INSPECTION INTELLIGENCE NDT GLOBAL

LINEEXPLORER® UCc

Ultrasonic Crack Detection

Inspection Report

Revision	Date	Comment
Issue # 1	14 Aug 2014	Original issue
Issue # 2	15 Aug 2014	Re-issue as requested by client
Issue # 3	20 Mar 2017	Update of pipe grade

Customer: Enbridge Pipelines Inc.

Pipeline: 4.13 mi. x 20" North Straits East – Mackinaw, Line 5

Run Date: 10.07.2014

Run ID: ENBNM14U0

Document No.: IR-ENBNM14U0-NorthStraitsEast-Mackinaw-Line5-en

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- **Spreadsheets** – the result lists of this report in Excel format

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Executive Summary

Enbridge Pipelines Inc. contracted NDT Global to perform an Ultrasonic Crack Detection survey for a 4.13 mi. section of the 20" Line 5, from North Straits East to Mackinaw. The primary objectives of this survey were to detect, size, and locate circumferential cracks and crack-like features.

The major results of this in-line inspection can be summarized as follows:

14 anomalies classified as **crack-like anomalies** were detected.

- The deepest of these anomalies is the internal anomaly with ID 900015, which has an estimated depth of 51 mil and is located at distance 6182.34 ft. The feature is possibly a notch-like anomaly.
- The second deepest is the internal anomaly with ID 900014, which has an estimated depth of 43 mil and is located at distance 6182.34 ft. The feature is possibly a notch-like anomaly.
- The remaining anomalies have an estimated depth of < 39 mil.

In UCc data analysis, a distinction between, on the one hand, crack-like or crack field and, on the other hand, notch-like or metal loss anomalies is difficult. Therefore, these anomalies were, in a conservative way, classified as crack-like or crack field anomalies, but they could also be manufacturing-related or metal loss anomalies. Features that are assumed to be manufacturing-related or metal loss anomalies have a corresponding comment.

One **dent** was entered into the result lists. The dent with ID 339340 is located at the top of the pipeline.

For clarification of any aspect of a survey, please contact our office. NDT Global welcomes the opportunity to provide continued service to Enbridge Pipelines Inc..

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1 Scope of Inspection

Enbridge Pipelines Inc. contracted NDT Global to perform an Ultrasonic Crack Detection survey for a 4.13 mi. section of the 20" Line 5, from North Straits East to Mackinaw. The primary objectives of this survey were to detect, size, and locate circumferential cracks and crack-like features.

2 Operational Details

2.1 Pipeline & Medium Information

Launch – Trap	North Straits East – Mackinaw
Pipeline Name	Line 5
Length of Inspected Pipeline Section	4.13 mi.
Pipeline Diameter	20"
Wall Thickness Range	0.480 in. – 0.984 in., prevalent: 0.815 in.
Weld Type	seamless
Minimum Bend Radius	5D/90°
Pipe Grade(s)	API 5L X30, Grade A
Usual Medium	crude oil
Medium Used for Inspection	crude oil
Sound Velocity in Coupling Medium	50.866 mil/µsec @ 63 °F
Attenuation in Coupling Medium	5 dB @ 63 °F
Temperature of Medium during Inspection	60 – 68 °F
Flow Velocity during Inspection	approx. 2.03 mph

Table 1 – Pipeline and medium information

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2.2 Pipeline Preparation

In order to remove debris from the internal pipeline walls such as wax and tar deposits, clay, sand, and other debris, Enbridge Pipelines Inc. performed a cleaning procedure on this section of pipeline prior to the inspection run. A very small amount of debris was received.

The passage clearance was verified by means of a geometry run in 2013; the smallest listed nominal bore of the pipeline was 17.89 in.

2.3 Inspection Run Details

After the ability to traverse the pipeline had been confirmed, the following inspection was performed:

Run ID	Departure	Arrival	Tool Condition
ENBNM14U0	10 July 2014, 00:55 a.m.	10 July 2014, 02:55 a.m.	good

Table 2 – Inspection run

2.4 Data Quality

During the LineExplorer UCc inspection run, data were recorded by all channels, covering the complete circumference of the pipe and the entire length of the pipeline (21767.53 ft. according to the odometer reading).

The quality of the inspection data is good and fully meets the tool and feature specifications. This survey was accepted for final data analysis.

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2.5 Run Profiles

2.5.1 Speed Profile

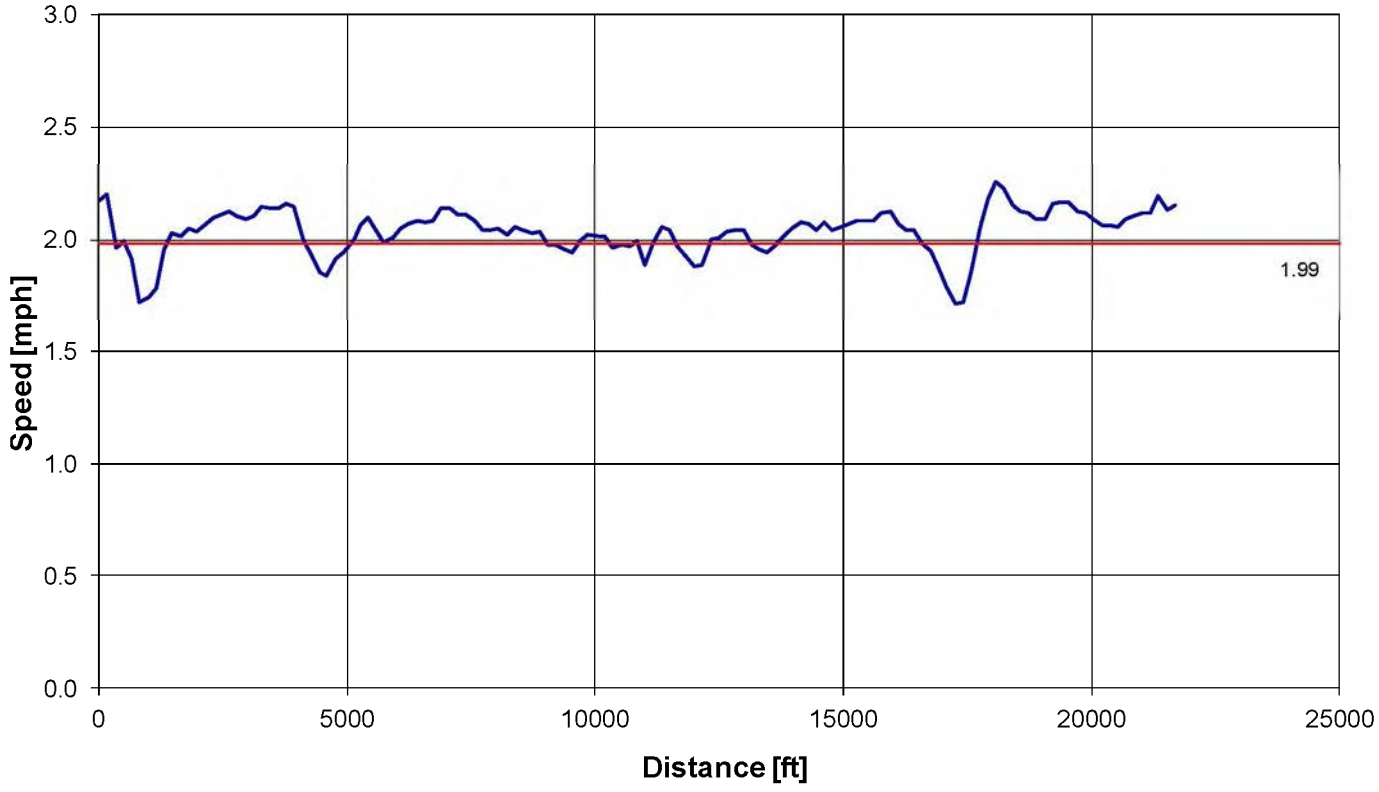


Figure 1 – Speed profile

The speed diagram shows that the specified maximum tool speed (1.99 mph) was exceeded by up to approx. 14 % in some distance ranges, i.e. the axial sampling distance is increased from 59.06 mil to up to 67.32 mil. Therefore, the feature specifications regarding POD[1] and confidence level for the sizing accuracy are not significantly affected.

[1] POD = Probability of Detection (The probability of a feature being detected by the intelligent tool.)

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2.5.2 Temperature Profile

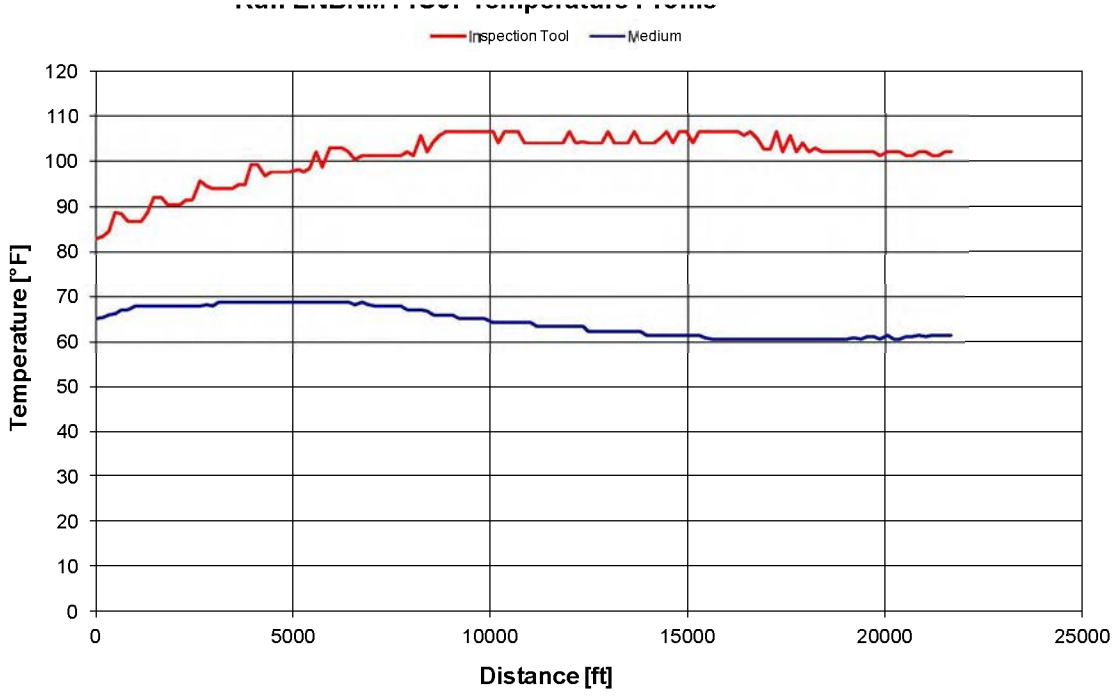


Figure 2 – Temperature profile

2.5.3 Pressure Profile

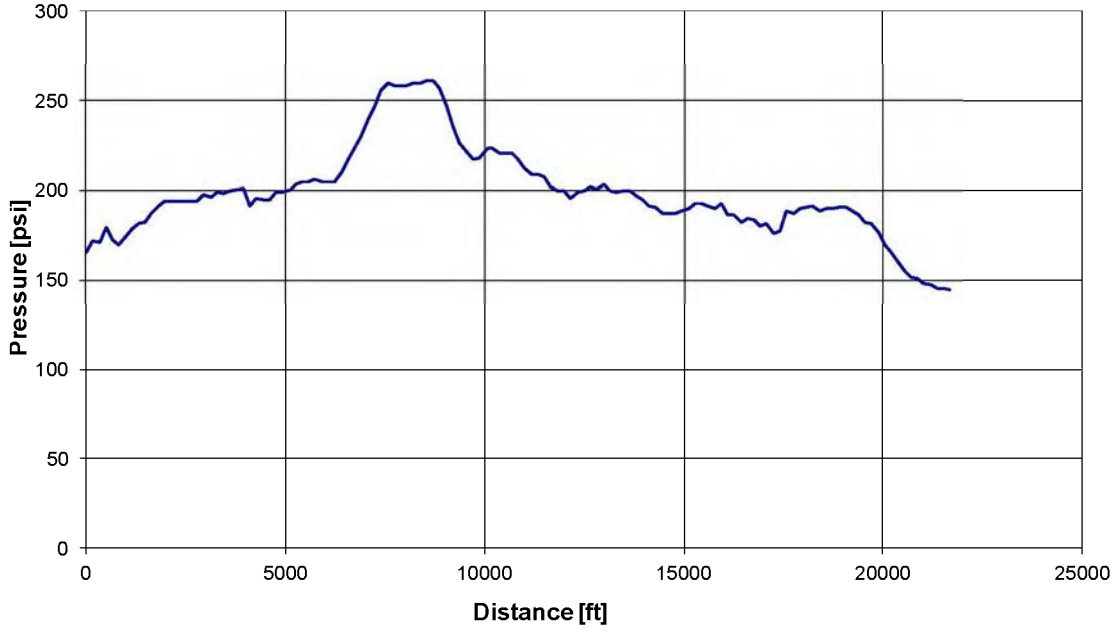


Figure 3 – Pressure profile

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2.5.4 Pendulum Profile

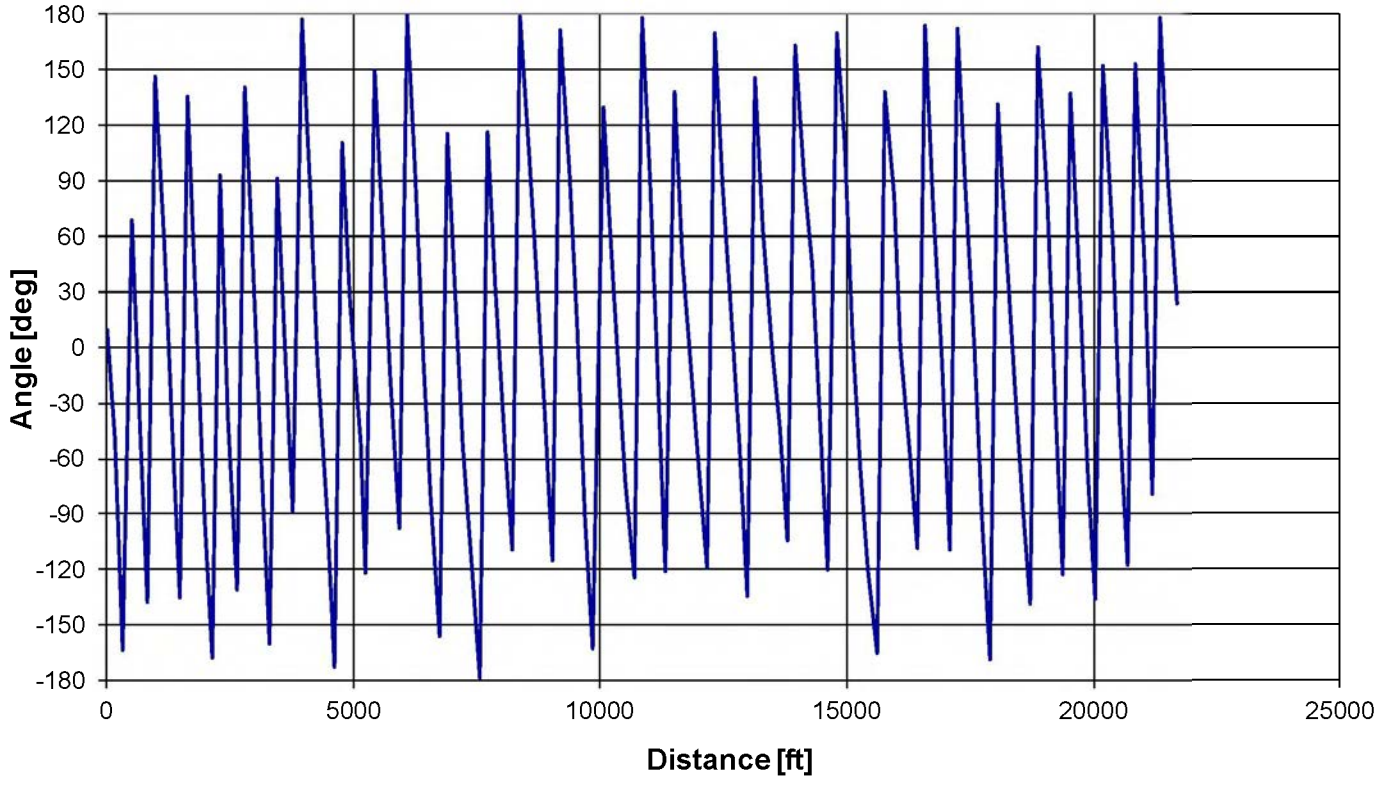


Figure 4 – Pendulum profile

The pendulum profile shows that the inspection tool rotated in some distance ranges. The tool rotation does not affect data analysis because the rotation is recorded by the pendulum and considered during data processing.

