A Case Study of the Findings of the RunCom Corrosion Growth Assessments –

Paul Clayton and Derek Balmer, GE Oil and Gas

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imagination at work

Why do we need to measure corrosion growth?

1. To assess corrosion activity & severity with time

2. To prevent failure occurring prior to conducting repair or re-inspecting

3. To establish the safe and economic remaining life of a pipeline

4. **To monitor the effectiveness** of corrosion mitigation activities

What methods can operators use to estimate corrosion growth?

Estimating Corrosion Growth Rates

Internal Corrosion Rates

- Worst case estimates from theoretical models (e.g., deWaard & Milliams, Norsok…).
- Utilise monitoring data, weight loss coupons, probes, etc…
- Limitations - Average rates. None identification of worst features.

External Corrosion Rates

- Correlations available between soil corrosivity & corrosion rate.
- Monitoring corrosion development in repeat excavations/examinations.
- Limitations - Prediction is complex & currently no mechanistic models.

Single ILI Run

- From deepest corrosion defect present.
- Statistical treatment of corrosion dimensions.
- Limitations – Generally very conservative. None ID of worst features.

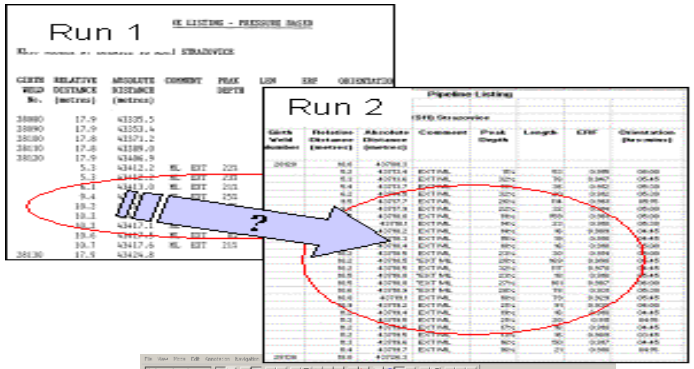
Repeat ILI Runs

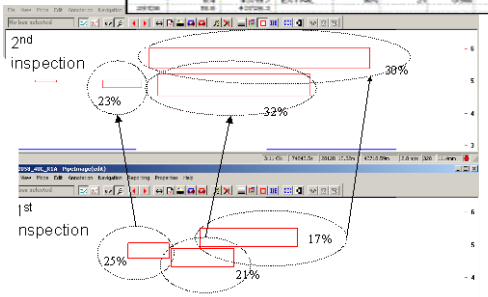
- ***Most accurate method available – can provide growth information at every corrosion site.***

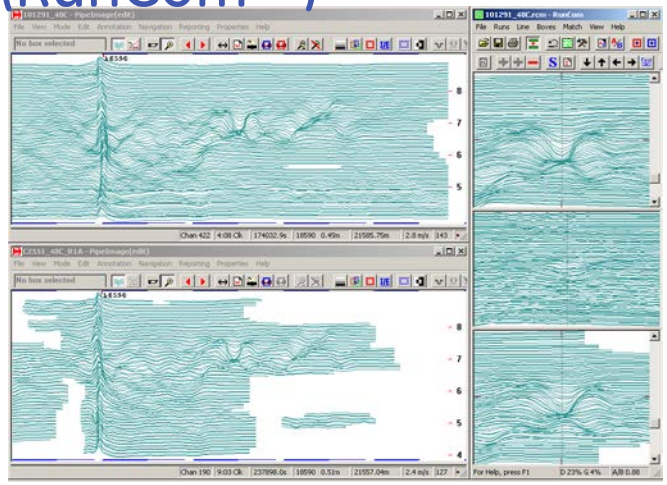
Determining Corrosion Growth Rates from Repeat ILI Data

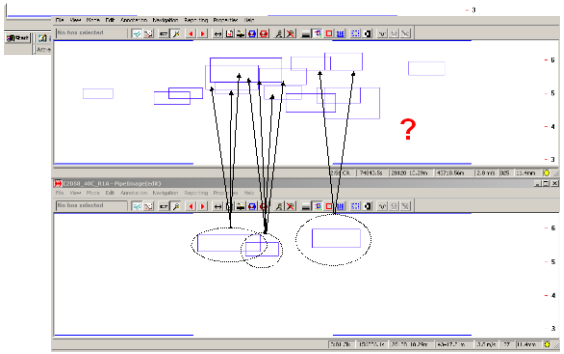
- Feature matching from spread sheet
- Feature matching using visual display software
- Box matching
- Signal matching(RunCom™)

Increasing level of accuracy









At least 3 times more accurate, matching is made easier

GE RUNCOM software

Feature Matching from Listing

1st inspection

GIRTH WELD No.	RELATIVE DISTANCE (metres)	ABSOLUTE DISTANCE (metres)	COMMENT		PEAK DEPTH	LEN	ERF	ORIENTATIO (hours-min
28080	17.9	43335.5						
28090	17.9	43353.4						
28100	17.8	43371.2						
28110	17.8	43389.0						
28120	17.9	43406.9						
	5.3	43412.2	ML	EXT	22%	18	0.91	05-30
	5.3	43412.2	ML	EXT	23%	23	0.91	05-30
	6.1	43413.0	ML	EXT	21%	17	0.91	05-30
	9.4	43416.3	ML	EXT	25%	55	0.93	05-30
	10.2	43417.1	ML	EXT	17%	84	0.93	05-30
	10.2	43417.1	ML	EXT	21%	17	0.91	05-00
	10.2	43417.1	ML	EXT	25%	20	0.91	04-30
	10.6	43417.5	ML	EXT	8%	10	0.91	06-00
	10.7	43417.6	ML	EXT	21%	54	0.92	06-00
28130	17.9	43424.8						

2nd inspection

Girth Weld Number	Relative Distance (metres)	Absolute Distance (metres)	Comment	Peak Depth	Length	ERF	Orientation (hrs:mins)
28120	18.0	43708.3					
	5.2	43713.4	EXT ML	11%	53	0.915	08:00
	5.3	43713.6	EXT ML	32%	76	0.947	05:45
	5.4	43713.7	EXT ML	13%	36	0.912	05:30
	6.2	43714.5	EXT ML	32%	20	0.912	05:30
	9.5	43717.7	EXT ML	26%	114	0.961	05:15
	9.6	43717.9	EXT ML	22%	32	0.914	05:00
	9.7	43718.0	EXT ML	19%	159	0.961	05:00
	9.9	43718.1	EXT ML	14%	23	0.910	05:30
	9.9	43718.2	EXT ML	14%	16	0.909	04:45
	10.0	43718.3	EXT ML	15%	19	0.910	04:45
	10.2	43718.4	EXT ML	18%	16	0.910	05:00
	10.2	43718.5	EXT ML	23%	30	0.914	05:00
	10.2	43718.5	*EXT ML	28%	169	0.998	05:45
	10.2	43718.5	EXT ML	32%	117	0.978	04:45
	10.5	43718.8	*EXT ML	23%	18	0.910	05:45
	10.5	43718.8	*EXT ML	27%	161	0.987	06:00
	10.6	43718.9	*EXT ML	20%	78	0.931	05:30
	10.8	43719.1	EXT ML	18%	79	0.929	05:45
	10.9	43719.2	EXT ML	21%	91	0.939	06:00
	11.2	43719.4	EXT ML	19%	16	0.910	04:45
	11.2	43719.5	EXT ML	21%	20	0.911	04:15
	11.2	43719.5	EXT ML	17%	16	0.910	04:45
	11.2	43719.5	EXT ML	13%	16	0.909	03:45
	11.3	43719.6	EXT ML	16%	50	0.917	04:45
	11.4	43719.7	EXT ML	16%	21	0.910	04:15
28130	18.0	43726.3					

Clusters of corrosion in Listings makes matching very difficult.

VERY DIFFICULT to ensure correct match

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Feature Matching

Even when only a few features on a listing its very difficult to say for sure if a feature is growing – only deepest point is reported.

2001 Report

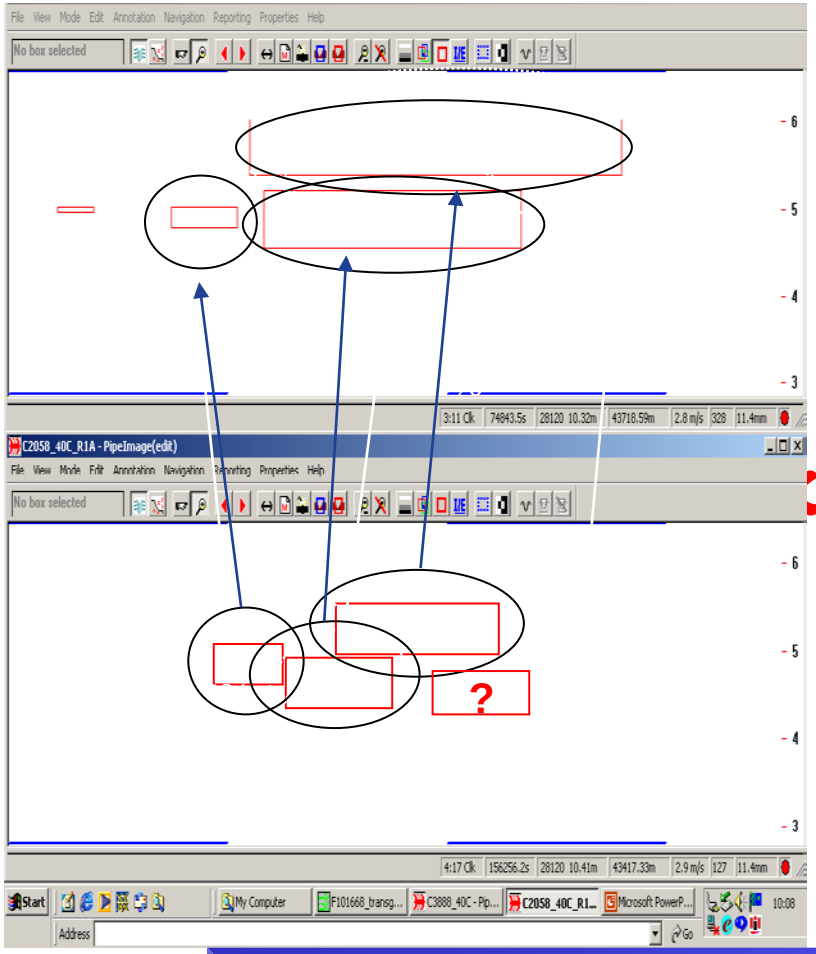
Upstream Girth Weld	Relative Distance (feet)	Absolute Distance (feet)	Comment	Peak Depth (%wt)	Length (in)	Width (in)	Local Wall Thickness (in)	Steel Grade
	28.5	9019.3	EXT ML	26%	9.7	7.7	0.335	X52

