INSPECTION INTELLIGENCE NDT GLOBAL

FINAL REPORT

Ultrasonic Crack Inspection
Evo Series 1.0 UCc

Enbridge Energy, Limited Partnership

4.10 mi. x 20" Line 5
North Straits East – Mackinaw

Run ID	ENBNM18U0	
Run date	10 Apr 2018	
Contract no.	MSA 23252	
NDT project no.	300965	
Issue # 1	07 Aug 2018	Initial release
Issue # 2 (Customer internal 1.1)	13 Aug 2018	Renaming of feature type from *geometric anomaly* to *deformation – geometric anomaly* Update only in Excel listing
Issue # 3	08 Oct 2018	Change of feature classification

NDT Global Inc.

6302-39 Street
Leduc, Alberta T9E 0Z3
Canada
+1 780 612 3100
www.ndt-global.com

Account Representative	Tom Machnik
Project Manager	Johnathan El-Anaty
Tool Operator	Evan Irvine
Data Analysis Project Leader	Achim Notheisen
Technical Writer	Nadja Kursawe
Report verified by	Rogelio Guajardo, Global Manager UC Data Analysis Johnathan El-Anaty, Project Manager

Terms and Definitions used in this report can be found in Part 3, page 18.

Abbreviations are indicated in Part 3, page 22.

This inspection report is EXPRESSLY SUBJECT to the terms of the agreement governing the pipeline inspection that produced the data on which the report is based and to the BELOW STATED DISCLAIMER.

This inspection report including any recommendations made by the contractor relating to the pipeline has been prepared by the contractor to his best knowledge and belief. All recommendations are made in good faith and are a reliable expert opinion of the contractor, according to common practice prevailing in the pipeline industry. The report or measures based on it will not constitute a warranty of the quality, capacity, safety or fitness for purpose of the pipeline.

Copyright © 2018, NDT Global, Issue # 3

Contents

Executive Summary

Part 1: Inspection Run & Summary of Results

1 Scope of Inspection

2 Operational Details

2.1 Pipeline Information
2.2 Medium Information
2.3 Pipeline Preparation
2.4 Tool Preparation
2.5 Inspection Run Details

3 Run Profiles

3.1 Speed Profile
3.2 Temperature Profile
3.3 Pressure Profile
3.4 Pendulum Profile

4 Data Quality

5 Summary of Results

5.1 Reporting Criteria
5.2 Results
5.3 Examples of Features
5.4 Charts

Part 2: Listing

1 Key to the Listing

1.1 Generic Attributes
1.2 Metal Loss Attributes
1.3 Crack Attributes

Copyright © 2018, NDT Global, Issue # 3

1.4 Geometry Attributes
1.5 Strain Attributes

Part 3: Appendix

1 Tool Specifications

2 Performance Specification Evo Series 1.0 and LineExplorer UCc
2.1 Introduction
2.2 Detection Capabilities
2.3 Depth Sizing Accuracy
2.4 Length Sizing Accuracy
2.5 Location Accuracy
2.6 Probability of Identification (POI)
2.7 Constraints and Definitions

3 Data Evaluation Procedure

4 Ultrasonic Crack Inspection Technology

5 Glossary

6 Abbreviations

7 ILI PQ Certifications
7.1 Tool Operator
7.2 Data Analysis Project Leader
7.3 Global Manager Data Analysis

Copyright © 2018, NDT Global, Issue # 3

Executive Summary

Enbridge Energy contracted NDT Global to perform an ultrasonic circumferential crack detection survey for 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.

To achieve these objectives, NDT Global utilized a 20" Evo Series 1.0 UCc inspection tool, recording a total of 21694.15 ft. of data.

NDT Global's Data Analysts have analyzed the full data set and present their results in this report.

During the inspection run, data was recorded by all channels, covering the complete circumference and length of the pipeline.

The recorded data quality fulfills the acceptance criteria for a successful run according to POF 2016.

Based on the statistics and results of the data quality assessment it can be concluded that the quality of the recorded data is good, complete and has consistent amplitudes over the total inspection distance.

The total coupling loss over the complete inspection distance is 0 % for the crack signals. There are no sensors with continuous coupling loss over the entire section distance.

The stated performance specifications can be achieved over the entire pipeline length and circumference.

The inspection run is therefore classified as successful.

This survey was accepted for final data analysis.

Copyright © 2018, NDT Global, Issue # 3

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

The comment of the feature with ID 8966 was changed to “verified: geometric anomaly with minor scrapes (<10% NWT)” compared to issue # 2 (customer internal issue 1.1) of this report, respectively the Excel listing of the inspection results.

In UCc data analysis, it is sometimes difficult to distinguish crack-like or crack field anomalies from notch-like or metal loss anomalies. Therefore, these anomalies were, in a conservative way, classified as crack-like or crack field anomalies. However, it cannot be excluded that they are really manufacturing-related or metal loss anomalies. In this case, a corresponding comment is added in the listing.

Crack-like Anomalies: 2 crack-like anomalies were entered into the listing.