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2.5.5 Pendulum Speed Profile

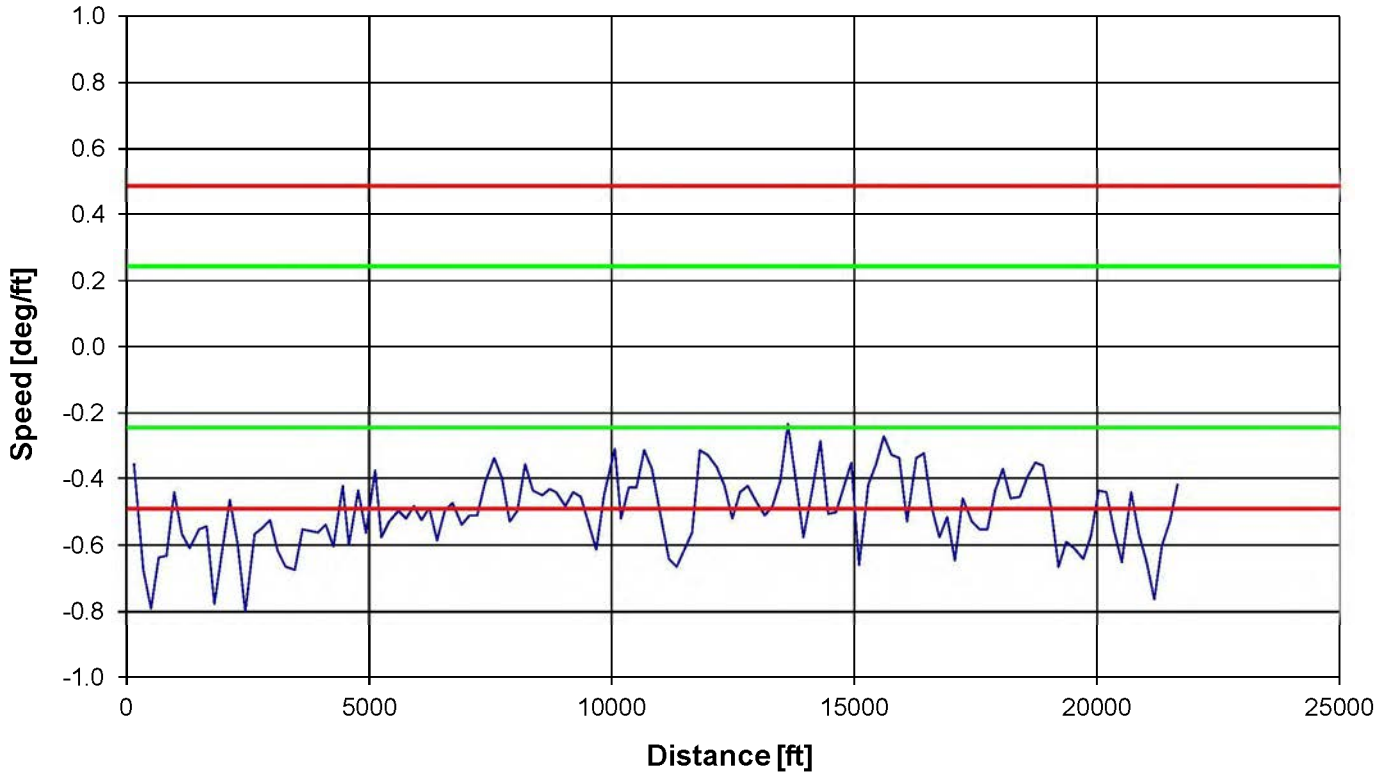


Figure 5 – Pendulum speed profile

The pendulum speed profile shows that the inspection tool rotated nearly over the whole distance with a speed lower than 0.8 deg/ft.

The speed of the tool rotation does not affect data analysis.

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3 Summary of Results

3.1 Reporting Criteria

The following criteria[1] were applied to the dimensions of a feature to be included in the Pipeline Register and all other appropriate spreadsheets:

circumferential crack or crack-like anomaly	amplitude threshold[2] 49 dB
installation	all

Table 3 – Reporting criteria

3.2 Results

The following **features** detected by the LineExplorer UCc tool are entered into the Pipeline Register and all other appropriate spreadsheets:

Feature Type	Quantity
crack-like (crack-like anomaly in the weld seam, fatigue crack, etc.)	14
dent	1
installation	14
Total	**29**

Table 4 – Overview of the reported features, LineExplorer UCc

[1] Several features with a length and/or depth below the reporting threshold were entered into the pipeline register. The specified confidence level is not applicable to features with dimensions below the feature specifications and may therefore be reduced.
[2] Minimum value of the maximum amplitude within a feature box.

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3.2.1 Crack-like Anomalies

The major results of this in-line inspection can be summarized as follows:

14 anomalies classified as **crack-like anomalies** were detected.

- The deepest of these anomalies is the internal anomaly with ID 900015 (see Figure 8), which has an estimated depth of 51 mil and is located at distance 6182.34 ft. The feature is possibly a notch-like anomaly.
- The second deepest is the internal anomaly with ID 900014 (see Figure 9), which has an estimated depth of 43 mil and is located at distance 6182.34 ft. The feature is possibly a notch-like anomaly.
- The remaining anomalies have an estimated depth of < 39 mil.

In UCc data analysis, a distinction between, on the one hand, crack-like or crack field and, on the other hand, notch-like or metal loss anomalies is difficult. Therefore, these anomalies were, in a conservative way, classified as crack-like or crack field anomalies, but they could also be manufacturing-related or metal loss anomalies. Features that are assumed to be manufacturing-related or metal loss anomalies have a corresponding comment.

The following table gives an overview of the **distribution of crack-like anomalies** according to their estimated depths:

Depth (mil)	Crack-like Quantity
< 39	12
39 – 78	2
79 – 118	0
≥ 119	0
Total	**14**

Table 5 – Distribution of the crack-like anomalies according to depth

3.2.2 Dents (Geometrical Deformation)

One dent was entered into the result lists. The dent with ID 339340 (see Figure 10) is located at the top of the pipeline.

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3.2.3 Installations

The following features detected by the LineExplorer UCc were classified as installations during data analysis and entered into the result lists:

Installation Type	Quantity
valve	2
flange	3
T-piece	4
offtake	4
stopple	1
Total	**14**

Table 6 – Overview of the pipeline installations

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3.3 Examples of Features

The following screenshots explain the major information provided in the LineExplorer UCc C-scan and B-scan pictures:

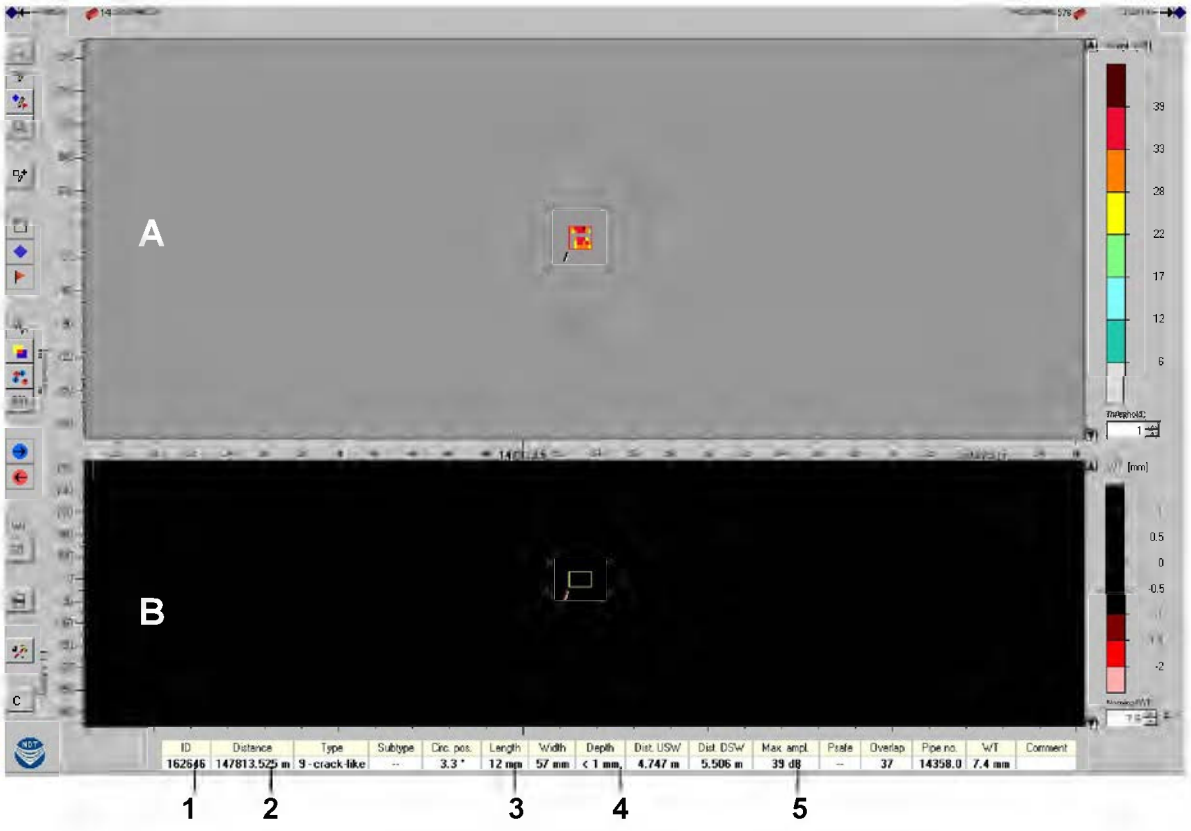


Figure 6 – Information provided in the C-scan picture

Item	Meaning
A	Crack detection C-scan display
B	Wall thickness C-scan display

Item	Meaning
1	Feature ID
2	Absolute distance of the feature
3	Length of the feature box
4	Estimated depth of the feature
5	Maximum amplitude of the feature

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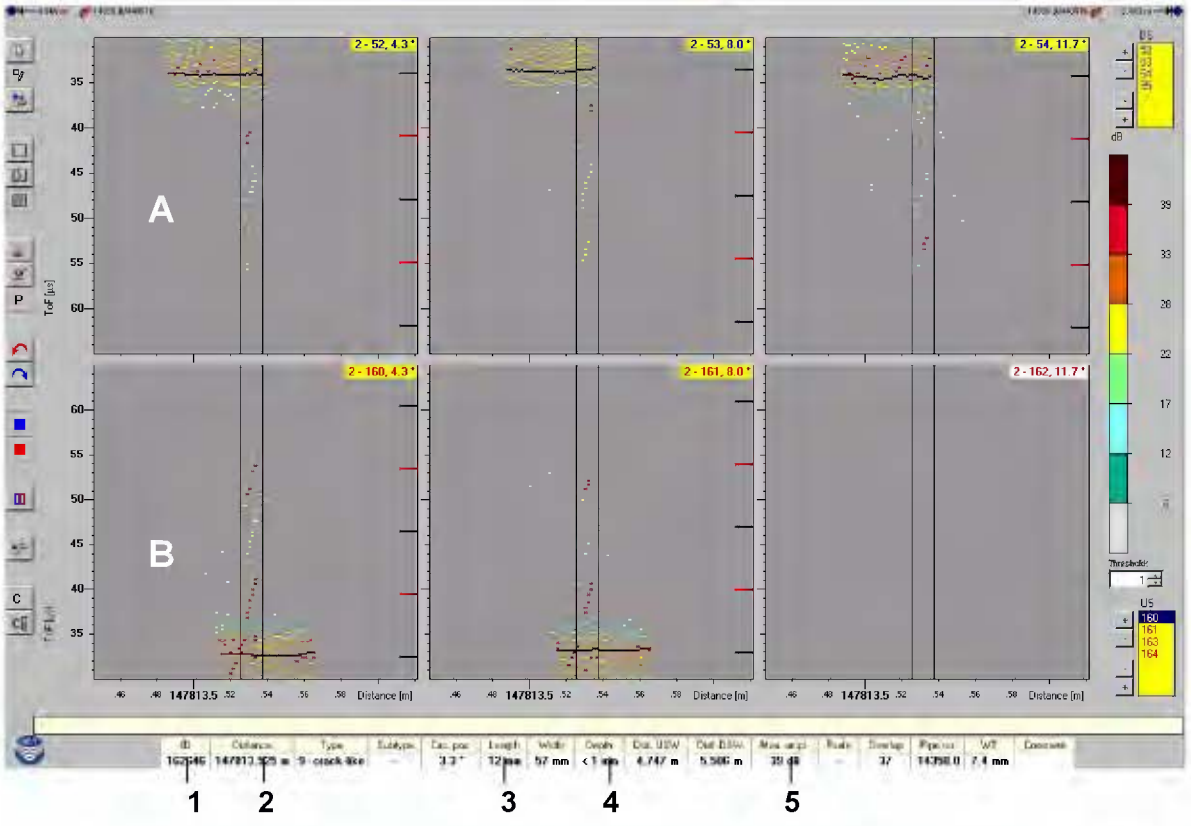


Figure 7 – Information provided in the B-scan pictures

Item	Meaning
A	B-scan display of three neighboring sensors (downstream sensors)
B	B-scan display of three neighboring sensors (upstream sensors)

Item	Meaning
1	Feature ID
2	Absolute distance of the feature
3	Length of the feature box
4	Estimated depth of the feature
5	Maximum amplitude of the feature

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Figure 8 shows the C-scan and B-scans of the deepest anomaly classified as crack-like anomaly (ID 900015), with an estimated depth of 51 mil. The anomaly is located at odometer distance 6182.34 ft. and is possibly a notch-like anomaly.