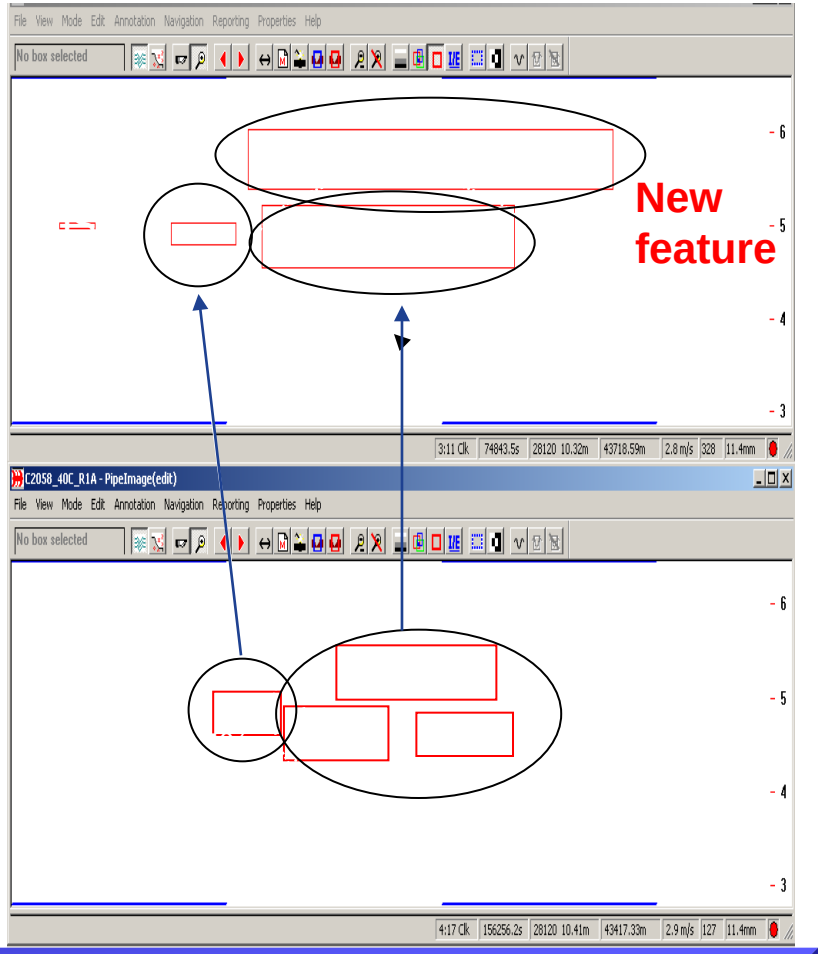
2006 Report

Upstream Girth Weld	Relative Distance (feet)	Absolute Distance (feet)	Comment	Peak Depth (%wt)	Length (in)	Width (in)	Local Wall Thickness (in)	Steel Grade
	28.9	9019.6	EXT ML	29%	10.9	8.0	0.335	X52

Is this feature growing?

