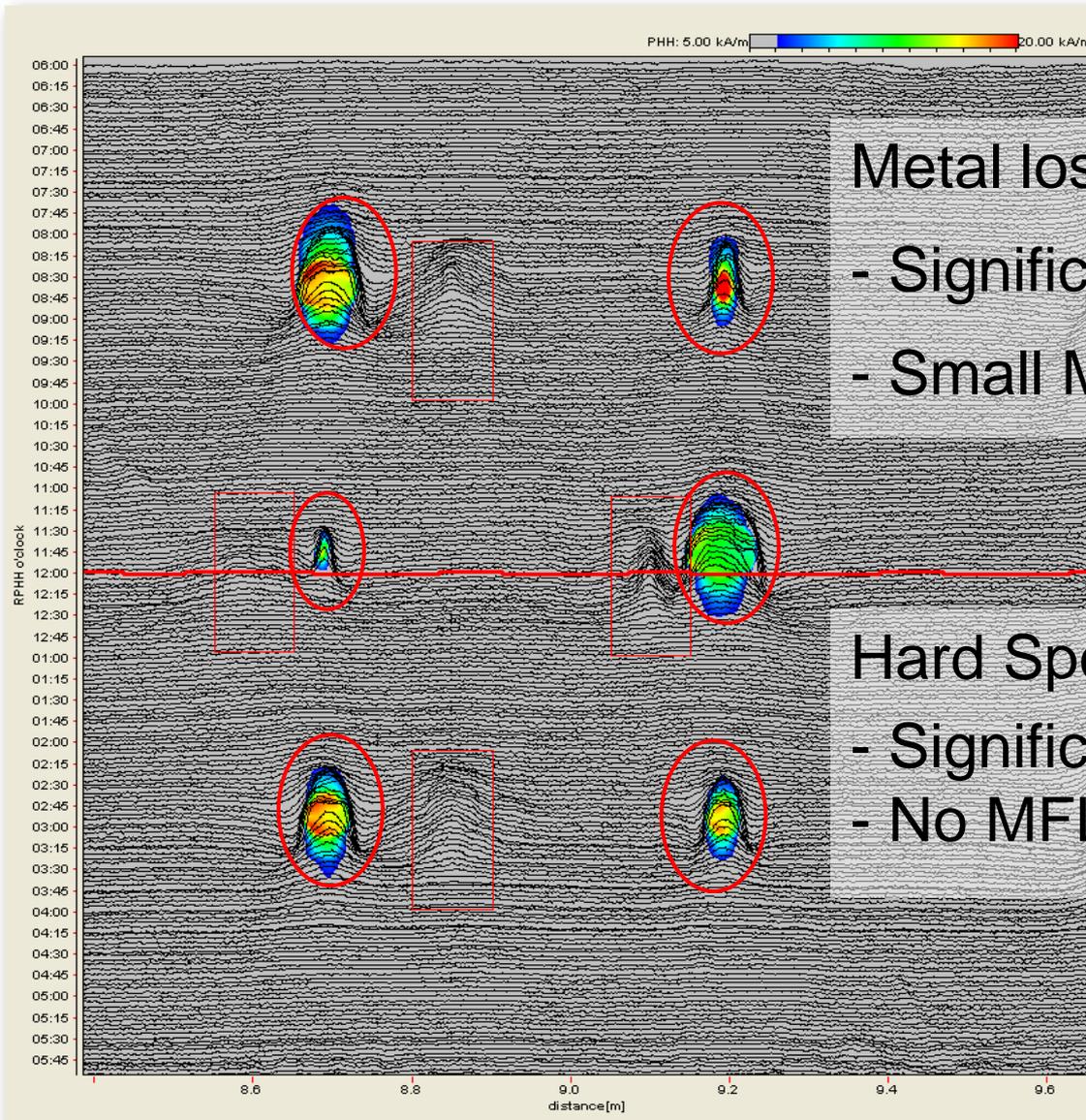
- a) Weld defects in SAW and COW pipes shall be repaired by welding in accordance with Clause C.4.
- b) The sections of pipe containing the surface defects shall be cut off, within the limits on length.
- c) The entire pipe length shall be rejected.

# Hard Spot Detection

Example of low field and high field data. Hard spot signals (circled) are clearly visible in the low field data, but not in the high field data.



# Pull test examples



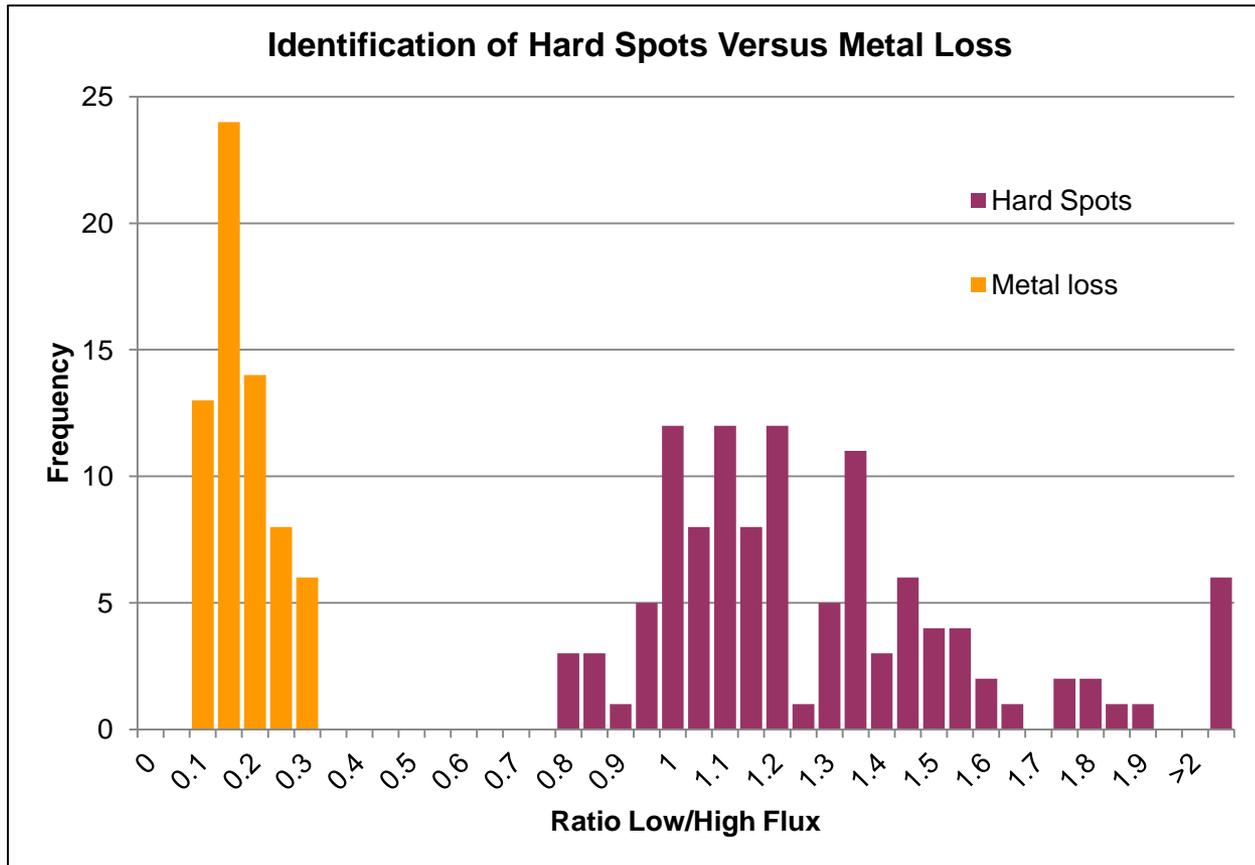
Metal loss (Ellipses):