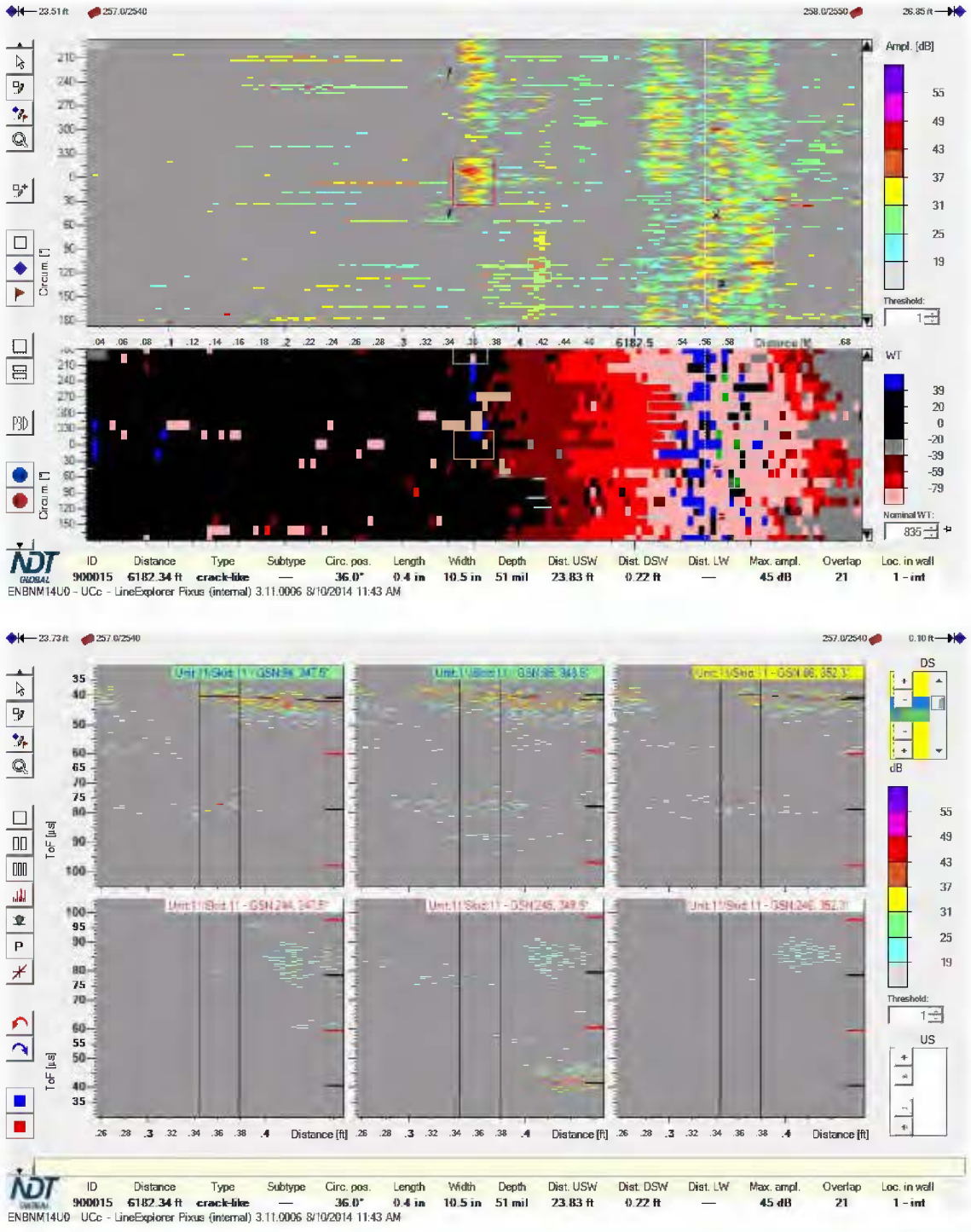


Figure 8 – Top: C-scan, bottom: B-scans of the deepest anomaly classified as crack-like anomaly (ID 900015)

Figure 9 shows the C-scan and B-scans of the deepest anomaly classified as crack-like anomaly (ID 900014), with an estimated depth of 43 mil. The anomaly is located at odometer distance 6182.34 ft. and is possibly a notch-like anomaly.

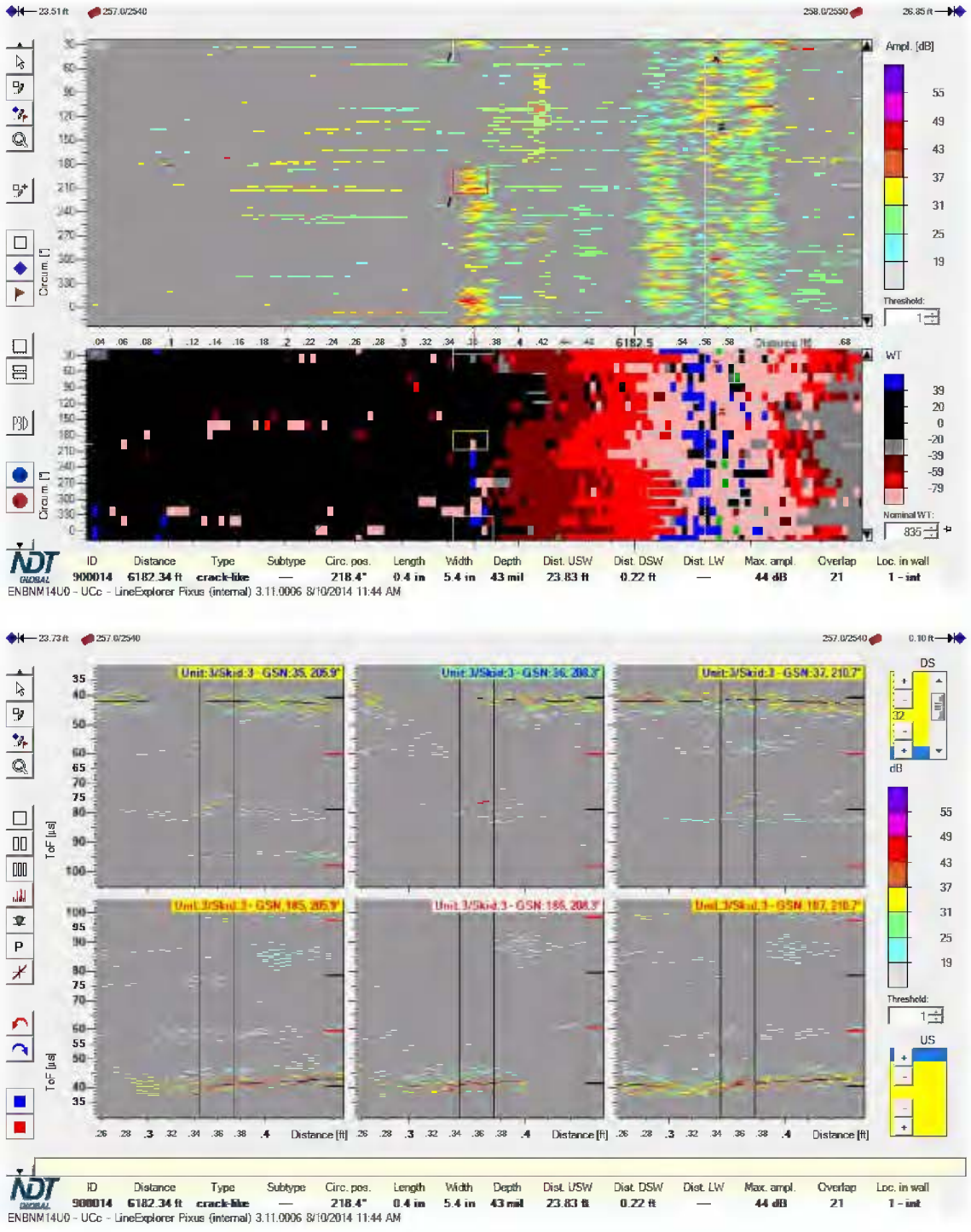


Figure 9 – Top: C-scan, bottom: B-scans of the deepest anomaly, classified as crack-like anomaly (ID 900014)

Figure 10 shows the C-scan and B-scans of a dent (ID 339340). The dent is located at odometer distance 19768.64 ft.

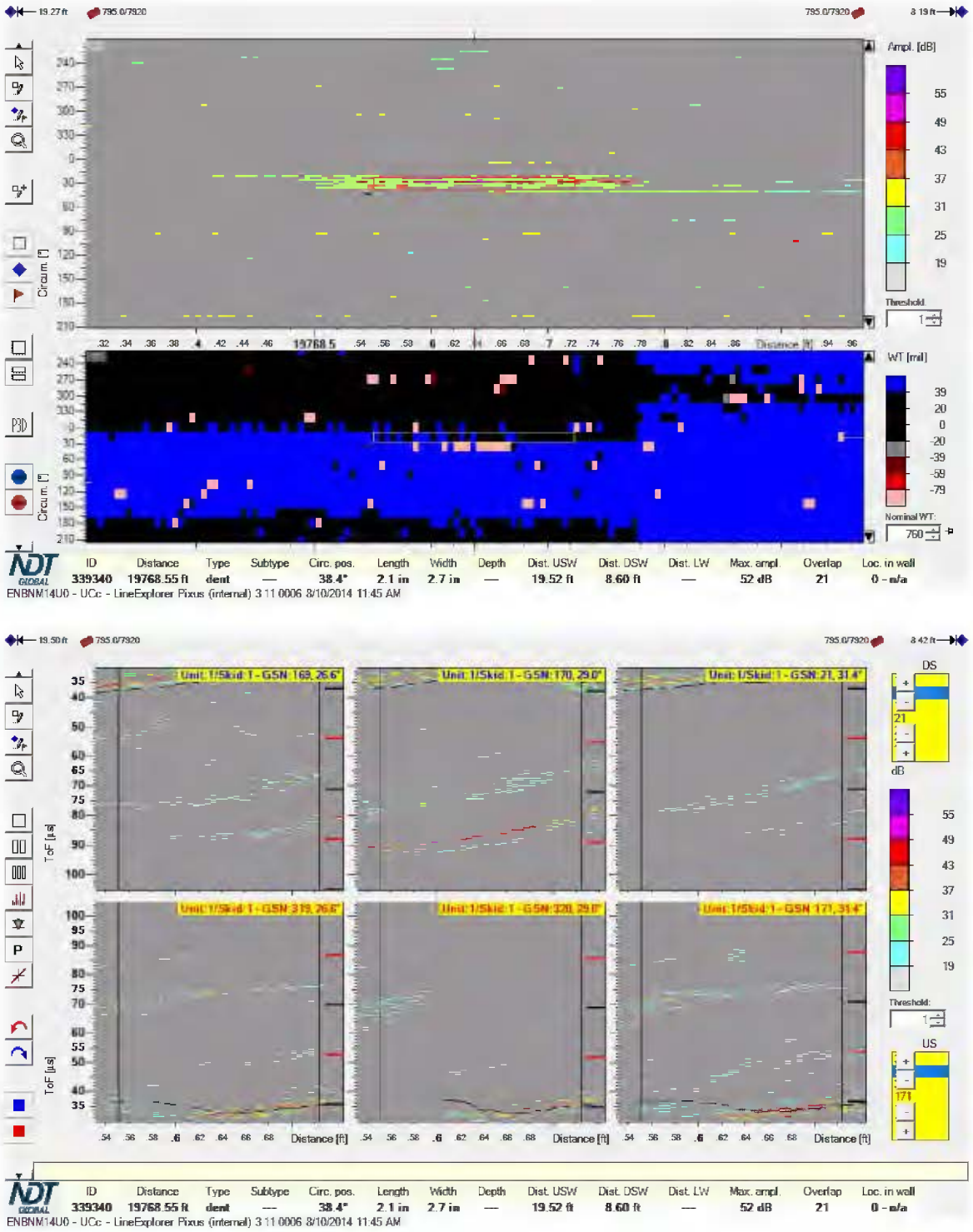


Figure 10 – Top: C-scan, bottom: B-scans of a dent (ID 339340)

3.4 Charts & Histograms

3.4.1 Distribution of Crack-like Anomalies

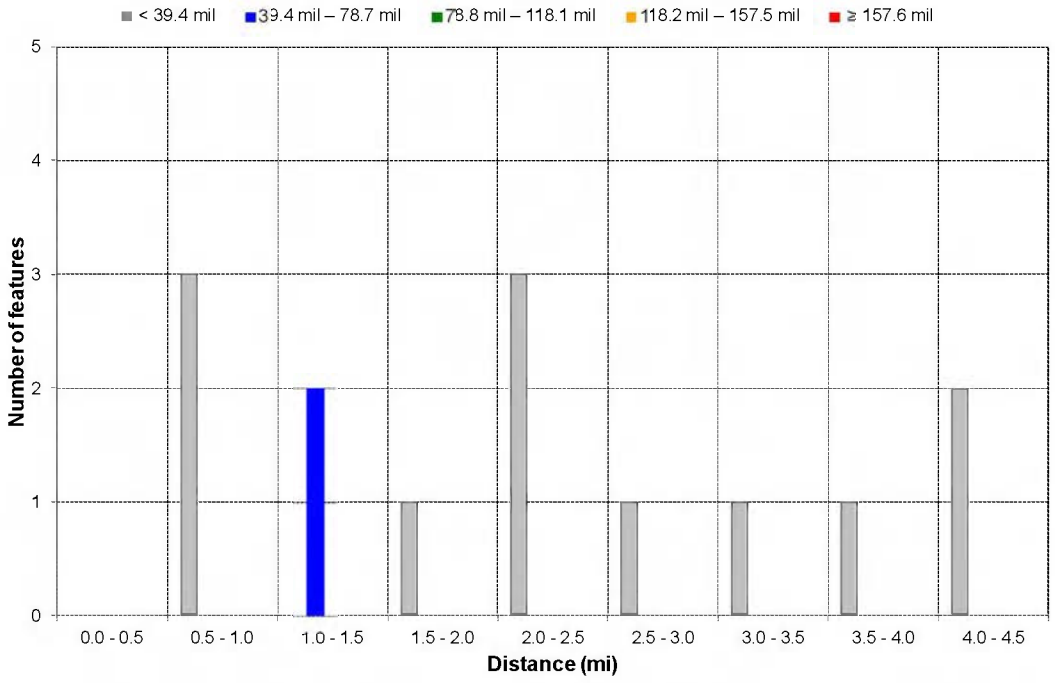


Figure 11 – Distribution of crack-like anomalies according to depth – number vs. distance

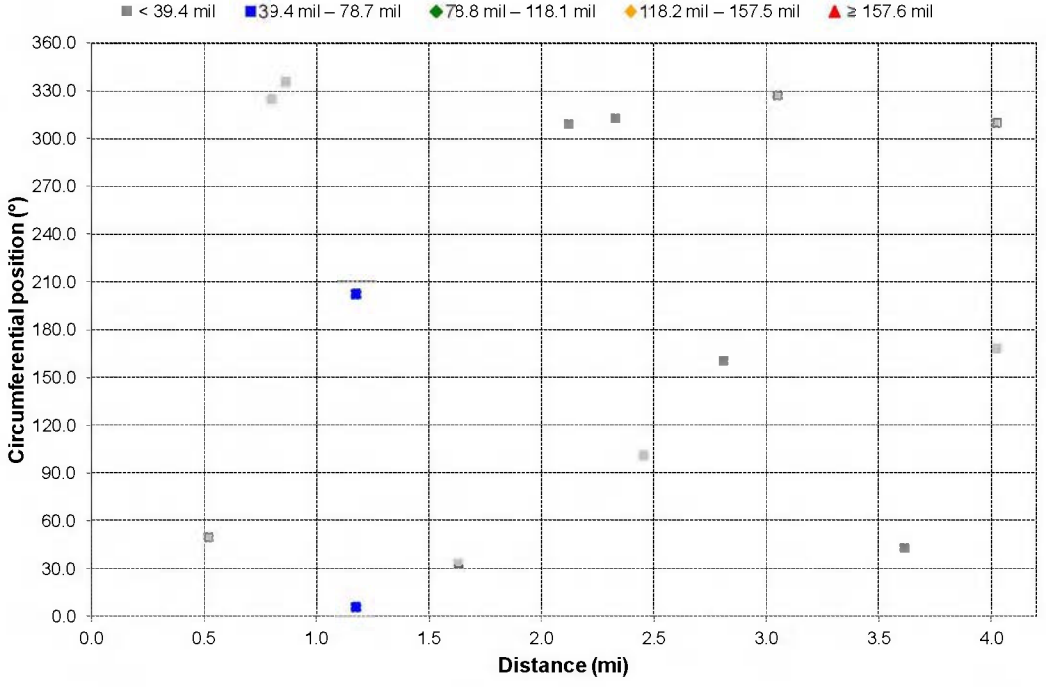


Figure 12 – Circumferential distribution of crack-like anomalies according to depth

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3.4.2 Distribution of Wall Thickness