Feature Matching Using Cluster Display Software

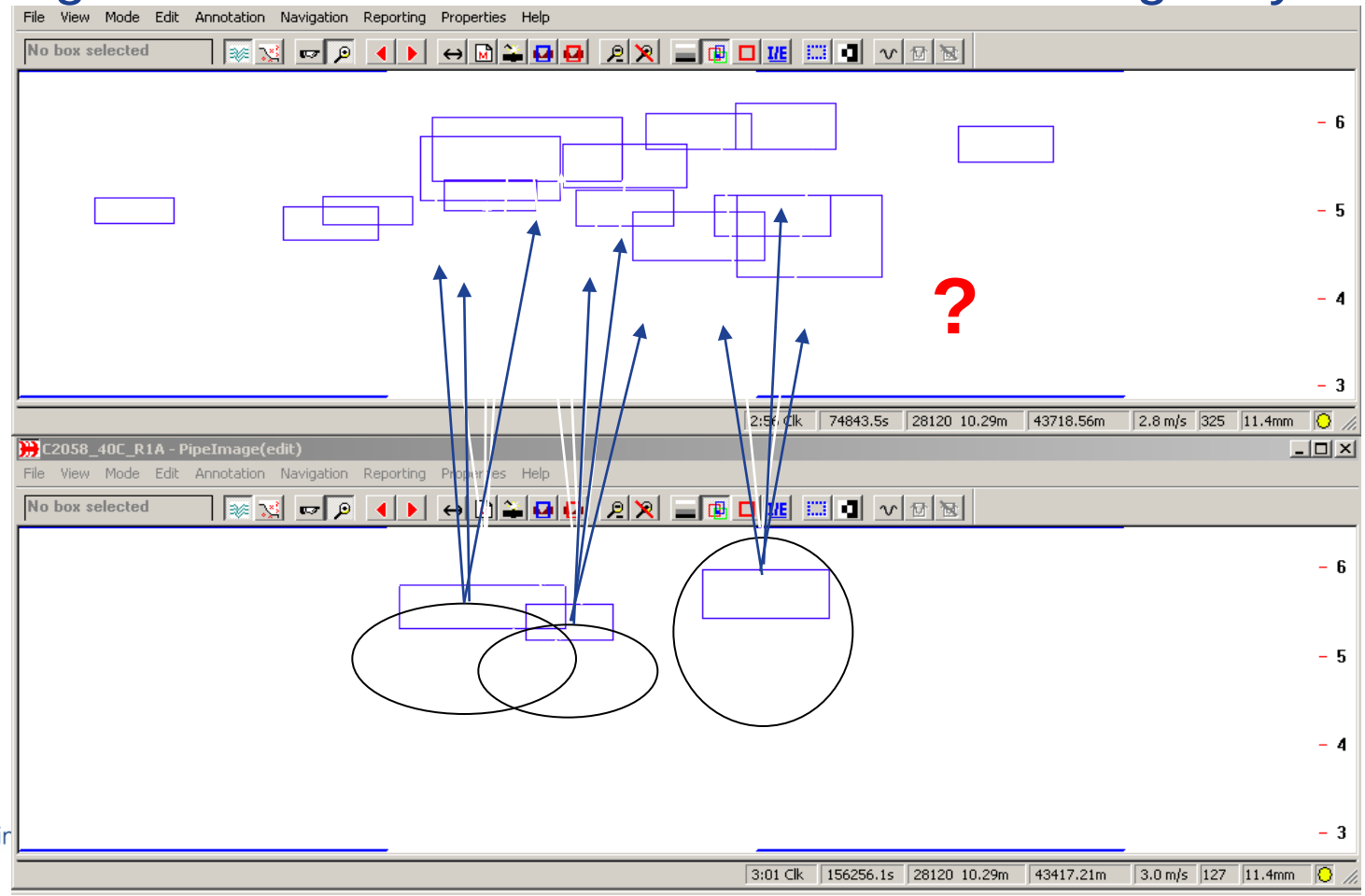




STILL VERY DIFFICULT to ensure correct match

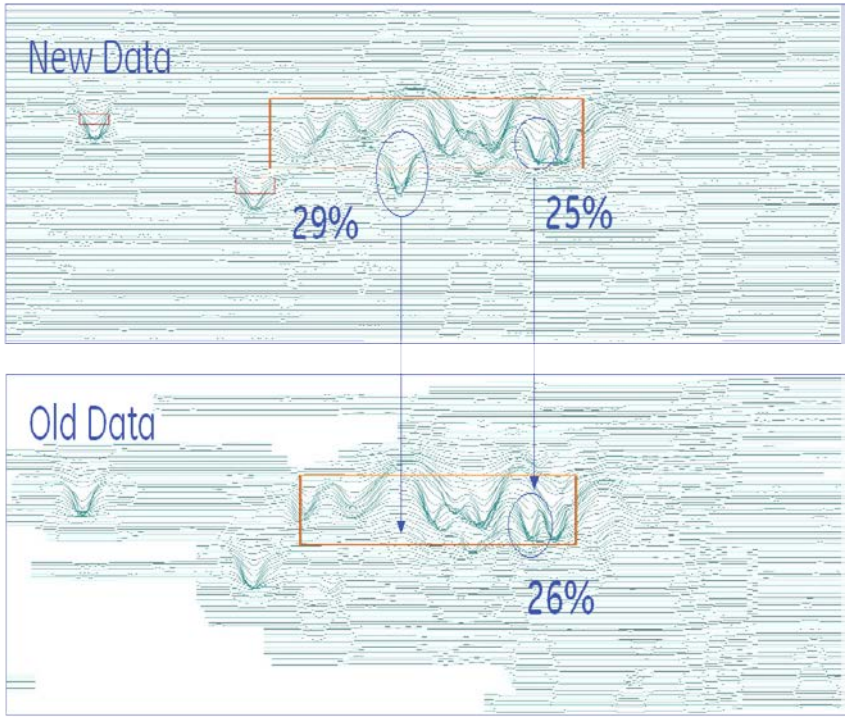
Box Matching

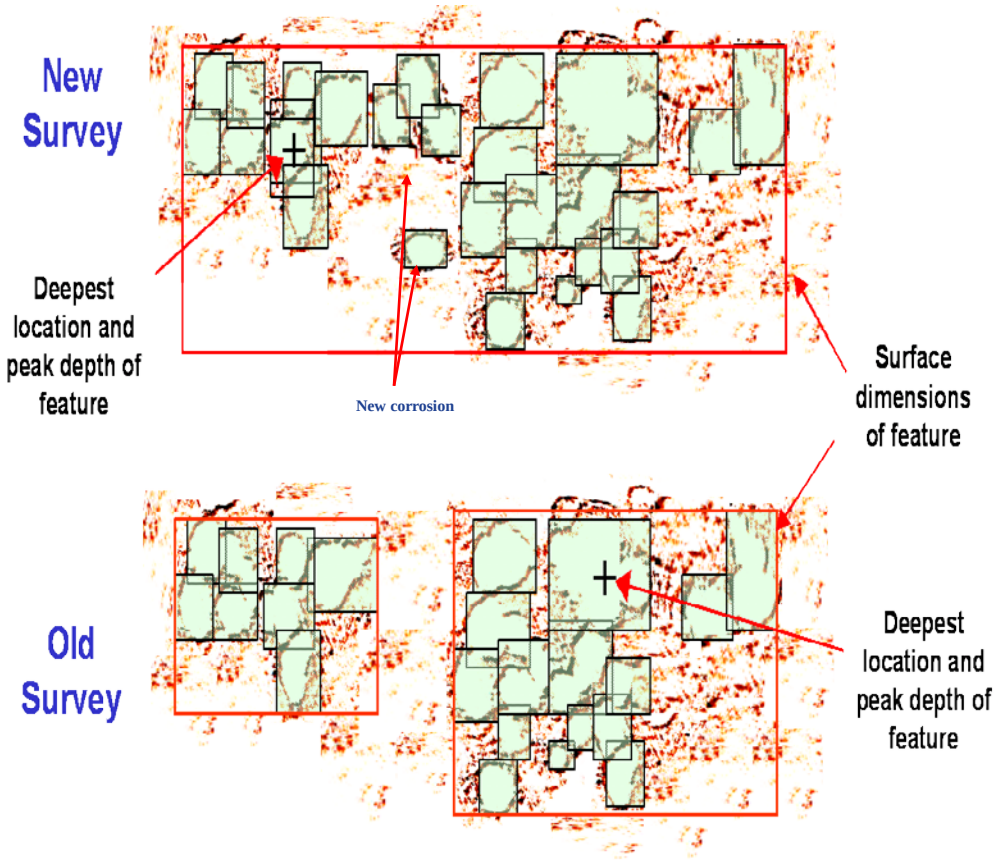
- Even if we try to match boxes – still difficult to get correct!
- Boxing thresholds on ‘old’ data makes matching very difficult



GE RunCom Methodology

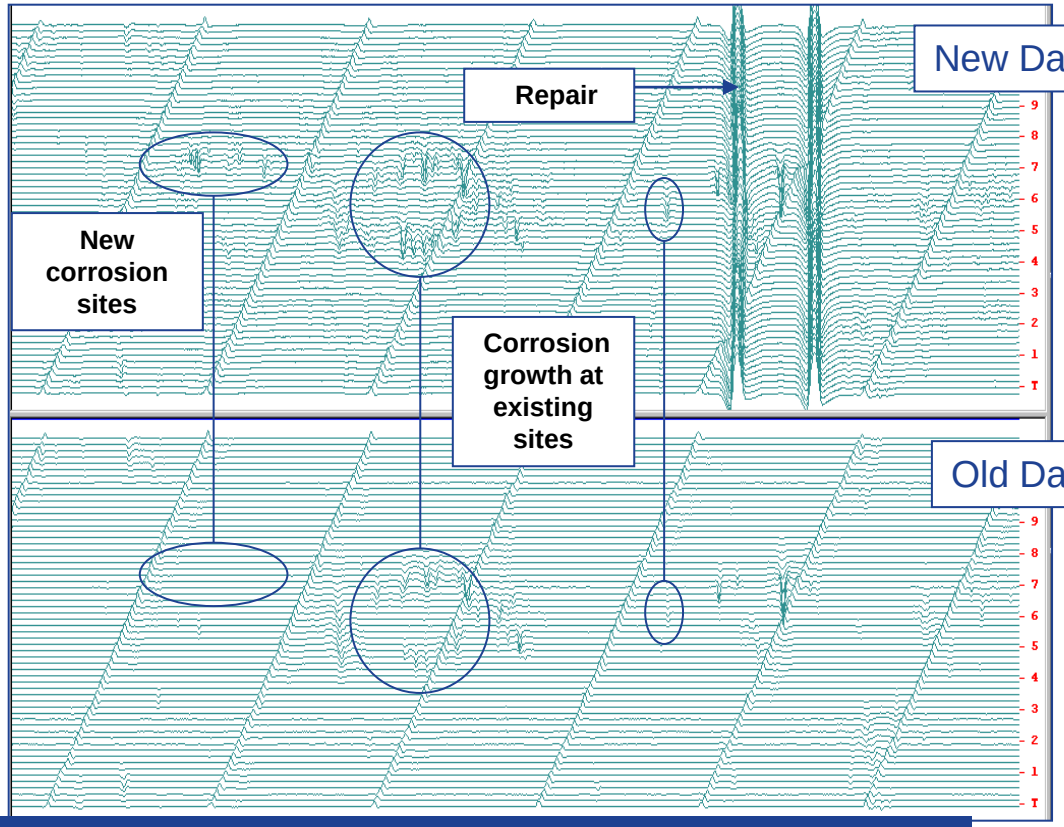
- RunCom allows us to compare 2 sets of data side by side ensuring exact defect matches.
- Ensures cluster changes have no effect on corrosion growth predictions.
- Thus ensuring the signal that is changing (growing) is identified regardless of whether this is the deepest feature in a reported cluster or not.



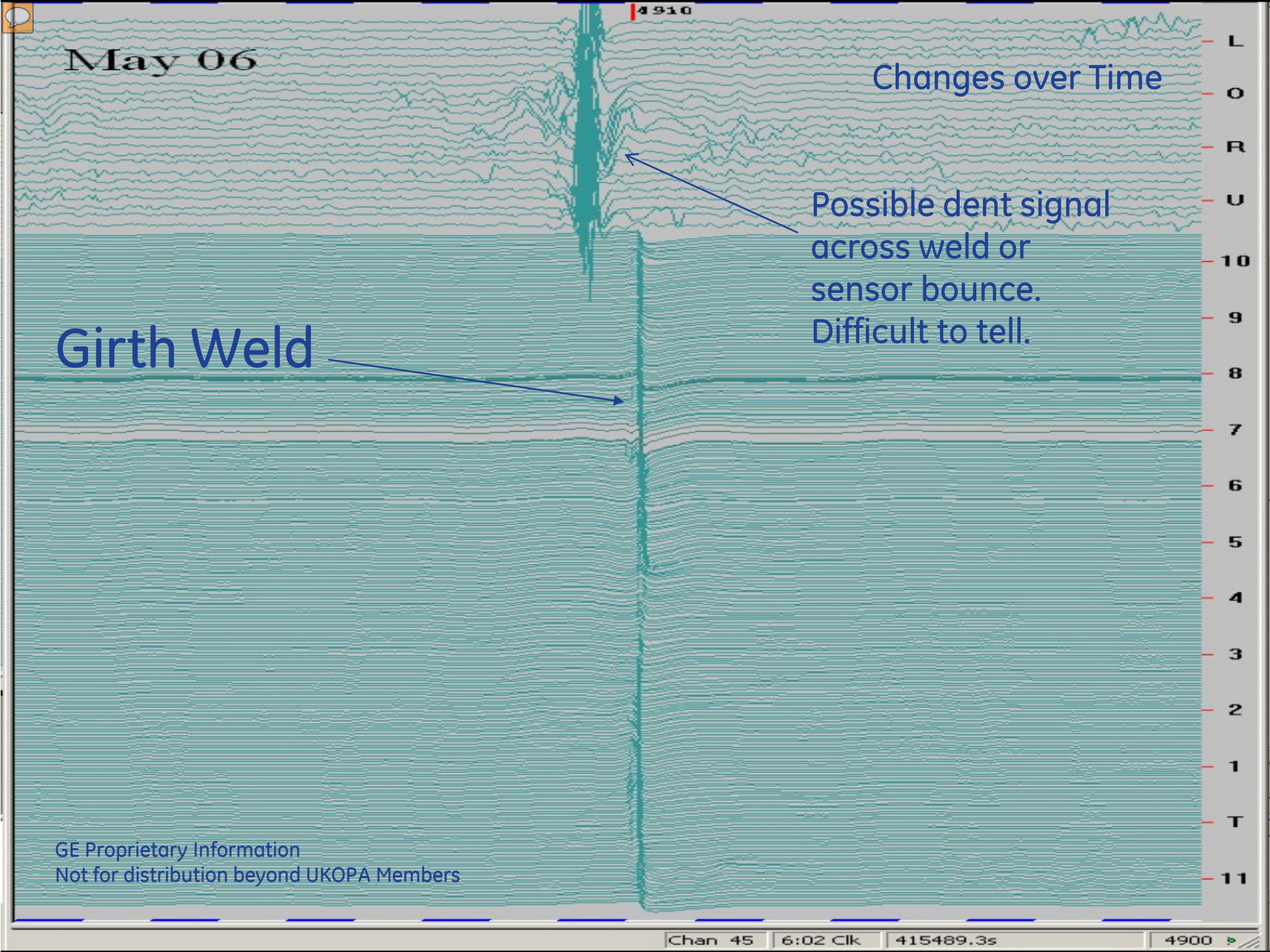


GE RunCom Methodology

- Also eliminates errors in defect magnetic differences, modelling predictions, sizing inconsistencies etc.
- Identifies and quantifies active corrosion sites and 'hotspots'
- Locates areas of new corrosion activity.
- Identifies effectiveness of repairs.
- Can identify changes to other features over time, e.g. dents, girth weld corrosion etc.