- Significant MFL at HIGH field
- Small MFL at LOW field

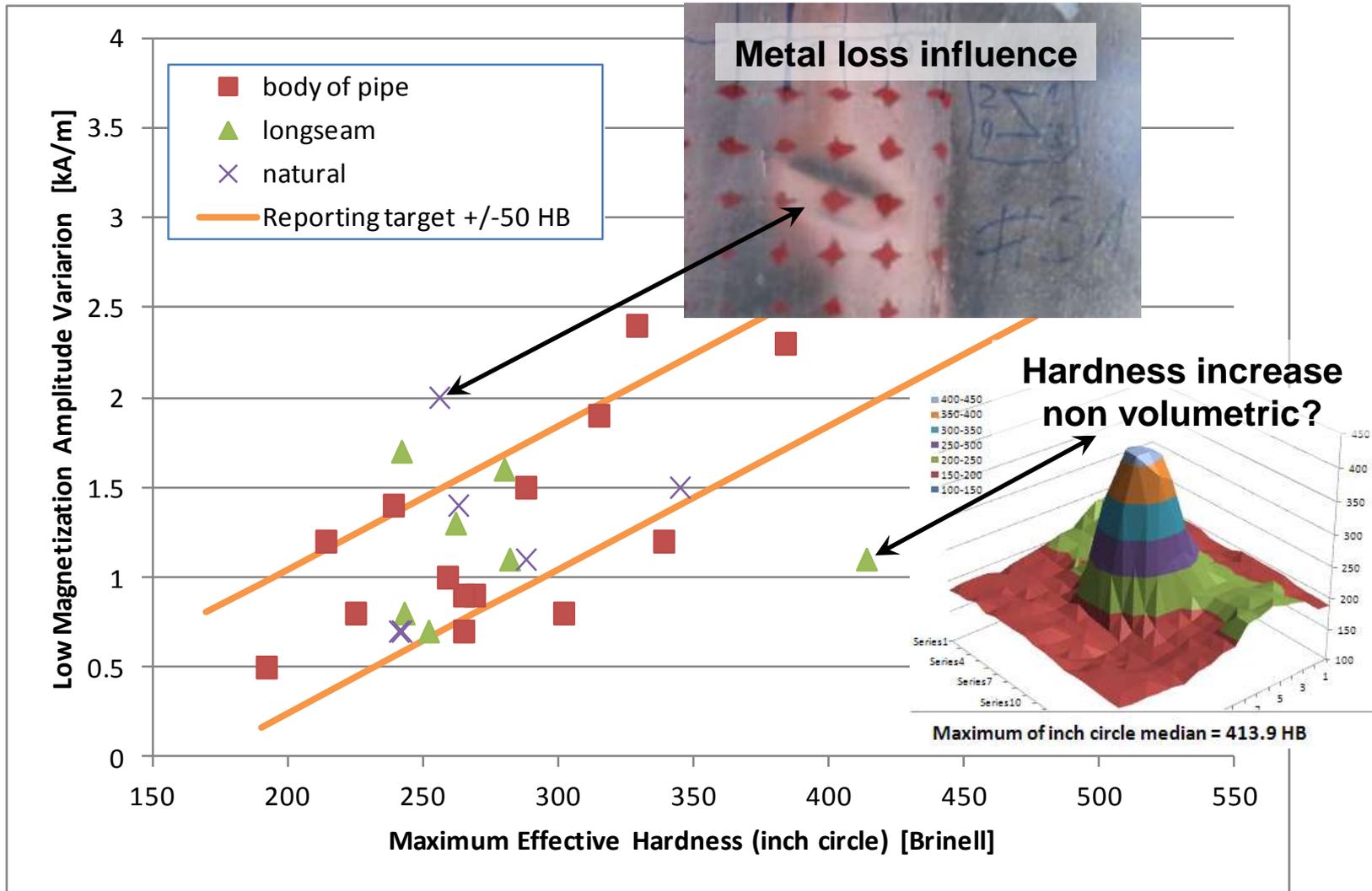
Hard Spot (Boxes):

- Significant MFL at LOW field
- No MFL at HIGH field

The ratio of flux leakage on the low magnetization unit and flux leakage on the high magnetization unit provides a clear separation between hard spot and metal loss:

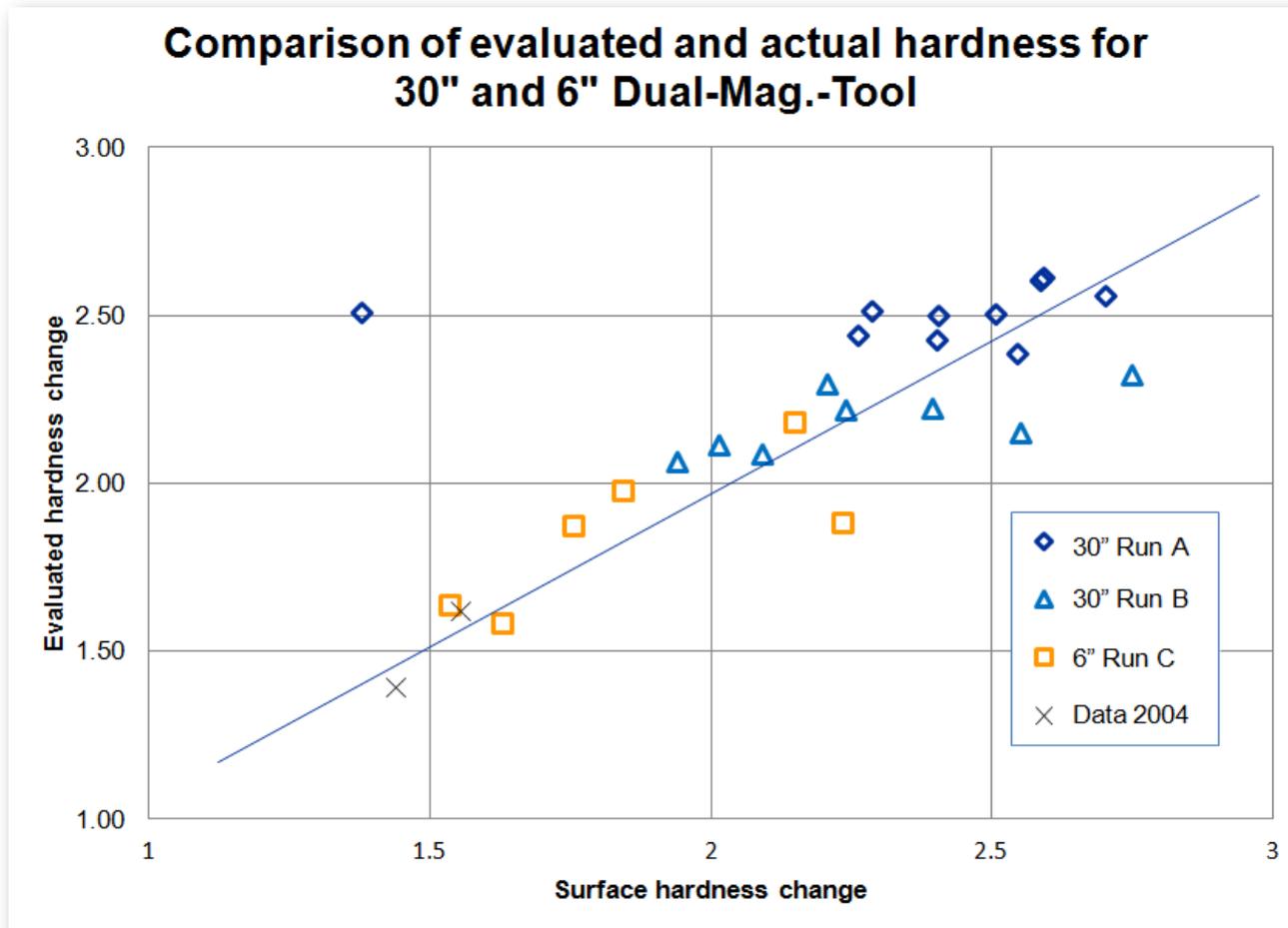


# Sizing – Reporting of Hardness



# Sizing – Reporting of Hardness

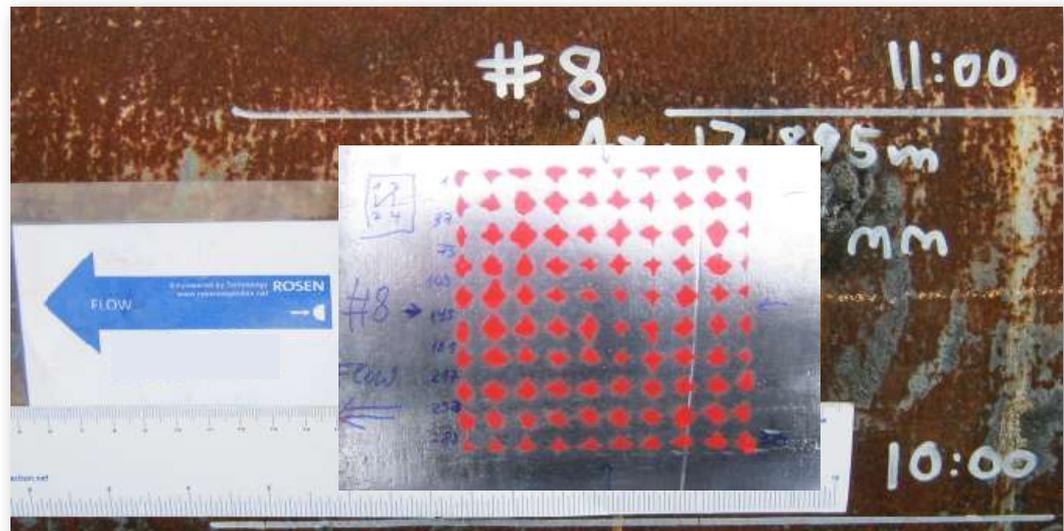
Sizing quality can be estimated from unity graph of hardness change:



# Hardspot Verification

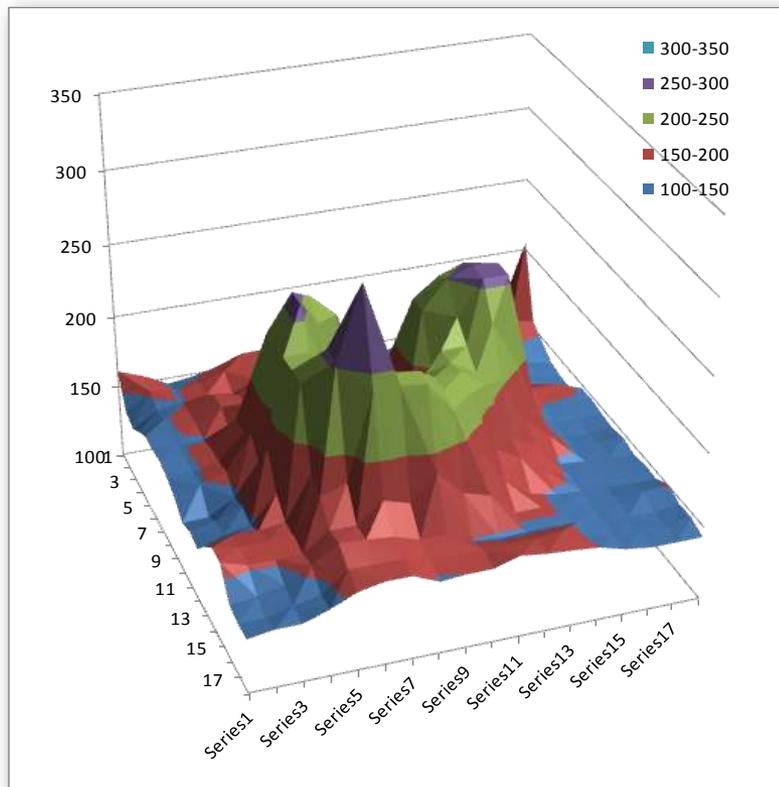
- spots grinded up to smooth surface
- absolute hardness of joints determined with mobile rockwell hardness tester
- complete shape of defect measured with Ultrasonic Contact Impedance (UCI)
- measurement grid 10 mm

	1	2	3	4	5	6	7	8	9
A	191	192	182	192	194	183	193	181	179
B	190	189	210	184	189	176	186	189	182
C	210	204	198	193	180	195	197	204	175
D	198	212	198	189	181	207	187	182	181
E	218	198	197	197	184	194	195	197	175
F	186	172	219	185	202	198	215	203	168
G	209	201	170	217	209	212	205	189	179
H	229	235	250	236	257	209	213	189	215
I	236	233	246	267	236	189	199	165	203
J	206	208	241	241	187	197	205	184	201
K	201	193	211	208	182	183	207	187	202

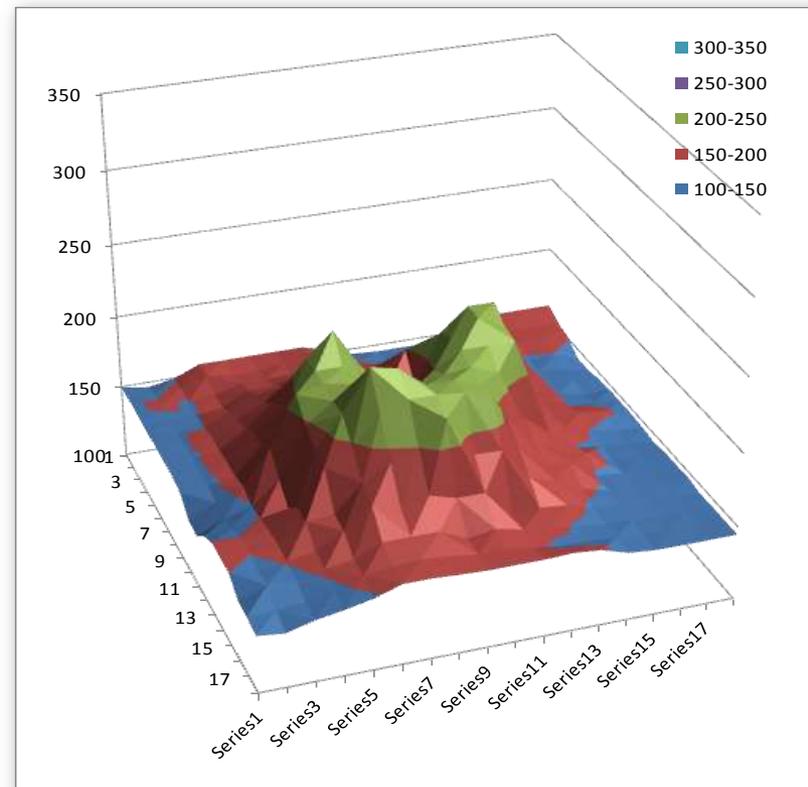


-Procedures for effective hardness determination

-A: Median of 9 values,  
e.g. Max. of 301 HB



-B: Median of 21 values,  
e.g. Max. of 239 HB



- Basic Principle
- Tool Design
- Hard Spot Characterization
- **Mechanical Damage Characterization**
- Combined Inspection Technologies
- Conclusion