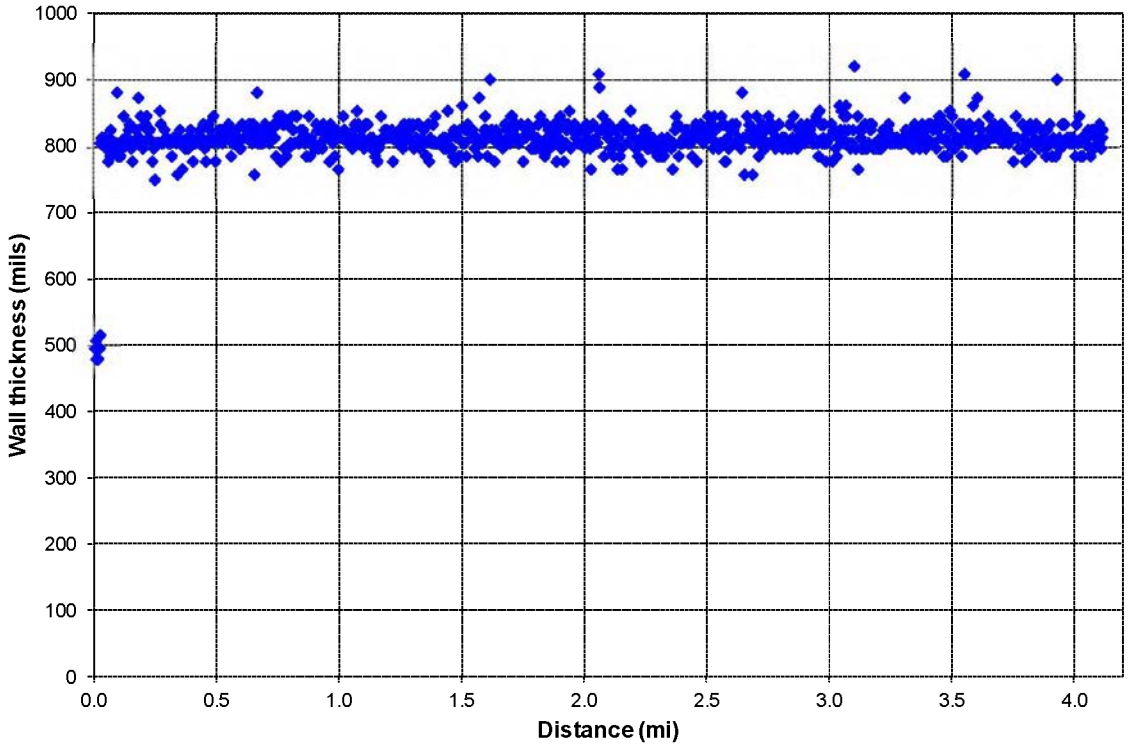


Figure 13 – Wall thickness distribution of the pipe joints

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Part 2: Result Lists

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11 Section List

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The Pipeline Register and the other spreadsheets consist of the following columns:

US weld ID	number of the upstream girth weld
Joint length (ft.)	length of the pipe joint
Long seam orient. (°)	circumferential position of the longitudinal weld; 0° is at the top; the angular degree increases in clockwise direction when looking downstream
Weld type	indicates the longitudinal weld type if detected and identified, e.g. SAW, DSAW, ERW, seamless, spiral
Event name	five classifications of events: anomaly, marker, weld, fixture, and deformation
Feature/marker ID	unique identifier of the feature or marker
Ref. box ID	ID of the feature to which the main spot belongs or ID of the cluster to which the cluster member belongs
Absolute distance (ft.)	distance value of the beginning of the feature to the reference distance 0 ft.
Relative distance (ft.)	distance value of the beginning of the feature to the upstream girth weld
MSP dist. to US weld (ft.)	the relative distance of the most significant/deepest point of the feature (or the middle of the box unless a deepest point is available) to the upstream girth weld
Feature type	possible feature types are: • crack field (group of several crack-like anomalies, e.g. SCC = stress corrosion cracking) • crack-like • dent • installation (flange, T-piece, valve, offtake, etc.)
Feature subtype	feature subtype, e.g. "T-piece" for feature type "installation"
Rel. pos.	relative position of the feature with respect to the weld seams: bm = in base material — aws = at welds[1] ilw = in long weld — alw = at long weld igw = in girth weld — agw = at girth weld isw = in spiral weld — asw = at spiral weld
Radial pos.	location of the feature within the pipe wall, such as internal, external, mid-wall
Start degree (°)	circumferential position of the upper border of the feature box, with regard to the flow direction

[1] At girth weld and longitudinal weld or at girth weld and spiral weld or at spiral weld and coil weld.

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End degree (°)	circumferential position of the lower border of the feature box, with regard to the flow direction
MSP orient. (°)	circumferential position of the most significant/deepest point of a feature or the middle of the box unless a deepest point is available
Length (in.)	length of the feature box in axial direction; for the feature types crack-like, crack field, notch-like, and ambiguous, this corresponds to the anomaly width
Width (in.)	width of the feature box in circumferential direction; for the feature types crack-like, crack field, notch-like, and ambiguous, this corresponds to the anomaly length
Peak depth (mil)	estimated depth of the feature
Peak depth (nom. wt) (%)	depth of the feature in percent of the nominal wall thickness
Nom. wt (in.)	nominal wall thickness value of the pipe joint
Local joint wt (in.)	most frequently measured wall thickness value of the pipe joint (for girth welds); if this field is empty, the wall thickness exceeds the maximum wall thickness measureable with the tool settings used for this inspection (e.g. in an installation)
Top/bottom dent	top of pipe deformation (dents) are those located between 8 o'clock and 4 o'clock
Comment	additional information on the feature, if necessary

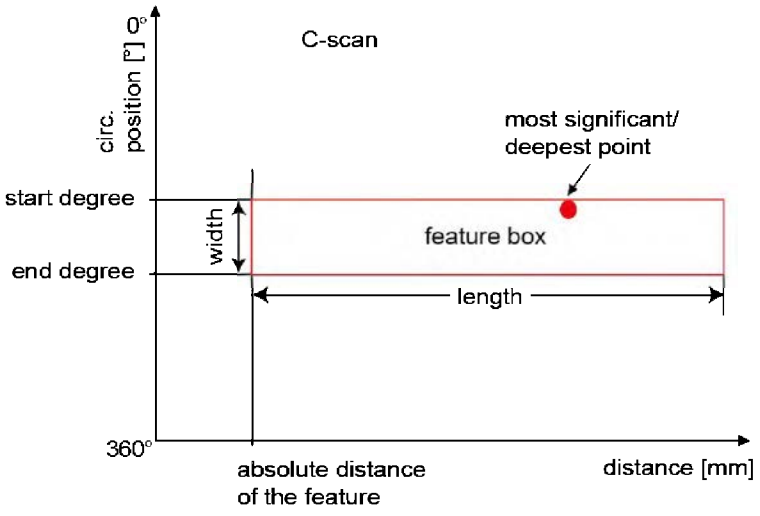


Figure 14 – Illustration of box coordinates

A feature is described by a surrounding rectangular box. In the C-scan representation, the absolute distance of the feature refers to the upstream border of the feature box and the circumferential start and end

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positions of the feature refer to the upper and lower borders of the feature box, respectively. 0° is at the top. The angular degree increases in clockwise direction when looking downstream.

Note: The width and length sizing in the Feature Specifications refer to the actual dimensions of the anomaly which may deviate from the width and length of the feature box, e.g. in the case of a diagonally oriented anomaly.

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1 Pipeline Register

The Pipeline Register contains detailed information on the various anomalies, girth welds and other pipeline features detected during this inspection run.

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2 Feature List

The Feature List contains detailed information on the anomalies identified during data analysis which meet the feature specifications and reporting criteria.

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3 Long Seam Anomaly List

The Long Seam Anomaly List contains detailed information on anomalies located near or in the long seam weld.

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4 Girth Weld Anomaly List

The Girth Weld Anomaly List contains detailed information on anomalies located near or in the girth weld.

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5 Dent List

This list contains all dents found in the pipeline surveyed.

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6 Lamination List

This list contains all laminations found during this survey, with information on position, length, and width.

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7 Welded Repair List

This list contains all the repair sleeves and patches found during this ultrasonic survey.

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8 Detailed Feature Descriptions

8.1 Severity List

The Severity List consists of all crack-like features and crack fields with a depth of ≥ 39 mil. There are two features entered into the Severity List and sorted by distance.

8.2 Dig Sheets & Screen Shots

The dig sheets and screen shots presented in this report are the most severe graded features from the Severity List. The dig sheets have a detailed description of the anomaly, including the anomaly dimensions, orientation, location of the anomaly within a pipe joint, location of the pipe joint in respect to upstream and downstream reference points, as well as a sketch of the pipe joint and the adjacent pipe joints. The screen shots consist of a color printout of the data in a C-scan and B-scan format.

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The following screenshots explain the major information provided in the LineExplorer UCc C-scan and B-scan pictures:

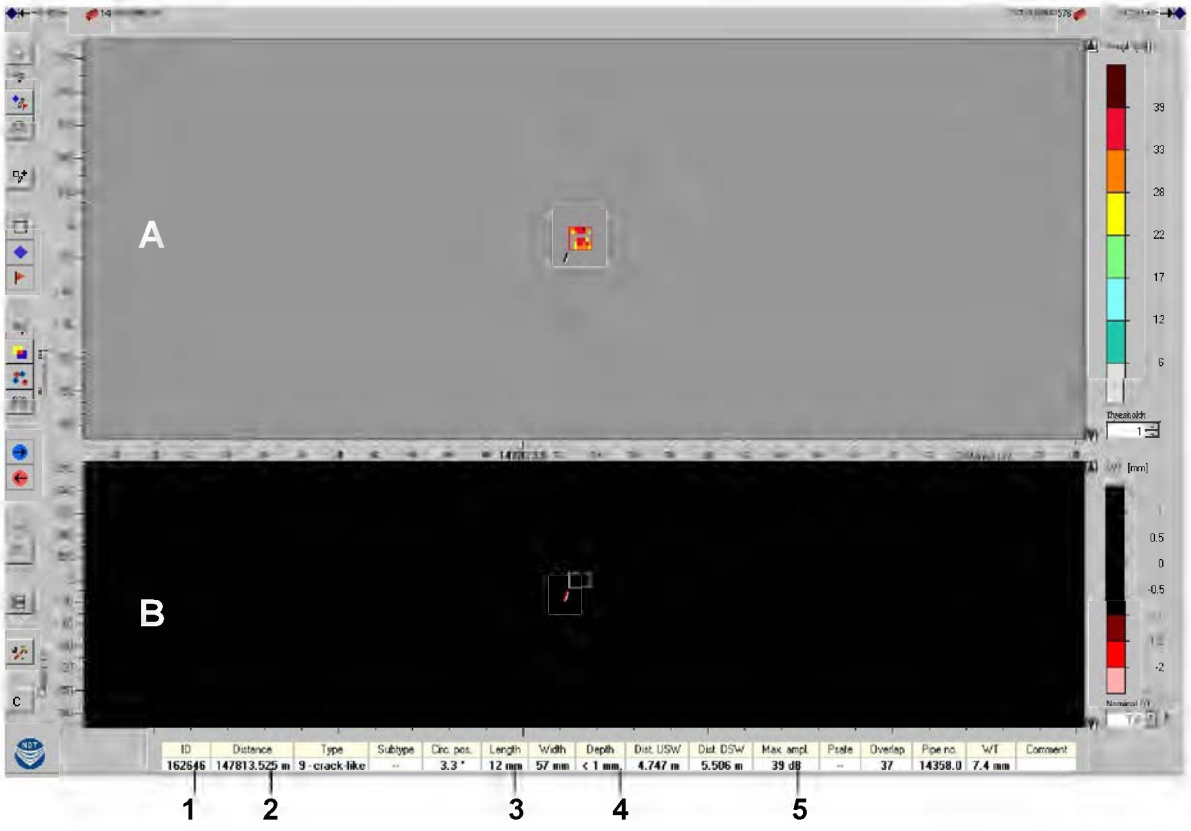


Figure 15 – Information provided in the C-scan picture

Item	Meaning
A	Crack detection C-scan display
B	Wall thickness C-scan display

Item	Meaning
1	Feature ID
2	Absolute distance of the feature
3	Length of the feature box
4	Estimated depth of the feature
5	Maximum amplitude of the feature

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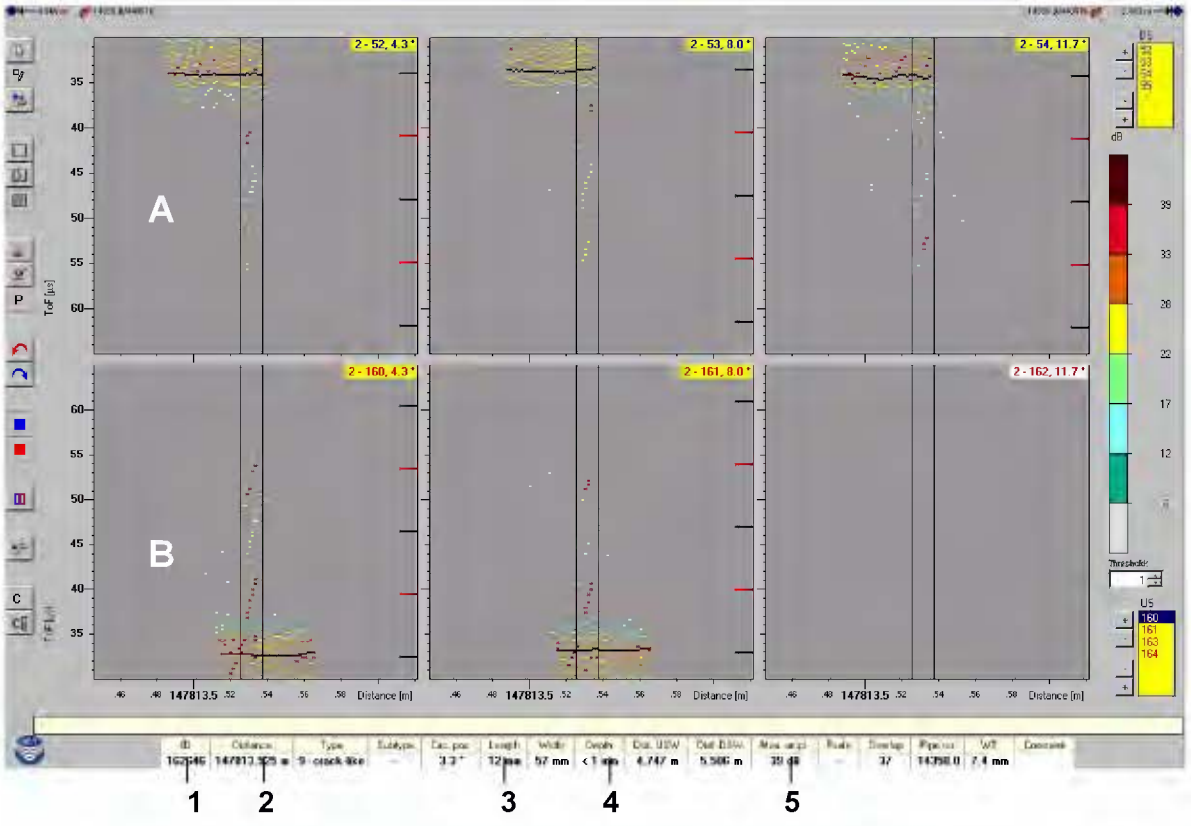


Figure 16 – Information provided in the B-scan pictures

Item	Meaning
A	B-scan display of three neighboring sensors (downstream sensors)
B	B-scan display of three neighboring sensors (upstream sensors)

Item	Meaning
1	Feature ID
2	Absolute distance of the feature
3	Length of the feature box
4	Estimated depth of the feature
5	Maximum amplitude of the feature

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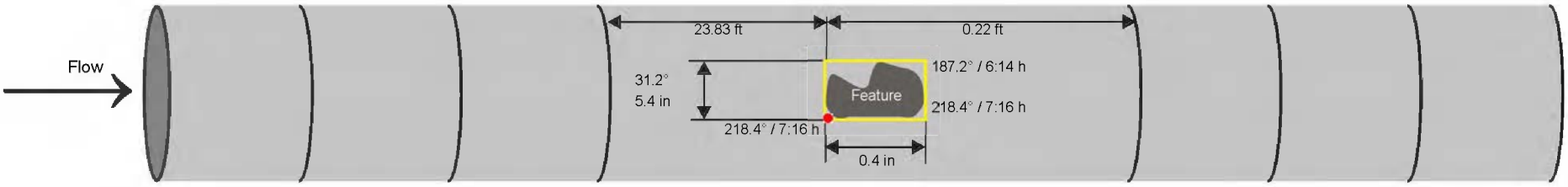
LINEEXPLORER® UCc Detailed Feature Description

Enbridge Pipelines Inc.