Identifies corrosion activity & quantifies rates along an entire pipeline


4910
May 06
Changes over Time
Possible dent signal
across weld or
sensor bounce.
Difficult to tell.
Girth Weld
L
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GE Proprietary Information
Not for distribution beyond UKOPA Members
Chan 45
6:02 Clk
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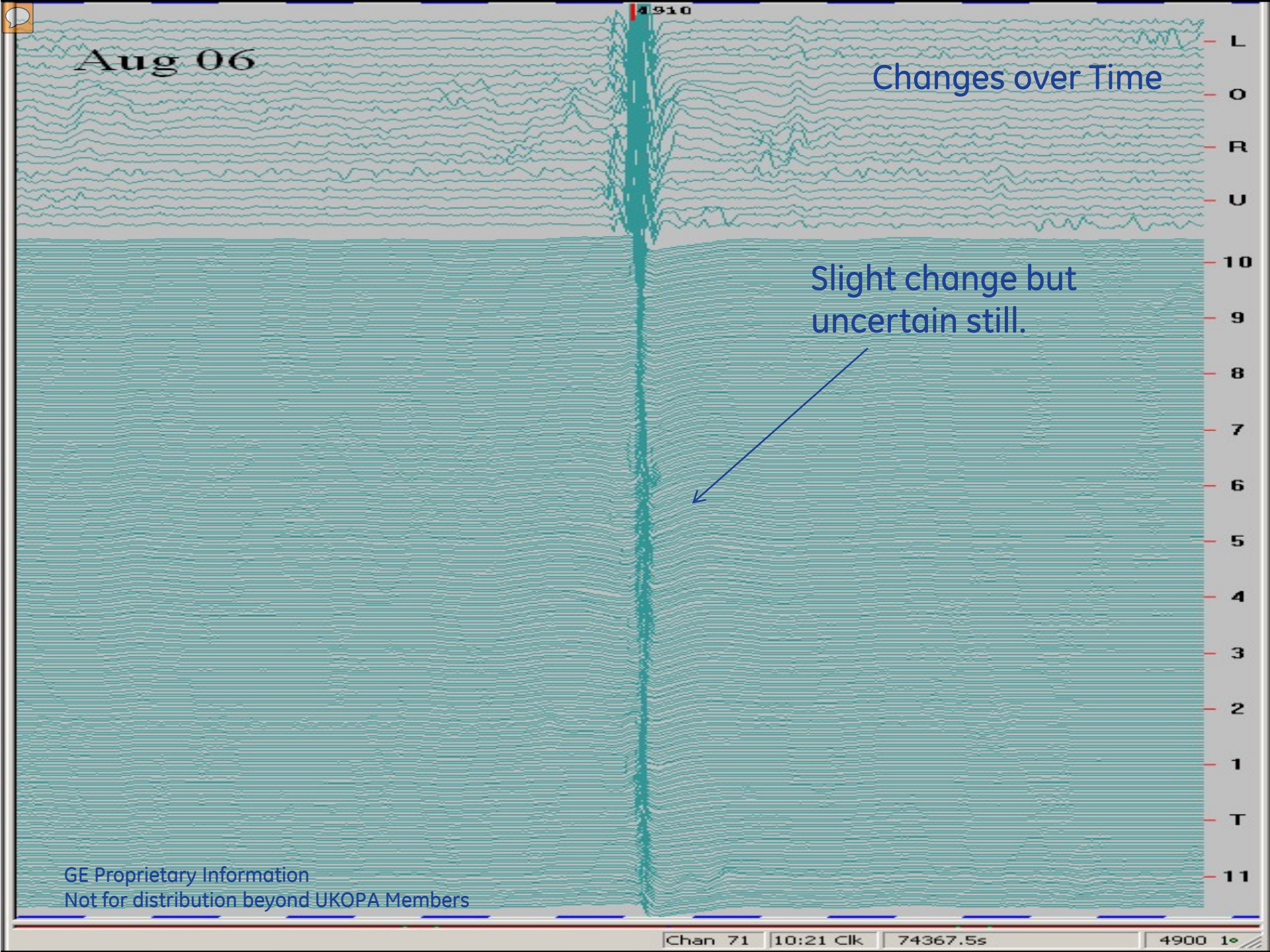
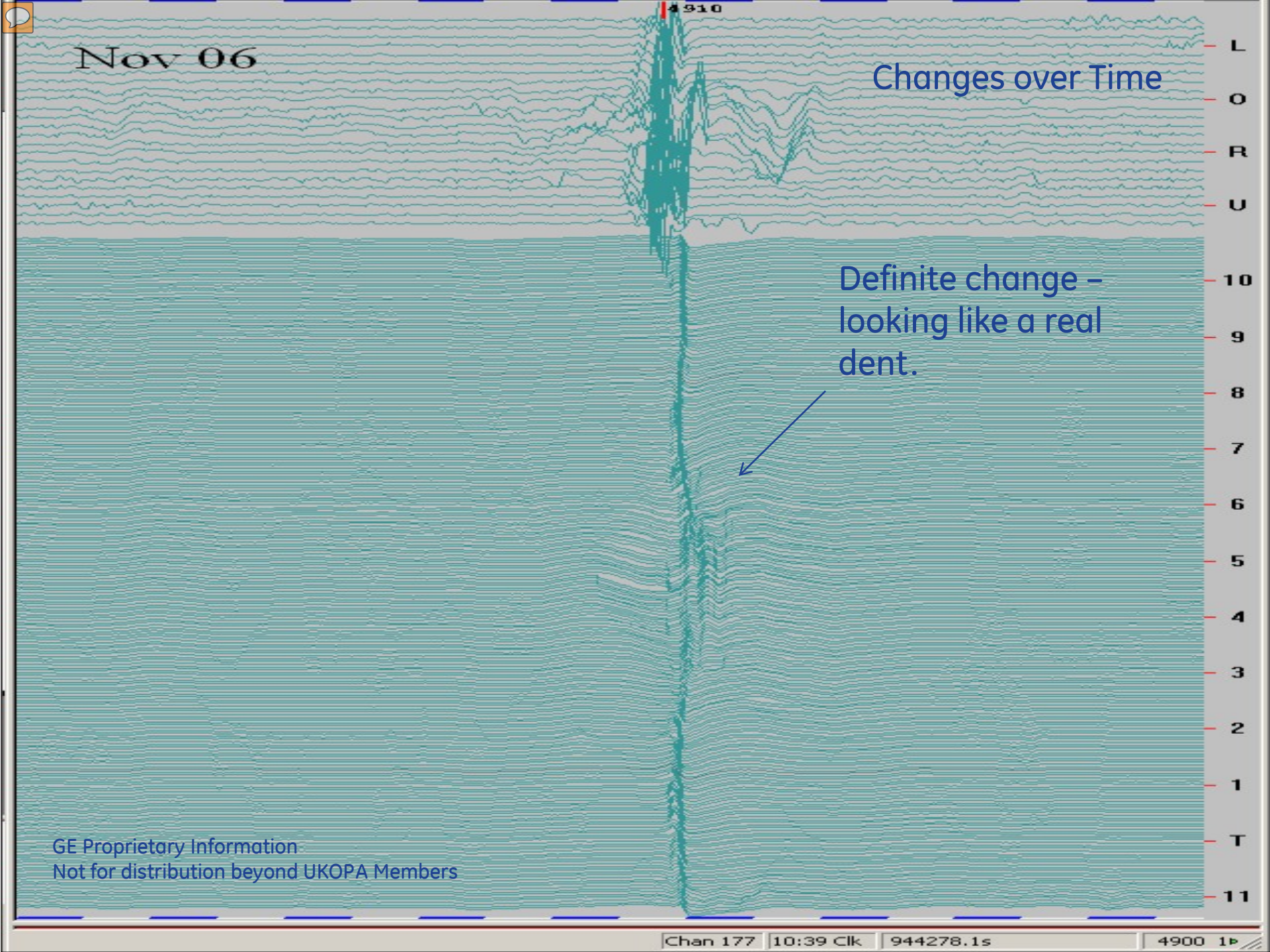
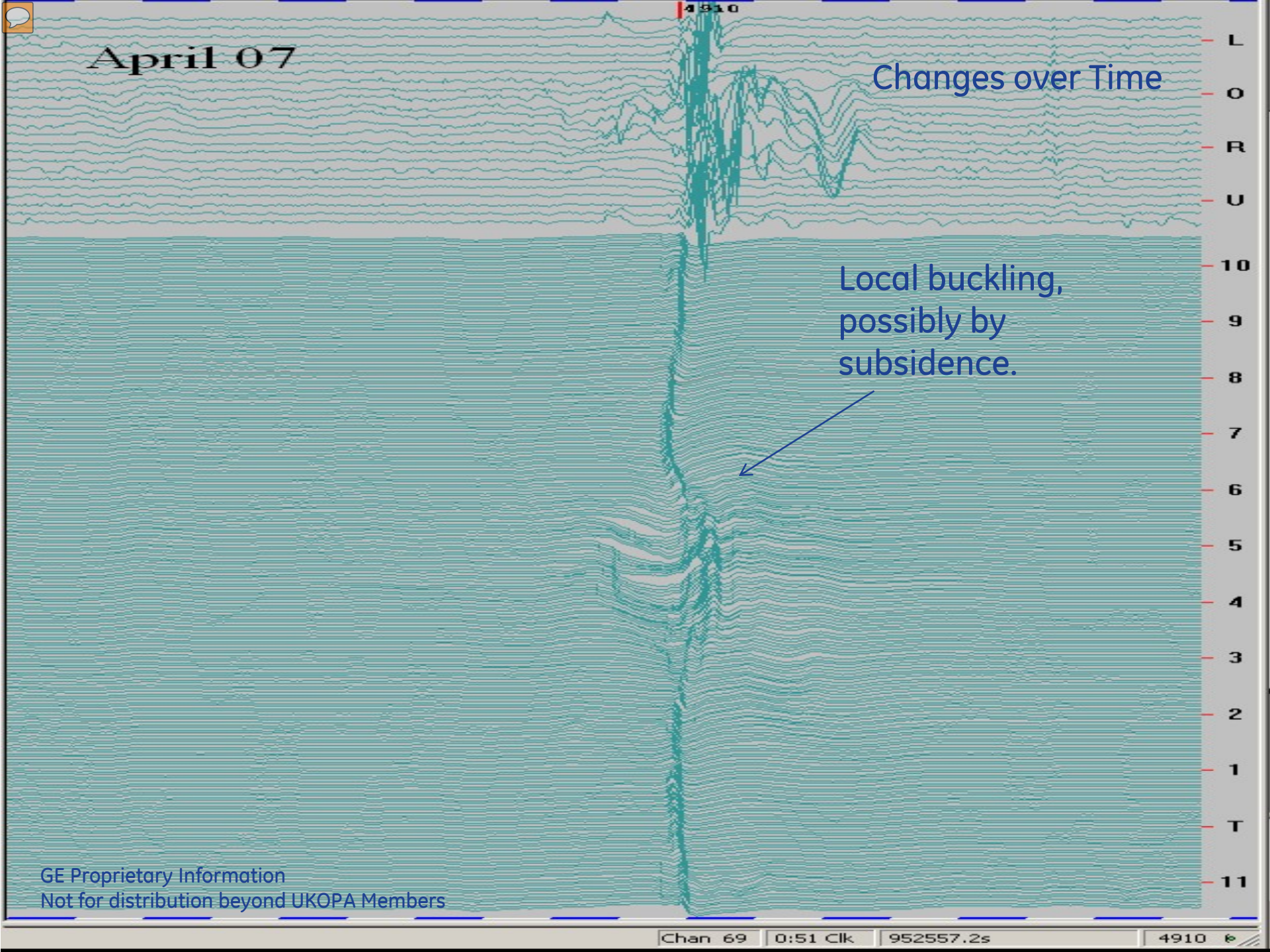
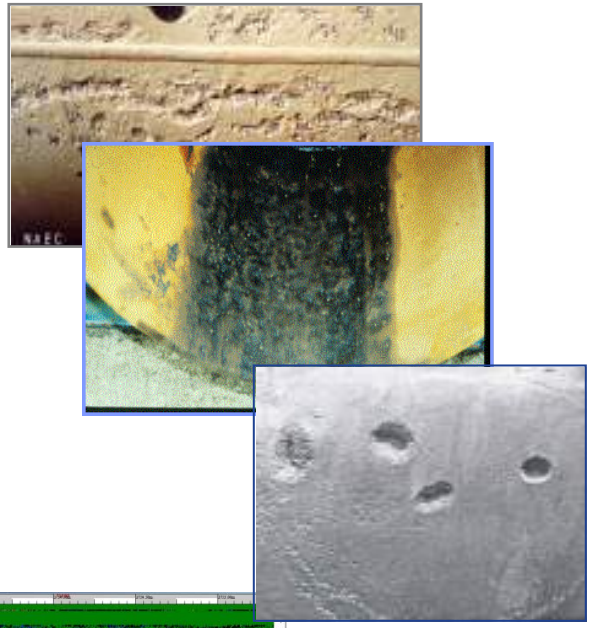