# Mechanical Damage

## Dents, Gouges and the Combination thereof

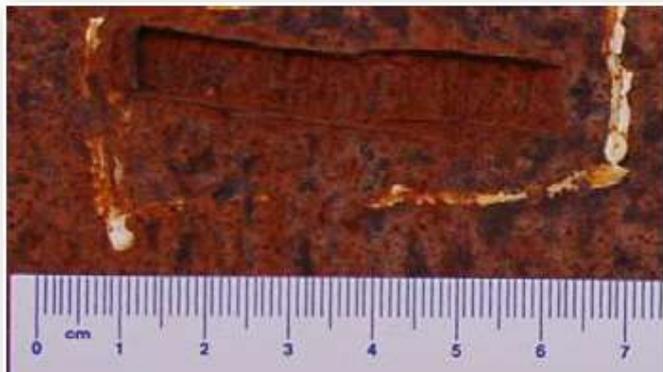
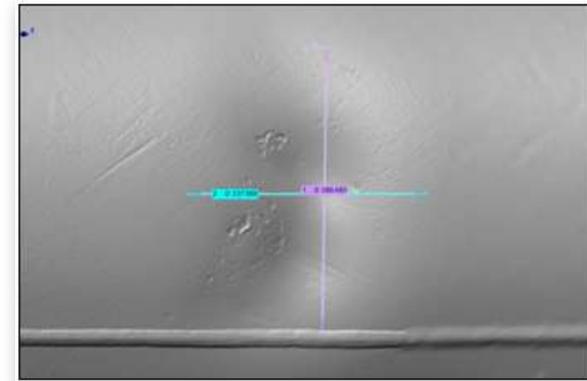


### Denting, Re-rounding and Pressure Cycling

a blunt dent is re-rounded due to the internal pipeline pressure; pressure cycles work on cold worked areas around a dent

### Gouging and Plowing

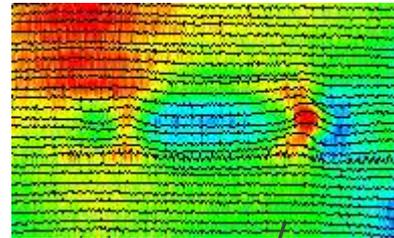
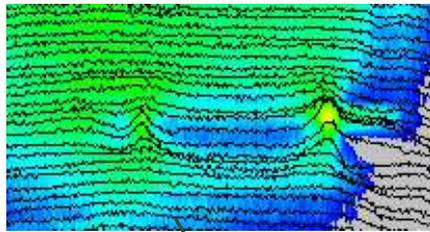
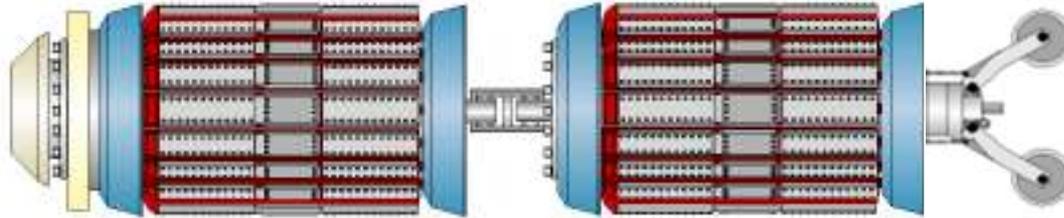
plowing is the start point of the indentation process; gouging the lateral continuation of cold working and forming of the material



# Mechanical Damage

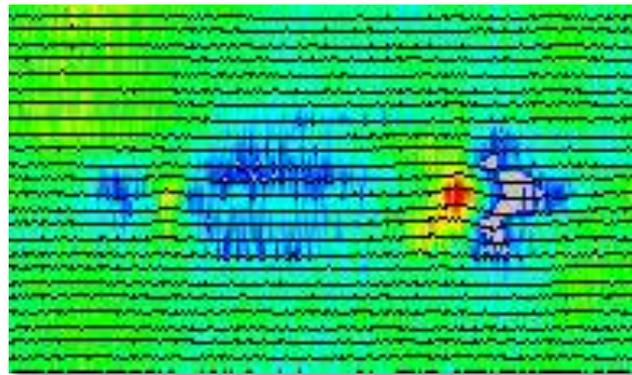
HIGH Field

LOW Field

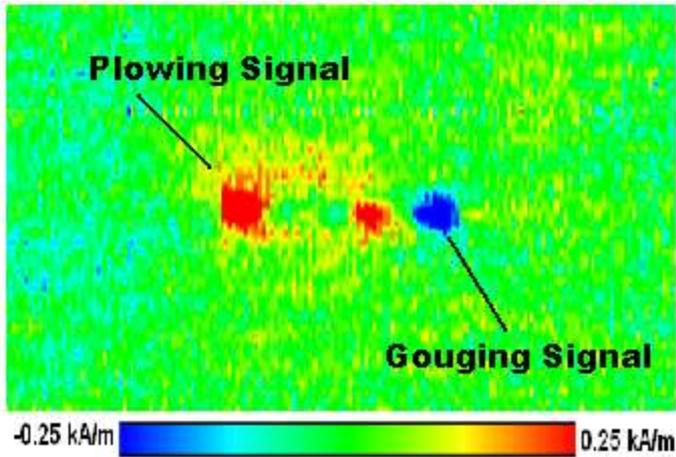


Dent Defect

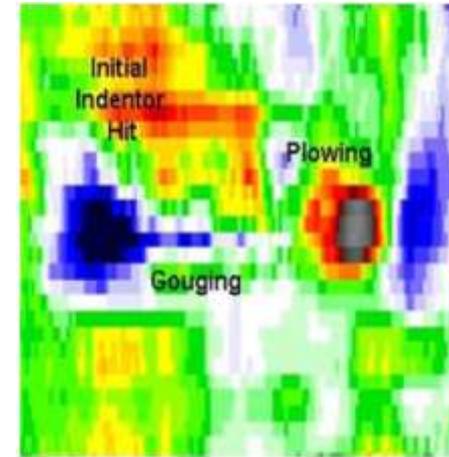
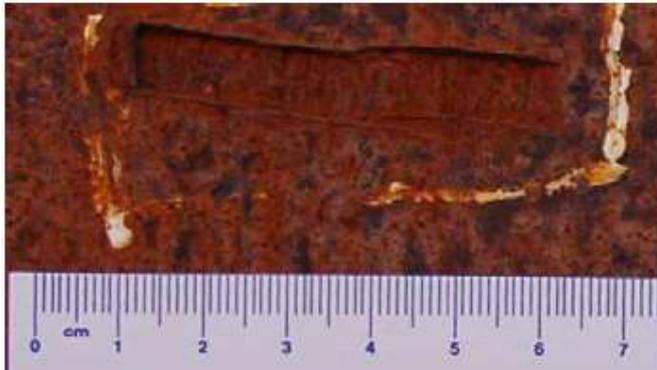
Decoupled MFL Data



