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Achieving Critical Assessments of pipelines through Accurate and Reliable Inspection information

BAKER HUGHES a GE company

TECMA

Introduction

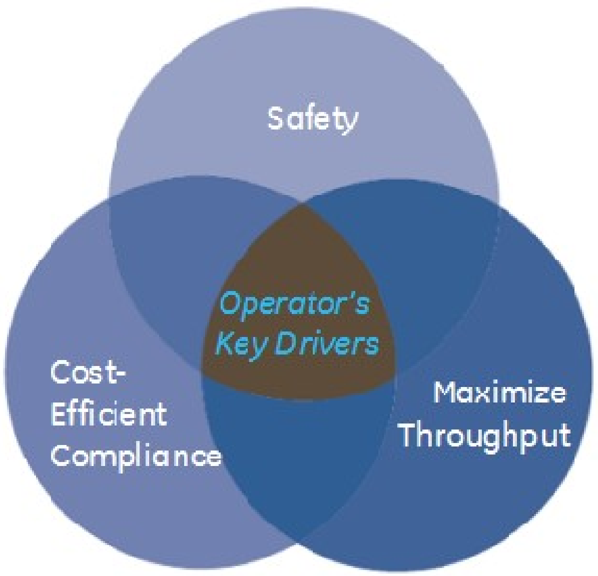
Pipeline operators must balance key concerns while running a business:

- People
- Environment
- Reputation
- Shareholders

This circumstance being an even greater challenge in tough economic times when budgets are continually under pressure.

Inspection datasets can be used to provide a priority focus and advanced analysis on **targeted and problematic regions of interest**.

Such areas may be of high consequence or other regions identified from historic inspections or from risk assessment.



State of Health of a Pipeline

"Health" for ageing pipelines vs. new pipelines, infers deterioration and impact of change over a pipeline's lifetime.

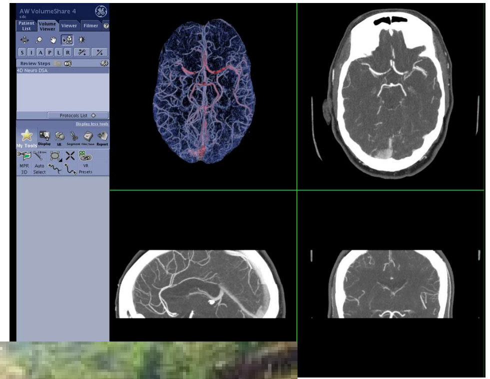
Healthcare as
1) form of accidental injurious incidents (e.g. outside force),
2) fundamental chronic issues (e.g. corrosion)
3) cumulative issues (e.g. fatigue).

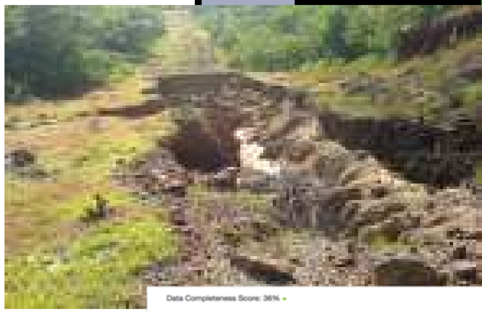
We may see hints of the issue via symptoms: but can confirm with tests/inspection, then decide scale of treatment required.

Prioritization results from accurate and reliable diagnosis - this relies on accurate and reliable measurements, including sensitivity to changes over time.

An effective diagnosis considers the potential presence and role of multiple issues, vs. simply targeting a singular cause.

The "holistic approach" centers itself to establish a reliable engineering assessment as the diagnosis, through the use of appropriate inspection tools, but also effective data analysis and engineering methods.





Value of Accuracy for Remediation Programs

Case Example: Deterministic Corrosion Assessment

Case Parameters

- 24" x 7.92mm, X52 liquid product pipeline
- MAOP of 67 bar (72% SMYS)
- 2900 external metal loss anomalies detected and reported
- Deepest anomaly reported as 74%wt
- Minimum predicted burst pressure (using RSTRENG [5] method) = 62 bar
- 49 as-reported features considered as baseline repair program
- $100,000 /dig

Assumed POD similar for all ILI systems (which may not be reality)

	Sizing Accuracy		
	+/- 8% WT	+/- 10% WT	+/- 15% WT
Confidence Level	80%	80%	80%
Standard Deviation	6.1	7.8	11.7
95% Upper Bound	+12%	+15%	+23%
Total repairs identified (As Reported + deterministic Tolerance)	125	175	262
Cost (assuming $100,000 per excavation and repair)	$7,500,000	$12,500,000	$21,500,000
Incremental Cost	-	*+5,000,000*	*+14,000,000*

Deterministic e.g., through use of 95% Upper bound of defect population

Note: values refer to the incremental cost on top of the baseline case (49 repairs-> assumed 50 to easy calculations)

(Reminder – Improved sizing tolerance does not necessarily change the value of maximum feature reported overall – but the overall count and distribution of features to be considered as threats)

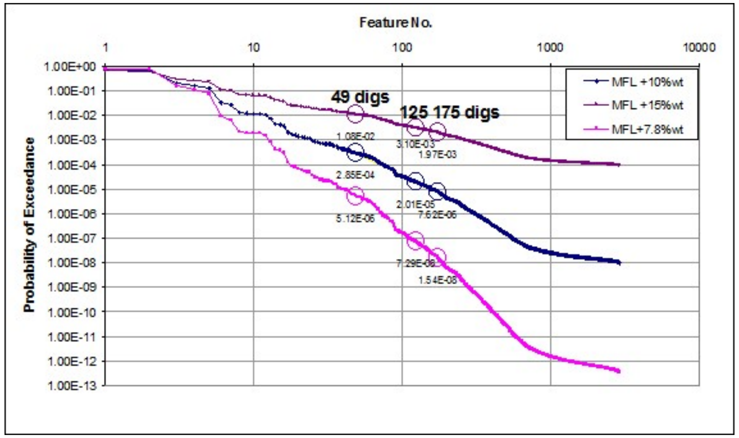
Value of Accuracy for Remediation Programs