Aug 06
Changes over Time
Slight change but uncertain still.
GE Proprietary Information
Not for distribution beyond UKOPA Members
Chan 71
10:21 Clk
74367.5s
4900

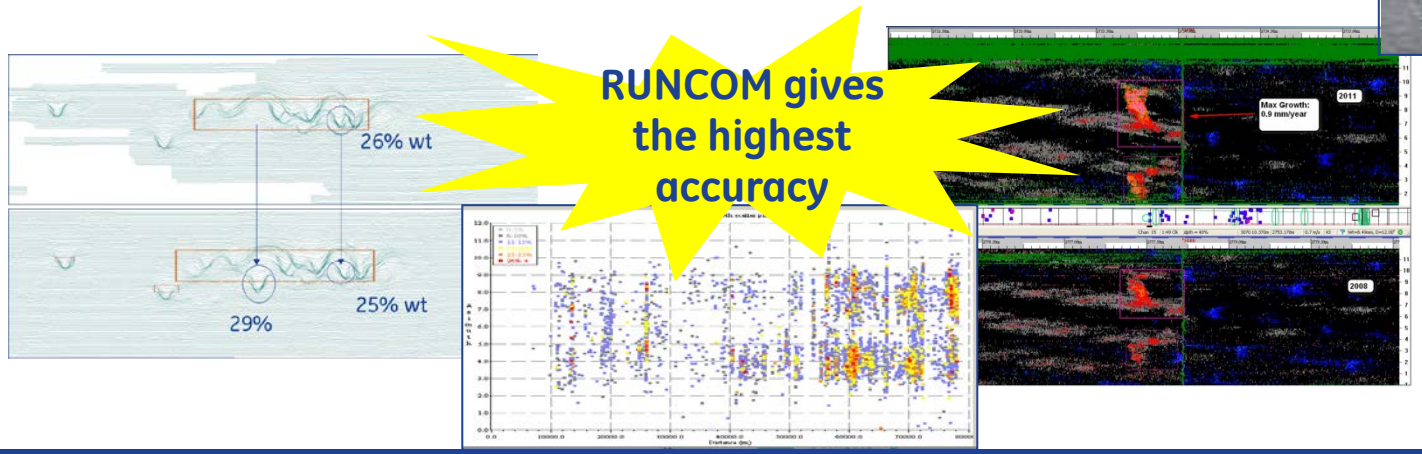




RUNCOM™ Corrosion Growth Assessment

- RUNCOM is the engineering assessment of repeat ILI data to quantify corrosion growth activity along an entire pipeline .
- Applicable for all corroded pipelines with 2 or more ILI's (GE or other vendor).
- Applicable to MFL vs MFL data, USWM vs USWM data, PII Data vs Other Vendor data.
- Accuracy is dependent on data types and vendors data.

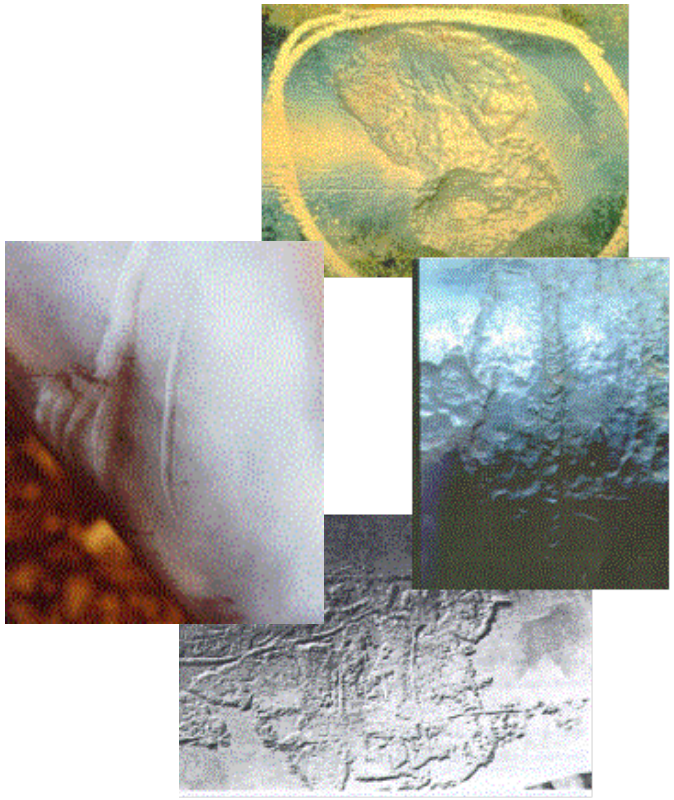




Predict with confidence future maintenance needs

Integrity Engineering Assessment

A case study in the Use of RunCom



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Case Study - 12” Light Crude Oil Pipeline Operational & ILI Data

Diameter	12”/324mm
Length	9km
Commissioned	1973
Nominal WT	8.38mm
Pipe Type	Seamless
MAOP	48 bar (38% SMYS)
ILI Dates (MFL)	MFL - 97, 00, 03. USWM – 04, 06, 08, 11

Ext ML	1542
Int ML	105
Dents	11
Laminations	49

Comparison	Max Rate (mm/Year)	Tech
2008 - 2006	1.12	US v US
2004 - 2006	1.62	US v US
2003 - 2004	2.22	MFL V US
2000 - 2003	1.06	MFL V MFL
1997 - 2000	0.83	MFL V MFL

USWM Technology

Many repairs and replacement sections over the years.
On-going Corrosion Growth.