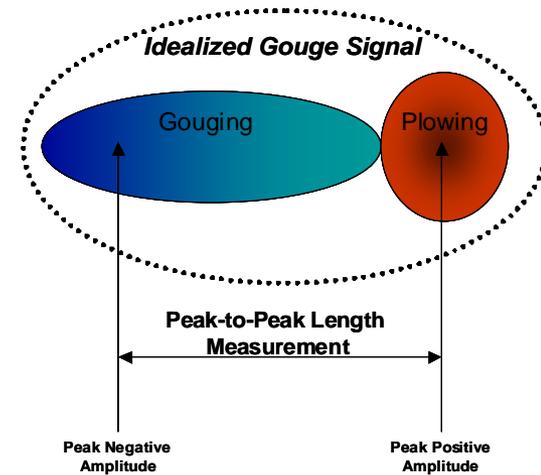
# Gouging and Plowing



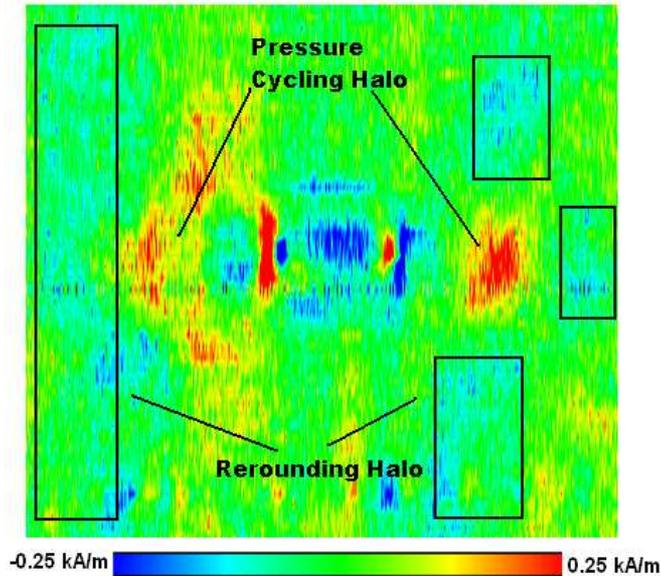
Decoupled pull test results with background subtraction from gouge



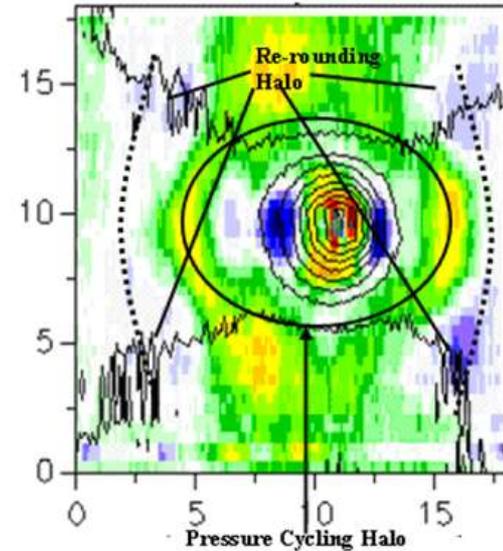
Signal pattern from initial laboratory work



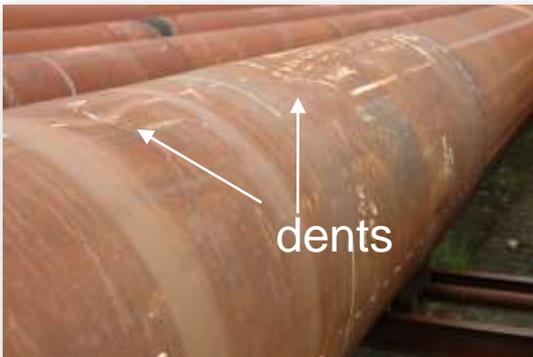
# Denting and Pressure Cycling



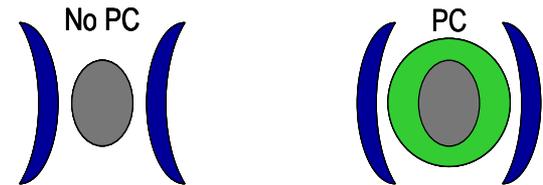
Decoupled pull test results with background subtraction from gouge



Signal pattern from initial laboratory work



2% Dent made with cylindrical indenter; pressurized pipe; subsequent cyclic loading

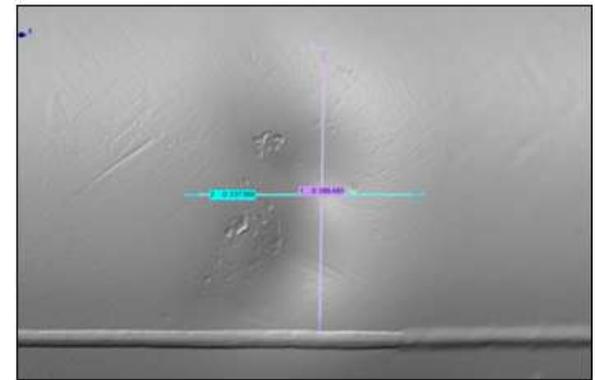
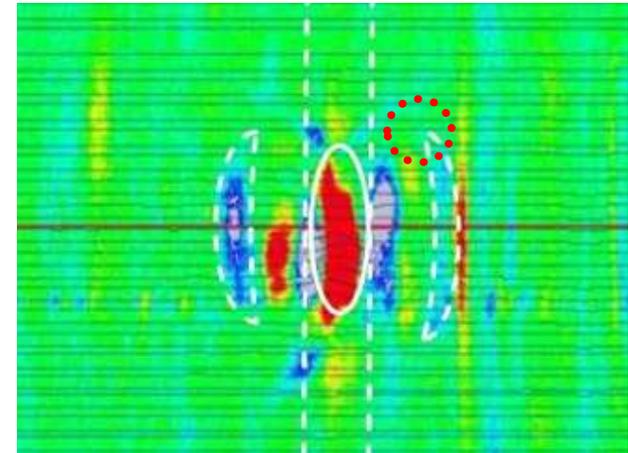


# Field Examples – Dual Field Inline Inspection

## Reported:

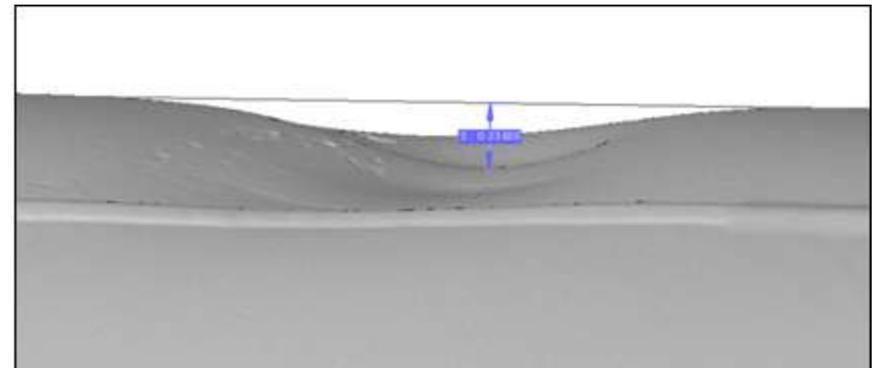
Severity Ranking HIGH:

- No Plow/Gouge Signal,
- Pressure Cycling,
- Residual Dent > 2%, > 6% Dent Strain
- with 11:46 on Top of Pipe
- Hard Spot in Dent Area 



## In Field:

- > 2% Dent Depth
- No Gouge

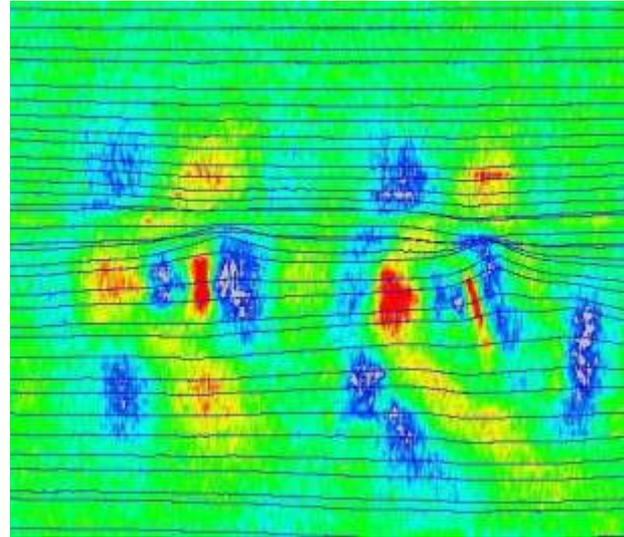


# Field Examples – Dual Field Inline Inspection

## Reported:

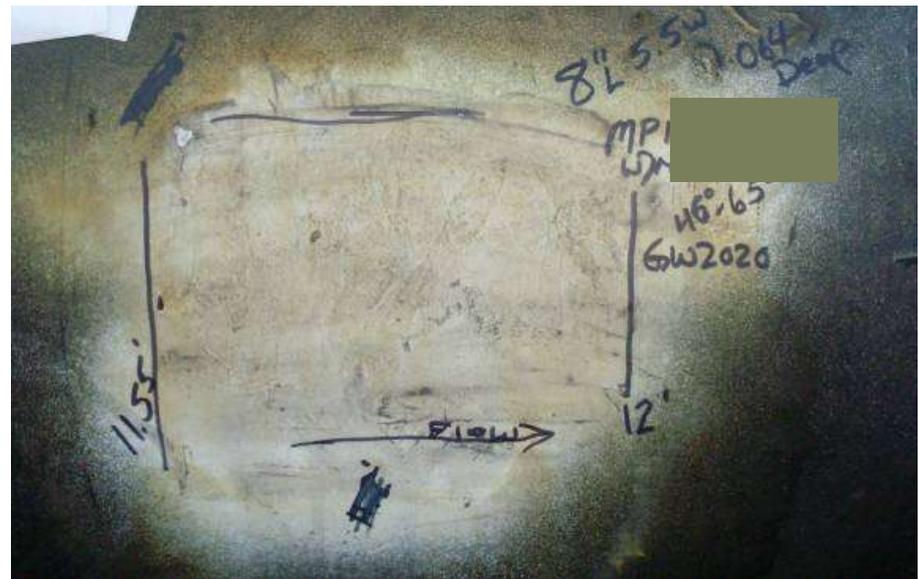
Severity Ranking HIGH:

- Plow/Gouge signal,
- Re-rounding, Pressure Cycling
- Residual Dent >2%,
- With 5:30 Bottom of Pipe

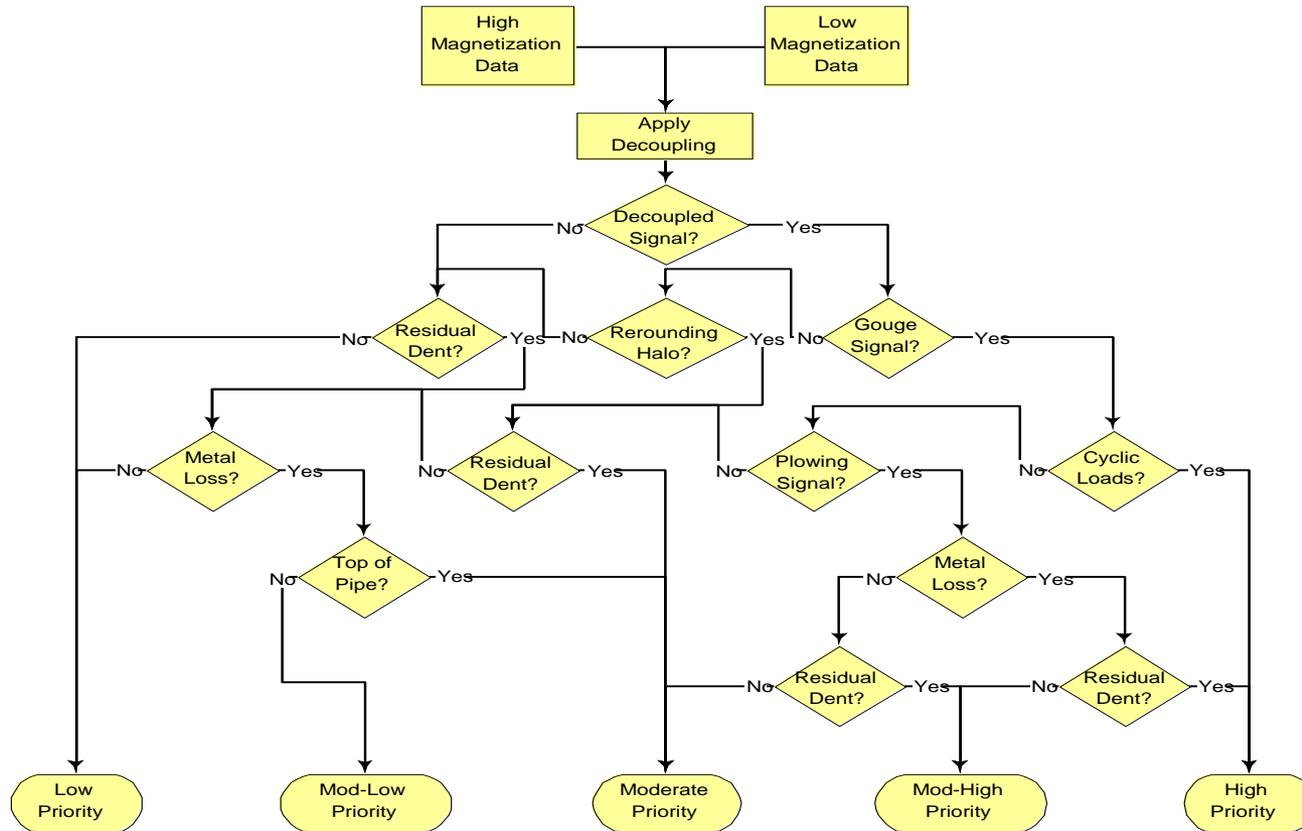


## In Field

- 9% Wall Thinning
- 1% Field Depth
- Gouging confirmed



## Classification and Priority Ranking



Detailed Classification Process of Decoupled Dual-Mag Signal, leads to Characterization and Prioritization of Mechanical Damage. Prioritization Model based on PRCI Research