Case Example: Probabilistic Corrosion Assessment

Case Parameters

- 24” x 7.92mm, X52 liquid product pipeline
- MAOP of 67 bar (72% SMYS)
- 2900 external metal loss anomalies detected and reported
- Deepest anomaly reported as 74%wt
- Minimum predicted burst pressure (using RSTRENG [5] method) = 62 bar
- 49 as-reported features considered as baseline repair program
- $100,000 /dig

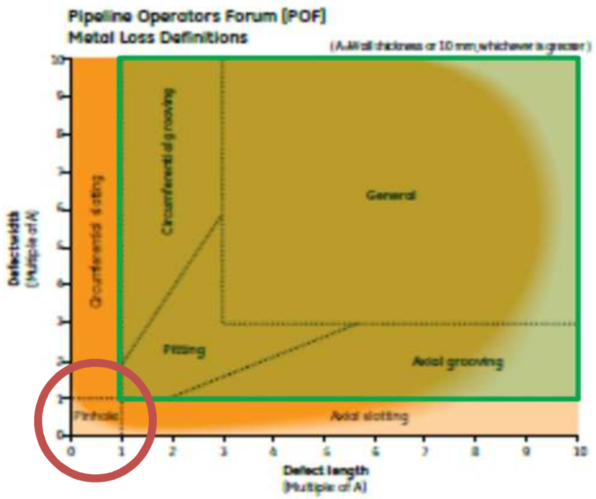
Radical improvements to pipeline reliability can be achieved due to tolerance accuracy, with the added benefit of fewer digs required



	Sizing Accuracy		
	+/- 8% WT	+/- 10% WT	+/- 15% WT
Total repairs identified (As Reported + deterministic Tolerance)	125	175	262
Probability of Exceedence achevied for all digs per case	7.30E-08	7.60E-06	1.03E-03
Probability of Exceedence achieved for ~ 50 digs	5.10E-06	2.80E-04	1.08E-02

Note: The Probabilty of Exceedence is explained in the last slide of the presentations.

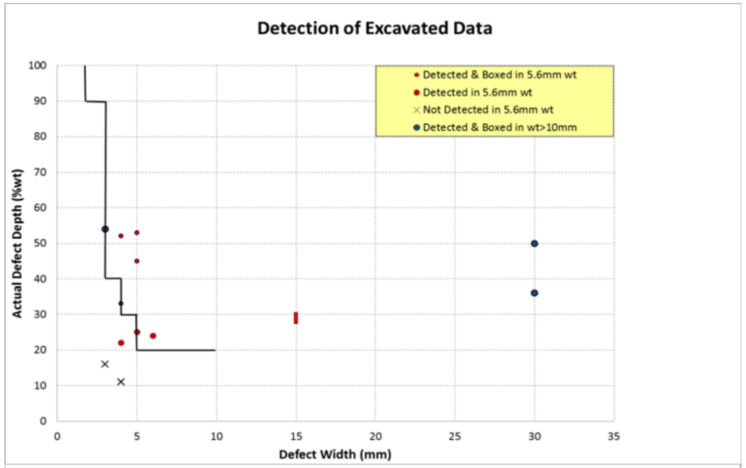
Case Example: Pinholes

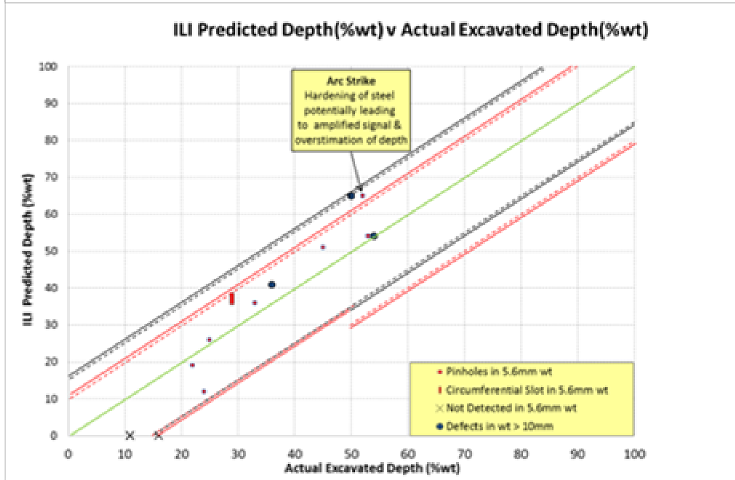


Blind test result = 100% for > 20% WT depth

Current global track record:
100s of pinholes identified and verified in field with 90+% sizing certainty

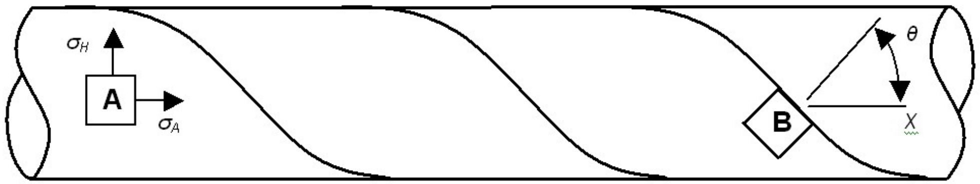
Therefore there is now a means for managing the threat from pinholes whether due to corrosion or pilferage (tapping)





