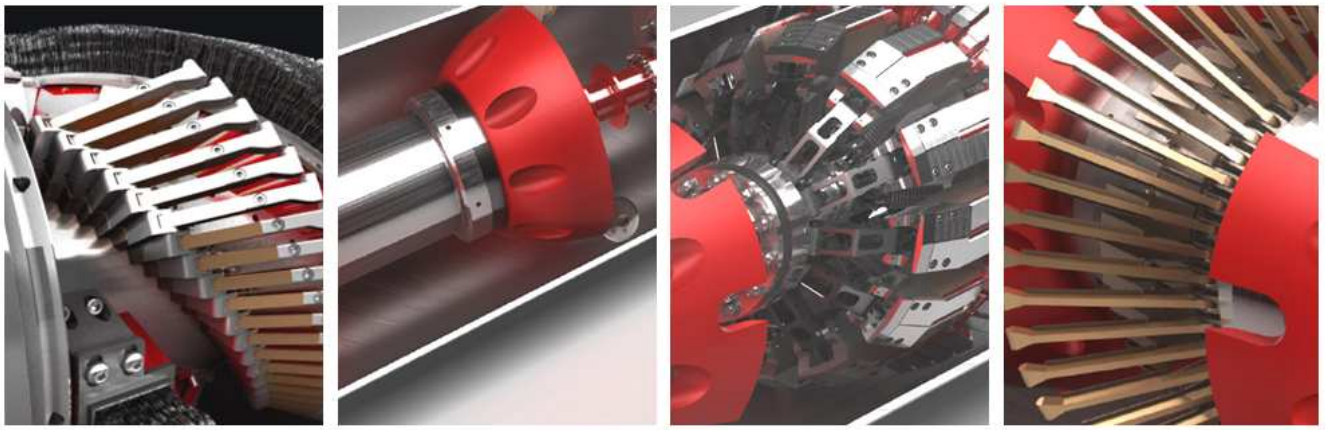
Pipeline Performance™



Multiple DataSets Platform: Value, Application and Enhanced Characterization of Pipeline Defects

UKOPA 2012 Technical Seminar
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May 29, 2012

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- Technology Limitations
- Value of Multiple DataSets
- Axial MFL
- Circumferential MFL
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- High Resolution Deformation
- Multiple DataSets (DEF+SMFL+MFL+RES+XYZ)
- Characterization of Anomalies
- Mechanical Damage Prioritization
- Mechanical Damage Characterization
- Summary

Technology Limitations

SP0102-2010

Table 1: Types of ILI Tools and Inspection Purposes[6]

Anomaly	Imperfection/ Defect/Feature	Metal Loss Tools			Crack Detection Tools		Deformation Tools
		Magnetic Flux Leakage (MFL)		Ultrasonic Compression Wave[M]	Ultrasonic Shear Wave[M]	Transverse MFL	
		Standard Resolution (SR)	High Resolution (HR)				
Metal Loss							
	External Corrosion	Detection,[A] Sizing[B]	Detection,[A] Sizing[B]	Detection,[A] Sizing[B]	Detection,[A] Sizing[B]	Detection,[A] Sizing[B]	No Detection
	Internal Corrosion						
	Gouging	No ID/outer diameter (OD) discrimination					
Crack-Like Anomalies							
	Narrow Axial External Corrosion	Detection[A]	Detection[A]	Detection,[A] Sizing[B]	Detection,[A] Sizing[B]	Detection,[A] Sizing[B]	No Detection
	Stress Corrosion Cracking	No Detection	No Detection	No Detection	Detection,[A] Sizing[B]	Limited Detection,[A][C] Sizing[B]	No Detection
	Fatigue Cracks	No Detection	No Detection	No Detection	Detection,[A] Sizing[B]	Limited Detection,[A][C] Sizing[B]	No Detection
	Long Seam Cracks, etc. (toe cracks, hook cracks, incomplete fusion, preferential seam corrosion)	No Detection	No Detection	No Detection	Detection,[A] Sizing[B]	Detection,[A][C] Sizing[B]	No Detection
	Circumferential Cracks	No Detection	Detection,[C] Sizing[B]	No Detection	Detection,[A] Sizing[B][D]	No Detection	No Detection
	Hydrogen-Induced Cracking (HIC)	No Detection	No Detection	Detection [A]	Limited Detection	No Detection	No Detection
Deformation							
	Sharp Dents	Detection[E][G]	Detection[E][L]	Detection[E][G]	Detection[E][G]	Detection[E][G]	Detection,[F] Sizing

[6] For additional information, refer to API 1163.[3]

Technology Limitations

SP0102-2010

Table 1: Types of ILI Tools and Inspection Purposes (Continued)

Anomaly	Imperfection/ Defect/Feature	Metal Loss Tools			Crack Detection Tools		Deformation Tools
	Flat Dents	Detection[E][G]	Detection[E][L]	Detection[E][G]	Detection[E][G]	Detection[E][G]	Detection,[F] Sizing
	Buckles	Detection[E][G]	Detection[E][L]	Detection[E][G]	Detection[E][G]	Detection[E][G]	Detection,[F] Sizing
	Wrinkles, Ripples	Detection[E][G]	Detection[E][L]	Detection[E][G]	Detection[E][G]	Detection[E][G]	Detection,[F] Sizing
	Ovalities	No Detection	No Detection	No Detection	No Detection	No Detection	Detection, Sizing[B]
Misc. Components							
	In-Line Valves and Fittings	Detection	Detection	Detection	Detection	Detection	Detection
	Casings (Concentric)	Detection	Detection	No Detection	No Detection	Detection	No Detection
	Casings (Eccentric)	Detection	Detection	No Detection	No Detection	Detection	No Detection
	Bends	Limited Detection	Limited Detection	Limited Detection	Limited Detection	Limited Detection	Detection,[H] Sizing[H]
	Branch Appurtenances/Hot Taps	Detection	Detection	Detection	Detection	Detection	No Detection
	Close Metal Objects	Detection	Detection	No Detection	No Detection	Detection	No Detection
	Thermite Welds	No Detection	No Detection	No Detection	No Detection	No Detection	No Detection
	Pipeline Coordinates	No Detection	Detection[K]	Detection[K]	Detection[K]	Detection[K]	Detection[K]
Previous Repairs							
	Type A Repair Sleeve[6]	Detection	Detection	No Detection	No Detection	Detection	No Detection
	Composite Sleeve	Detection[I]	Detection[I]	No Detection	No Detection	Detection[I]	No Detection
	Type B Repair Sleeve[6]	Detection	Detection	Detection	Detection	Detection	No Detection
	Patches/Half Soles	Detection	Detection	Detection	Detection	Detection	No Detection
	Puddle Welds	Limited Detection	Limited Detection	No Detection	No Detection	Limited Detection	No Detection
Misc. Damage							
	Laminations	Limited Detection	Limited Detection	Detection, Sizing[B]	Limited Detection	Limited Detection	No Detection

Technology Limitations

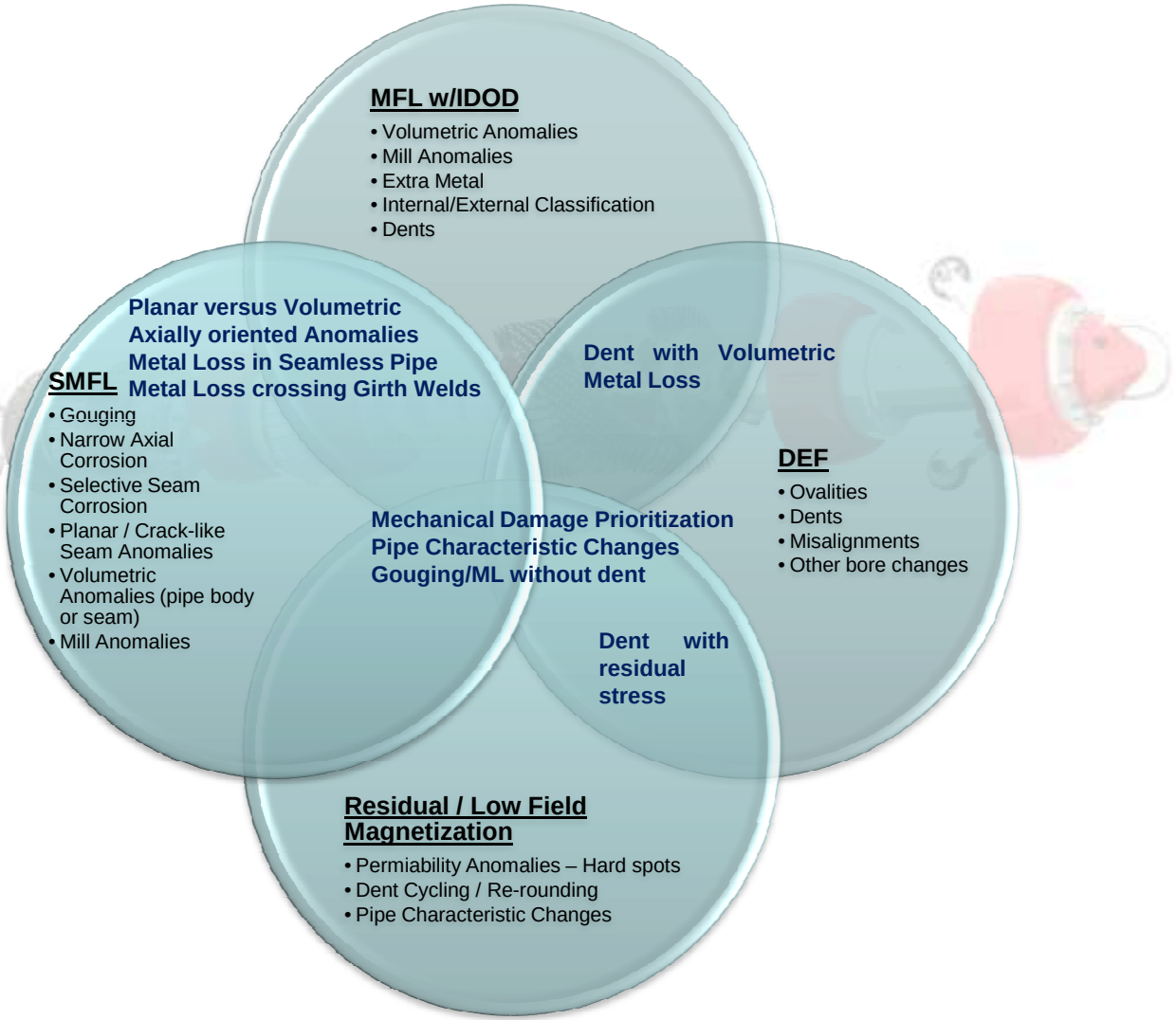
SP0102-2010

Table 1: Types of ILI Tools and Inspection Purposes (continued)

Anomaly	Imperfection/ Defect/Feature	Metal Loss Tools			Crack Detection Tools		Deformation Tools
	Inclusions (Lack of Fusion)	Limited Detection	Limited Detection	Detection, Sizing[B]	Limited Detection	Limited Detection	No Detection
	Cold Work	No Detection	No Detection	No Detection	No Detection	No Detection	No Detection
	Hard Spots	No Detection	Detection[J]	No Detection	No Detection	No Detection	No Detection
	Grind Marks	Limited Detection[A]	Limited Detection[A]	Detection[A][B]	Detection[A][B]	Limited Detection[A][B]	No Detection
	Strain	No Detection	No Detection	No Detection	No Detection	No Detection	Detection[J]
	Girth Weld Anomaly (voids, etc.)	Limited Detection	Detection	Detection	Detection[D]	No Detection	No Detection
	Scabs/Slivers/Blisters	Limited Detection[A]	Limited Detection	Detection[A][B]	Detection[A][B]	Limited Detection[A]	Limited Detection

[A] Limited by the detectable depth, length, and width of the indication.
[B] Defined by the sizing accuracy of the tool.
[C] Reduced probability of detection (POD) for tight cracks.
[D] Transducers to be rotated 90°.
[E] Reduced probability of detection (POD) depending upon size and shape.
[F] Also circumferential position, if tool is equipped.
[G] Sizing not reliable.
[H] If tool is equipped for bend measurement.
[I] Composite sleeve without markers is not detectable.
[J] If tool is equipped, dependent on parameters.
[K] If tool is equipped with mapping capabilities.
[L] Sizing is tool dependent.
[M] ILI technologies that can be used only in liquid environments, i.e., liquids pipelines or in gas pipelines with a liquid couplant.