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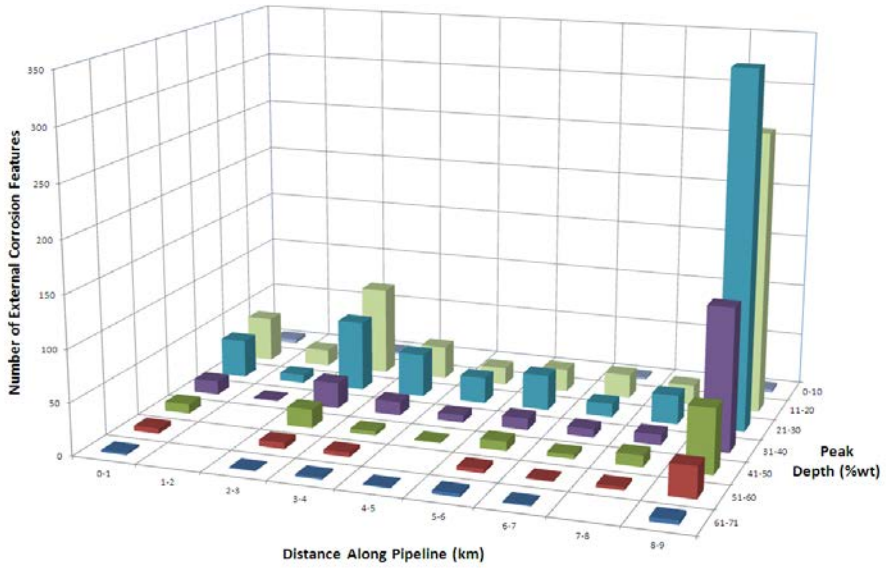
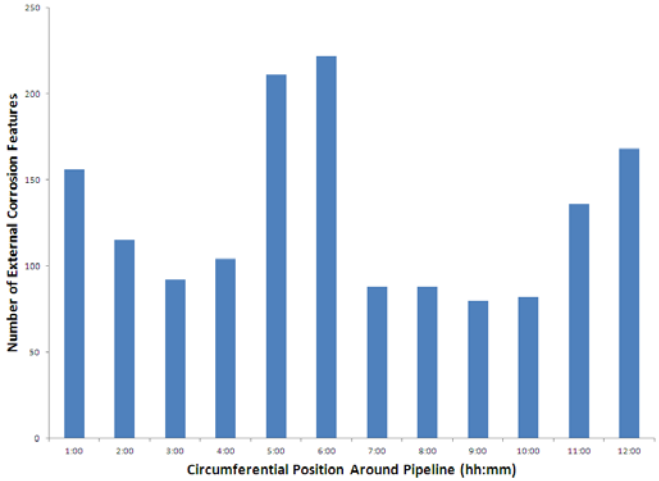
2011 ILI - External Metal Loss



- Description of Defects
  - 1542 ext ML features
  - Max, 71% wt at Launch – Clamp repaired in 2004.
  - Max unrepaired - 67% wt at 6km
  - 74 features > 50% wt
  - Majority (82%) < 35% wt
  - Fairly even distribution around pipe

- Origin of Defects
  - Typical of pitting and general corrosion –
  - thermal cycling .
  - Coating dis-bonding.
  - water ingress.
  -



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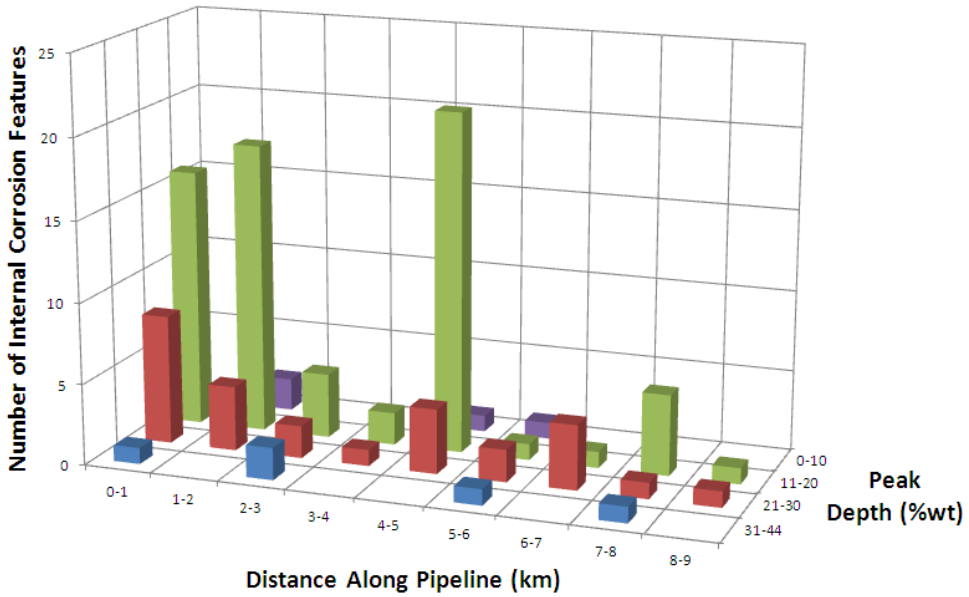
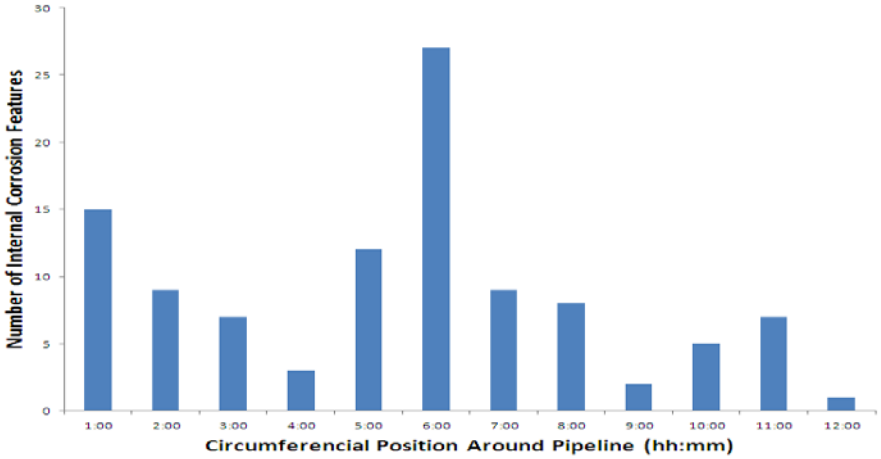
2011 ILI - Internal Metal Loss

- Description of Defects
  - 105 int ML features
  - Max, 44% wt (2km)
  - Majority (94%) <30% wt
  - Majority in 0 – 2km
  - Centered around 4 and 8 o'clock positions





- Origin of Defects
  - Pattern indicative of internal corrosion

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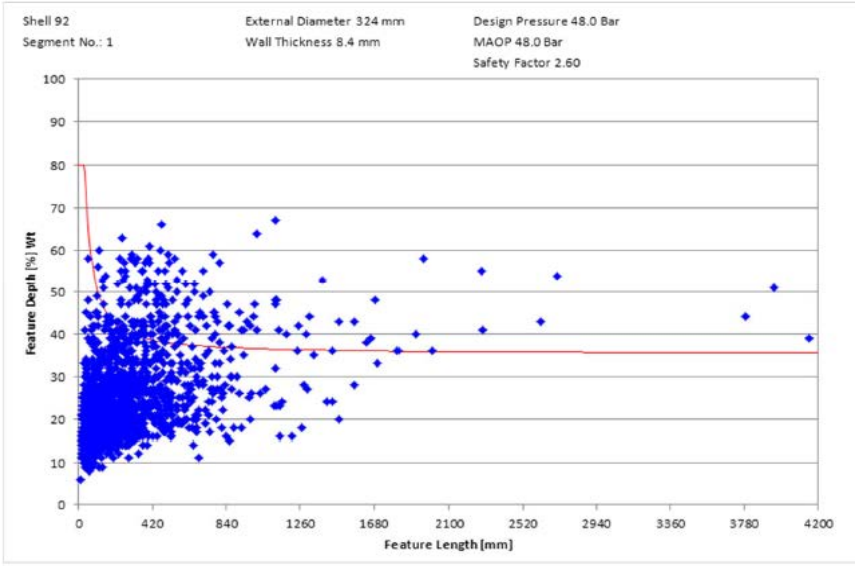
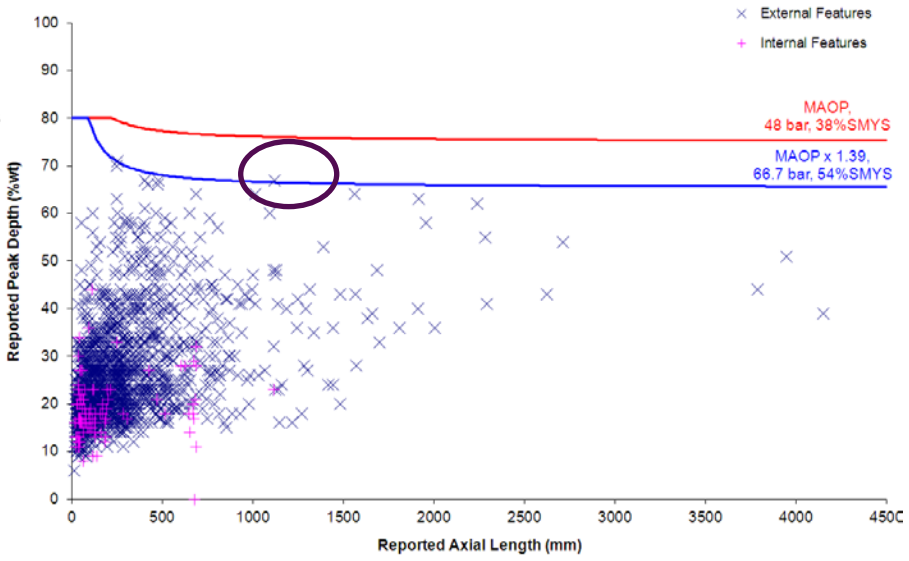
Assessment of Immediate Integrity



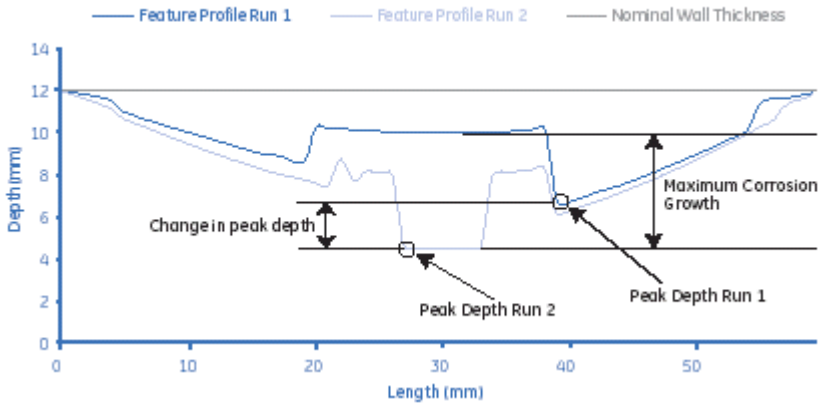
- Depth Vs Axial Length
  - Initial Report Assessment.
  - 177 Repairs