Case Example: Spiral Weld Crack Like Defects

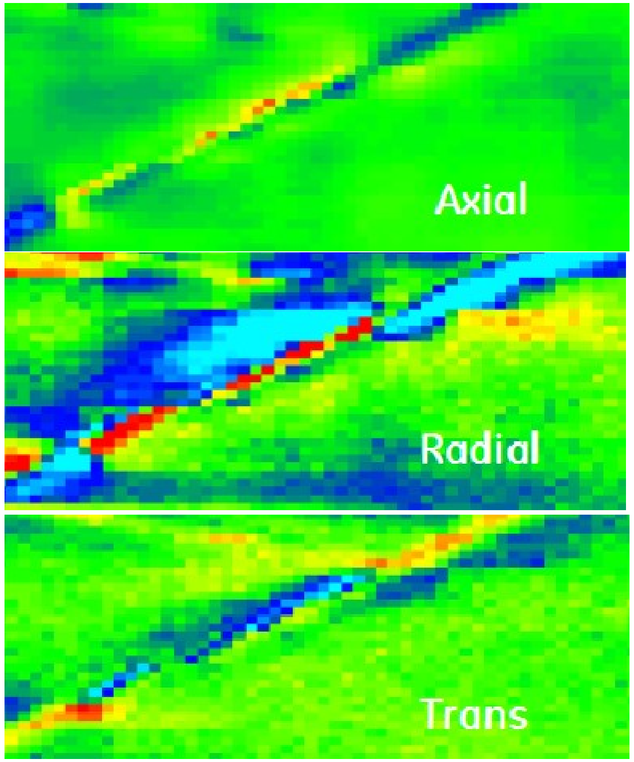
Integrity assessment of spiral weld cracking has different parameters and decision factors than if it was spiral corrosion.



Development efforts resulted in successful means of spiral weld crack threat identification via New Magnescan (“Triax”) methodology and not a typical “corrosion & MFL” scenario.

100s of features identified and mitigated to date.

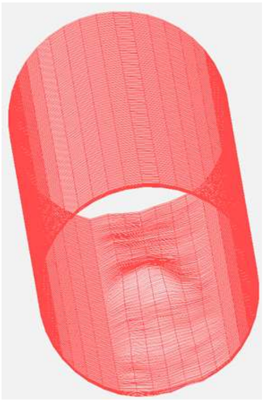
A need to identify and treat an “uncommon” but critical health threat → solved by accurate and reliable information made possible through effective ILI/Operator collaboration.

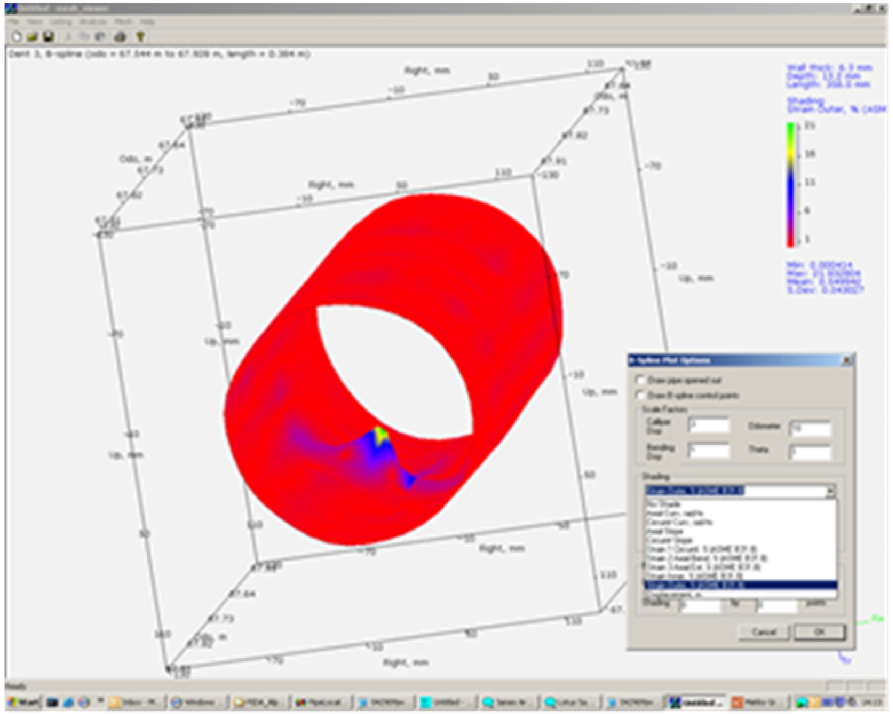


Case Example: Dent Strain Assessment with High Resolution Caliper Data

High Resolution Caliper provided for accurate shape determination which provided an accurate strain assessment based on shape.

Dent depth was not the critical attribute…strain was.