Value of Multiple Datasets



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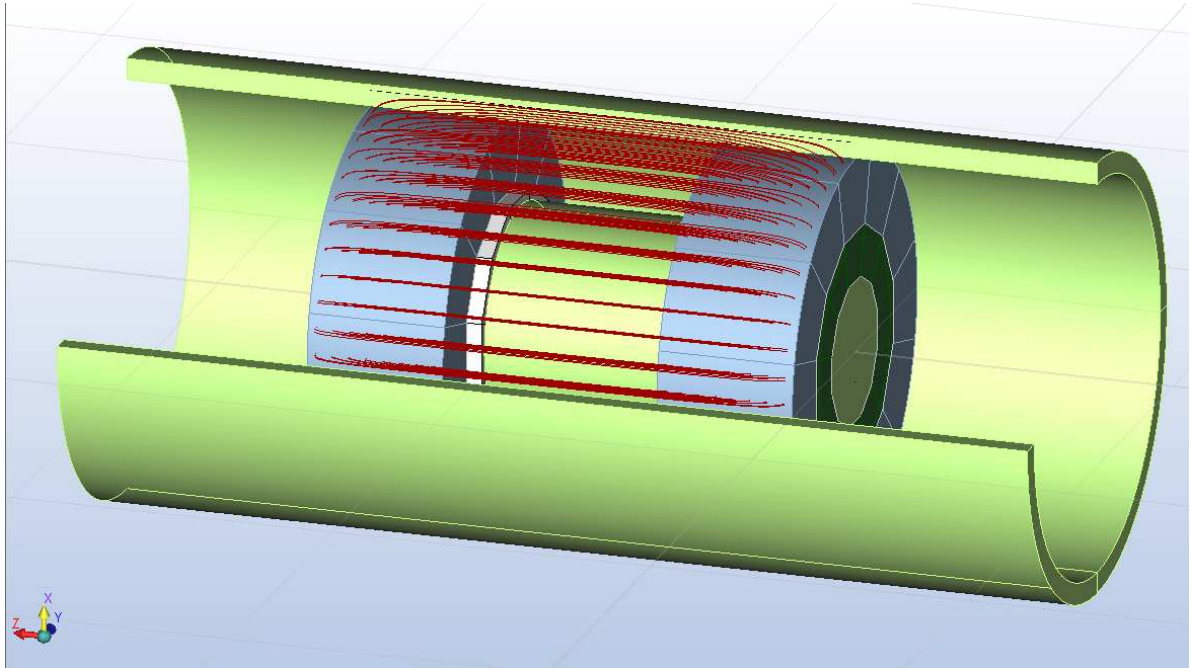
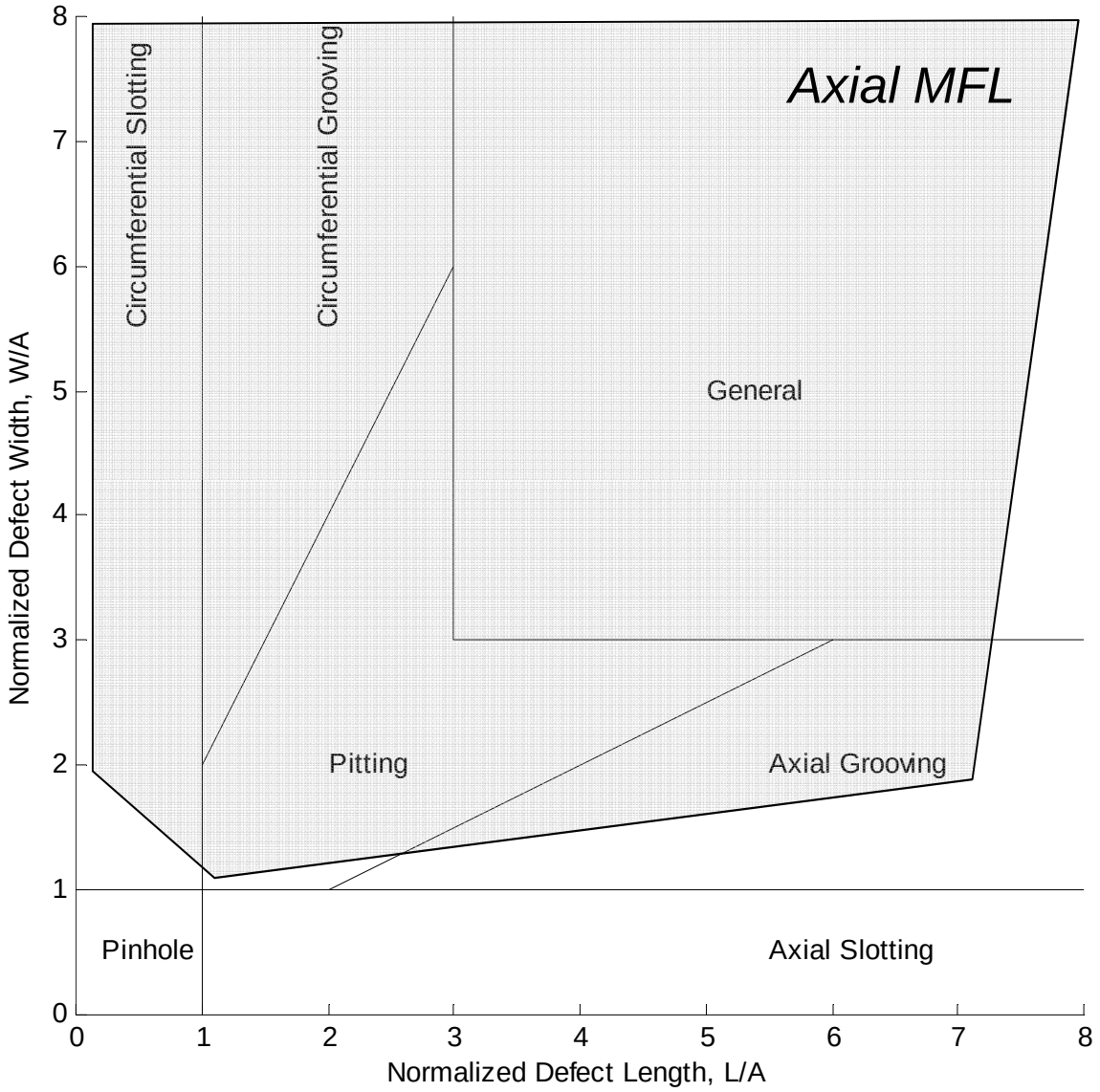
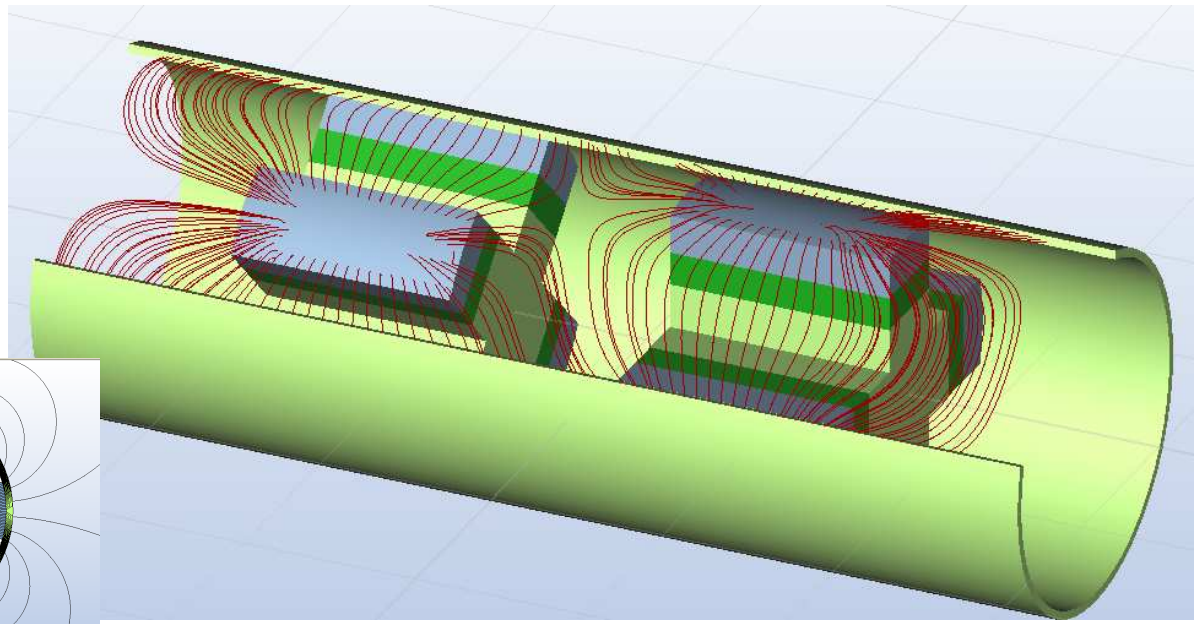
Axial MFL