- Basic Principle
- Tool Design
- Hard Spot Characterization
- Mechanical Damage Characterization
- **Combined Inspection Technologies**
- Conclusion

# Combined In-Line Inspection

## Mechanical Damage and Longseam Integrity

corrosion – pitting – axial anomalies – ID/OD – deformation – IMU



### Mechanical Damage

- Metal Loss
- Gouges
- accurate sizing
- ID/OD discrimination

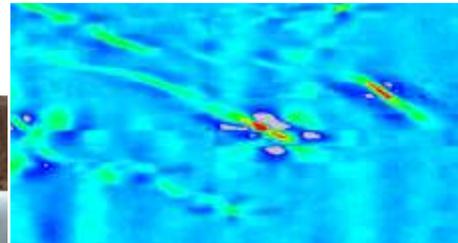
HighRes  
CMFL



HighRes  
CMFL

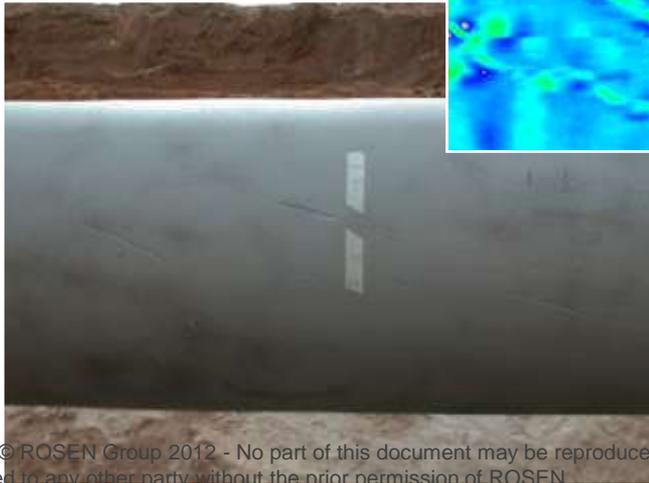


HighRes  
XYZ GEO



### Longseam

- LOF
- Dents
- Gouges
- Corrosion



Needs Sleeve  
Lack of Fusion in Long Seam

ODG22  
MAX D = .040"  
LENGTH = .02  
CIRC W = .015"  
AX: +26.52  
TDC: +.42  
UT: 330

R.B.W. 227

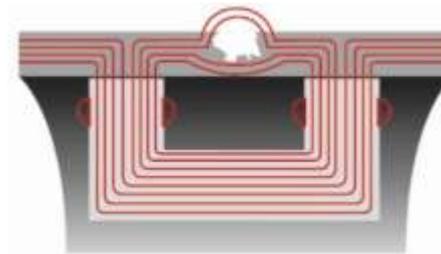
## Solution

High Resolution CMFL technology magnetization perpendicular(!) to pipe axis and parallel to seamless pattern

High Fidelity Raw Data allow Accurate Analysis

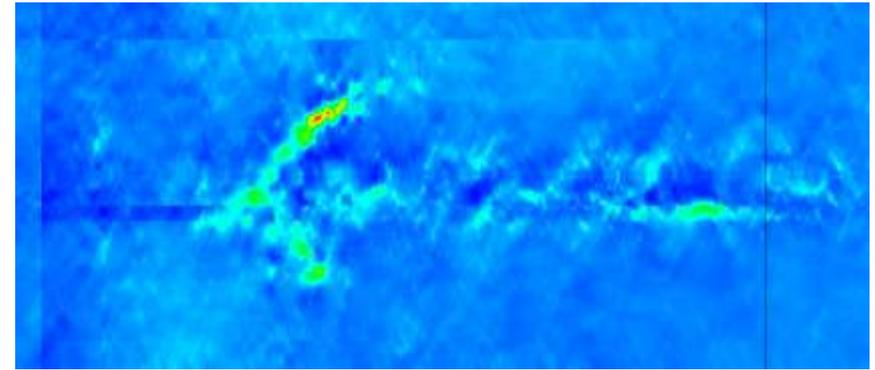


seamless variation affect MFL path. MFL Raw data require adaptive noise filter to reduce influence of seamless pattern. Filter Method typically sufficient for smaller wt-tolerances

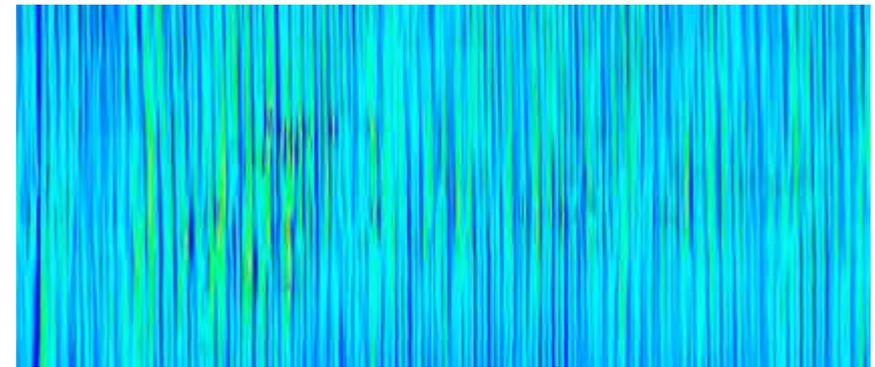


## Heavy Seamless Pipe

( $\pm 15\%t$ )



CMFL RAW Data – **Principal Noise Cancellation**



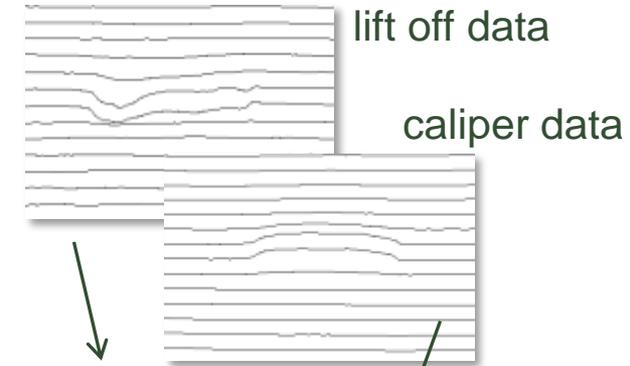
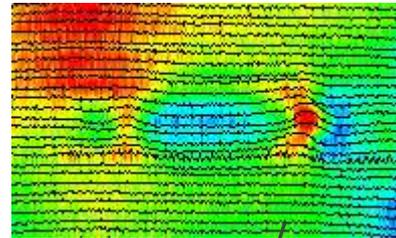
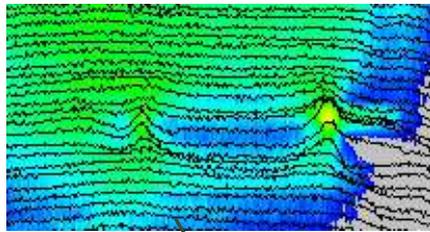
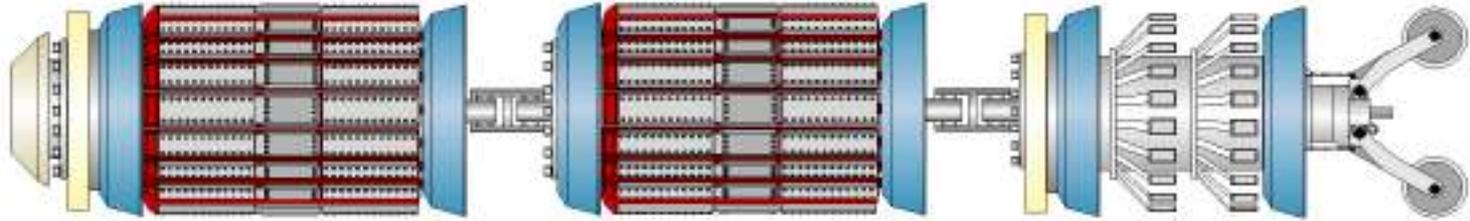
MFL RAW Data – **Adaptive Noise Filter** Required