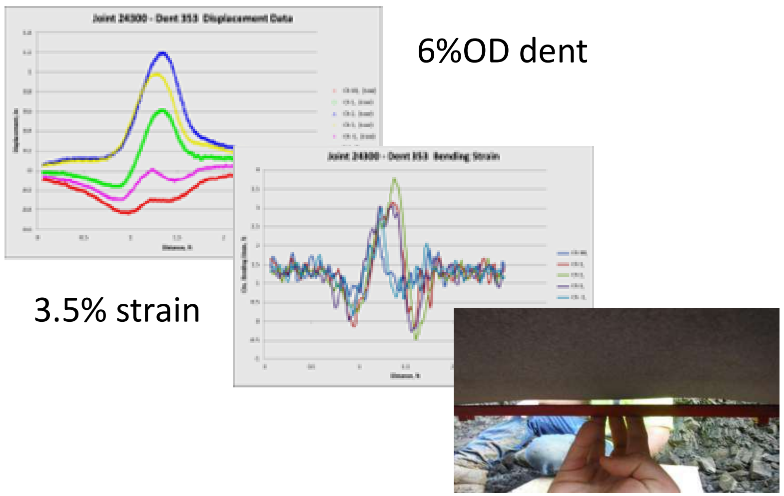


Dent size exaggerated for visibility

Case Example: Dent Strain Assessment – Summary of Published Guidance

- Plain dents up to 6%OD (or strain up to 6%) are acceptable; some exceptions for top of line dents & for dents in liquid pipelines (fatigue threat)
- Dents with cracking or gouging are not permitted - severest form of defect & can have low burst pressures & fatigue lives
- Dents with corrosion … several codes allow the dent and corrosion to be assessed independently; but other codes apply the same rule as a dent with gouging
- Dents on welds … some codes allow up to 2%OD in depth (or 4% strain) whilst other codes do not permit this combination

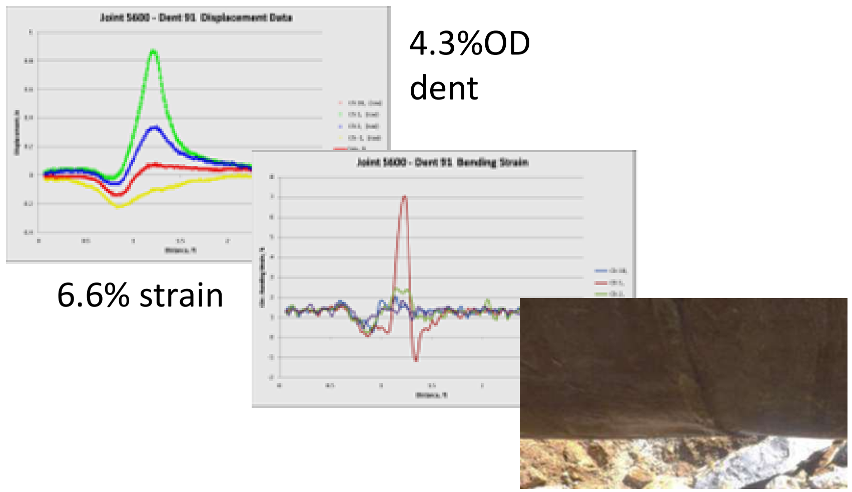
Strain now considered more relevant for assessing the real severity of plain dents or dents on welds under static loading … 2 examples below show why dent strain is more relevant than dent depth



6%OD dent

3.5% strain

Deep dent over large area
BUT lower strain due to gradually sloping sides



4.3%OD dent

6.6% strain

Shallow dent over small area
BUT higher strain due to steeper sides of this sharp dent

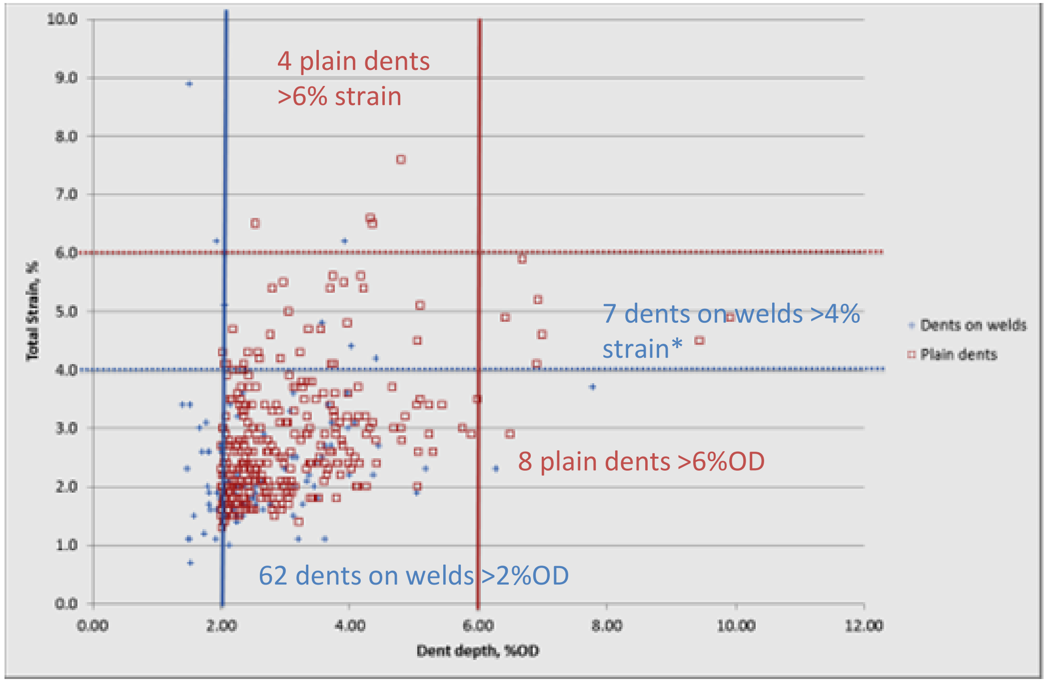
Case Example – Dents / Mechanical Damage

Dent strain results - 397 dents in 42 pipelines

- 70 dents (18%) unacceptable to depth criteria
- Of the 70 dents, 65 pass strain criteria – unnecessary digs