4.13 mi x 20" North Straits East – Mackinaw, Line 5

Feature Details for ID	900014	Feature Position Relative to Reference Points	
Feature type:	crack-like	Distance to upstream GW:	23.83 ft
Subtype:		Distance to downstream GW:	0.22 ft
Depth:	43 mils	Distance to upstream ref. point:	6147.09 ft
Axial length:	0.4 in	Distance to downstream ref. point:	15500.71 ft
Circumferential lenght:	31.2° / 5.4 in	**Reference Points**	
Location in wall:	internal	**Upstream Ref. Point**	1:(valve;)
Relative pos.:	base material	Distance:	35.25 ft
Circ. pos.:	218.4° / 7:16 h	**Downstream Ref. Point**	
Distance:	6182.34 ft	Distance:	21683.05 ft
Comment:	possibly notch like		

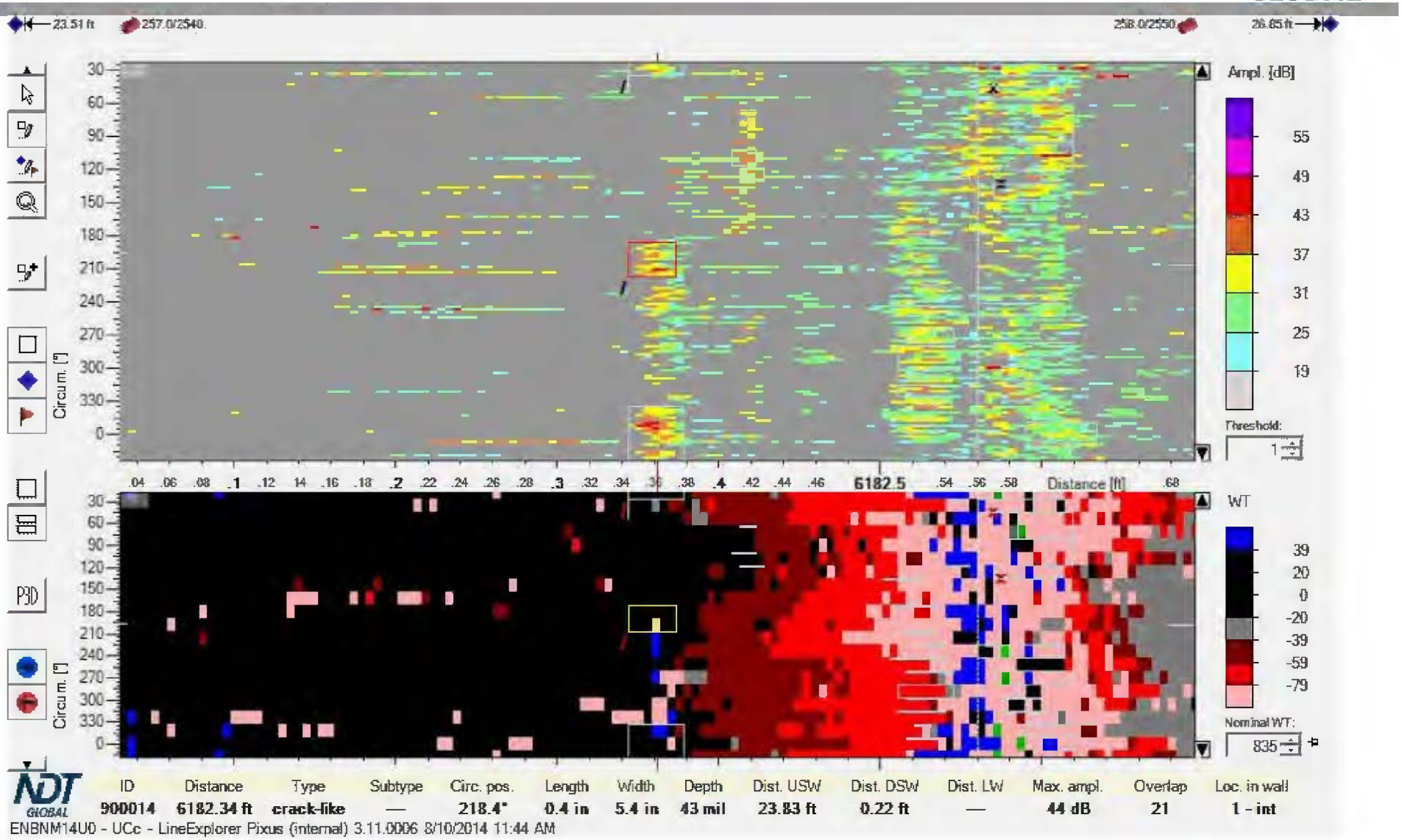
Pipe Joints



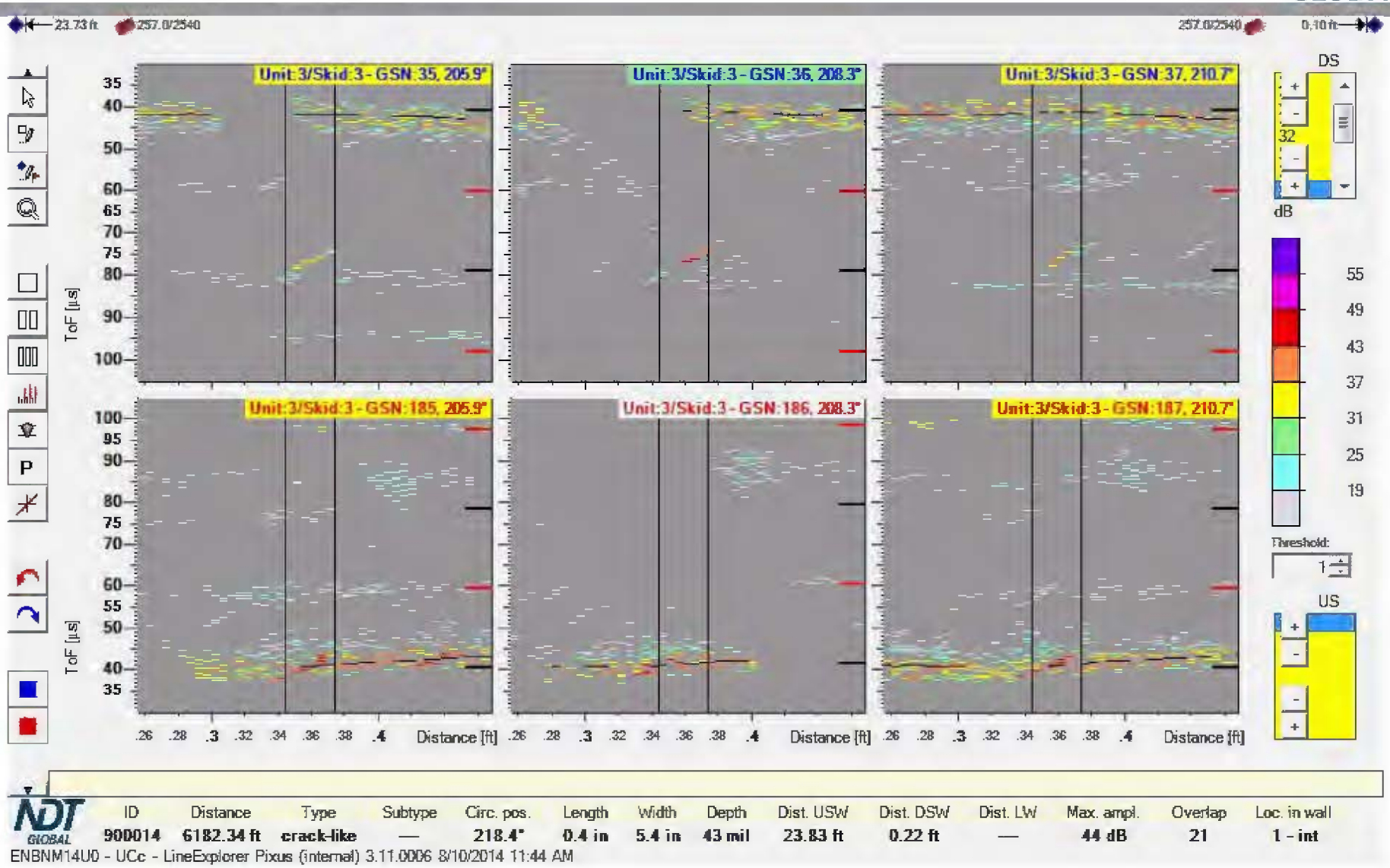
	-3	-2	-1	0	1	2	3
NDT pipe/weld No.:	254.0	255.0	256.0	257.0	258.0	259.0	260.0
Client pipe/weld No.:	2510	2520	2530	2540	2550	2560	2570
Length [ft]:	26.65	24.44	25.87	24.04	26.97	24.09	26.50
Wall thickness [mils]:	799	780	799	807	846	815	815
Long. seam orientation [hh:mm]:							

Comment:

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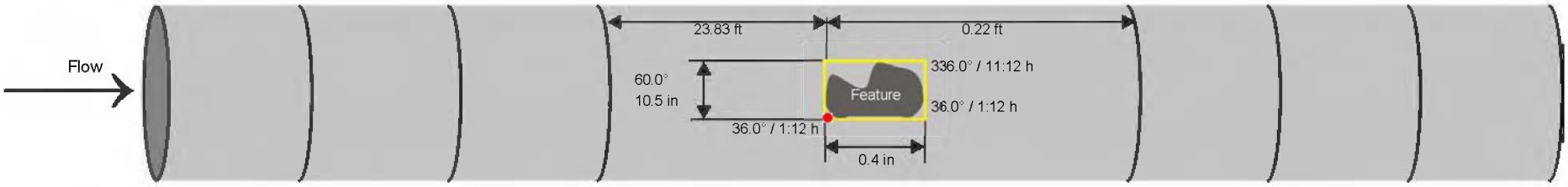
ID	Distance	Type	Subtype	Circ. pos.	Length	Width	Depth	Dist. USW	Dist. DSW	Dist. LW	Max. ampl.	Overlap	Loc. in wall
900014	6182.34 ft	crack-like	—	218.4°	0.4 in	5.4 in	43 mil	23.83 ft	0.22 ft	—	44 dB	21	1 - int

ENBNM14U0 - UCc - LineExplorer Pixus (internal) 3.11.0006 8/10/2014 11:44 AM

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Feature Details for ID	900015	Feature Position Relative to Reference Points	
Feature type:	crack-like	Distance to upstream GW:	23.83 ft
Subtype:		Distance to downstream GW:	0.22 ft
Depth:	51 mils	Distance to upstream ref. point:	6147.09 ft
Axial length:	0.4 in	Distance to downstream ref. point:	15500.71 ft
Circumferential length:	60.0° / 10.5 in	**Reference Points**	
Location in wall:	internal	**Upstream Ref. Point**	1:(valve;)
Relative pos.:	base material	Distance:	35.25 ft
Circ. pos.:	36.0° / 1:12 h	**Downstream Ref. Point**	
Distance:	6182.34 ft	Distance:	21683.05 ft
Comment:	possibly notch like		