# Combined Inspection Technologies

**HIGH Field**

**LOW Field**

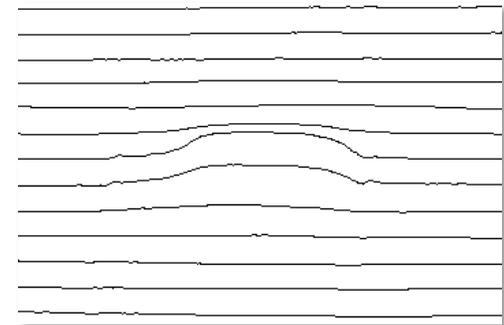
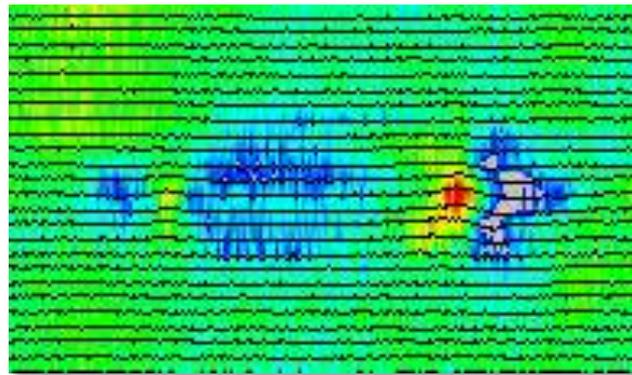
**Geometry**



Dent Defect

Decoupled MFL Data

Combined Profile

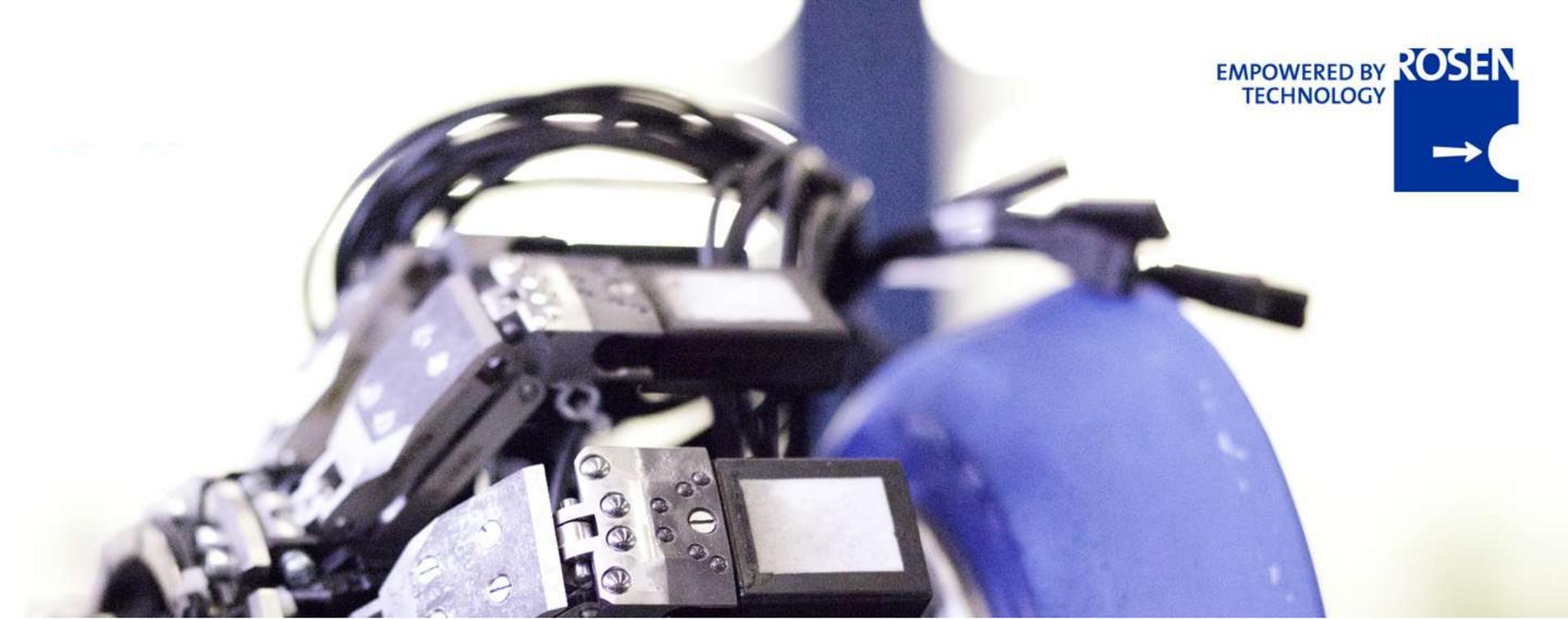


	High Resolution MFL	High Resolution Dual MFL	XYZ Mapping	High Resolution Geometry	High Resolution ID Mapping
Description	High Field MFL	Low Mag. Field	IMU	mech. Caliper + Eddy Current	Eddy Current
Resolution	axial: 3mm circ: 5mm	axial: 3mm circ: 5mm	200 Hz	axial: 3mm circ <sub>EC</sub> : 12mm circ <sub>Cal</sub> : 40mm	axial: 3mm circ: 12mm
Corrosion	+/- 0.1*wt				
Internal Shallow Corrosion	+/- 0.1*wt				+/- 0.6mm
Ovalities; ID	Identification			+/- 1% OD	
Centerline Mapping (UTM)			1:2000		
Centerline Bending Strain			+/- 0.5%		
Dents	identification			D: +/- 0.8mm	
Dent Strain				based on curvature + membrane strain	
Mechanical Damage	Identification & Characterization				
Cold Working (around Dents)	identification & Characterization				
Hardspots	+/- 50HV				

\* more detailed informatioun can be obtained from ROSEN performance specification

- Basic Principle
- Tool Design
- Hard Spot Characterization
- Mechanical Damage Characterization
- Combined Inspection Technologies
- **Conclusion**

- **Pipeline Anomalies** like Hard Spots, Cold Working, Plastic Deformation and Residual Stress can be characterized by the Dual Magnetization Method
- In Combination with **High Resolution Geometry** Technology, Dual Magnetization is a useful extension to better characterize a Pipeline
- **Hard Spots** are reported with +/- 50HV accuracy
- Cold Working and Cyclic Loading around mechanical damage can be analyzed with a **pattern recognition model**.
- In-line Inspection Tools are available **in All Sizes** from 6" to 60".
- **Combined Inspection Technologies** use the Dual Magnetization Method as a useful add-on



**Thank you for joining this presentation.**