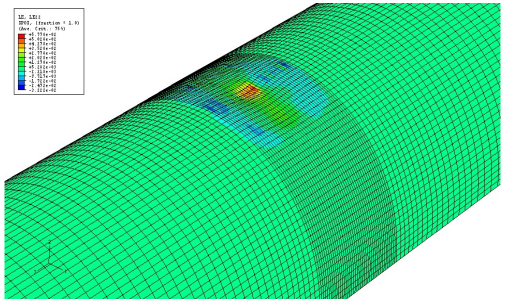
- 11 dents (3%) unacceptable to strain criteria
- Of the 11 potentially injurious dents, 6 pass the depth criteria – missed digs if only depth considered

Many operators use both criteria to make decisions



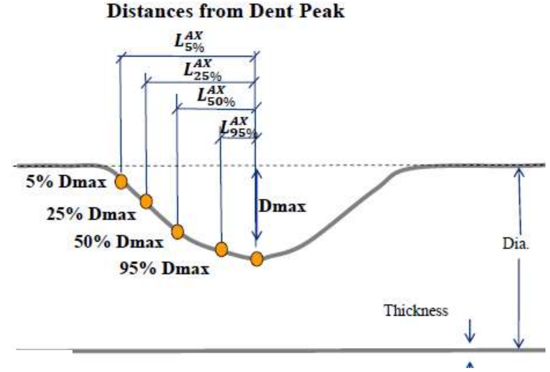
* To apply 4% strain limit at welds, the weld must be of sound quality (not brittle or containing weld defects)

Case Example: Dent Fatigue Assessment – New methodology



- In pipelines subjected to cyclic pressure loading the presence of a dent produces a stress concentration that can develop and grow fatigue cracks
- A new dent fatigue assessment methodology that uses high resolution dent profile data has been developed by BMT Fleet Technologies as part of a PRCI research project, reference…

  Improved Pipeline Dent Integrity Management, Tiku et al (BMT Fleet Technologies), IPC2016, Calgary.



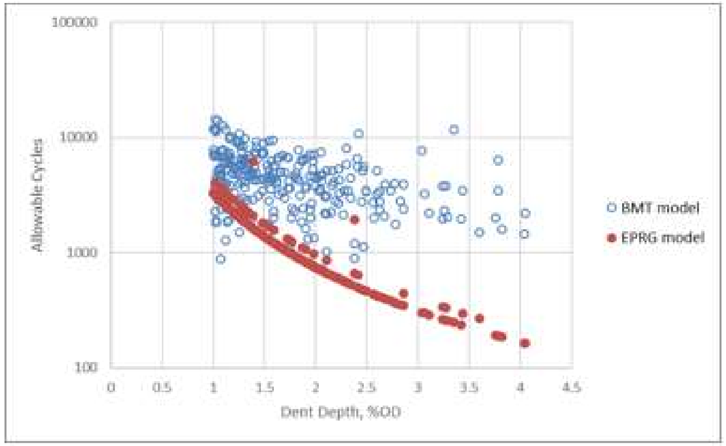
- It is based on extensive FEA studies on wide range of pipe & dent geometries and cyclic loadings & validated using results of full scale dent fatigue tests
- BHGE have shown that this fatigue model provides a more realistic & comprehensive assessment of dent fatigue vs the older depth based approaches

Example shows predicted dent fatigue lives of a liquid pipeline with 350 plain dents (1%-4.5%OD).

BMT (dent profile based) and EPRG (dent depth based) methods are compared.

BMT method gives longest fatigue lives for 94% of the dents

A. Liquid pipeline - 60% SMYS cyclic stress range



Case Example: Full Use of Available Data

Pipeline through mountainous region -
MFL + GEO + IMU inspection.

MFL + GEO data analyzed and reported – but IMU strain analysis not requested.

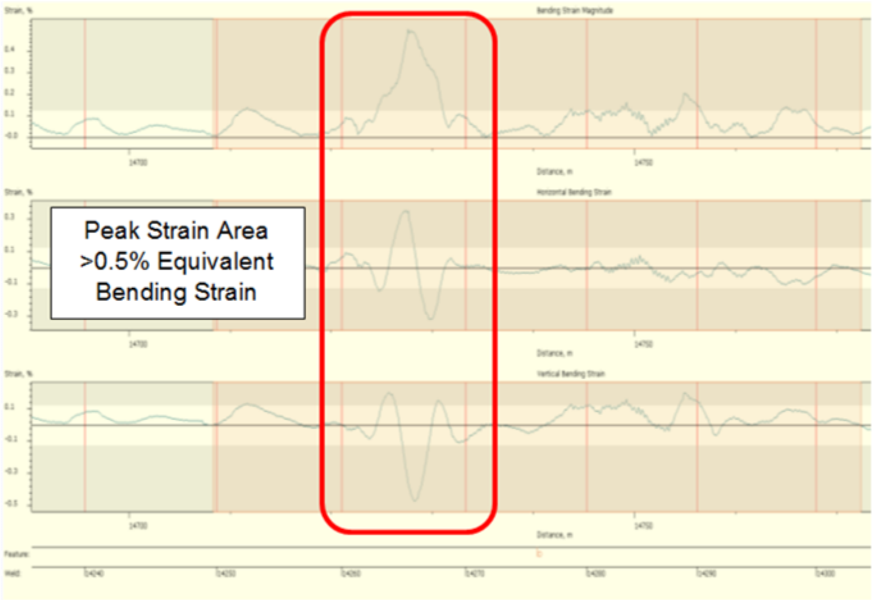
No MFL or GEO feature reported in area.

Pipeline experienced a failure 6 months later….

Post failure request for IMU analysis was made & distinctly identified > 0.5% strain location correlated with failure site.

No corrosion or stress riser feature was present .

Investigation conclusion cause deemed due to catastrophic external loading.