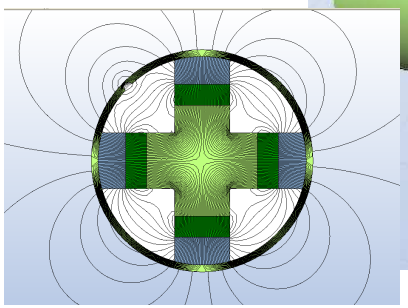


Axial MFL

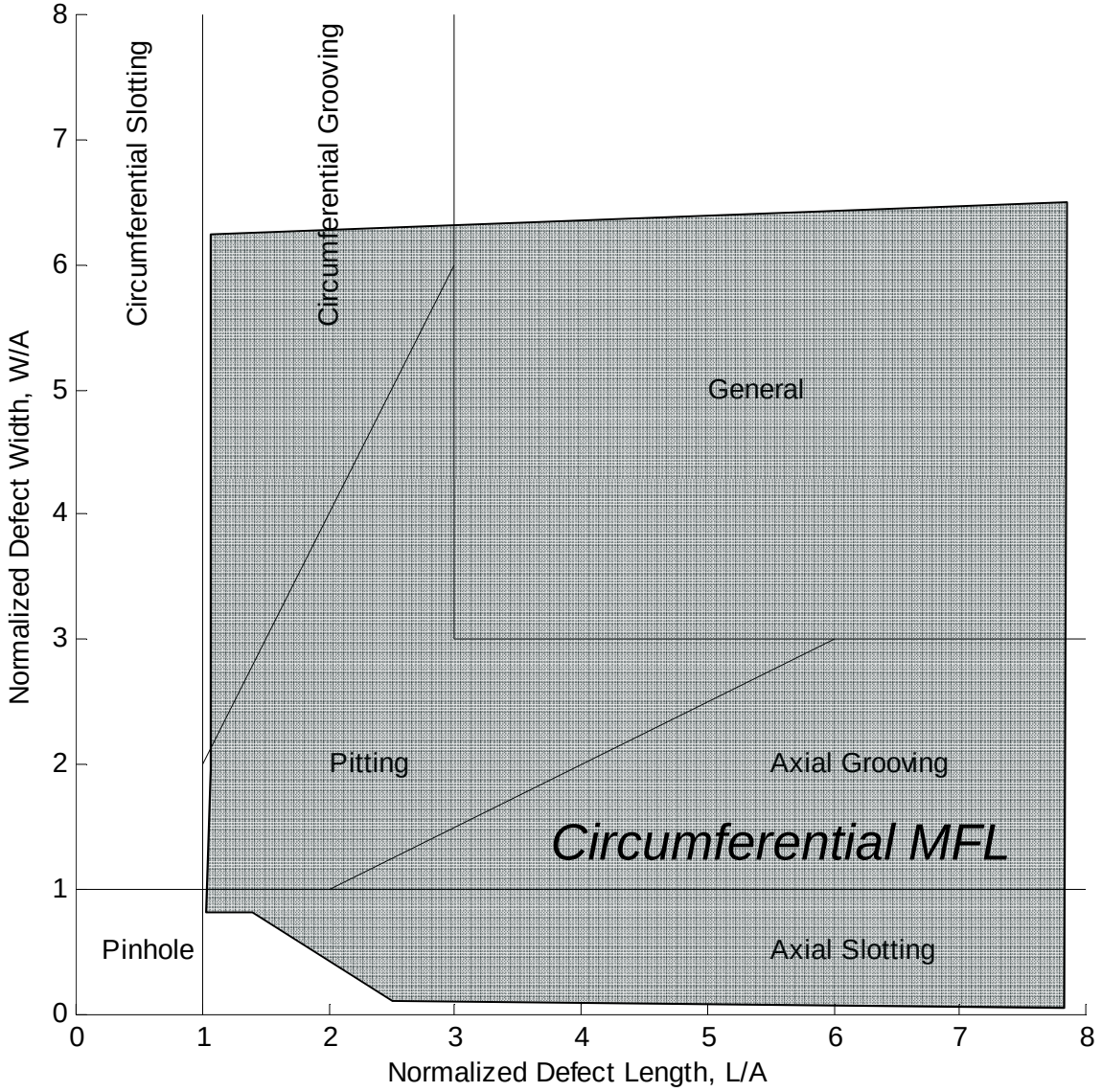


Circumferential MFL





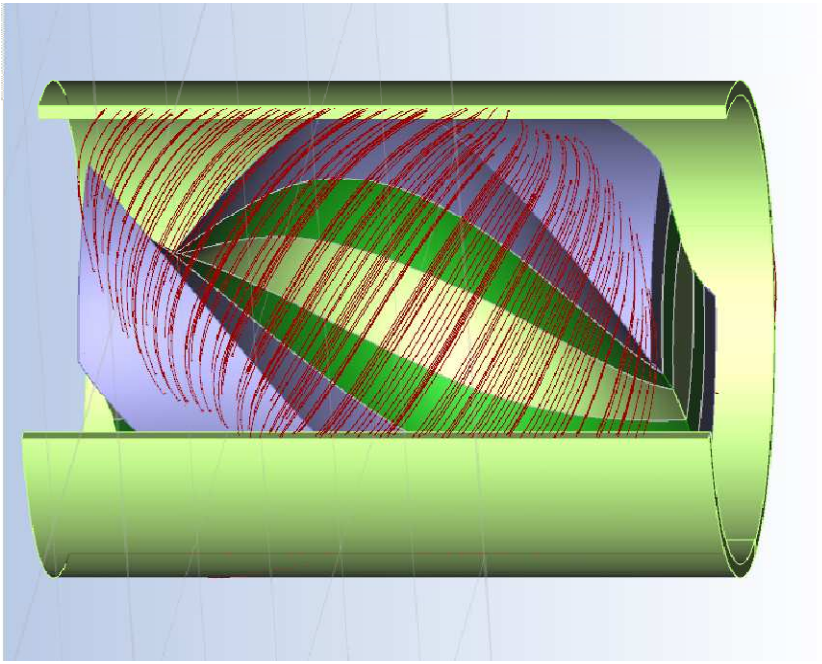
Circumferential MFL



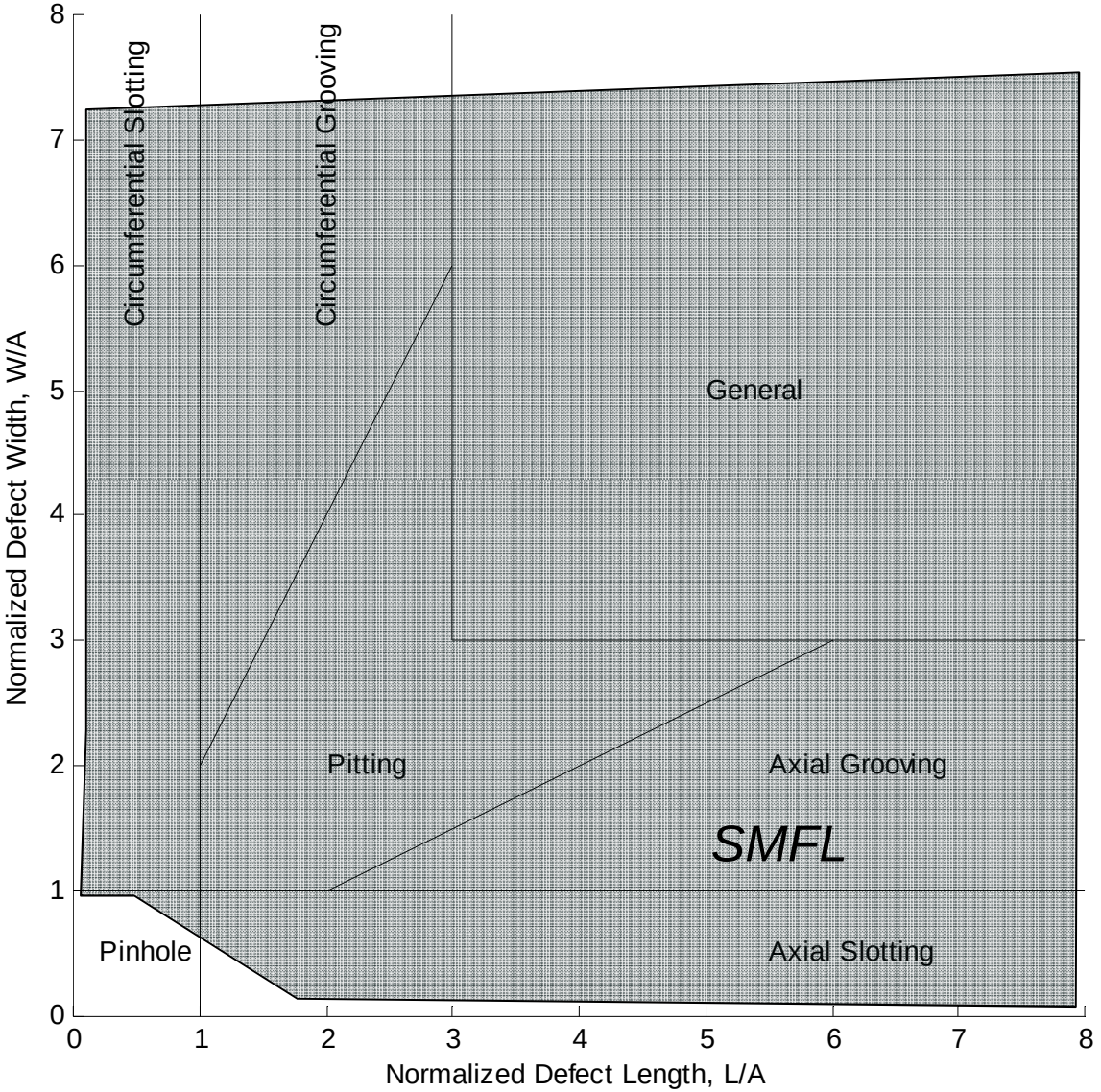
Pipeline Performance™

Pipeline Performance™

SpirALL™ MFL Technology



SpirALL™ MFL



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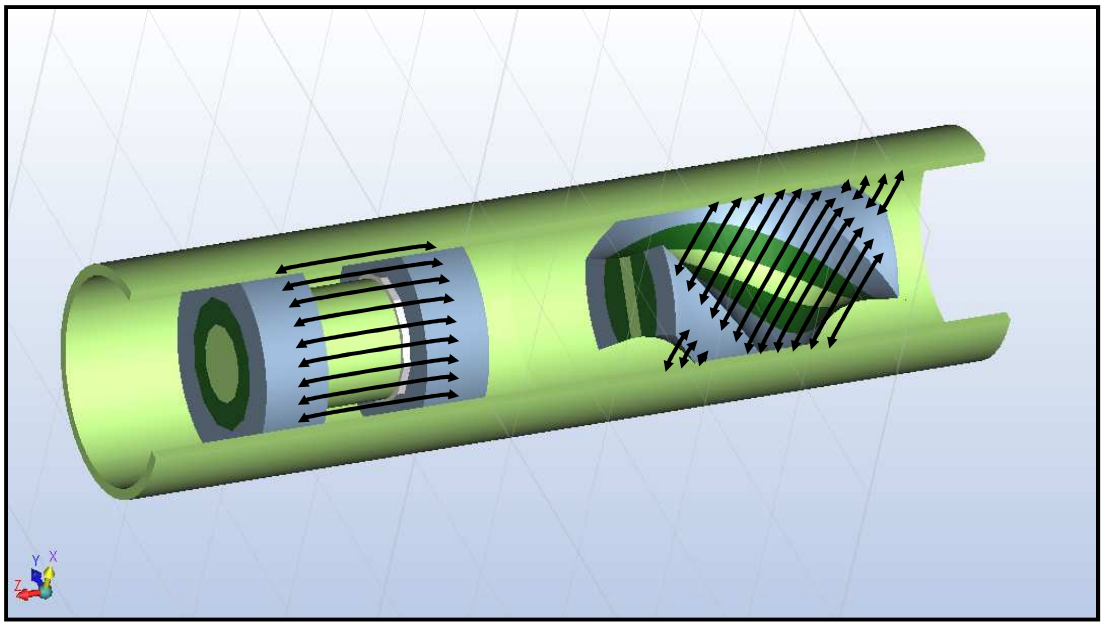
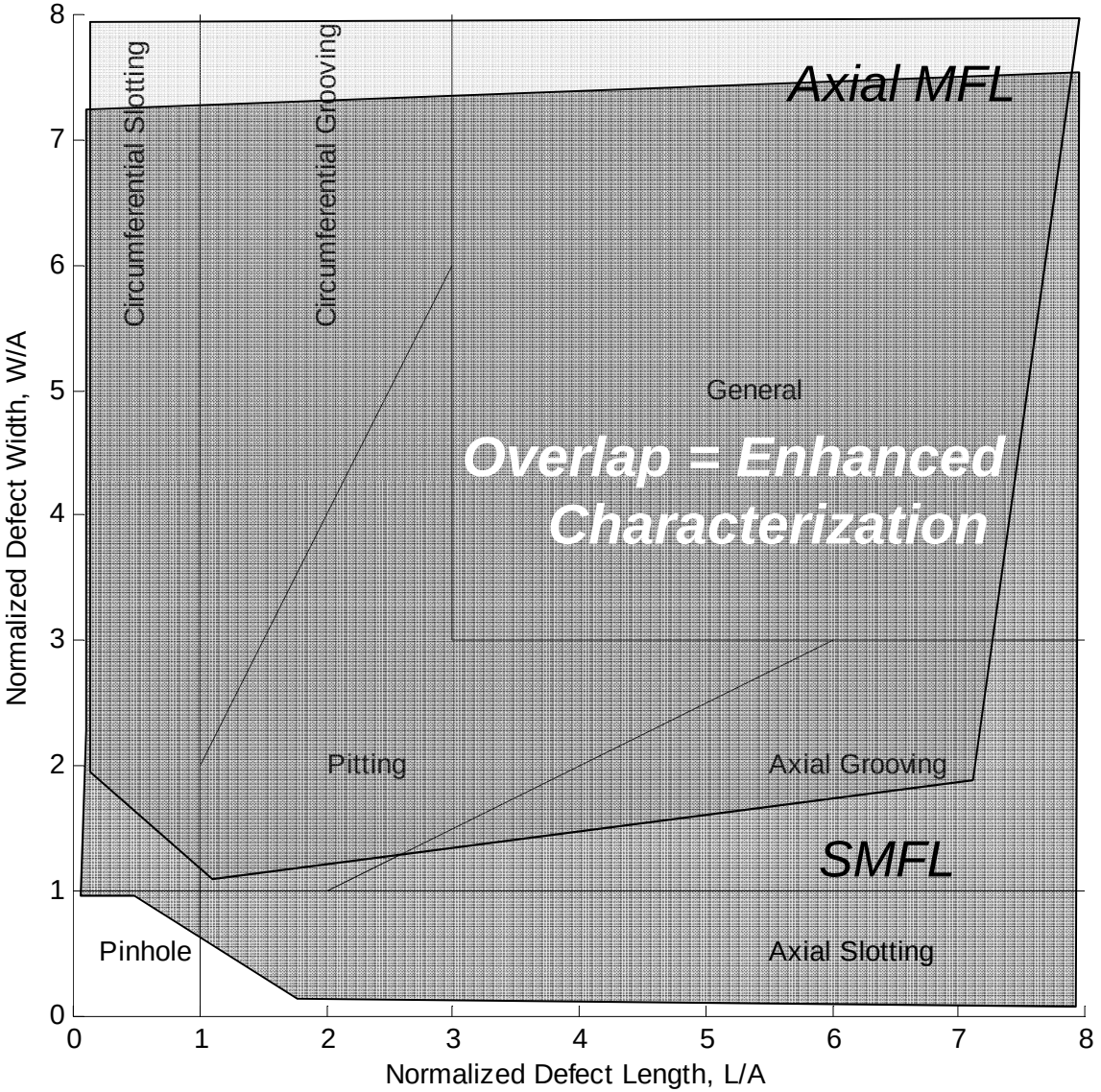
Pipeline Performance™

Axial MFL + SMFL



Axial MFL + SMFL



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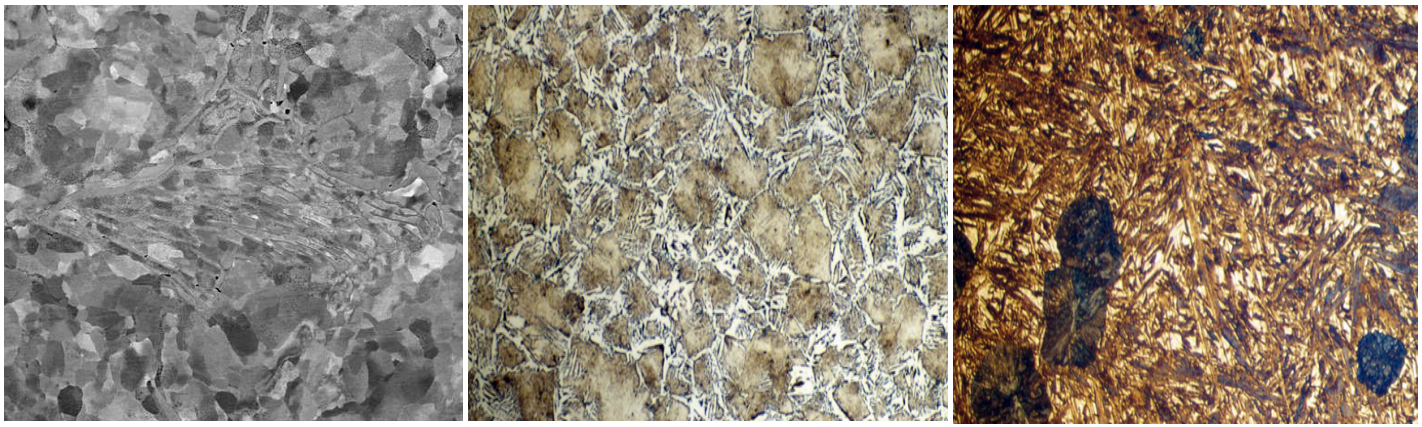
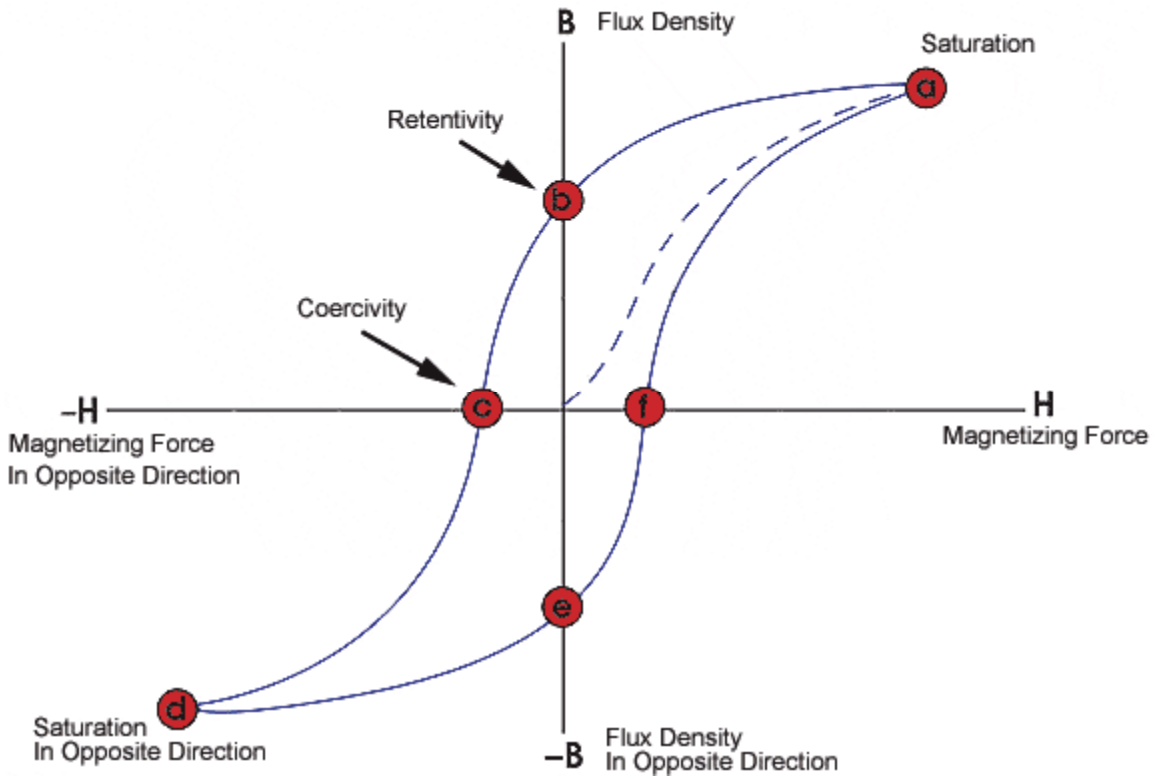
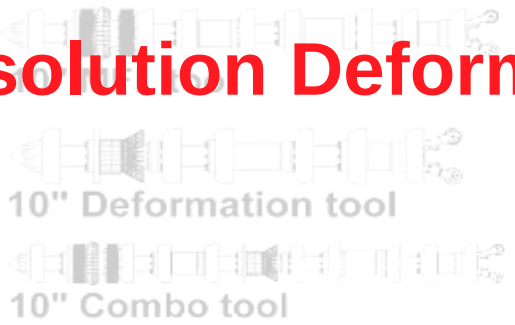
Residual MFL



Theory: B vs H (terminology)



High Resolution Deformation

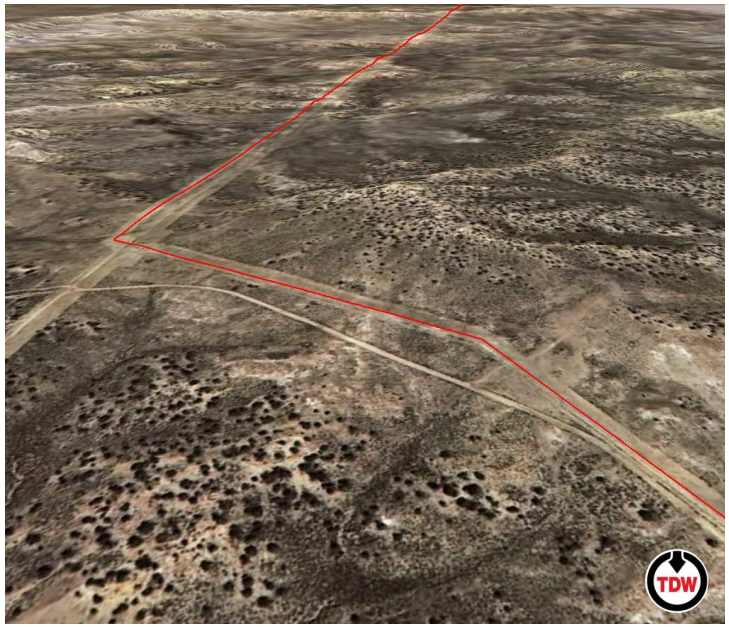


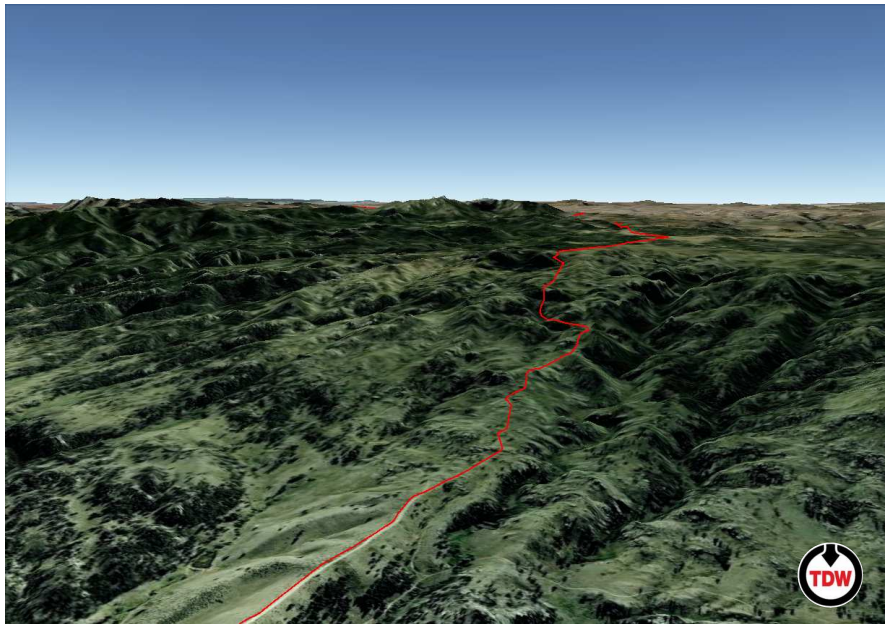
Hi-Res Deformation Tools

- **Provides high resolution geometry data to help operators better manage their IMP**
- **Provides resolution needed for further analysis of I.D. restrictions**

XYZ Mapping

Output from high resolution mapping





IMU's are internal within the tool and therefore nothing is visible on the tool itself. The above screenshots show pipeline routes based on IMU data captured during inspections.