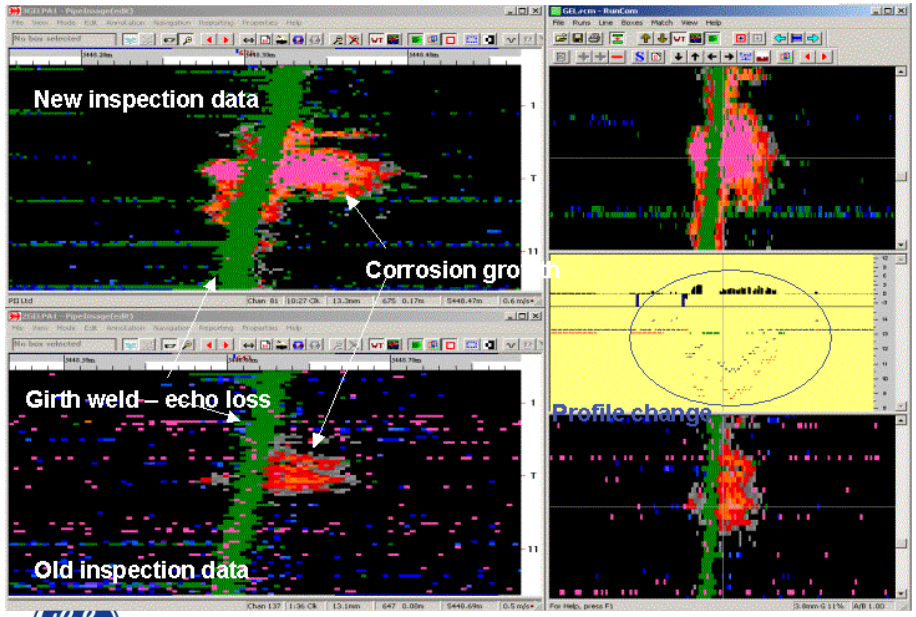


- Depth Vs Axial Length .
  - More appropriate assessment.
  - 1 Repair

1st Step - Avoid Unnecessary Immediate Repairs

Future Integrity - USWM to USWM Comparisons - signal matching





- Exact matching of corrosion sites in the pipeline
- Direct measurement of the reduction in wall thickness in both data sets to provide accurate computation of growth rates
- Identification of the change in corrosion profile between the ILI runs
- Based on standard deviation of confidence levels of sizing using USWM - there was at least a 95% probability of success of correctly identifying growth above 0.65mm change (0.2mm/year).

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The RunCom Process

- Run automatic software to:
  - Identify areas of potential growth.
  - Visually review potential external growth sites for evidence of growth.
- Select all external metal loss sites > a X% depth to determine growth rates.
- Select all external metal loss above ERF = 1 to determine growth rates.
- Select all internal metal loss > Y% depth to determine growth rates.
- Review previous repair areas (blast and wrap).
- Select representative sample along length of pipeline.
- Review other features (dents and laminations) for evidence of change.

With the aim of:

- Identifying sites of growing corrosion.
- Identify sites of new corrosion.
- Identifying max and mean growth rates along the entire pipeline.
- Identify max and mean growth rates in section of the pipeline.
- Identify repair areas where growth is continuing.

The Challenge - Avoid Unnecessary Repairs without Risk of Leak

The RunCom Results

External Corrosion

Max Rate Identified	Mean Rate Measured
1.2 mm/year	0.2 mm/year

Section	Environment	Max Growth Rate (mm/year)	Mean Growth Rate (mm/year)
1	Above Ground	0.70	0.32
2	Below Ground	0.60	0.30
3	Muddy Foreshore	0.60	0.30
4	Below Ground	1.10	0.26
5	Rocky Foreshore	0.30	0.09
6	Below Ground	1.20	0.34
7	Above Ground	0.70	0.13

Internal Corrosion

Max Rate Identified	Mean Rate Measured
0.2 mm/year	0.1 mm/year

No Growth ≤ 0.2mm/year repeatability

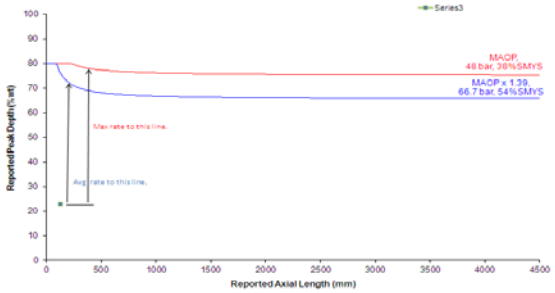
Scenario 1 – Use Line Results

Determine investigation/repairs based upon simulating growth of all external corrosion:

1) At maximum rate for line to MAOP.
2) At mean rate for line to MAOP x Safety Factor.
3) For both above to when peak depth exceeds 80% nominal wall.

Use earliest predicted investigation repair dates.

Max Rate Identified	Mean Rate Measured
1.2 mm/year	0.2 mm/year



The Negatives:
Very Conservative.
Predicts large number of investigation/repairs over 5 years.

The Positives:
Use RunCom to identify 53 repaired sites that are predicted to require repair but which are not growing significantly. Avoid repairs.
Use RunCom to identify 27 previous repair sites that are still growing. Issues still not resolved.

Repair/ Investigation Year	No of Predicted Repairs/ Year	Cumulative Repairs	No of None Growth Repaired Sites Avoided/Yr	True Cumulative Repairs	No of growing Repairs
Nov-11	1	1	0	1	0
Nov-12	10	11	5	6	5
Nov-13	59	70	17	48	10
Nov-14	175	245	25	198	10
Nov-15	500	745	6	692	2
Nov-16	745	1490	0	1437	0
Total			53	1437	27

Very Conservative

Scenario 2 – Use Section Results

Determine investigation/repairs based upon simulating growth of all external corrosion:

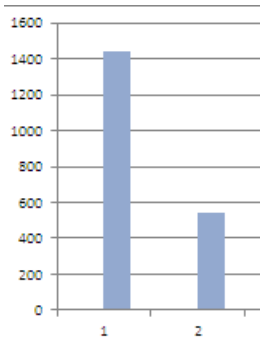
1) At maximum rate for section to MAOP.
2) At mean rate to for section to MAOP x Safety Factor.
3) For both above to when peak depth exceeds 80% nominal wall.

Use earliest predicted investigation repair dates.

Section	Environment	Max Growth Rate (mm/year)	Mean Growth Rate (mm/year)
1	Above Ground	0.70	0.32
2	Below Ground	0.60	0.30
3	Muddy Foreshore	0.60	0.30
4	Below Ground	1.10	0.26
5	Rocky Foreshore	0.30	0.09
6	Below Ground	1.20	0.34
7	Above Ground	0.70	0.13

The Negatives:
Still conservative.
Still predicts large number of investigation/repairs over 5 years.

The Positives:
Use RunCom to identify 52 repaired sites that are predicted to require repair but which are not growing significantly . Avoid repairs.
Use RunCom to identify 25 previous repair sites that are still growing. Issues still not resolved.



Repair/ Investigation Year	No of Predicted Repairs/ Year	Cumulative Repairs	No of None Growth Repaired Sites Avoided/Yr.	True Cumulative Repairs	No of growing Repairs
Nov-11	1	1	1	0	0
Nov-12	8	9	4	4	2
Nov-13	18	27	6	16	6
Nov-14	78	105	22	72	10
Nov-15	167	272	12	227	5
Nov-16	322	594	7	542	2
Total			52	542	25

Still Conservative

Scenario 3 – Use Half Life

Not using RunCom Data:

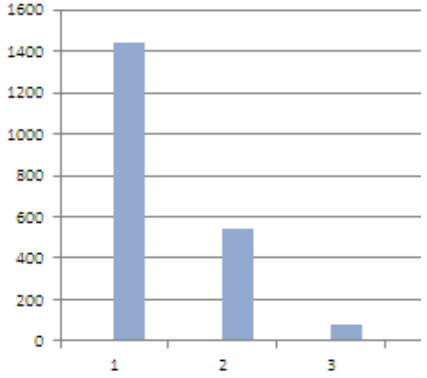
Determine investigation/repairs based upon simulating growth of all external corrosion:

1) At half life rate for entire line to MAOP x Safety Factor.
2) To when peak depth exceeds 80% nominal wall.

Use earliest predicted investigation repair dates.

The Negatives:
Uncertain results.
Are any growing at a faster rate?
Predicts 25 none growing repaired sites for investigation – are they really still growing?
Predicts 16 still growing repair sites for investigation – are they really still growing?

The Positives:
Less Conservative (is this a positive?)
Less Repairs.



$$\text{Half Life} = \frac{71\% \times 9.7\text{mm wt}}{19 \text{ years}} = 0.36\text{mm/year}$$

Repair/ Investigation Year	No of Predicted Repairs/ Year	Cumulative Repairs	No of None Growth Repaired Sites Investigated /Yr	True Cumulative Repairs	No of growing Repairs
Nov-11	1	1	0	1	0
Nov-12	11	12	4	12	5
Nov-13	5	17	3	17	1
Nov-14	16	33	5	33	2
Nov-15	20	53	5	53	3
Nov-16	32	85	7	85	5
Total			25	85	16

Less Conservative – Uncertain Results

Scenario 4 – Use Spool Results

Determine investigation/repairs based upon simulating growth of all external corrosion:

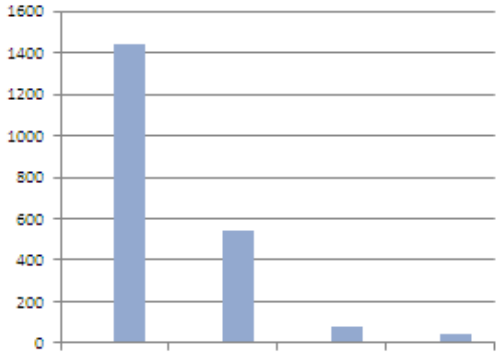
1) At spool max rate for active spools to MAOP .
2) At repeatability (0.2mm/yr) for stable spools to MAOP.
3) At mean rate to for section to MAOP x Safety Factor.
4) For all above to when peak depth exceeds 80% nominal wall.