Case Example: Coincident Features

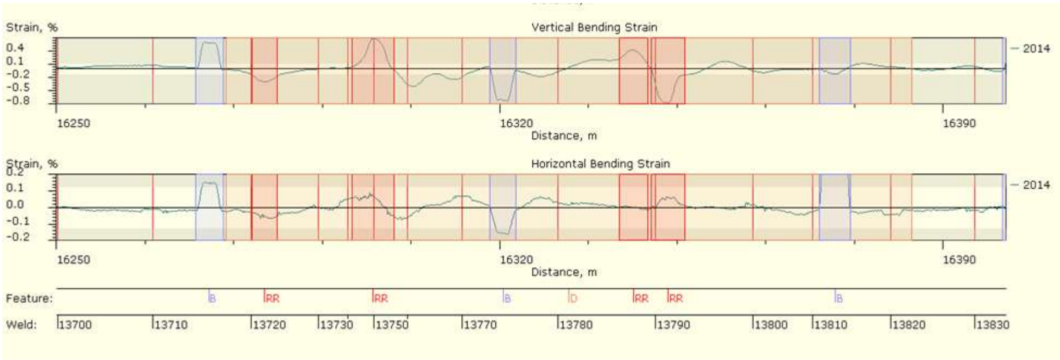
39% metal loss defect detected

First response would be to assess burst pressure based on hoop stress, e.g., ASME B31G

But internal pressure was not the only threat here…

A local, intensified longitudinal bending stress/strain was the cause of the defect.

Knowledge of both local feature and presence of bending strain identified this feature as critical, thus avoiding a loss of containment incident.



Estimating corrosion rates

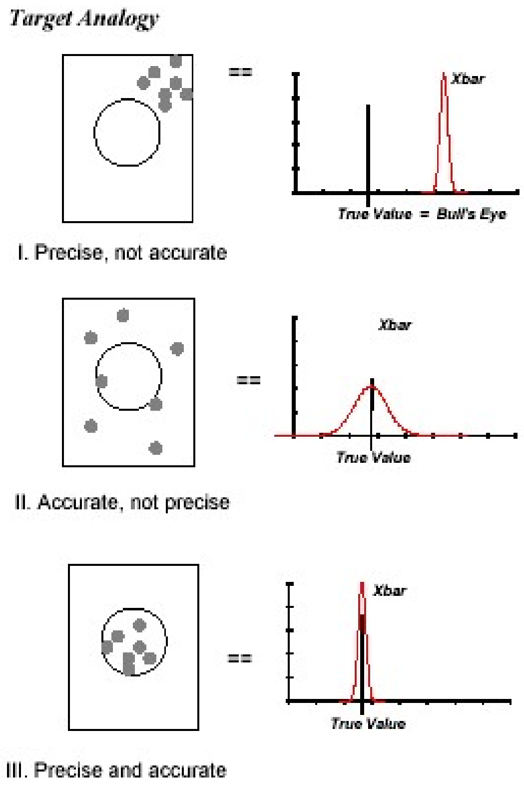
- Highly variable & difficult to predict due to localized nature & the many factors influencing corrosion reaction
- Models available for internal corrosion but limited guidance for external corrosion e.g.: some guidance on max. rates
- NACE RP0502: 16mpy (0.4mm/yr)
- GRI-00/0230: 22 mpy (0.56mm/yr) pitting rate & 12mpy (0.30mm/yr) general corrosion rate
- ASME B31.8S App B (ECDA): 12mpy (0.31mm/yr)
- **Comparing repeat ILI data along full pipeline length is the best method for estimating the rate of growth throughout the pipeline**

ILI growth measurement - sources of errors

- 2 main sources of error
  - Inaccurate matching of corrosion sites
  - Inaccuracies associated with growth measurement

- Growth measurement has 2 parts
  i. Bias – systemic difference in depth sizing can vary by defect type
  ii. Scatter – represents random variations in measurements made under same conditions

- Using same ILI tool for both runs reduces both data matching & growth measurement errors



Comparison methods

- Cluster matching

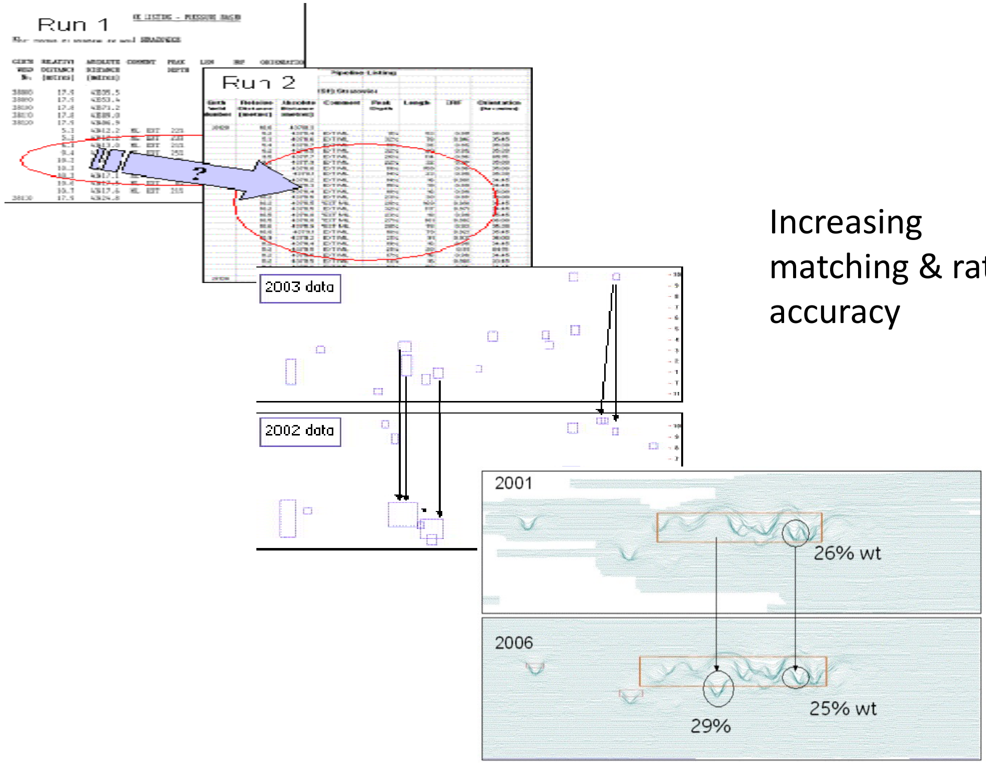
  Data matching error: High
  Growth est. error: High