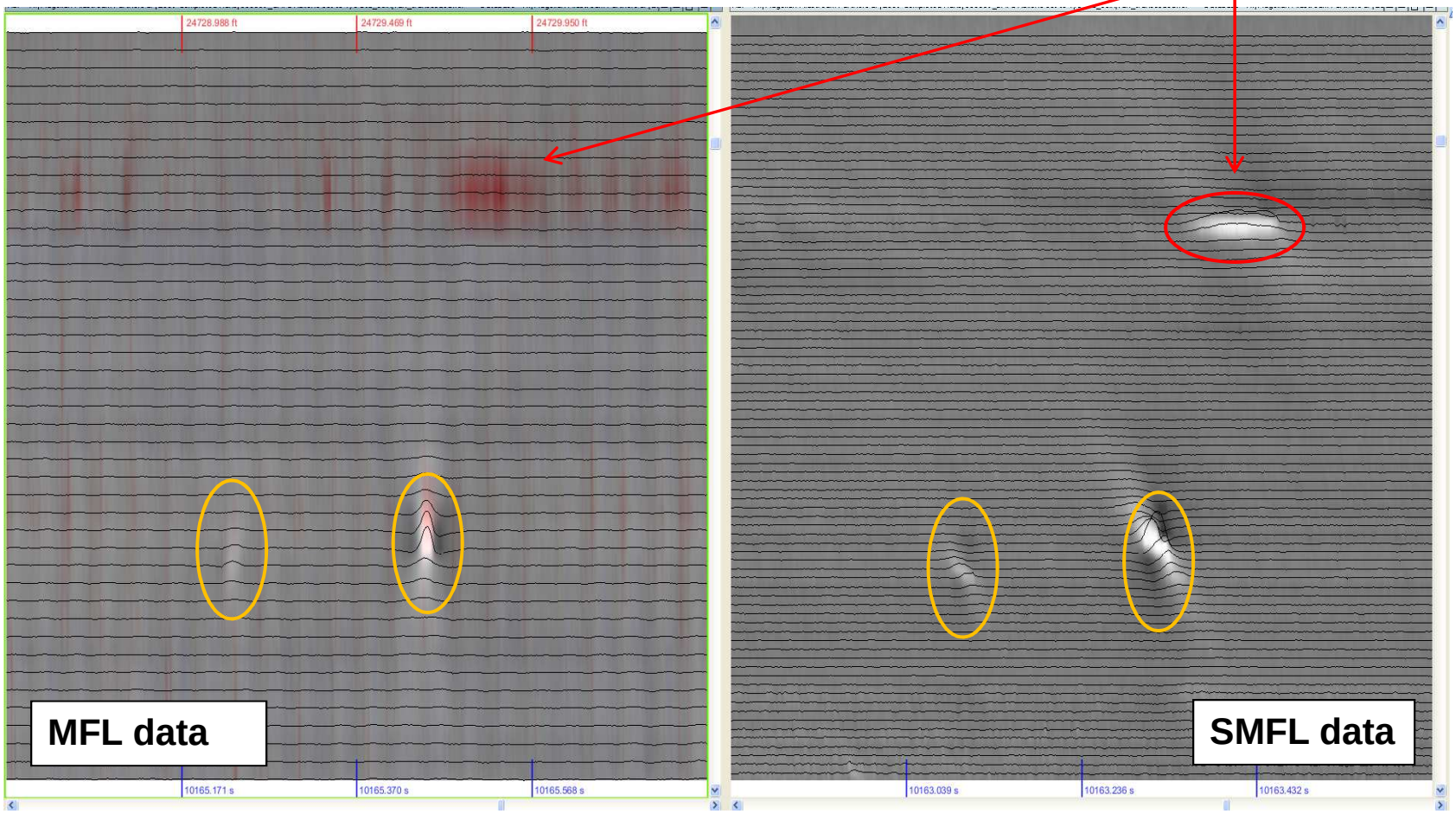
Characterization – Multiple DataSets

- Planar versus Volumetric
- Axially oriented anomalies
- Low level metal loss in seamless pipe
- Metal loss crossing girth welds
- Pipe characteristic changes
- Mechanical damage
  - Ranking system

Characterization

Volumetric versus Planar anomalies

Planar anomaly not visible in MFL

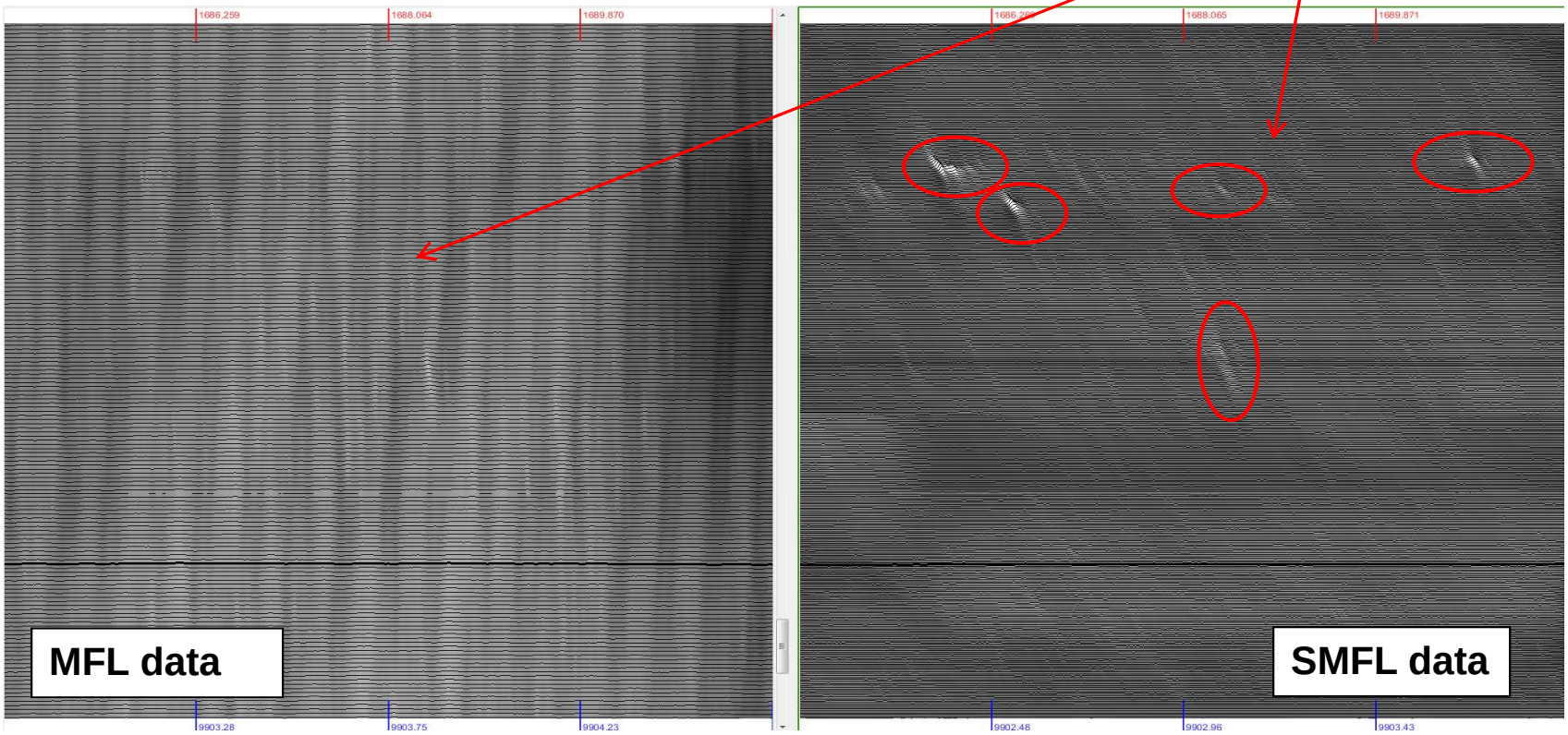


Pipeline Performance™

Characterization

Low-Level Metal Loss in Seamless Pipe

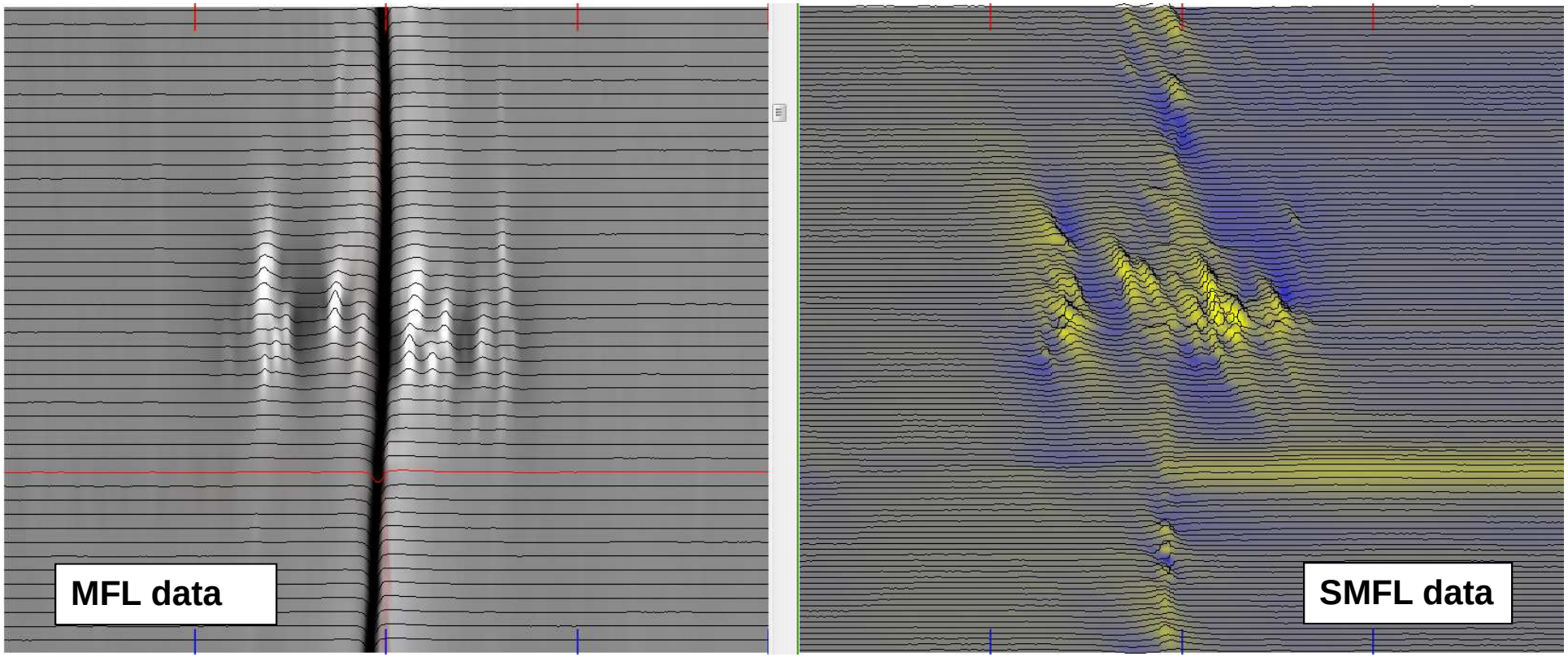
SMFL eliminates seamless noise pattern which makes low-level metal loss visible



Pipeline Performance™

Characterization

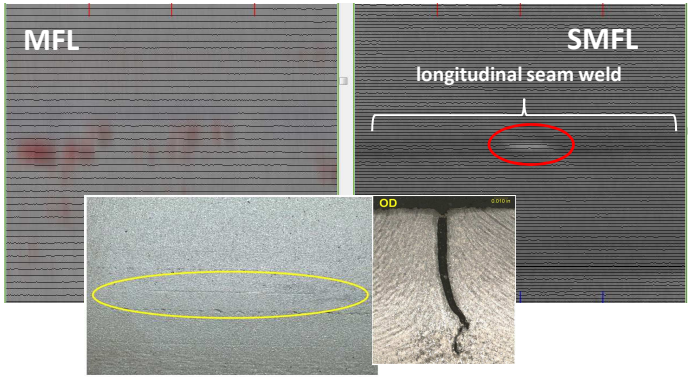
Metal Loss Crossing and in Girth Weld



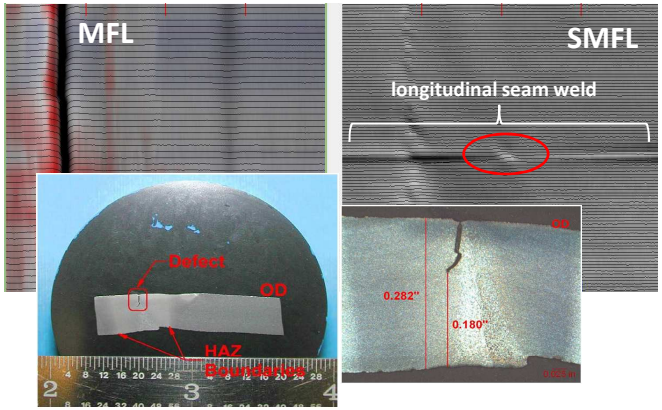
Characterization

Planar/Crack-like anomalies in the Long Seam

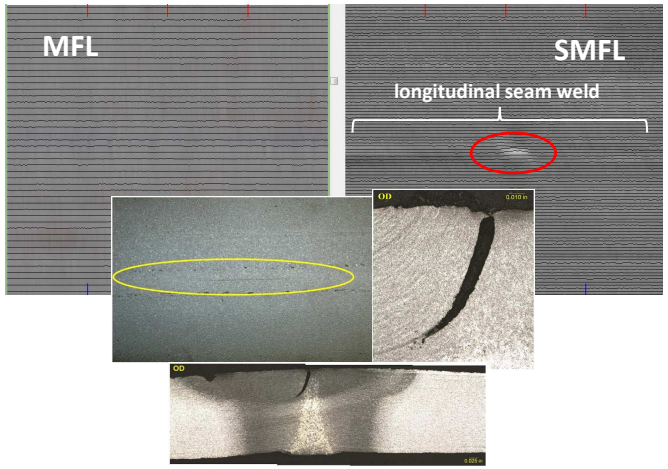
Anomaly 1



Anomaly 2



Anomaly 3



#	Descr.	ILI %	Field %	ILI Length (in.)	Field Length (in.)	ILI Width (in.)	Field Width (in.)
1	Planar	37	39	2.22	2.18	0.04	0.01
2	Planar	35	36	1.92	1.22	0.03	0.01
3	Planar	28	35	1.88	2.00	0.06	0.01

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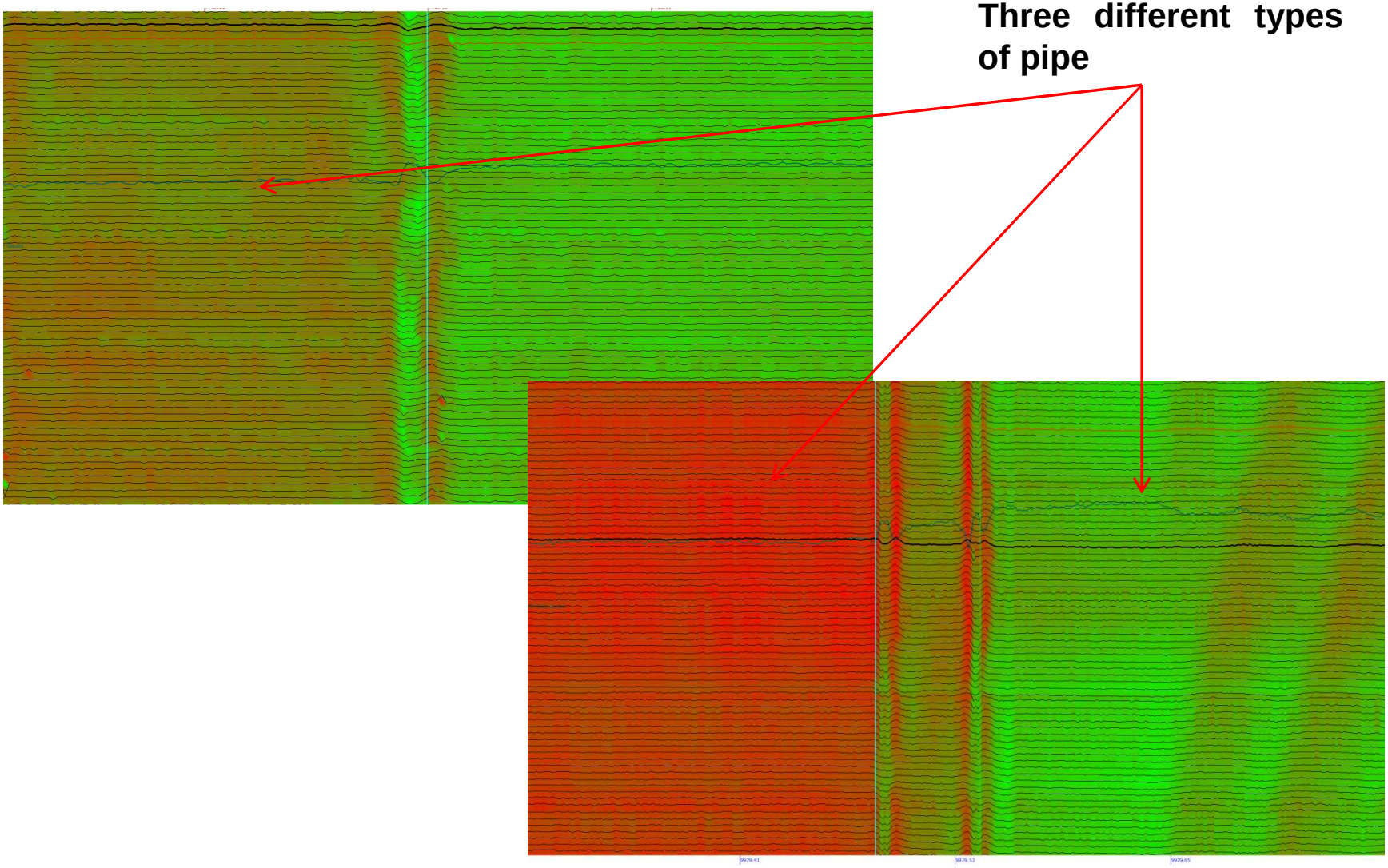
Characterization