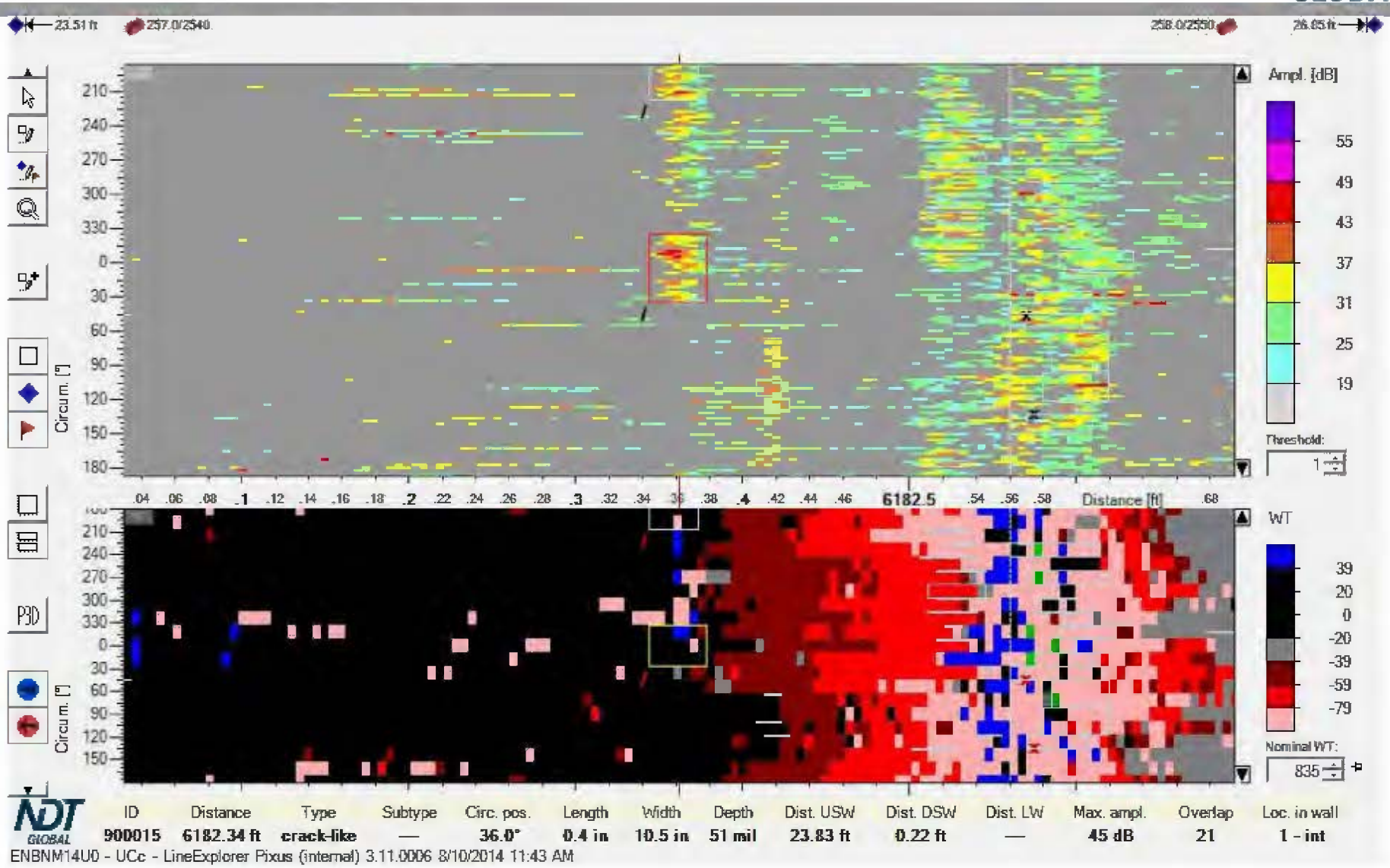
Pipe Joints



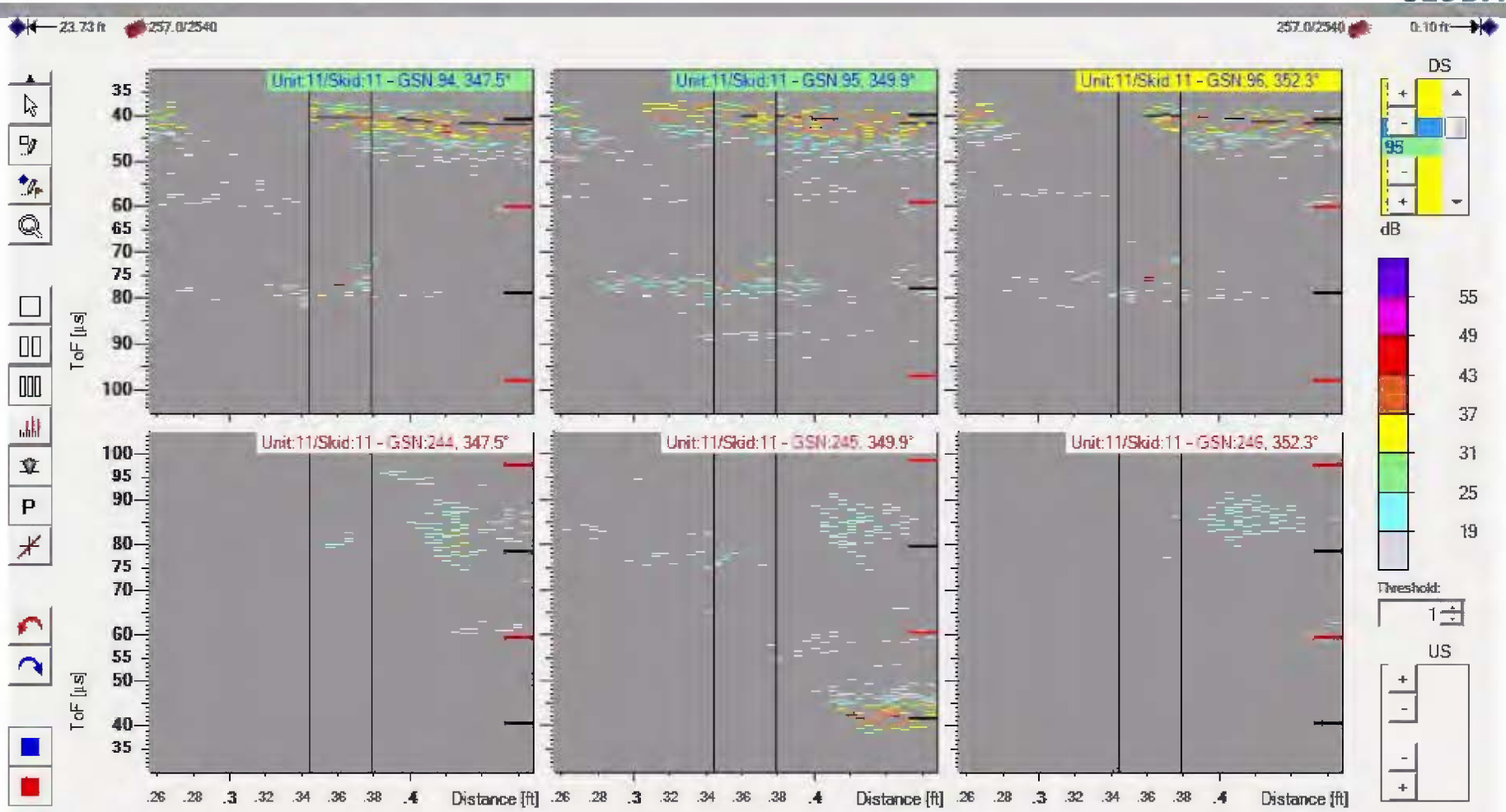
	-3	-2	-1	0	1	2	3
NDT pipe/weld No.:	254.0	255.0	256.0	257.0	258.0	259.0	260.0
Client pipe/weld No.:	2510	2520	2530	2540	2550	2560	2570
Length [ft]:	26.65	24.44	25.87	24.04	26.97	24.09	26.50
Wall thickness [mils]:	799	780	799	807	846	815	815
Long. seam orientation [hh:mm]:							

Comment:

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ID	Distance	Type	Subtype	Circ. pos.	Length	Width	Depth	Dist. USW	Dist. DSW	Dist. LW	Max. ampl.	Overlap	Loc. in wall
900015	6182.34 ft	crack-like	—	36.0°	0.4 in	10.5 in	51 mil	23.83 ft	0.22 ft	—	45 dB	21	1 - int

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9 Reference Point List

This is a list of AGMs placed on the pipeline and natural markers such as valves, T-pieces and offtakes used as reference points to locate anomalies. The total number of reference points identified is **two**.

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10 Pipe Tally

The Pipe Tally is a list of pipe segments with information on joint lengths, long seam positions, and wall thicknesses.

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11 Section List

The Section List contains detailed information on section lengths and wall thickness.

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Part 3: Appendix

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1 Tool Specifications

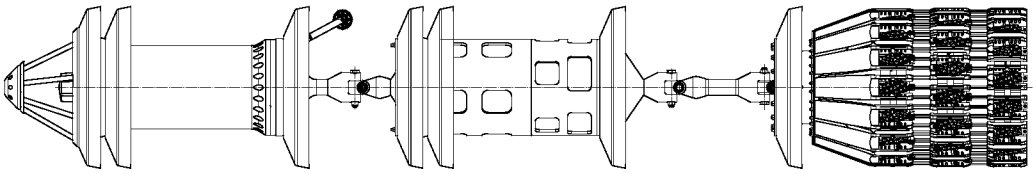


Figure 17 – Schematics of the 20" NDT LineExplorer UCc

Based on the specified pipeline and operating parameters, the inspection tool was configured for this inspection run as follows:

Velocity @ full spec	≤ 1.99 mph
Temperature range	14 – 122 °F
Maximum allowable pressure	1740 psi
Minimum internal diameter in straight pipe	17.00 in.
Minimum internal diameter in the smallest bend	17.99 in.
Minimum bend radius	3D/90°
Tool length	approx. 11.647 ft
Tool weight	approx. 1764 lbs
Number of bodies incl. sensor carrier	3
Distance range	approx. 70.2 mi. @ 2.02 mph
Battery life time	approx. 35 hrs
Number of crack detection sensors	300
Number of reference wall thickness sensors	20
Axial sampling distance	0.06 in.
Circumferential sensor spacing	approx. 0.39 in.

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2 Feature Specifications

FS-002-ENG-GLB, Rev. Aa

Identification of Features

Feature	Yes POI[1] > 90 %	No POI < 50 %	May be 50 % ≤ POI ≤ 90 %
Int./ext./mid-wall discrimination	X		
Additional metal/material			
• debris, magnetic			X
• debris, non-magnetic			X
• touching metal to metal		X	
Anode	X		
Anomaly			
• arc strike		X	
• artificial defect	X		
• buckle	X		
• corrosion		X	
• corrosion cluster		X	
• (circumferential) crack[2,3]		X	
• dent[4]			X
• dent with metal loss		X	
• gouging[5]			X
• grinding		X	
• girth weld crack	X		
• girth weld anomaly			X
• HIC	X		
• lamination	X		
• longitudinal weld crack[6]		X	
• longitudinal weld anomaly		X	
• ovality		X	
• pipe mill anomaly			X

1 POI = Probability of Identification. The indicated probabilities are estimated unless covered by the tool's Feature Specifications regarding detection and sizing.
2 Axial crack-like anomalies will be identified by LineExplorer UC and spiral crack-like anomalies by LineExplorer UCs.
3 Crack anomalies are classified as "crack-like" or "crack field".
4 Shape of dent may affect measurement capabilities.
5 If axially oriented steep walls are present.
6 Will be detected by LineExplorer UC.

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Feature	Yes POI[1] > 90 %	No POI < 50 %	May be 50 % ≤ POI ≤ 90 %
• pipe mill anomaly cluster			X
• SCC	X		
• spalling			X
• spiral weld crack[1]		X	
• spiral weld anomaly		X	
• wrinkle			X
Crack arrestor		X	
Eccentric pipe casing		X	
Change in wall thickness	X		
CP connection			X
External support		X	
Ground anchor		X	
Offtake[2]			X
Pipeline fixture	X		
Reference magnet		X	
Repair			
• welded sleeve repair[3]			X
• composite sleeve repair		X	
• weld deposit			X
• coating		X	
Tee	X		
Valve	X		
Weld			
• bend[4]	X		
• diameter change		X	
• wall thickness change (pipe/pipe connection)	X		
• adjacent tapering	X		
• longitudinal weld[5]	X		
• spiral weld	X		
• not identifiable seam			X

1 Will be detected by LineExplorer UCs.
2 Larger than 25 mm (1 in.).
3 If welded to the pipe.
4 Bend radius < 5D/90°.
5 DSAW; if ERW weld is trimmed, detectable only if there are marks.

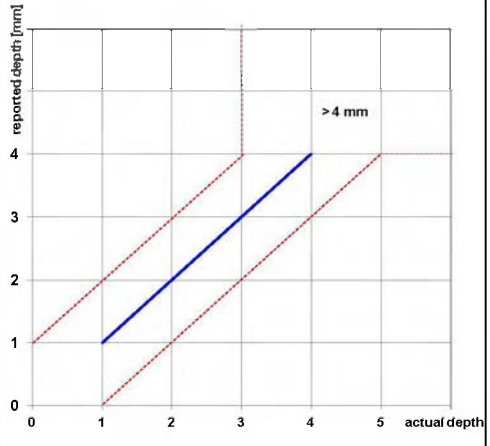
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Feature	Yes POI[1] > 90 %	No POI < 50 %	May be 50 % ≤ POI ≤ 90 %
• seamless	X		

Table 7 – Identification of features

Detection and Sizing Accuracy for Circumferential Cracks and Crack-like Anomalies[1]

Depth at POD[2] = 90 % of crack with L = 30 mm (1.2 in.)	in base material & at weld: in weld:	1 mm (0.04 in.) 2 mm (0.08 in.)
Minimum crack opening		0 mm (0 in.)
Depth sizing accuracy at 80 % certainty:		
• Depth classification in ranges	for t = 10 mm (0.4 in.):	< 1 mm (< 0.04 in.)[3]; 1 – 2 mm (0.04 in. – 0.08 in.); 2 – 4 mm (0.08 in. – 0.16 in.); > 4 mm (> 0.16 in.)

• Depth classification in absolute values[4]	for depth = 1 – 4 mm (0.04 – 0.16 in.):
	for depth > 4 mm (0.16 in.):
	
		absolute value with one decimal, accuracy ± 1 mm (± 0.04 in.)
		> 4 mm (> 0.16 in.)

Length sizing accuracy at 90 % certainty	L ≤ 150 mm (6 in.): L > 150 mm (6 in.):	±15 mm (±0.6 in.) 10 % of L
Orientation limits (in degrees) for detectability:		
• Circumferential orientation		α < ± 10°

1 Axial crack-like anomalies will be detected and sized by LineExplorer UC and spiral crack-like anomalies by LineExplorer UCs.
2 POD = Probability of Detection (The probability of a feature being detected by the intelligent tool.).
3 The < 1 mm classification is not included in the inspection report.
4 On request.

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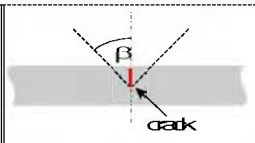
• Radial orientation		β < ± 45°
Standard axial resolution		1.5 mm (0.06 in.)

Table 8 – Detection and sizing accuracy for circumferential cracks and crack-like anomalies

Location Accuracy

Accuracy of distance to upstream girth weld at 90 % certainty	± 10 cm (± 4 in.)
Accuracy of circumferential position at 90 % certainty	± 5° for diameters ≥ 20", else ± 10°

Table 9 – Location accuracy

Note: Certain geometries or pipeline conditions may affect accuracies. Details on request.

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3 Data Evaluation Procedure

After the inspection run, the data of the ultrasonic inspection is recorded on a storage medium and checked for quality and completeness. Along with the inspection documents, the inspection data is then handed over to the analysis department where it is pre-processed for actual analysis.

In an initial step, a pipe tally is created on the basis of an automatic girth weld search and compared to the information provided by the customer. After that, a reference point list is generated which includes both AGM marker points placed on the pipeline during inspection and natural markers such as installations.

At first, anomaly candidates are determined by an automatic search program according to the specified criteria and saved in a database. In a next step, the anomaly candidates are selected from the database according to defined criteria (length, depth etc.). These selected data are then analyzed, sized and classified by trained data analysts with the help of a special data analysis software. The results are collected in a feature list which is checked by a senior data analyst for correctness and completeness.

The most severe features are selected to be fully assessed and reported on a dig sheet.

Finally, all the individual results and run-specific information are centrally collected in order to generate the inspection report consisting of report text, statistics and diagrams, result lists and Detailed Feature Descriptions.

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4 LineExplorer UC Inspection Technology

Objective of the ultrasonic crack inspection in pipelines is the early detection of crack-like anomalies which allows the pipeline operator to take appropriate measures at an early stage in order to avoid pipeline failures caused by cracks.

The principle of the ultrasonic crack inspection is based on the 45° angle beam technique using transverse waves. Due to the so-called corner reflection, even minor cracks from approx. 1 mm onwards give quite strong reflections. The pulse echo technique is applied, i.e. the same probe serves both as transmitter and as receiver; then the signals undergo further processing.

The following figure shows the measuring principle and a schematic representation of the measuring signal (A-scan). The position of the anomaly (external, internal) can reliably be determined from the distance between the entry echo and the anomaly echo.

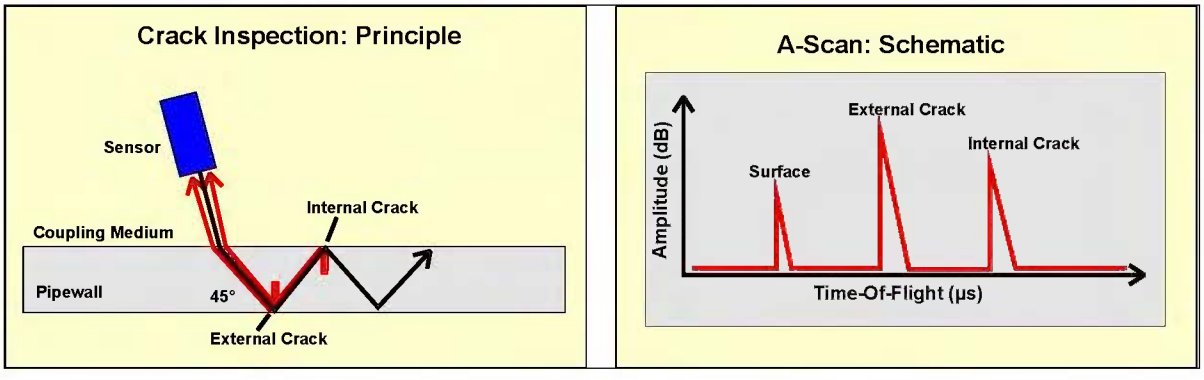


Figure 18 – Principle of ultrasonic crack inspection

For inline inspection, the coupling of the ultrasonic pulses into the pipe wall is achieved through the pipeline medium (usually oil). Due to the different sound velocities in the coupling medium and in steel, an angle of incidence of approx. 17° is required in order to obtain a refraction angle of approx. 45° in the pipe wall. Crack-like anomalies will be recorded if their amplitude exceeds a pre-defined threshold and if the anomaly is present over a pre-defined minimum length (typically 30 mm or 1.2").

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5 Feature Verification Guide[1]

5.1 General Procedure

The verification of each dig site location is a fundamental requirement of the inline inspection (ILI) program. This allows the information collected from the in-ditch examination portion of the program to verify the accuracy of the ILI data and ensure that the pipeline has been remediated per Customer specifications and regulatory requirements.

Measuring and recording the actual pipe condition is an essential element of the verification process. The anomaly can only be considered remediated if the measured data has been correlated with the data provided by the ILI tool.

The additional information to be gathered by this procedure can be used for determining the root cause of the anomaly and used by the analysts and the Customer to correct the existing conditions to prevent future problems with the pipeline.

No further excavation or dig site investigation should be carried on until the location is confirmed with the guidance provided by this procedure.

The Excavation Report shall clearly state the location verification procedure that has been utilized for each anomaly dig site location.

Verification digs should be carried out according to the following procedure:

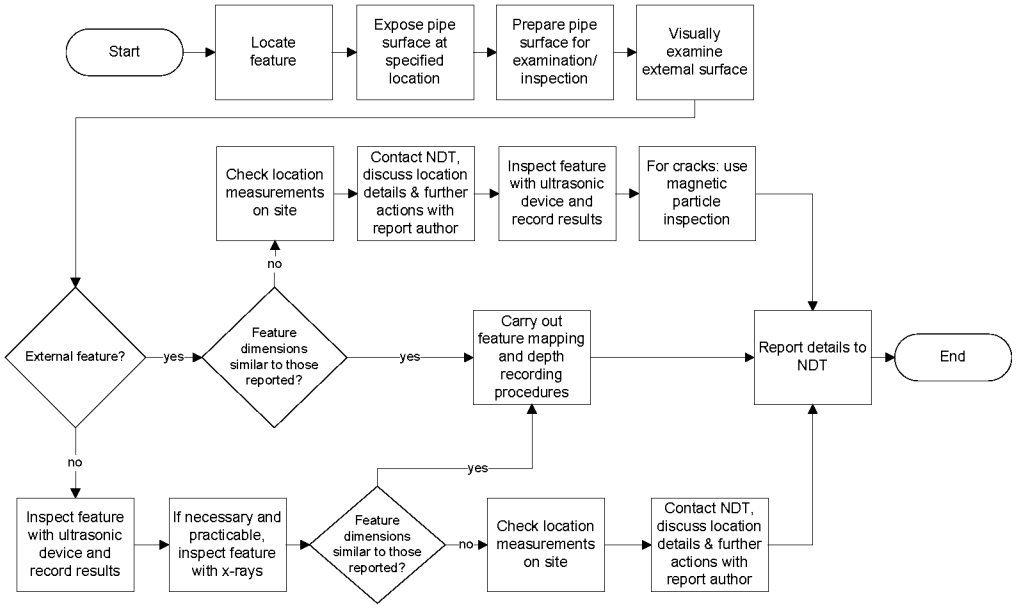


Figure 19 – Procedure for inspecting and recording reported features (e.g. metal loss anomalies, dents, mid-wall anomalies, etc.)