- Individual site (box) matching

  Data matching error: Mod
  Growth est. error: Mod

- Signal matching

  Data matching error: Low
  Growth est. error: Low to mod*

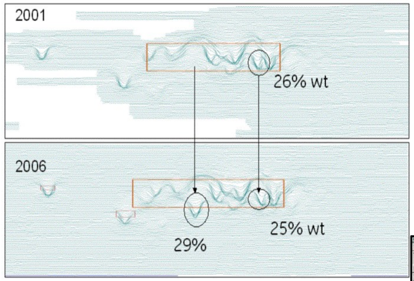


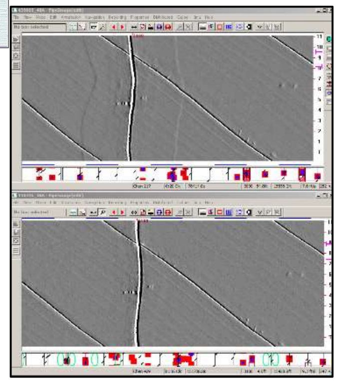
Increasing matching & rate accuracy

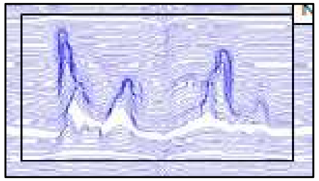
* Growth est. error can be high for different vendor comparisons as calibration of ILI signals difficult

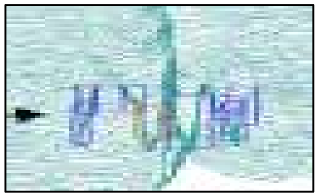
Signal matching

- Proven to be the most accurate ILI comparison method
- Involves matching defects via direct alignment of signal data
- Requires signal data from both ILI runs
- Can be difficult with different vendor data due to different signal conventions, magnetic field strength, signal modelling, time vs dist. based sampling
- Requires expertise of trained ILI signal analysts





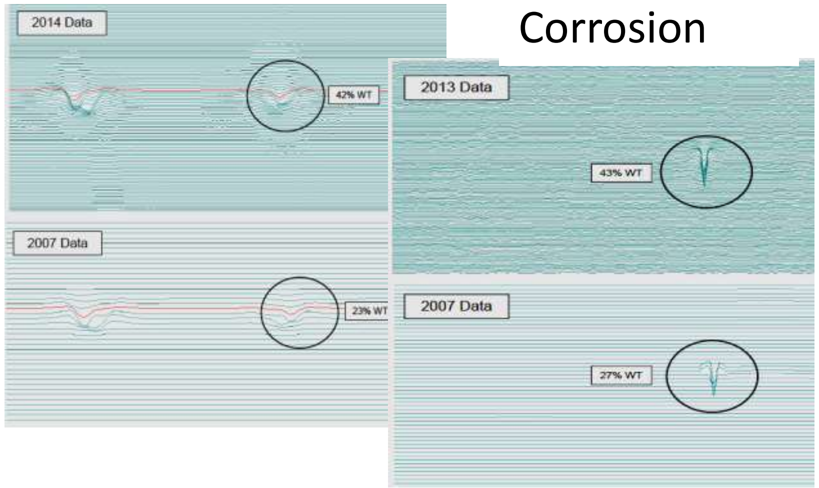


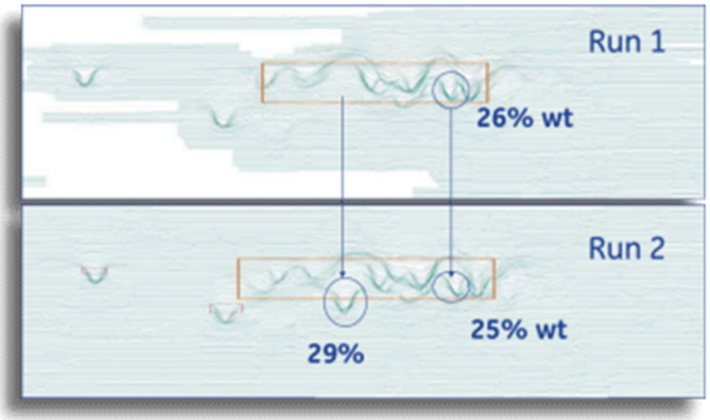


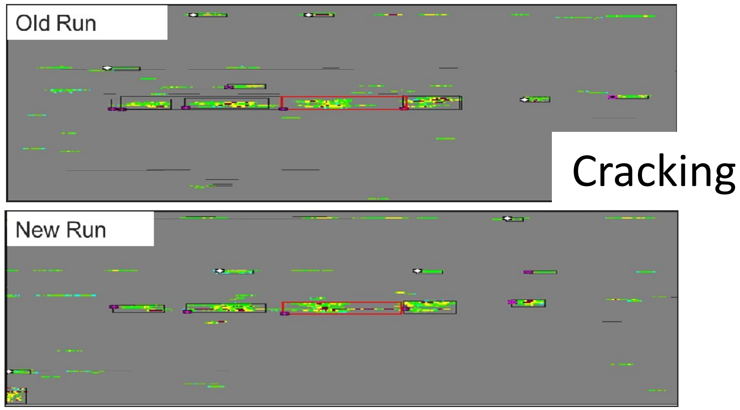
Change Estimation (Growth) using multiple data sets from different times