Pipe Characteristic Changes



Pipeline Performance™

Mechanical Damage

Pipeline Incidents By Cause

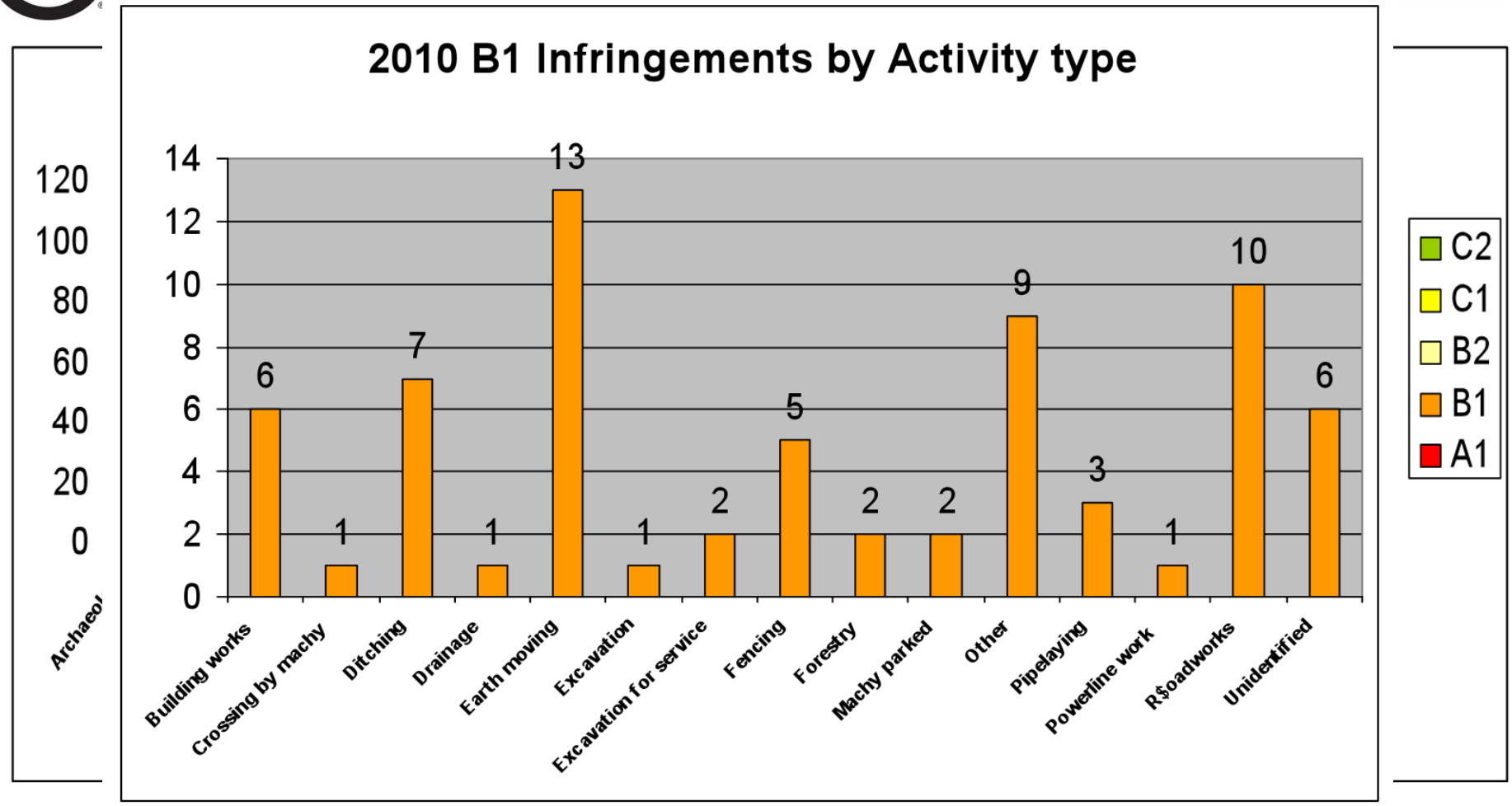


Figure 3: B1 Infringements by Activity Type

From the "2010 Report for the UKOPA Infringement Database", Prepared by the UKOPA Infringement Working Group

Prepared by the Conservation of Clean Air and Water in Europe (CONCAWE) Oil Pipelines Management Group's Special Task Force on oil pipeline spillages (OP/STF-1)

Mechanical Damage

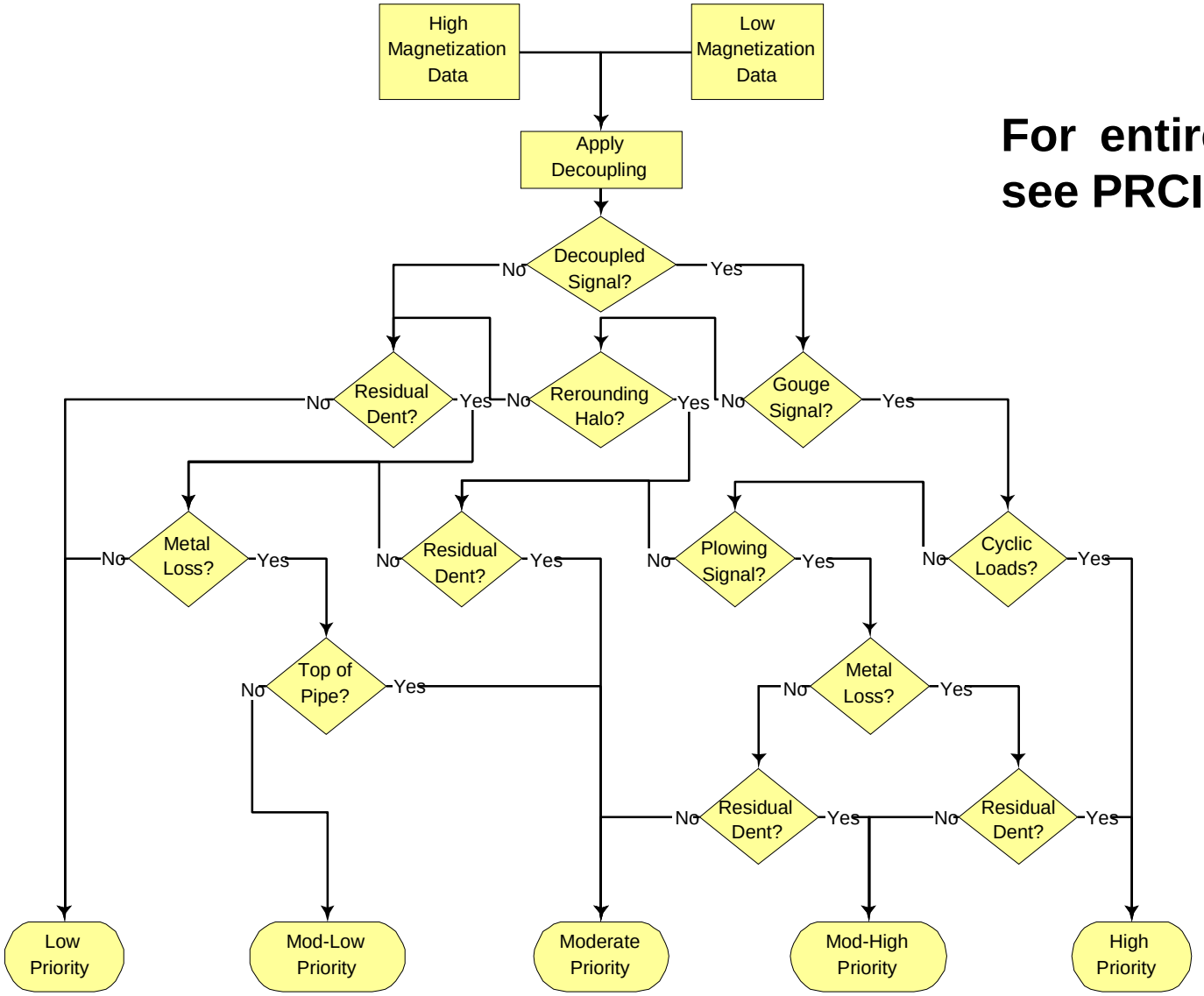
- Mechanical damage is a leading cause of pipeline incidents globally

- To properly determine the severity of mechanical damage the following 4 categories should be measured:
  - Stress
  - Strain
  - Cracking
  - Metal loss

Characterization – Mechanical Damage

- Current mechanical damage system is based off of Battelle research conducted in late 1990's – 2002
- TDW supplemented Battelle work with dent strain analysis and SpirALL™ MFL data set
- Field results from a 16" x 208km (129 mile) pipeline:
  - Built in 1954
  - Has history of very shallow mechanical damage causing product release
  - Every available technology has been run in this pipeline over its history
  - MDS inspection requested to help prioritize mechanical damage