[1] This chapter is based on the POF document "Guidance on Field Verification – Procedures for In-Line Inspection".

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5.2 Personnel

The personnel that are deemed qualified to carry out this location and feature verification procedure shall have, as a minimum, the following:

- An Introductory Pipeline Integrity Course (5-day, 40-hour course outlining the elements that affect pipeline integrity projects)
- A minimum of three “Location Verification” assessments performed under the direct supervision of a senior non-destructive testing specialist.

5.3 Equipment

The camera, selected GPS, ultrasonic equipment, and pipe locator equipment shall be fully operative and with batteries fully charged. Follow the check-up and maintenance procedures as stated in each equipment's manual. A spare set of fully charged batteries or an alternative power source must be available. Several GPS receivers have skyplot and DOP (satellite geometry) forecasting or they can be consulted online. Plan the GPS data collection around the times of the day when the satellite geometry is best in order to maximize productivity and accuracy.

5.3.1 GPS Receivers

A handheld GPS unit with on-board Everest Technology, Real Time correction support, horizontal sub-meter accuracy, and PDA capabilities should be used for information gathering. An equivalent (or better) GPS receiver with horizontal sub-meter accuracy can be substituted.

5.3.2 Pipeline Locator

A pipeline locator device capable of pinpointing the pipeline in a multi-pipeline corridor should be available for detection of the pipeline centerline.

5.3.3 Other Distance Measuring Devices

- Use a measuring tape or surveyor's chain with a length of at least 30 m (100 ft) for measurement of long distances along the pipeline or laser range finder for measuring locations that are not typically accessible. The laser range finder must have an accuracy of ±0.3 m at 300 m (±1 ft at 1000 ft) with a magnification of 6X.
- Use a 10 m (24 ft) or longer tape ruler to allow measurement of anomalies within a joint.
- 30 cm (12 in.) long magnetic rulers should be attached to the pipeline for measurement of anomaly lengths and photography reference.

5.3.4 Anomaly Measuring Devices

- Use a micrometer bar to adequately measure exterior corrosion to a depth of 80 % of the pipe wall, with a point less than 4 mm (1/64th of an inch), and a reach exceeding 60 cm (2 ft).

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- Use an ultrasonic hand-held device to adequately detect and size cracks and internal metal loss anomalies.

5.3.5 Marking Devices

- Grease pencils
- Black markers
- Use magnet mounted paper to mark indications and measurements for photographs.

5.3.6 Calibration

All applicable equipment used in the field requires calibration as stated by the respective manufacturers.

5.4 Locating Anomalies in the Field

Locating features (e.g. metal losses, dents, mid-wall anomalies, etc.) is a difficult task which can cost the pipeline operator valuable time and resources. Therefore, it is important that appropriate techniques are used at each stage in locating these features.

This section gives guidelines for locating pipeline features efficiently and effectively.

5.4.1 Preparatory Measures

Before starting any field verification activities, it is advisable to check if the distance information in the Inspection Report fits into the customer's documentation.

If a customer's pipe tally is available, its pipe sequence should be correlated with the sequence provided in the Inspection Report. The identification of installations can be used as references for the correct numbering of the pipe joint sequences.

Additionally, for proving whether the odometer factor of the ILI tool was appropriately chosen, the pipe lengths of a number of pipe joints within an easily accessible pipeline section (e.g. immediately after the launcher) should be measured and compared with the figures provided in the Inspection Report. Thus the general accuracy of the odometer system can be assessed and, if necessary, corrected at an early stage.

Before excavation begins, a competent person shall develop a pre-plan. The plan shall include the type of soil, depth of excavation, type of shoring or sloping required, proximity to structures, and traffic issues.

The following measures shall be carried out:

- Review all onsite staking marking and ensure the correct information is noted and checked for obvious errors. Record any errors.
- Determine other facilities (pipelines, utilities, etc.) that might impact the excavation activities. Identify and discuss procedure modifications to address these concerns.
- Record location description and photographs. Determine starting point for excavation.

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5.4.2 Reference Points

Wherever possible, the position of reported features is related to reference points that can be easily identified and located in the field.

Reference points can refer to pipeline fixtures such as mainline valves, offtakes, or significant bends. They can also be artificial reference points such as line markers, which will have been placed on or near the pipeline at the time of the inspection.

At least one reference point is provided for each metal loss feature reported on the dig sheets. If the reference point is more than 500 m (1640 ft) from the metal loss feature, then a second reference point will usually be provided, if possible.

This section describes the procedure to identify the spatial location of a pipeline by locating the pipeline centerline and measuring the depth of cover (DOC). Both operations are completed by use of a pipeline locator.

The centerline and DOC are measured for reasons associated with preserving the integrity all along the pipeline as work is performed.

Precise determination of the centerline of a pipeline is critical to identify its spatial position. Furthermore, a precisely obtained centerline is the backbone for spatially based alignment of additional data collected on the right-of-way. Data corresponding to above-ground surveys are all aligned through common spatial coordinates.

The location of the pipeline must be accurately identified and clearly marked at sufficient distances to allow stakes showing location of the pipe to be visible from any location along the pipeline.

The reference point in the Inspection Report will identify a starting location and specify the length of the pipeline section to be measured and marked for centerline location and DOC.

5.4.3 Safety Analysis

Before attempting to locate the centerline of the pipeline, complete a Job Safety Analysis/Risk Assessment of the right-of-way to determine if any environmental/safety problems may exist (dangerous animals, uneven terrain, hunting season, etc.)

5.4.4 Locating the Centerline of the Pipe

Locate the centerline of the pipeline. In areas where direct soil access is available, identify the located centerline by driving a peg with orange flagging (in the case of natural gas pipelines, or other colors as indicated by the national standard of locating lines) into the ground. In areas covered with hard surfaces, use orange (or the appropriate color) spray paint to mark centerline location and DOC.

5.4.5 Marking (Signalizing) the Centerline of the Pipe

The centerline of the pipeline should be staked and flagged at intervals no greater than 60 m (200 ft) apart. In some cases, such as in hilly areas, near points of inflection (PIs), or near roads or other crossings of the

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pipeline right-of-way, the centerline should be staked at closer intervals, normally with 30 m (100 ft) between markers.

5.4.6 Measuring the Depth of Cover

Depth of cover (DOC) is the distance between the ground and the top of the pipeline. Measure the DOC at each staked location and write this depth on the peg with a permanent marker.

If the pipeline locator indicates that the DOC is less than 1.5 m (5 ft), verify the distance to the top of the pipe by physically probing the pipe. The probe tool should be designed so that neither the pipe coating nor the pipe is damaged during the physical probing operation.

5.4.7 Locating Features

The location of a feature can be carried out in two stages: locating the pipe joint that contains the feature, then locating the feature within that joint.

To locate the pipe joint containing the feature, refer to the distance from the reference point to the girth weld at the upstream end of the joint provided in the dig sheet. This distance refers to the pipeline route measured with the odometer wheels. The horizontal above-ground distance measured between two pipeline locations might be different if the pipeline route deviates from the straight connection line between these points.

To locate the feature within the pipe joint, refer to the distance from the upstream girth weld to the feature as well as the location of the feature around the circumference of the pipe (as viewed in the direction of flow) as provided in the dig sheet.

5.4.8 Identifying Features

Metal loss, dents, and girth weld anomalies will require an area of the protective wrap to be removed.

A minimum area of approximately 0.6 m (2 ft) along the pipe axis by 45° of the circumference, centered on the reported feature position, should be cleaned back to bare metal.

Once this has been done, any external metal loss, dents, or the girth weld that contains an anomaly should be easily identified. The position of internal metal loss or mid-wall anomaly should be marked on the outside of the pipe in preparation for further examination.

Shallow dents can usually be identified by running one's hand along the pipe surface, or by placing a straight edge along the pipe.

5.4.9 If Digging Leads to Wrong Pipe Joints

If a feature to be verified cannot be found in an excavated pipe joint, it should be assumed first that the located pipe joint might be wrong. For verifying this, proceed as follows:

1. Measure the length of the "wrong" pipe joint.
2. Measure the wall thicknesses of the "wrong" pipe joint as well as the two adjacent joints.

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3. Determine the positions of the longitudinal welds for the pipe joint concerned as well as for the two adjacent joints (o'clock position when looking downstream). If the pipes are spirally welded, determine the circumferential start and end positions of the spiral welds directly at the girth welds.
4. Provide this information to the Data Analysis Department of NDT Global. With this information, NDT Global can normally locate the right pipe joint relative to the "wrong" one.

Note: Knowing the lengths, as well as the wall thicknesses of three subsequent pipe joints, the corresponding sequence may often be identified from the pipe tally.

5.4.10 Contacting NDT Global

NDT Global aims to provide its customers with a quality service. If you cannot locate a reported feature from the information provided on the dig sheet, or if the feature type is very different from the description given on the dig sheet, do not hesitate to contact the Project Manager at NDT Global.

5.5 Recording Excavations

5.5.1 Introduction

To help in answering future queries, pipeline operators should supply the data shown in the sample Field Verification Feedback Form at the end of this section. This form includes feature dimensions and location information.

5.5.2 Preparing the Pipe Surface for Inspection and Recording

In order to achieve satisfactory recording and measurement of the feature, it is essential that the specified area of pipe surface be cleaned back to bare bright metal.

There are a number of methods for removing pipe wrap primer including:

- Solvent cleaning
- Chemical cleaning
- Wire brushing
- Grit blasting.

For certain types of corrosion product, it is possible to produce a finish resembling bright metal when cleaned using a wire brush. In this instance, grit blasting is the preferred method in order to remove all the corrosion product.

5.5.3 External Metal Loss Area Mapping

5.5.3.1 Rubbing and Photographic Methods

The preferred method of mapping is by taking a simple rubbing. This is achieved by placing a sheet of paper over the feature, holding the paper firmly in place (e.g. with small magnets), and rubbing the long edge of a

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wax crayon over the surface of the paper. The edges of the feature will be delineated and can be highlighted by careful manipulation of the crayon.

The following parameters should be annotated on the paper:

- Feature identity (e.g. report number and feature ID)
- Date and time
- Direction of flow
- Orientation of the feature
- Distance of the feature from the nearest girth weld.

Refer to the following figure for an example of a mapped area using the rubbing technique.

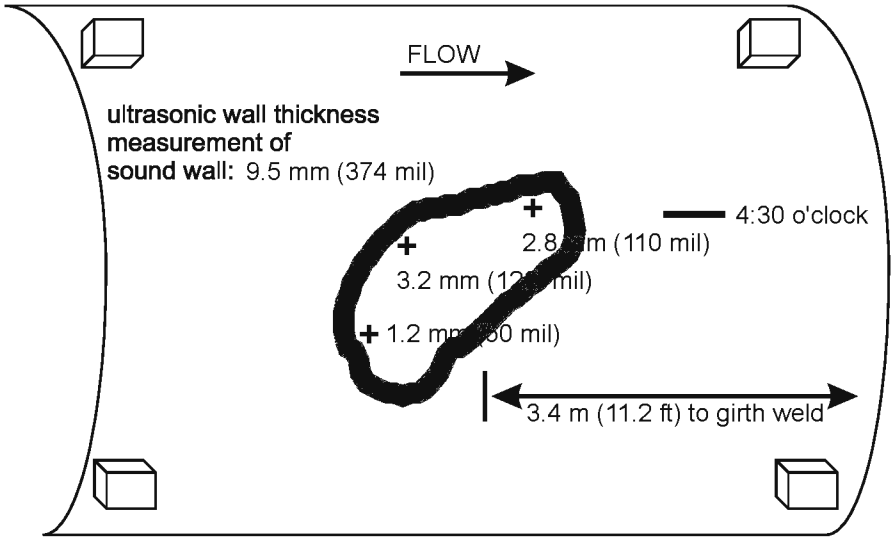


Figure 20 – Example of rubbing

The rubbing technique has a definite advantage over photographic recording methods in that it is possible to record all subsequent measurements directly on the rubbing in the appropriate location e.g. each individual pit depth in multiple pitting.

Photographic recording with digital camera can be used additionally.

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5.5.3.2 External Metal Loss Depth Recording

A suitable method for recording external metal loss depth is by using a profile comb:



Figure 21 – Example of a profile comb

Another method for recording external metal loss depth is by using a depth micrometer in conjunction with a large bridging bar:

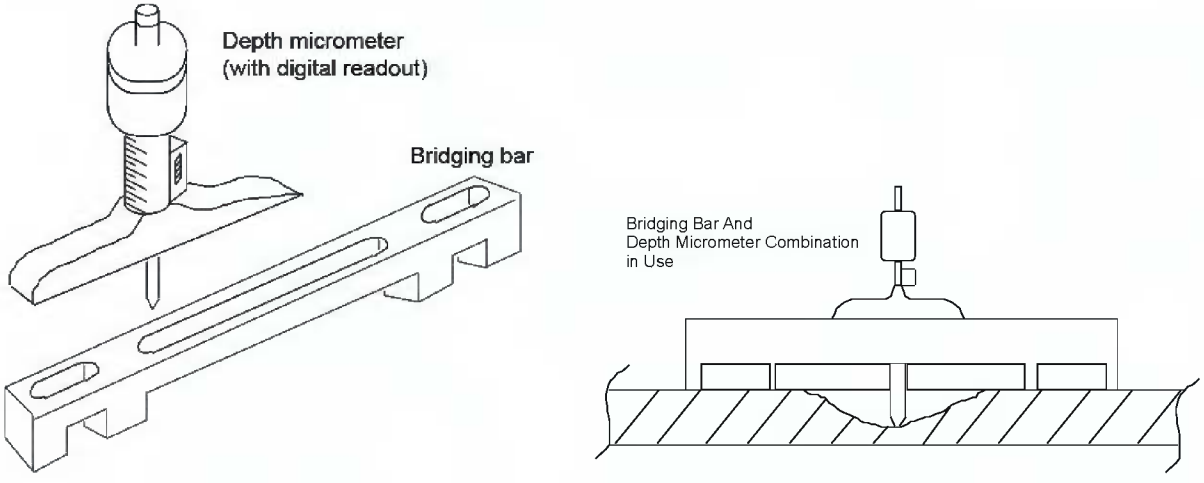


Figure 22 – Typical micrometer and bridging bar arrangement

It is recommended that the micrometer anvil be ground to a taper with a tip diameter of approximately 1.0 mm. This will enable entry into the small diameter pitting and concave surfaces found at the bottom of most metal loss features.

A pit gauge is not recommended because of its potential inaccuracy of up to 2.0 mm (80 mils).
A depth micrometer has a resolution of better than 0.05 mm (2 mils).

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5.5.4 Wall Thickness and Remaining Wall Thickness Recording

Pipe wall thicknesses and remaining wall thicknesses of internal damage can be measured to an accuracy of ±0.05 mm (2 mils) using standard ultrasonic wall thickness meters and suitable couplant.

Extreme care should be exercised when attempting to measure remaining ligament thicknesses directly within an area of external damage. There is extra couplant under the transducer when mounted on concave surfaces, which results in an overestimated reading.