Change and growth can be detected and estimated for all sensing technologies available on ILI
(Corrosion, Crack, Dents, movement…)

Proper normalization of signal data and comparison method can provide accurate and quantifiable rates.







Conclusions and Summary

Engineering assessments can be used to determine the immediate and future integrity needs by evaluating the criticality of anomalies identified during an ILI.

- Increased ILI accuracy and reliability directly affects immediate and short-term schedules and budgets, and enables justifiable long-term remediation activities and re-inspection intervals.
- A novel pinhole inspection capability has been realized. Similarly the identification and characterization of Spiral weld flaws vs corrosion has provided a more efficient and comprehensive integrity program.
- Coincidental anomalies and loading conditions, are important integrity considerations that influence how the anomalies are assessed.
- For re-inspections, using signal-matching techniques, active sites can be identified and the quantifiable rates estimated with high confidence. This provides the basis for optimizing the long-term remediation activities and re-inspection intervals.

Overall a holistic approach is promoted to achieve an effective and reliable engineering critical assessment.

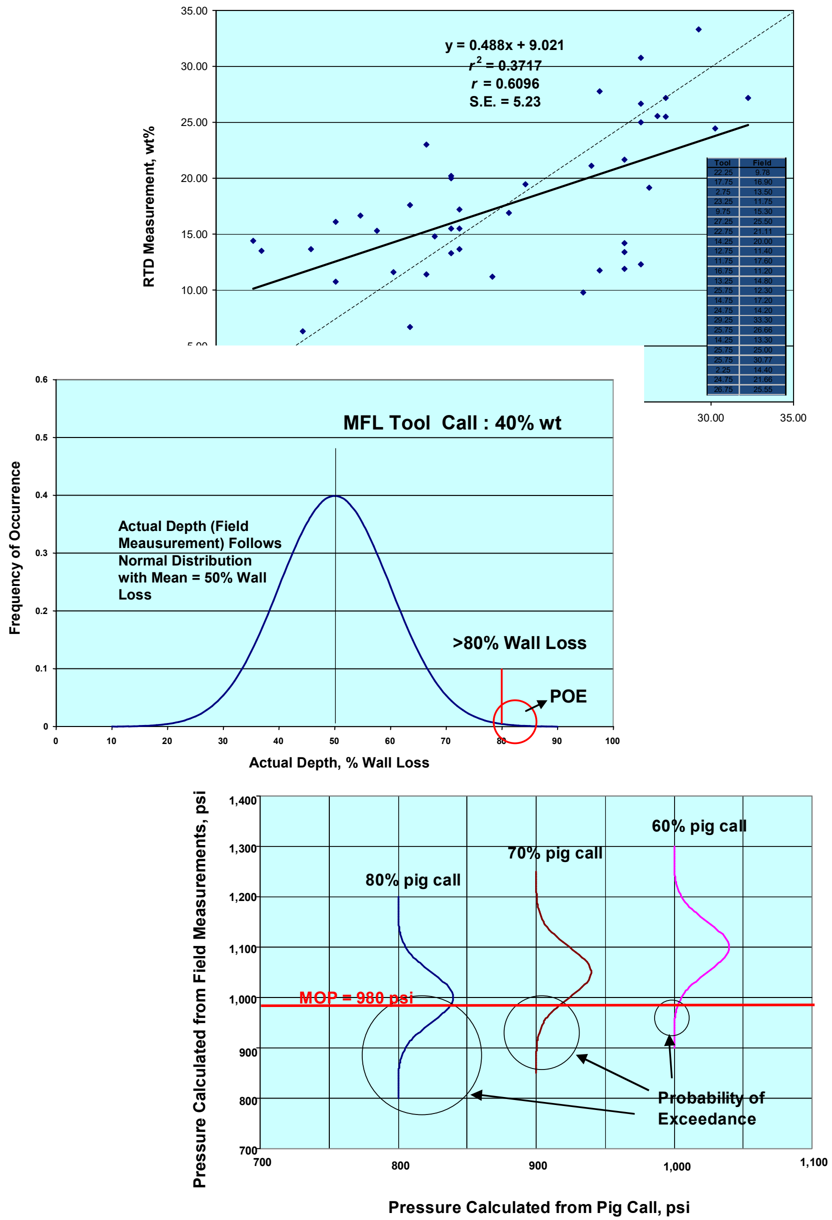
Thank you and questions

A version of this paper was originally presented at the Ageing Pipelines Conference in Ostend, October 2015.

We would like to thank Clarion Technical Conferences and Tiratsoo Technical (a division of Great Southern Press) for permission to use the paper.

Calculate safety/reliability using POE

- Probability of Exceedance (POE)
  - POE is the probability of exceeding a given allowable value (e.g., a max defect size or burst pressure)
  - POE gives likelihood of leak and rupture (burst)
  - Field measurements are used to quantify uncertainty in ILI tool predictions
  - Uncertainties are assumed to be normally distributed
  - POE is calculated for every anomaly in the pipeline



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