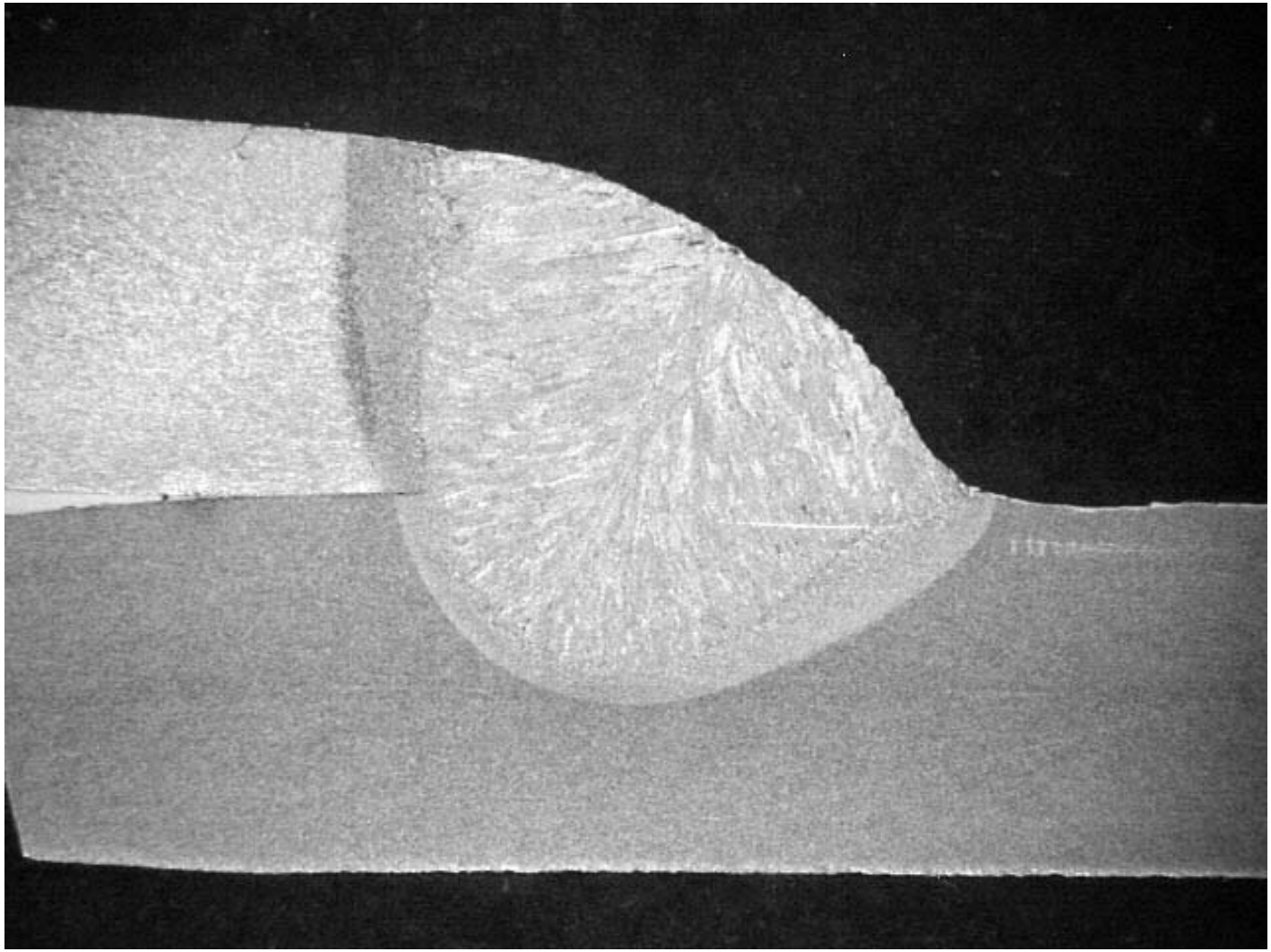
Battelle Ranking System



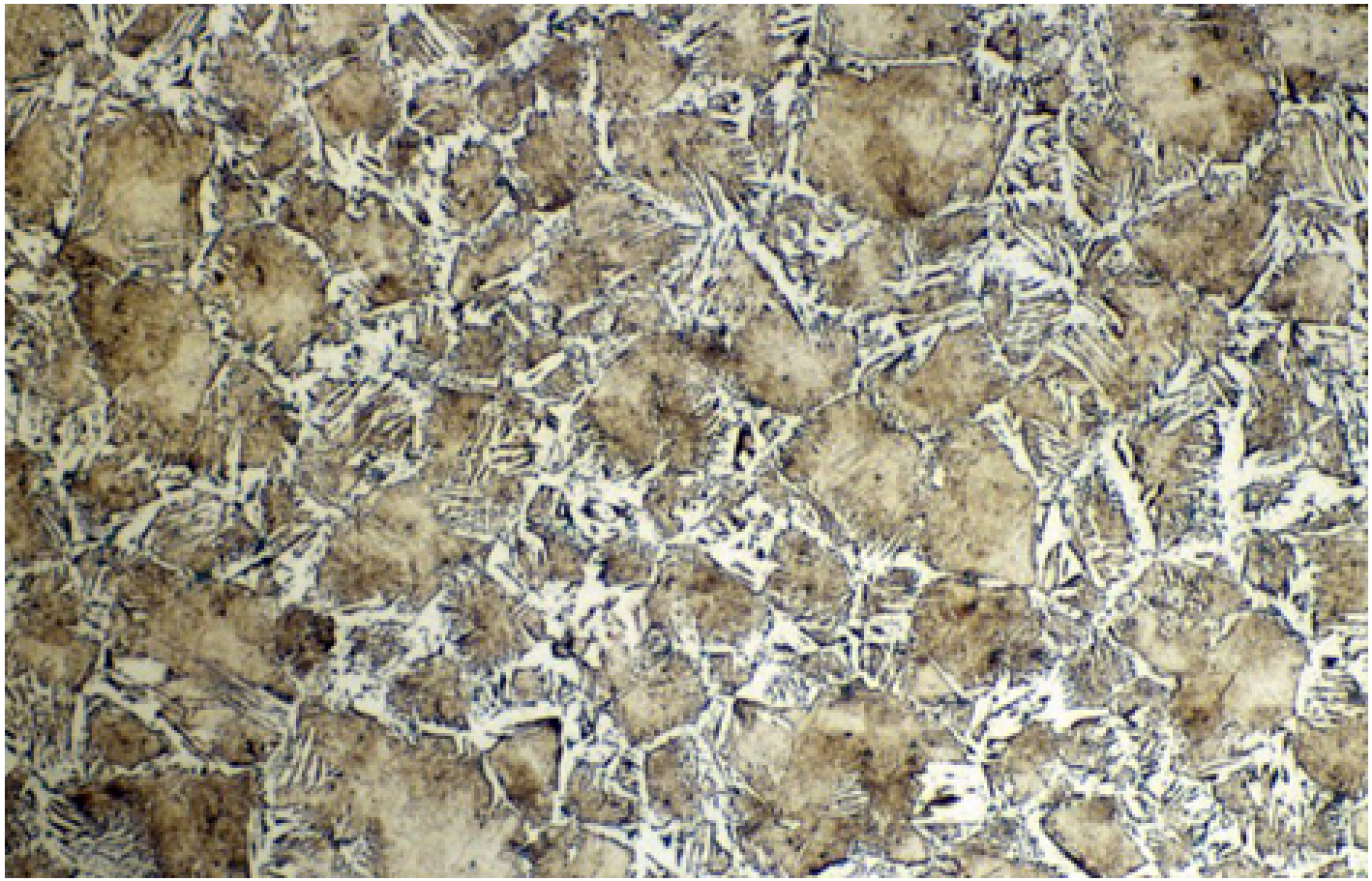
For entire model see PRCI L52084

Pipeline Performance™

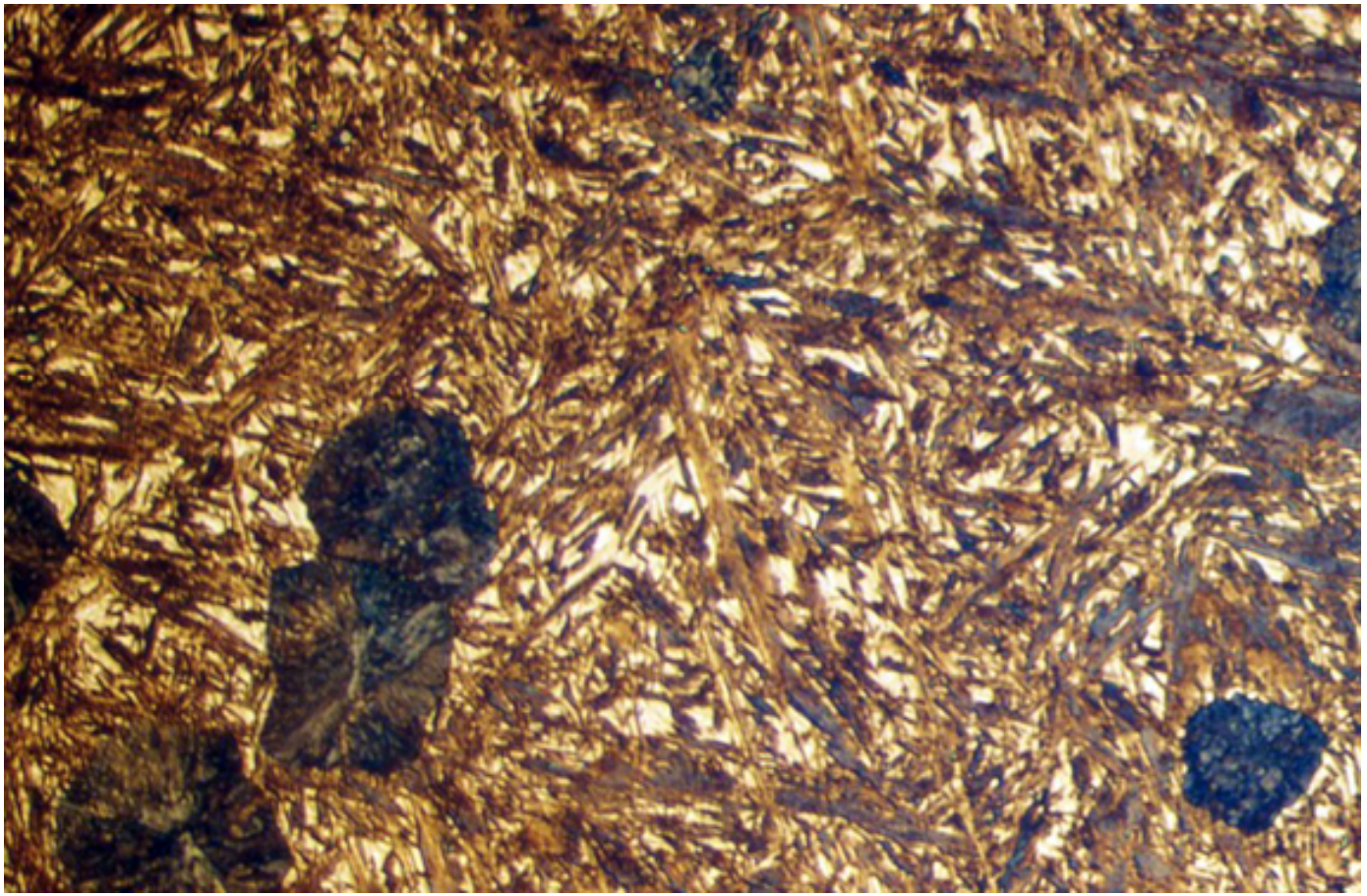
Steel Microstructure (Weld)



Steel Microstructure (Low-carbon)



Steel Microstructure (High-carbon)



Hard Spot / Crack

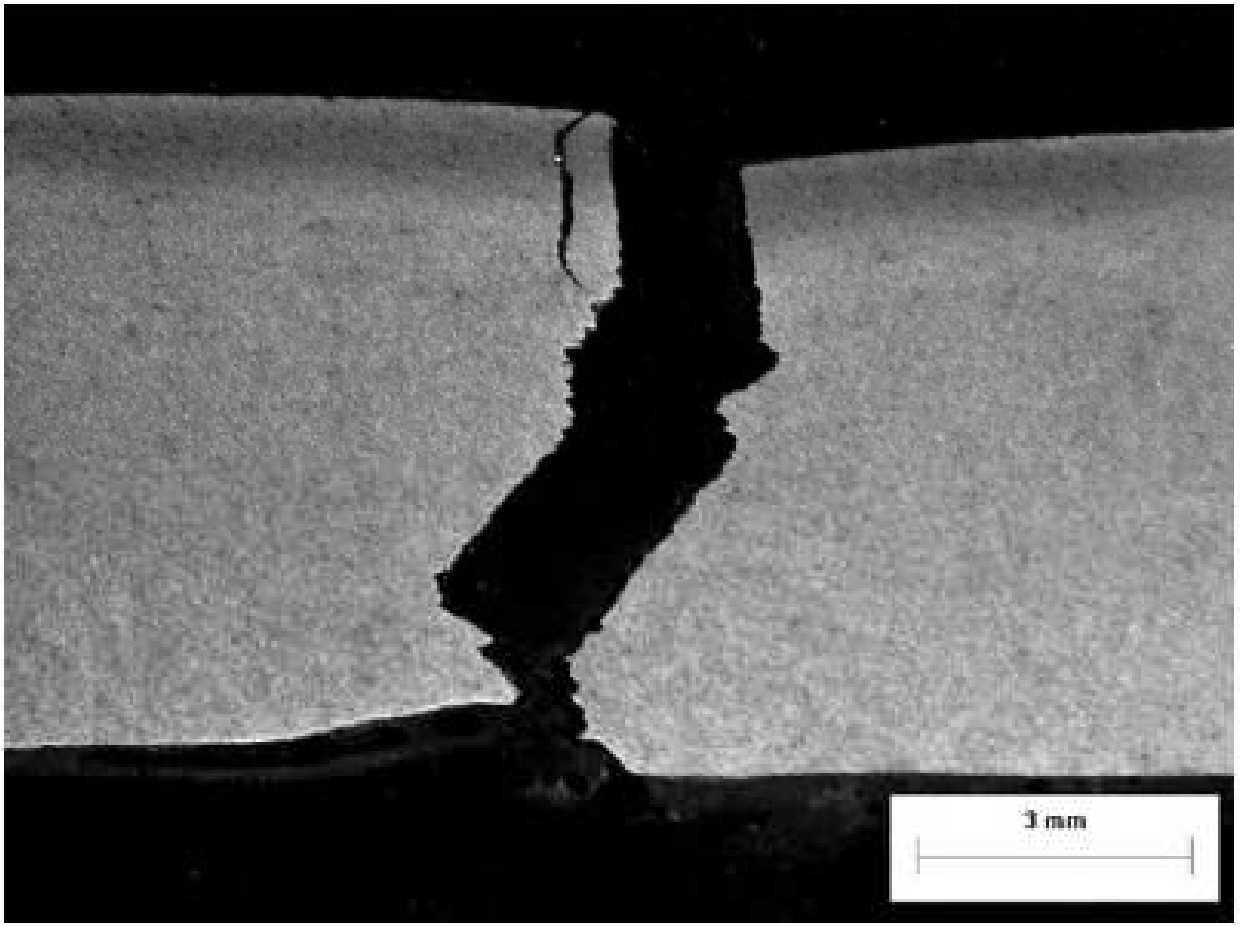


Figure 11. Photomicrograph of cracking initiating in a hard spot.

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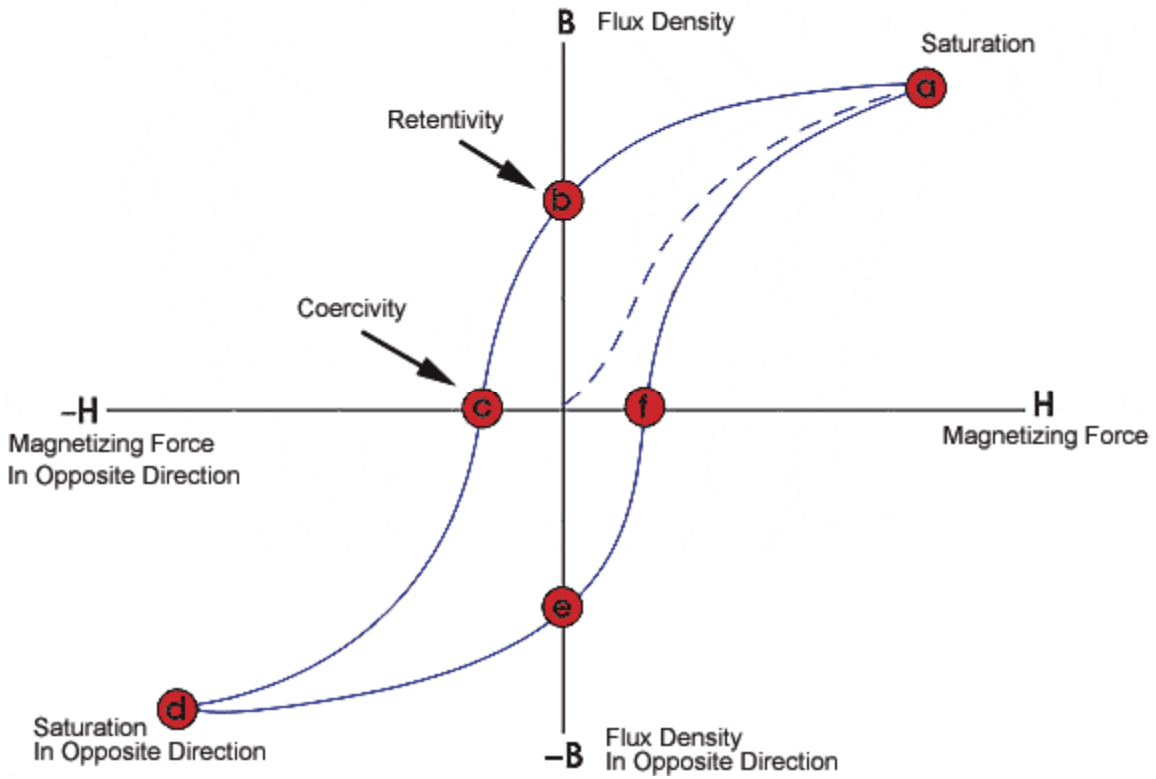
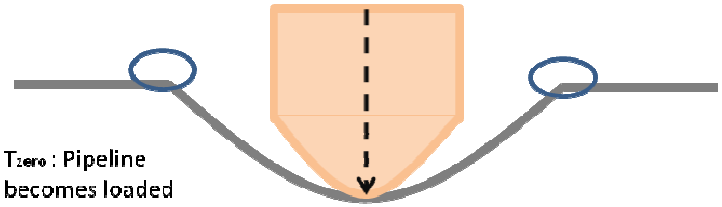
Theory: B vs H (terminology)

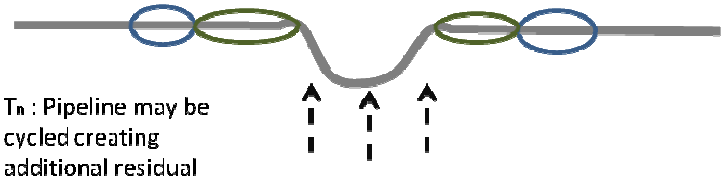


Re-rounded versus Cycled Dents

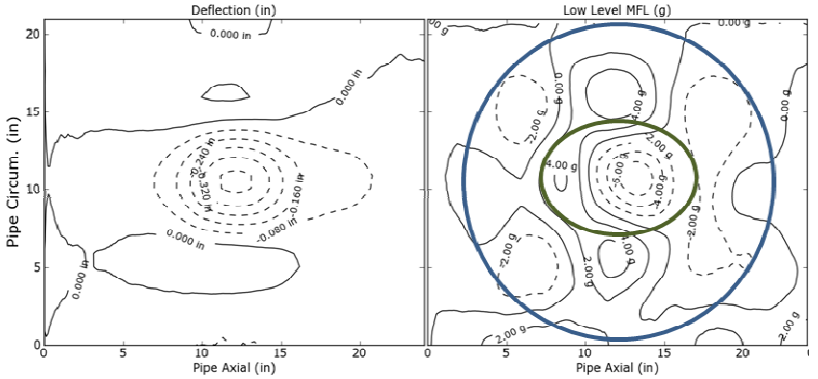


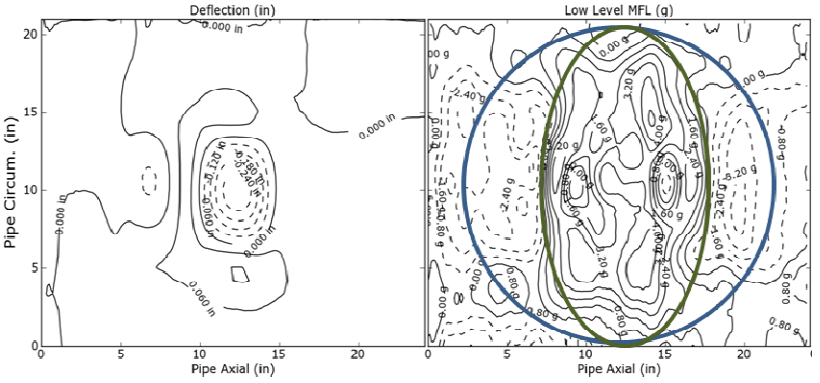
T_{zero} : Pipeline becomes loaded

T_1 : Load removed, leaving re-rounding stress, **blue**, detectable by low-field MFL



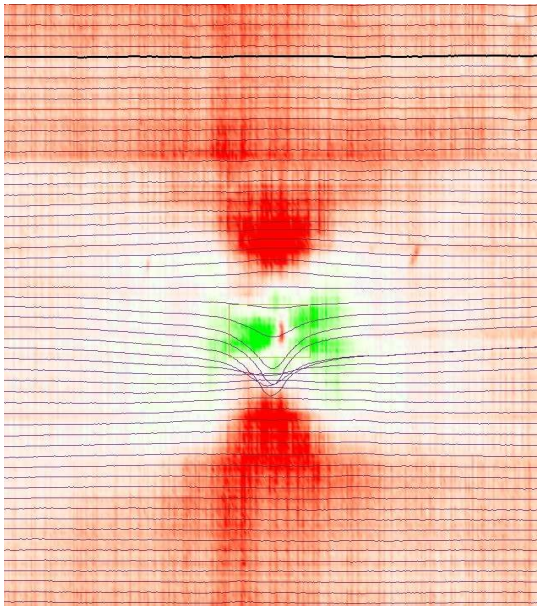
T_n : Pipeline may be cycled creating additional residual stresses, **green**, detectable by low-field MFL