Decisions on assessing the significance of the damage are primarily based on the remaining ligament thickness. It is therefore important to obtain a reliable reading. This is best accomplished by first obtaining the minimum ultrasonic thickness reading immediately surrounding the damage, then subtracting the mechanical depth measurement.

5.5.5 Recording of Cracks

Once a reported crack-like or crack field feature is identified in the field (e.g. by MPI), the following rules regarding the verification of its dimensions should be applied.

5.5.5.1 Determining the Location of a Crack Area

The feature list entries describing the location of a crack field area refer to the following anchor points:

- axial position = start position of the feature area (in upstream direction)
- circumferential position = circumferential position of the bottom left corner of the feature area

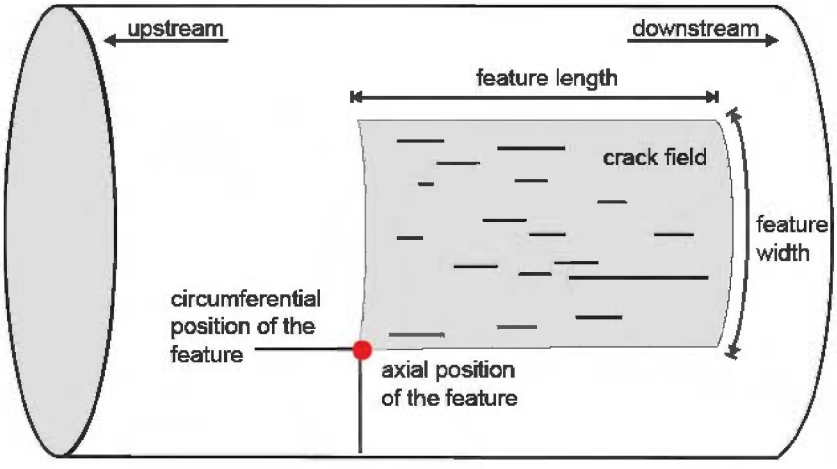


Figure 23 – Location of a feature area on the pipe

Generally, the overall extent of a crack field can be determined by different criteria.
A crack field consisting of different clusters of cracks can be treated as one large field or as several smaller crack fields. Compare the visual impression of the crack field onsite with the ultrasonic representation of the related feature area.

The deepest single crack of a crack field is not necessarily located in the center of the related feature area.

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5.5.5.2 Determining the Exact Length of a Crack

The verification of the length of an individual crack can lead to different results if different measurement methods are used. A common method for the verification of surface-breaking external cracks is the Magnetic Particle Inspection. With this method, the crack length is determined independently of any minimum crack depth.

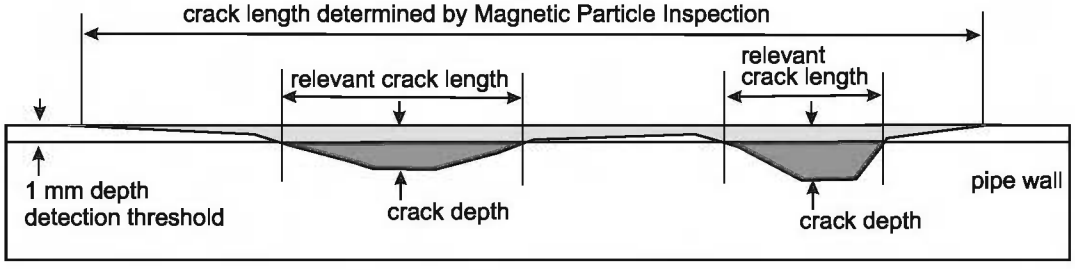


Figure 24 – Determination of crack length

The crack detection (UC) systems determine the edges at both sides of a crack using a minimum depth detection threshold, whereas the Magnetic Particle Inspection reacts on even the smallest crack depths. This allows cracks to possibly appear much longer than the ILI tool predicted.

To truly verify a predicted length, it is necessary to grind the crack area down by 1 mm (40 mils) and then repeat the Magnetic Particle Inspection. After grinding, only the "relevant" crack extent should be indicated by the magnetic particles.

5.5.5.3 Determining the Exact Depth of a Crack

With the LineExplorer UC inspection tool, the determination of crack depths is carried out by an indirect assessment method with four depth classes reported. The confidence levels stated in the LineExplorer UC Feature Specifications sheet regarding depth estimation only refer to these four depth classes. For the in-field measurement of crack depths the following procedures can be applied:

Reference Block Method

This is a direct ultrasonic echo comparison method using reference echoes from well-defined reflectors contained in a reference block (rather inaccurate method).

DGS Method

This is an indirect ultrasonic echo comparison method based on distance, gain, and size. The height of an ultrasonic echo is assessed with the theoretical echo of an equivalent disc shaped reflector using a suitable DGS diagram (rather inaccurate method).

TOFD – Time-of-Flight Diffraction Method

This technique quantifies the ultrasonic energy diffraction from the tips of cracks and uses certain algorithms to determine the depth class of a crack. This method is mainly suitable for mid-wall and internal cracks.

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Step-wise Grinding

This is the most accurate but also most time-consuming method. With this method, the crack area is first visualized by magnetic particles and the wall thickness within the crack area is measured. Then, the crack area is ground down by a small step and magnetic particles are applied to check whether the crack is still visible. More grinding steps are carried out until the crack can no longer be visualized by magnetic particles. Subtracting the wall thickness of the ground area from the wall thickness first measured leads to the maximum crack depth.

5.5.5.4 Identification of Cracks in Weld Areas

Detecting a crack within a weld zone using a hand-held device is sometimes rather difficult. This is due to the weld cap, which does not allow the ultrasonic probe to be properly placed at the pipe wall in order for the crack to be hit with the angular sound beam axis.

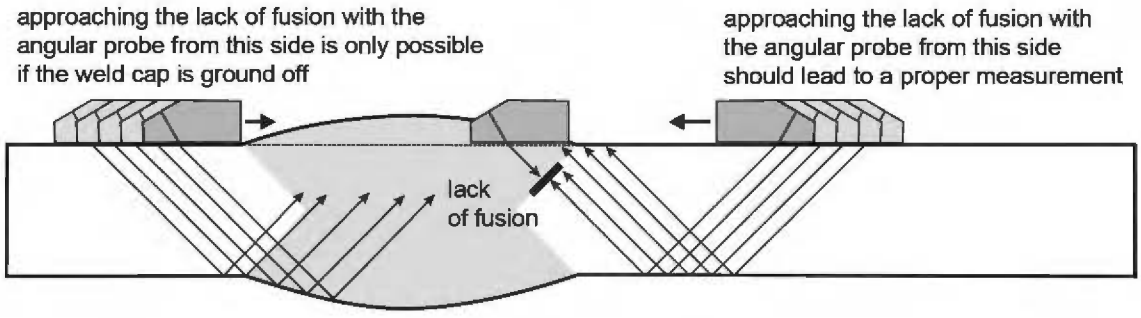


Figure 25 – Manual UT detection of a lack of fusion

The above figure shows a lack of fusion which can only be detected with an angular probe approaching from the right side via full skip. Detection from the left side via half skip is possible only if the weld cap is ground off. With both echoes (full skip from the right side and half skip from the left side), the lack of fusion can be detected with the best confidence.

5.5.5.5 Identification of Sloping Cracks

Generally, the detection capabilities of a crack are influenced by its angular orientation.
Cracks open to the surface of the pipe wall normally provide a strong corner reflection.

The echoes from parts of the crack which are located deeper within the pipe wall are received by a UT probe only if the incidence angle fits to the crack angle.

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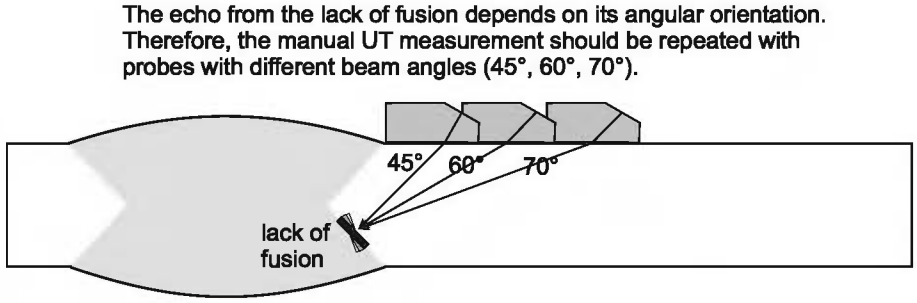


Figure 26 – Lack of fusion hit by sound beams of different angles

The above figure shows a lack of fusion hit by 45°, 60°, and 70° sound beams. Which of these beams has the strongest echo depends on the angular orientation of the lack of fusion. The 60° probe, for example, is the best solution for 30° sloping mid-wall cracks.

The best practice for the detection of mid-wall cracks is to use at least three angular probes (e.g. 45°, 60°, 70°) and compare the time-of-flight and signal amplitude values of the different probes with each other.

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5.6 Field Verification Feedback Form (Example)

Run name:		Customer:	
Pipeline name:		Launcher/ receiver:	
Date of verification:		NDT specialist:	

Feature ID:			
Pipe no.:		Odo distance (m):	
		Customer's distance (m):	
U/S ref. point:		D/S ref. point:	
Distance to U/S ref. point (m):		Distance to D/S ref. point (m):	

	Predicted	Verified
Feature type:		
Distance to upstream girth weld (m):		
Distance to downstream girth weld (m):		
Wall thickness in feature vicinity (mm):		
Depth (mm):		
Remaining wall thickness (mm):		
Length (mm):		
Width (mm):		
Orientation (o'clock):		
Orientation of long/spiral weld (o'clock):		
Pipe length (m):		

Comments on the Feature Verification	
Probe types used:	

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6 Glossary and Abbreviations[1]

Above Ground Marker (AGM):	*A device near the outside of a pipeline that detects and records the passage of an ILI tool or transmits a signal that is detected and recorded by the tool. Reference magnets can be applied to serve identical purposes.*
Anomaly:	*An indication, generated by non-destructive examination of an irregularity or deviation from sound weld or base pipe material, which may or may not be an actual flaw.*
Arc strike:	*Localized points of surface melting caused by an electrical arc (also referred to as hot spot).*
Buckle:	*A partial collapse of the pipe due to excessive bending or compression associated with soil instabilities, landslides, washouts, frost heaves, earthquakes, etc.*
Casing:	*A type of feature consisting of a larger diameter pipe placed concentrically around the pipeline, usually in high stress areas such as road crossings.*
Cluster:	*Two or more adjacent metal loss anomalies in the wall of a pipe or in a weld that may interact to weaken the pipeline more than either would individually.*
Confidence level:	*A statistical expression used to describe the mathematical certainty that the characteristics of a reported anomaly are within the stated tolerances.*
Construction feature:	Feature that arises during pipe manufacture, transport or constructing of the pipeline, including a girth weld anomaly, arc strike and grinding.
Corrosion:	*An electrochemical reaction of the pipe wall with its environment causing a loss of metal.*
Crack:	*A planar, two-dimensional feature with displacement of the fracture surfaces.*
Debris:	*Extraneous material in a pipeline which may interfere with the ILI tool.*
Dent:	*Distortion of the pipe wall resulting in a change of the internal diameter but not necessarily resulting in localized reduction of wall thickness.*
Detection threshold:	*The minimum detectable feature dimension.*
Double echo	When in the case of thin walls, the 1st back-wall echo (BWE) occurs in the range where no echoes are expected, while the 2nd BWE occurs in the expectation range of the 1st BWE, the 2nd BWE is erroneously interpreted as 1st BWE so that the wall thickness value is doubled.

[1] Items in italics are from: "Specifications and requirements for intelligent pig inspection of pipelines", Version 2009 – M, by POF

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EC:	*Eddy current*
EMAT:	*Electromagnetic-acoustic transducer*
ERF:	*Estimated repair factor*
Feature:	*Indication, detected by non-destructive examination, of a pipeline.*
Geometry tool:	*Configuration pig designed to record conditions, such as dents, wrinkles, ovalities, bend radius and angle, and occasionally indications of significant internal corrosion, by sensing the shape of the internal surface of the pipe.*
GPS:	Global Positioning System
Grinding:	*Reduction in wall thickness by removal of material by hand filing or power disk grinding.*
Gouge:	*Mechanically induced metal loss, which causes localized elongated grooves or cavities.*
Heat affected zone:	*The area around a weld where the metallurgy of the metal is altered by the rise in temperature caused by the welding process. For the purpose of this specification it is considered to be within 2A of the center line of the weld, where "A" is the geometrical parameter related to the wall thickness.*
In-Line Inspection (ILI):	*Inspection of a pipeline from the interior of the pipe using an In-Line Inspection tool.*
In-Line Inspection tool:	*Device or vehicle, also known as an intelligent or smart pig that uses a non-destructive testing technique to inspect the pipeline from the inside.*
Joint:	*Single section of pipe that is welded to others to make up a pipeline.*
Intermittent:	Annotation in the Comment column of the Pipeline Register when several anomalies are believed to be separated by base material into different anomaly components (not one solid area of metal loss or lamination).
Lamination:	*Imperfection or discontinuity with a layered separation that may extend parallel or angular to the pipe wall surface.*
Manufacturing-related:	Features that have indications similar to metal loss and are not related to the corrosion process.
MAOP:	*Maximum Allowable Operating Pressure*
Metal loss anomaly/feature:	*An area of pipe wall with a measurable reduction in thickness.*
Mid-wall feature:	*Any feature which does not run out to either the internal or external surface.*

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Measured wall thickness:	*Measured wall thickness that is representative for a whole pipe joint/component. For ultrasonic tools the value shall be based on direct wall thickness measurements, for magnetic tools on the inferred magnetic flux signals.*
Measurement threshold:	*The minimum dimension(s) of a feature to make sizing possible.*
MFL:	*Magnetic flux leakage*
MOP:	*Maximum operating pressure*
Nominal wall thickness:	*The wall thickness required by the specification for the manufacture of the pipe.*
PEC:	Pulsed eddy current: the eddy-current signal is generated by a pulse excitation.
Pig:	*Device that is driven through a pipeline, for performing various internal activities (depending on the pig type) such as separating fluids, cleaning or inspecting the pipeline.*
Pigging:	*Running of a pig or ILI tool in a pipeline.*
Pig Trap:	*An ancillary item of pipeline equipment, with associated pipework and valves, for introducing a pig into a pipeline or removing a pig from a pipeline.*
Pipeline:	*A system of pipes and other components used for the transportation of products between (but excluding) plants. A pipeline extends from pig trap to pig trap (including the pig traps), or, if no pig trap is fitted, to the first isolation valve within the plant boundaries or a more inward valve if so nominated.*
Pipe mill anomaly:	*An anomaly that arises during manufacture of the pipe, as for instance a lap, sliver, lamination, non-metallic inclusion, roll mark and seam weld anomaly.*
possibly deeper:	This comment is used when an anomaly could be deeper than reported due to echo loss within the ultrasonic signal.
Probability of Detection (POD):	*The probability of a feature being detected by the intelligent pig.*
Probability of Identification (POI):	*The probability that an anomaly or a feature, once detected, will be correctly classified.*
P_{safe}*:*	*Safe operating pressure as per calculated anomaly assessment method.*
Reference wall thickness:	*The actual undiminished wall thickness surrounding a feature, used as reference for the determination of the feature depth.*
Reporting threshold:	*Parameter which defines whether or not a feature will be reported.*
RPR	Rupture pressure ratio

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Sizing accuracy:	*Sizing accuracy is given by the interval within which a fixed percentage of all metal loss features will be sized. This fixed percentage is stated as the certainty level.*
Spalling:	*Abrasion of the pipe surface resulting in shallow surface laps and possibly hardening of the material below.*
Surface inhomogeneity:	Features that are believed to be surface irregularities but have signals similar to mill anomalies on the surface of the pipe.
UT:	*Ultrasonic technique (or ultrasonic testing).*
Weld:	*The area where joining has been done by welding and where the material has undergone a melting and solidification process. This area is distinct from the heat-affected zone, but surrounded by it.*
Weld anomaly:	*Anomaly in the weld or the heat affected zone.*
Weld affected areas:	*Area on both sides of a weld where ILI measurements are affected by the geometry of the weld (e.g. due to sensor dynamics).*

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7 Qualifications

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