Use earliest predicted investigation repair dates.

~20 Repairs. Re-Inspect in 2015

The Negatives:
None?

The Positives:
Conservative.
Accurate.
Less Repairs.
Avoids unnecessary re-repairs.
Identifies growing repaired areas.
Safe recommendation of a re-inspection Interval



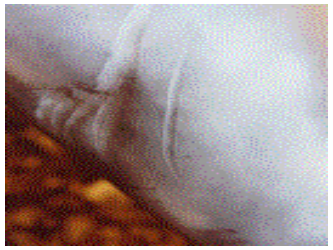
Repair/ Investigation Year	No of Predicted Repairs/ Year	Cumulative Repairs	No of None Growth Repaired Sites Avoided/yr	True Cumulative Repairs	No of Growing Repairs Found
Nov-11	1	1	0	1	0
Nov-12	5	6	3	3	2
Nov-13	8	14	3	8	3
Nov-14	7	21	2	13	2
Nov-15	11	32	4	20	1
Nov-16	22	54	2	40	3
Total			14	40	11

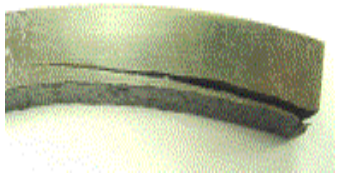
Most Accurate – Reliable Results

What about the Other Features?

- 11 Dents Reported in 2011, 7 in 2008.
  - All compared in RunCom.
  - 7 were re-reported. Not new – No Change.
  - 2 were in 2008 data (<2%OD) but missed in original analysis – Not new. No change.
  - 2 were in new replaced spools since 2008.

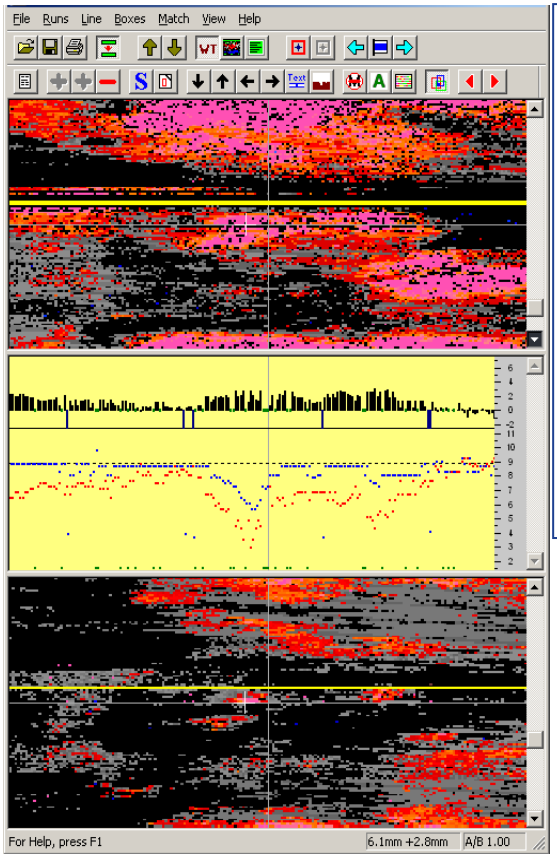
- 49 Laminations Reported in 2011, 41 in 2008.
  - All compared in RunCom.
  - 41 re-reported. Not new – no change.
  - 8 were in 2008 data but missed in original analysis. Not new.

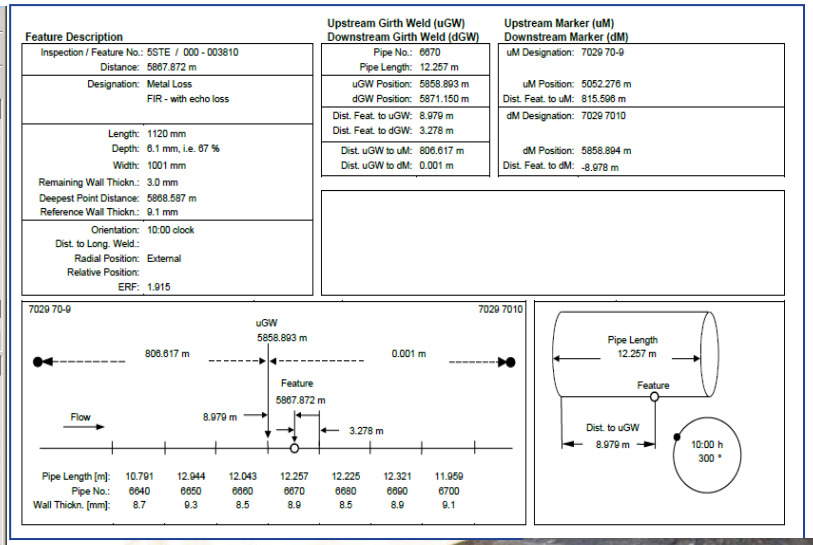




RunCom Used to Compare other Features

Turning Results in to Action





Note: Bolted Epoxy Sleeve due to road proximity.

67% Deep Growing Feature Requiring Immediate Repair.

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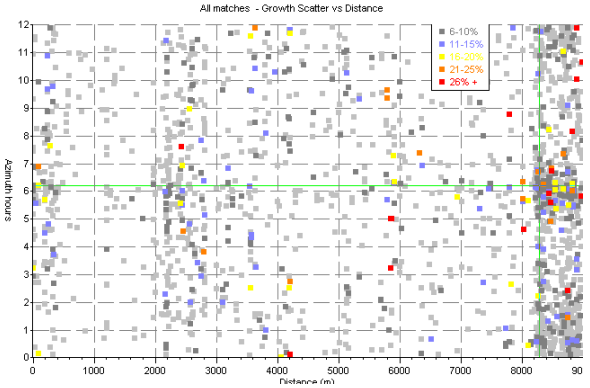
GE Offer Repair Service

Summary of Case Study

- Highest Accuracy Repeat Inspection Data chosen by Knowledgeable Client.
- Multiple Inspections/Client Discussions – Issues fully understood by GE and client.
- Corrosion Growth Analysis performed with goal of obtaining meaningful results for use in a Future Integrity Assessment.
- Supply of a list of maximum growth sites.
- Intelligent utilisation of Corrosion Growth scenarios to minimise repairs .
- Supply of trustworthy repair plan that minimises the risks of leaks.
- Review of changes to other reported features.
- Recommendation of Safe Re-Inspection Interval.



Spool	Absolute Distance (m)	Relative Distance (m)	Orientation (hh:mm)	Peak Depth (%wt)	Peak Depth (mm)	Length (mm)	Width (mm)	Local WT (mm)	Section	Repair Date	Scope of Work (SOW) Inspection Report Ref	Inspection Date
6670	5867.9	9.0	10:00	67	6.1	1120	1001	9.10	6	Oct-11		
30	4.0	1.2	06:22	71	6.89	253	161	9.70	1	Jan-12	14-SOW-04	Nov-04
5710	5111.0	0.7	05:10	67	5.56	480	207	8.30	5	May-12	--	Mar-05
5620	5018.2	1.4	11:10	70	6.51	248	585	9.30	5	Jul-12	09-SOW-01	Nov-04
5480	4910.4	10.2	11:02	67	6.10	405	417	9.10	5	Oct-12	04-SOW-04	Apr-05
6880	6002.4	0.2	02:10	66	7.52	475	466	11.40	6	Oct-12		
9640	8168.7	3.9	06:50	64	5.70	1562	889	8.90	6	Dec-12	17-SOW-04	Apr-05
3660	3195.6	0.0	04:26	64	5.31	1014	979	8.30	4	Jan-13	002SOW2004	Nov-04
11050	8807.7	0.1	05:22	66	5.74	420	314	8.70	7	Feb-13	01-SOW-05	Mar-05
2750	2423.5	8.7	04:12	62	5.52	2238	687	8.90	4	Apr-13	03-SOW-02	Aug-04
3870	3392.8	7.8	02:34	63	5.36	1915	1005	8.50	4	Apr-13	03-SOW-04	Mar-05
6660	5856.4	9.6	10:32	57	4.96	805	1002	8.70	6	Jun-13		
3640	3192.6	2.6	07:50	55	4.79	2283	1002	8.70	4	Jul-13	02SOW2004	Nov-04
10190	8367.5	2.2	00:16	64	5.95	685	997	9.30	7	Jul-13	01-SOW-05	Mar-05
2760	2427.4	0.5	07:42	58	4.93	335	144	8.50	4	Jan-14		

Collaboration is key to obtaining maximum benefits from RunCom

Why use GE to perform corrosion growth assessments?

- More than 9 years experience & > 40,000km assessed.
- Have a dedicated expert team experienced in ILI data analysis.
- Regular repeat business from > 20 operators.
- Case studies & published papers available.
- Can perform assessments on GE ILI data &/or other vendor data.
- **Selected by PRCI to develop corrosion growth assessment guidelines for the industry.**

> *The tool GE has developed is a real winner and will have immediate impact for a number of our members, and the pipeline industry in general. Your efforts are appreciated by PRCI and its members*

The industry "go-to" people for corrosion growth assessment

Contact Details

Paul Clayton – Account Manager.
General Electric – PII,
Atley Way,
Cramlington,
Northumberland.
NE23 1WW
Tel – 0191 2473458

Derek Balmer - Global Technical Lead (Magnetics).
General Electric – PII,
Atley Way,
Cramlington,
Northumberland.
NE23 1WW
Tel - 0191 2473481

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