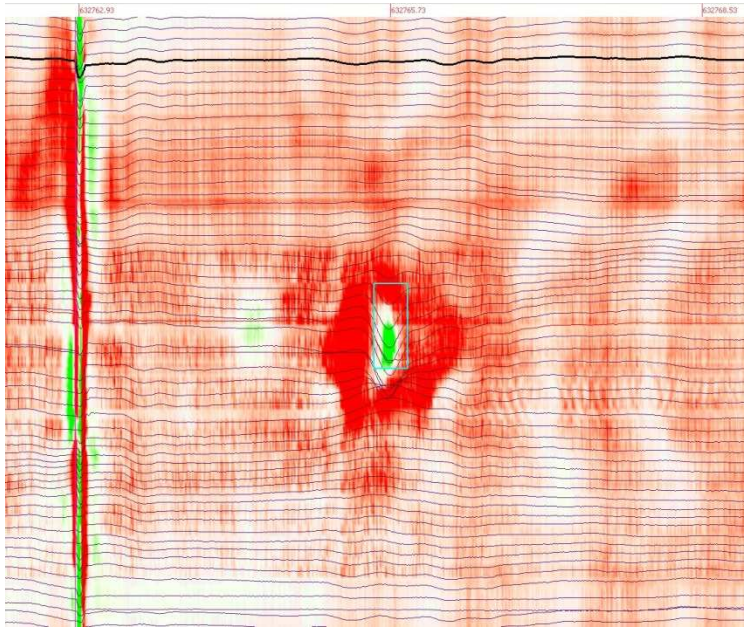


Pipeline Performance™

Re-rounded versus Cycled Dents



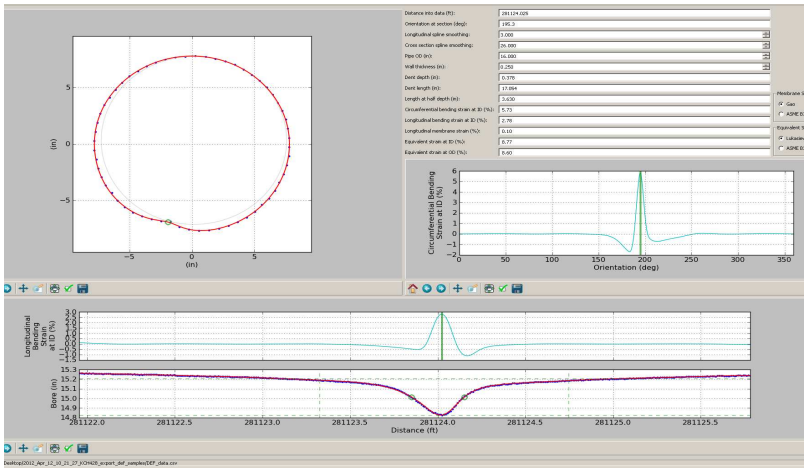
Re-rounded dent signature

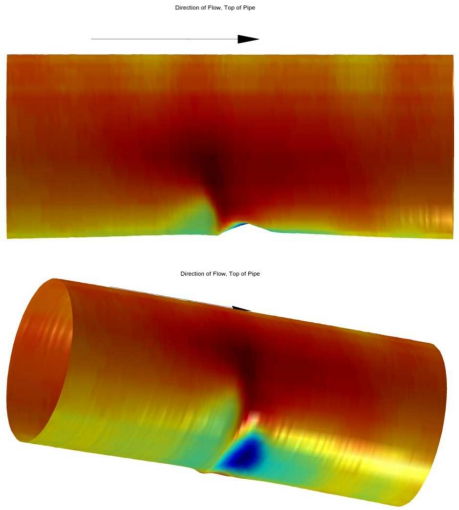


Cycled dent signature, notice the strong "halo" effect

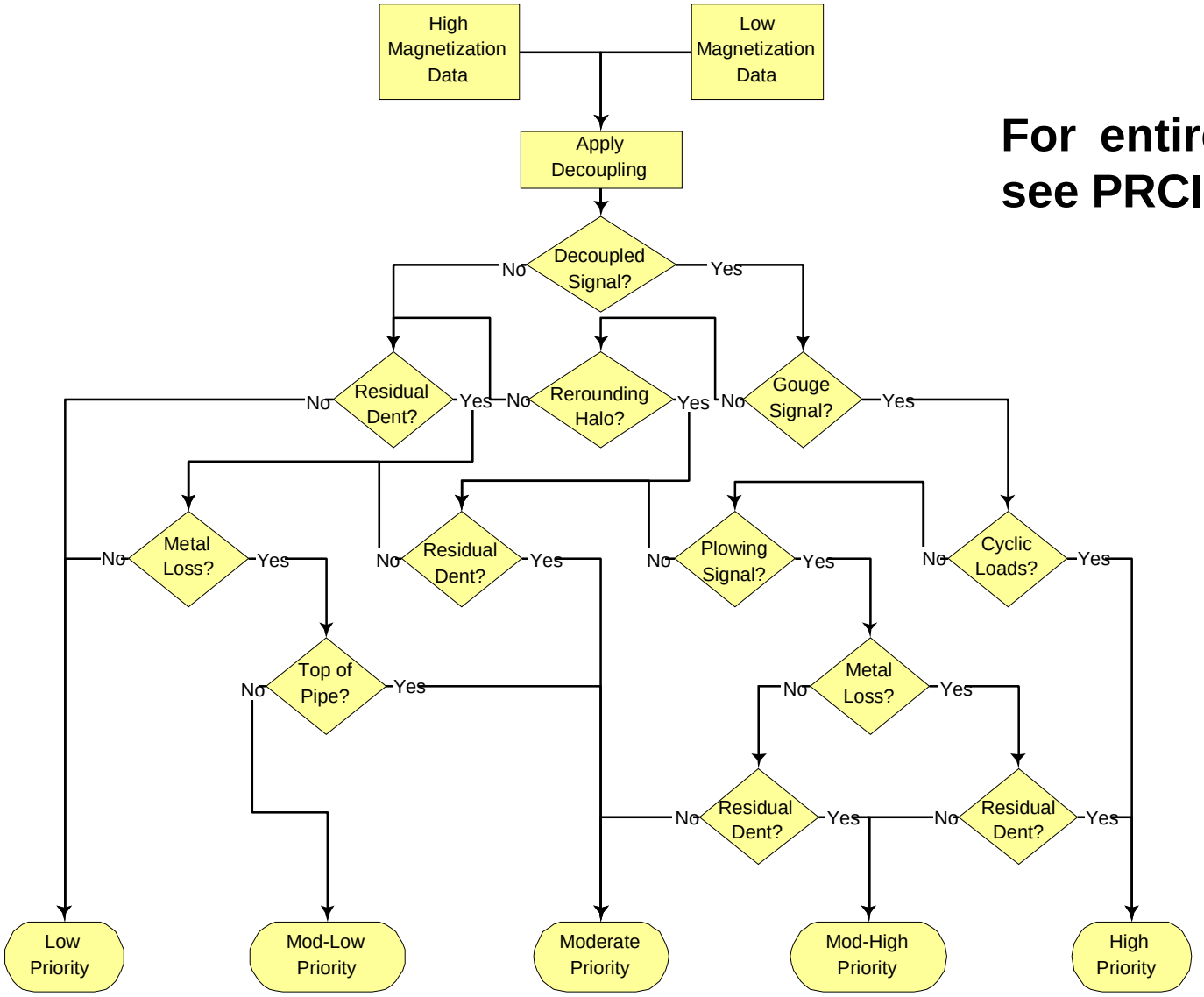
Strain Calculations

- ASME B31.8 provides non-mandatory Appendix R which outlines methods for estimating strains in a dent
  - Enhancements to the ASME formulas, suggested by recent industry research, have been incorporated
- Computations can be carried out using high resolution deformation data
- Local dent strain can be estimated by analyzing the deformed shape
- The Battelle prioritization model is then supplemented:
  - If a dent exhibits strain > 6% then considered higher priority





Prioritization – Mechanical Damage



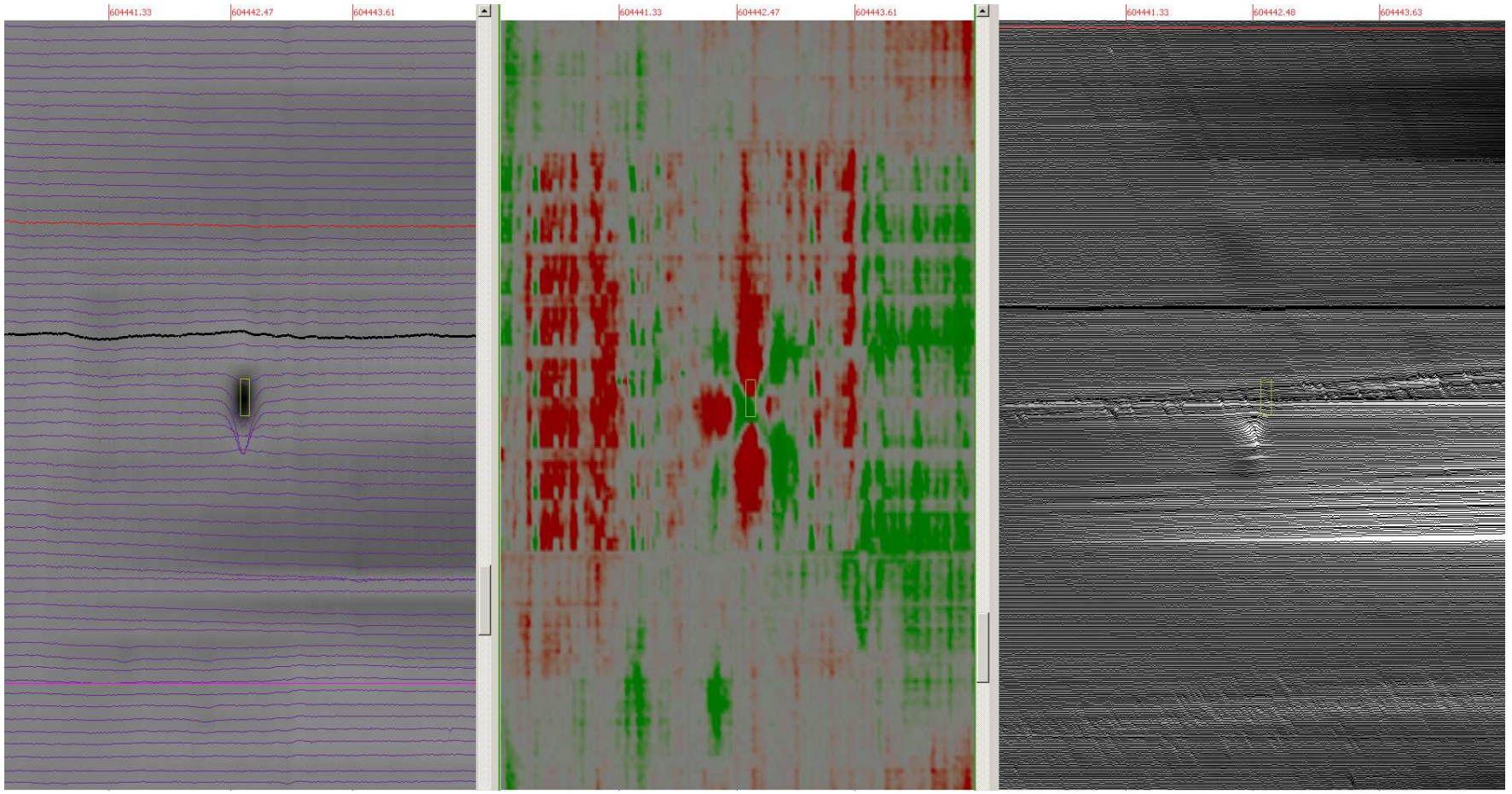
For entire model see PRCI L52084

Pipeline Performance™

Prioritization – Mechanical Damage

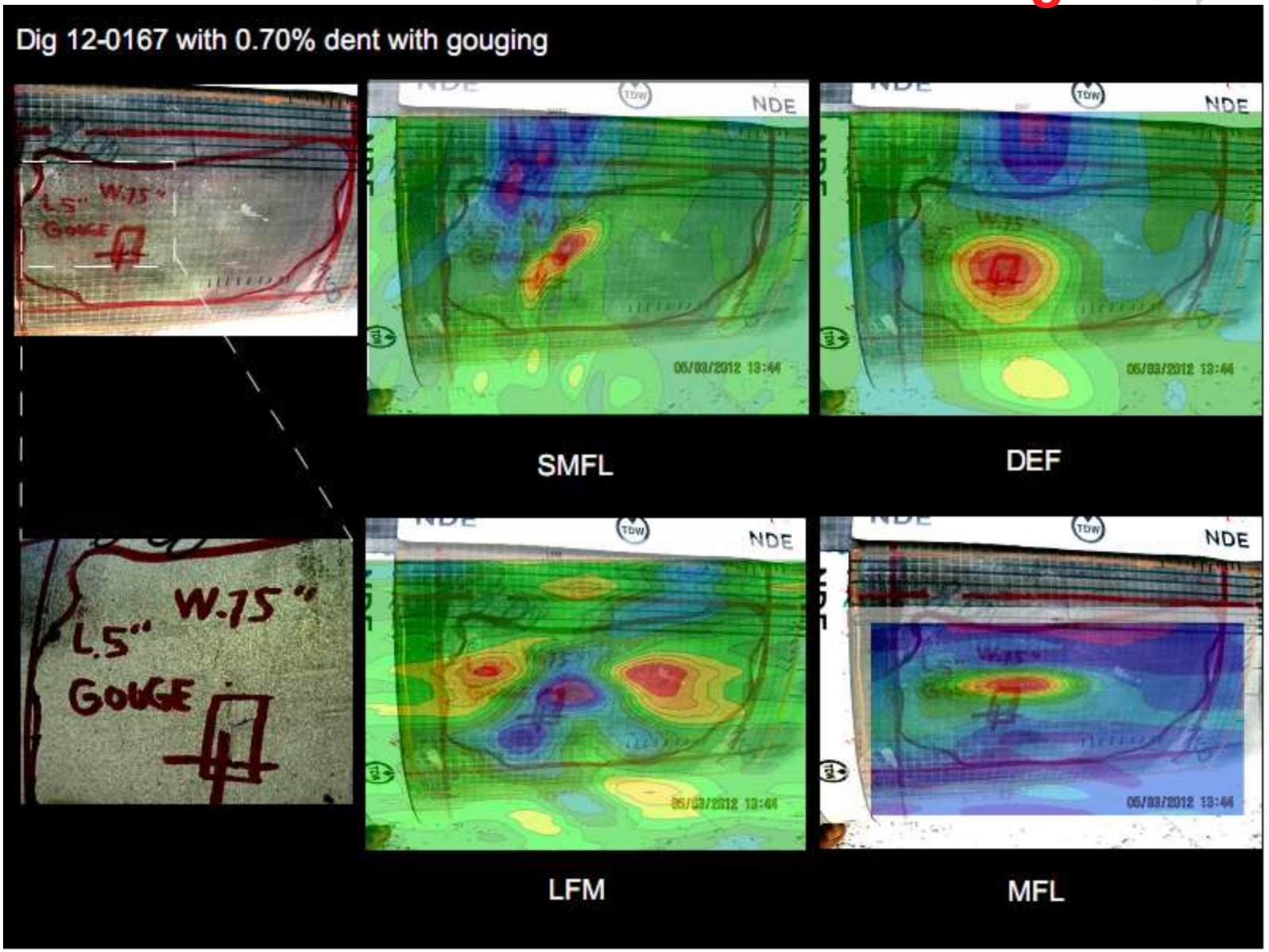
Dist Start	Dent Depth (in)	Orientation (Deg)	Description	Seam or not	Depth %	Dent Length (in)	Severity Number	Final Severity
563805.8569	0.32	146	Dent w/ Metal Loss - Re-rounded (3.61% Strain)		2.0%	4.24	1	High
659396.4219	0.19	6	Dent w/ Metal Loss (3.03% Strain)		1.2%	2.24	1	High
130172.3133	0.17	301	Dent w/ Metal Loss - Re-rounded (5.72% Strain)		1.1%	2.36	1	High
377391.8188	0.16	299	Dent w/ Metal Loss - Re-rounded, Found in SpirALL (4.75% Strain)		1.0%	4.24	1	High
565775.0268	0.16	334	Dent w/ Metal Loss - Re-rounded (2.27% Strain)		1.0%	3.18	1	High
366167.134	0.15	194	Dent w/ Metal Loss, Found in SpirALL (1.47% Strain) Cycled		0.9%	3.30	1	High
679479.7892	0.14	352	Dent w/ Metal Loss - Re-rounded, Found in SpirALL (1.67% Strain)		0.9%	11.43	1	High
286669.7504	0.14	65	Dent w/ Metal Loss - Re-rounded (2.67% Strain)		0.9%	1.53	1	High
274771.2529	0.12	103	Dent w/ Metal Loss - Re-rounded, Found in SpirALL		0.8%	3.06	1	High
281119.0863	0.47	173	Re-rounded (8.7% Strain)		2.9%	4.95	2	Moderate High
145897.5576	0.38	150	Re-rounded (8.56% Strain)		2.4%	5.42	2	Moderate High
82737.50682	0.24	352	Cycled		1.5%	4.71	2	Moderate High
604442.564	0.15	23	Re-rounded	Seam	0.9%	1.06	2	Moderate High
317119.5096	0.15	327	Re-rounded	Seam	0.9%	2.00	2	Moderate High
389412.3769	0.15	194	Dent w/ Metal Loss, Found in SpirALL (1.88% Strain)		0.9%	4.83	2	Moderate High
202455.0887	0.13	3	Re-rounded	Seam	0.8%	1.65	2	Moderate High
575501.0933	0.13	266	Cycled		0.8%	1.53	2	Moderate High
619295.5526	0.4	150	Re-rounded (4.58% Strain)		2.5%	5.42	3	Moderate
564414.8644	0.39	162	Re-rounded (5.37% Strain)		2.4%	4.71	3	Moderate
599695.4015	0.39	154	Re-rounded (4.7% Strain)		2.4%	6.95	3	Moderate
605422.7802	0.37	144	Re-rounded (3.03% Strain)		2.3%	4.95	3	Moderate
287642.8391	0.35	163	Re-rounded (4.5% Strain)		2.2%	3.65	3	Moderate
654564.5542	0.35	141	(2% Strain)		2.2%	4.48	3	Moderate
632760.8802	0.32	130	Cycled (3.3% Strain)		2.0%	3.65	3	Moderate
475118.7453	0.23	356	Re-rounded (5% Strain)		1.4%	2.12	3	Moderate
62031.35495	0.23	281	Re-rounded (2.65% Strain)		1.4%	3.30	3	Moderate
465704.099	0.21	321	Re-rounded		1.3%	1.41	3	Moderate
425597.8694	0.17	24	Re-rounded		1.1%	2.00	3	Moderate
121592.4458	0.16	316	Re-rounded		1.0%	2.71	3	Moderate
413966.4564	0.16	175	Re-rounded	Seam	1.0%	2.36	3	Moderate
325555.1375	0.15	33	Re-rounded		0.9%	4.59	3	Moderate
599471.0623	0.13	337	Re-rounded		0.8%	2.00	3	Moderate
434338.2514	0.13	45	Re-rounded		0.8%	2.12	3	Moderate
551561.8431	0.13	144	Cycled (2.38% Strain)		0.8%	4.01	3	Moderate
474250.7626	0.1	337	Re-rounded		0.6%	4.36	3	Moderate
363526.537	0.08	224	Cycled		0.5%	3.06	3	Moderate
142303.7616	0.01	284	Re-rounded		0.1%	0.82	3	Moderate
605031.3181	0.23	154	Re-rounded (3% Strain)		1.4%	2.59	4	Moderate Low
598349.445	0.23	169	Re-rounded		1.4%	2.71	4	Moderate Low
67242.64924	0.22	146	Re-rounded		1.4%	4.01	4	Moderate Low
432175.6281	0.21	159	Re-rounded		1.3%	6.83	4	Moderate Low
125388.8254	0.2	139	Re-rounded		1.3%	1.88	4	Moderate Low
442481.8584	0.19	146	Re-rounded		1.2%	6.60	4	Moderate Low
177801.1426	0.17	153	Re-rounded		1.1%	2.71	4	Moderate Low
223890.7645	0.16	127	Re-rounded		1.0%	3.42	4	Moderate Low
80958.45209	0.15	153	Re-rounded		0.9%	4.12	4	Moderate Low
195467.1257	0.15	138	Re-rounded		0.9%	5.18	4	Moderate Low
414568.2678	0.12	176	Re-rounded		0.8%	4.83	4	Moderate Low
61580.10436	0.09	200	Re-rounded		0.6%	2.12	4	Moderate Low
575503.2139	0.04	223	Re-rounded		0.3%	1.06	4	Moderate Low
575499.6501	0.04	196	Re-rounded		0.3%	0.71	4	Moderate Low
142072.992	0.02	231	Re-rounded		0.1%	0.35	4	Moderate Low

Characterization – Mechanical Damage



Dent on seam weld with re-rounding

Characterization – Mechanical Damage



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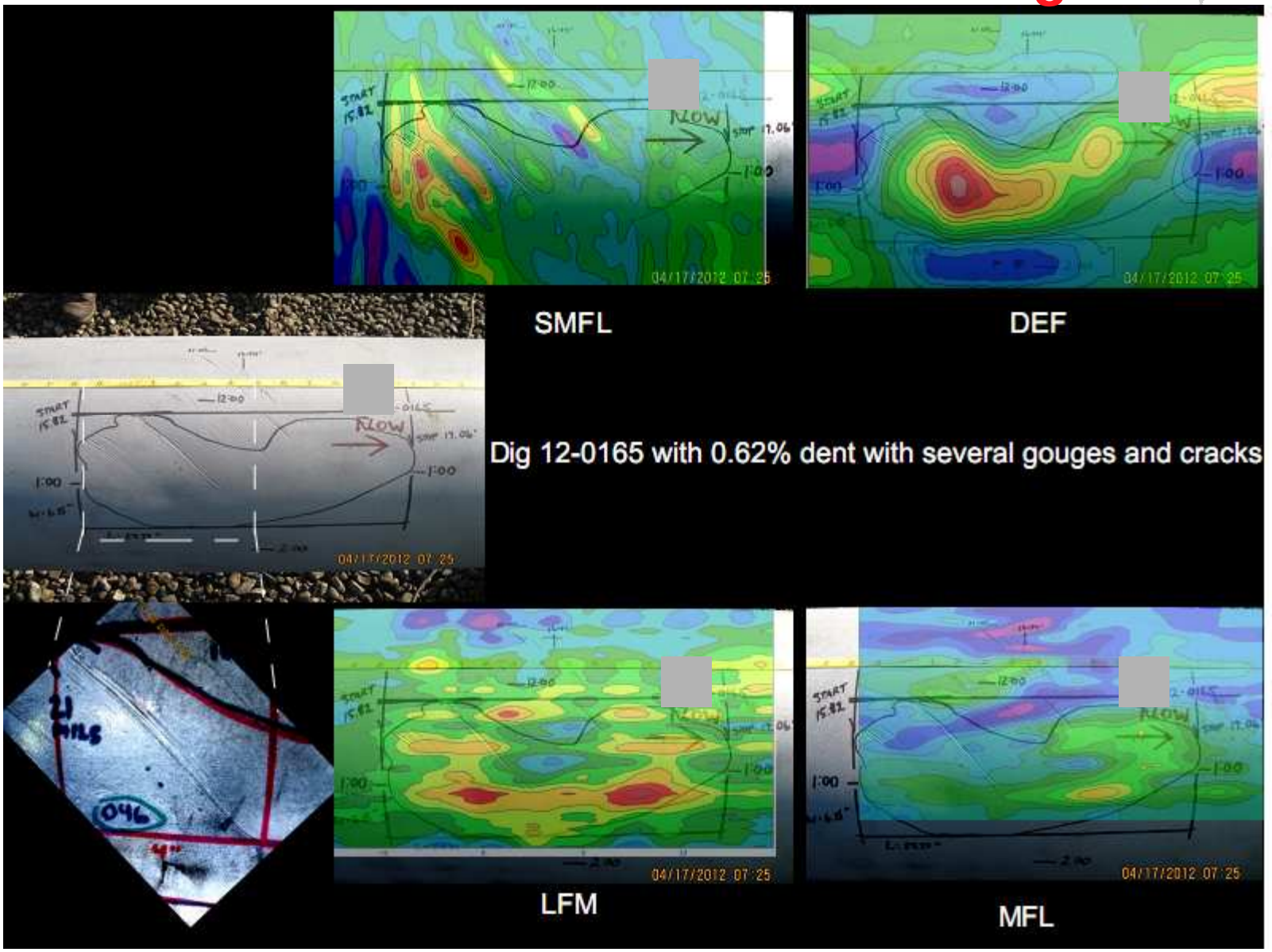
Characterization – Mechanical Damage



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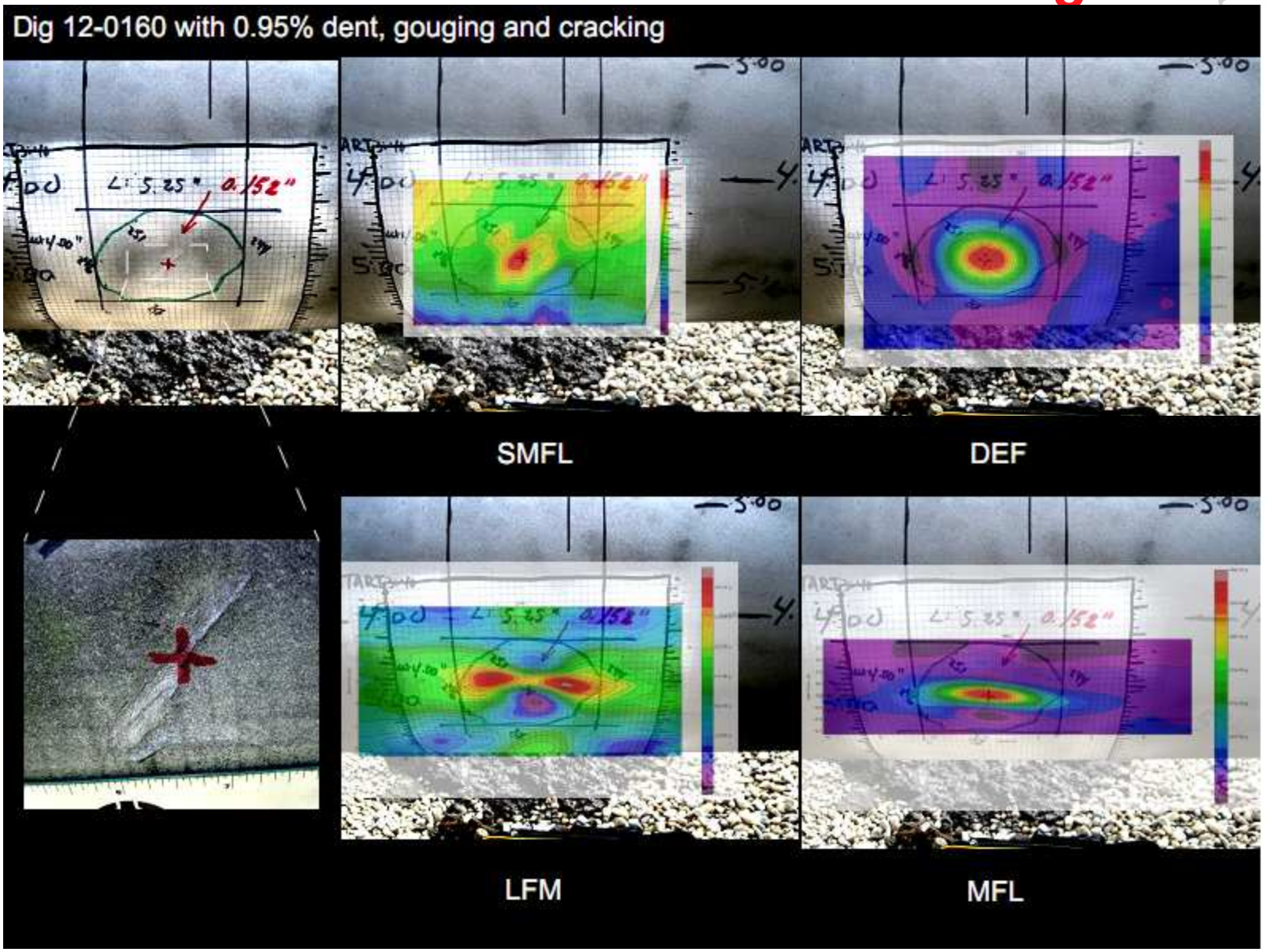
Characterization – Mechanical Damage



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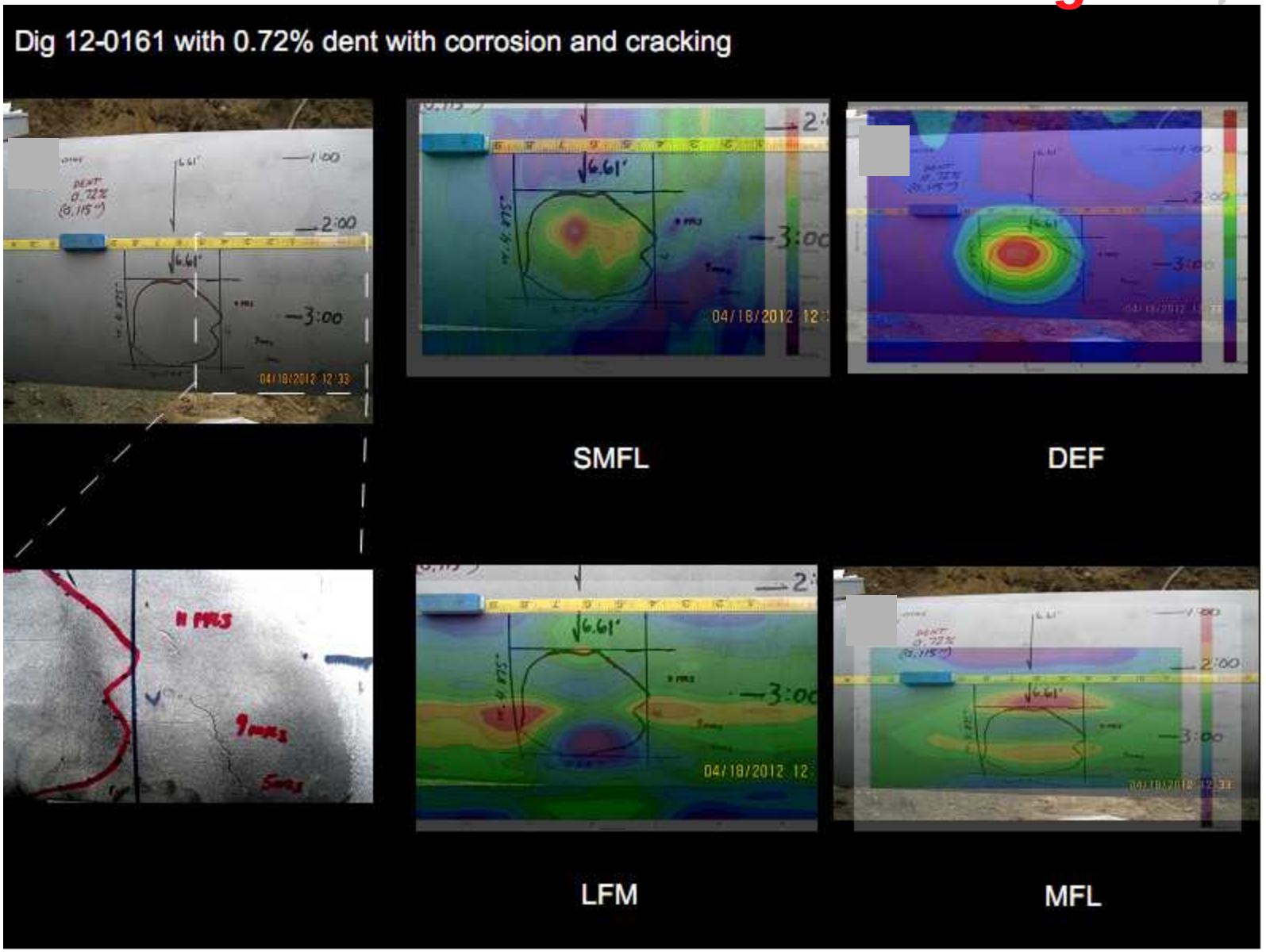
Characterization – Mechanical Damage



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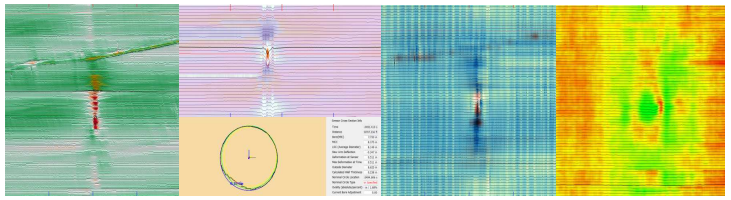
Summary



- Independent technologies have limitations as defined by Standards such as NACE SP0102, API 1160, etc.

- Combining Multiple DataSets on a single platform has distinct advantages and overcomes limitations

- Mechanical Damage continues to be a leading cause of pipeline failure

- Most “severe” or potentially injurious mechanical damage has proven to be shallow dents with other factors involved

- Multiple DataSets facilitate a comprehensive assessment and ranking system for Mechanical Damage

Thank You!

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