- The crack like anomaly with ID 19367 has a calculated depth of 63 mil and is located at distance 21010.09 ft. It has the location in wall “ambiguous” and the comment “possible weld anomaly”.
- The internal crack like anomaly with ID 5926 has a calculated depth of 43 mil and is located at distance 5521.02 ft. It has the comment “possible weld anomaly”.

Geometric Anomalies 2 geometric anomalies were entered into the listing.

- The geometric anomaly with ID 8966 has the comment “verified: geometric anomaly with minor scrapes (<10% NWT)”.
  Due to the lift-off of the sensor carrier, detection and distinction of anomalies at geometric anomalies are limited. In case of doubt, they were classified in a conservative way as linear anomalies. An overestimation or underestimation of the depth for these anomalies is not unusual.

The explanation for the variations observed between 2014, 2017 and 2018 is that these features are “borderline features”. Borderline features have depth estimations around 39 mil. They could show a calculated depth ≥ 39 mil in one inspection and a calculated depth < 39 mil in another inspection. The differences in depth calculation are caused by the measurement tolerances from the tool and the geometry and dimensions of the feature. The same will apply for features with lengths that are considered borderline, this is around 1.18 in.

Copyright © 2018, NDT Global, Issue # 3

The following table gives an overview of the linear indication severity in the pipeline.

Feature type	Depth > saturation limit	Depth 0.08 in. to saturation limit
Crack-like	0	0
Crack field	0	0
Notch-like	0	0
Total	**0**	**0**

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

Copyright © 2018, NDT Global, Issue # 3

Part 1: Inspection Run & Summary of Results

Contents

1 Scope of Inspection 3

2 Operational Details 4

2.1 Pipeline Information 4
2.2 Medium Information 4
2.3 Pipeline Preparation 5
2.4 Tool Preparation 5
2.5 Inspection Run Details 5

3 Run Profiles 6

3.1 Speed Profile 6
3.2 Temperature Profile 7
3.3 Pressure Profile 8
3.4 Pendulum Profile 9

4 Data Quality 10

5 Summary of Results 11

5.1 Reporting Criteria 11
5.2 Results 12
5.2.1 Crack-like Anomalies 13
5.2.2 Geometric Anomalies 14
5.2.3 Installations 14
5.2.4 Run Comparison 15
5.3 Examples of Features 17
5.4 Charts 21

Copyright © 2018, NDT Global, Issue # 3

5.4.1 Distribution of Crack-like Anomalies 21
5.4.2 Distribution of Geometric Anomalies 22
5.4.3 Distribution of Wall Thickness 23

Copyright © 2018, NDT Global, Issue # 3

1 Scope of Inspection

Enbridge Energy contracted NDT Global to perform an ultrasonic circumferential crack detection survey for 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.

To achieve these objectives, NDT Global utilized a 20" Evo Series 1.0 UCc inspection tool, recording a total of 21694.15 ft. of data.

NDT Global's Data Analysts have analyzed the full data set and present their results in this report.

Copyright © 2018, NDT Global, Issue # 3

2 Operational Details

2.1 Pipeline Information

Pipeline name	Line 5
Construction year	1953
Launcher – receiver	North Straits East – Mackinaw
Length of pipeline section	4.10 mi.
Length of recorded pipeline section	21694.15 ft.
Outer diameter	20"
Minimum bend radius	5D/90°
Wall thickness range	0.500 in. – 0.812 in., predominant: 0.812 in.
Weld type	Seamless
Steel grades	API 5L X30, API 5L X52, API 5L X60, API 5L X65

Table 1 – Information about the pipeline

2.2 Medium Information

Product for normal operation	Light crude oil
Product for inspection survey	Light crude oil
Sound velocity in coupling medium	53.23 mil/µsec @ 41 °F
Attenuation in coupling medium	7 dB @ 41 °F
Temperature during inspection	Min. 44 °F Avg. 48 °F Max. 50 °F

Table 2 – Information about the medium

Copyright © 2018, NDT Global, Issue # 3

2.3 Pipeline Preparation

No recent cleaning procedures were performed in this section of the pipeline.

2.4 Tool Preparation

The Evo Series 1.0 UCc in-line inspection tool was prepared in accordance with NDT Global Process Description PD-008-SE-GLB "Preparation of Inspection Tools". It was checked for functionality in compliance with POF 2016 Standard[1] and American Petroleum Institute Standard API 1163[2] by the Tool Operator on 02 Apr 2018.

2.5 Inspection Run Details

The following inspection was performed after validating the ability for the tool to successfully negotiate the pipeline:

Tool type	Evo Series 1.0 UCc
Run ID	ENBNM18U0
Insertion of the tool	10 Apr 2018, 08:00
Retrieval of the tool	10 Apr 2018, 11:43
Tool speed during inspection	Min. 2.02 mph Avg. 2.26 mph Max. 2.62 mph
Tool condition	Good
Amount of debris	Negligible amount of sand

Table 3 – Inspection run

[1] POF 2016: "Specifications and requirements for in-line inspection of pipelines", Pipeline Operators Forum, version 2016.
[2] API 1163: "In-line Inspection Systems Qualification", second edition, April 2013.

3 Run Profiles

3.1 Speed Profile

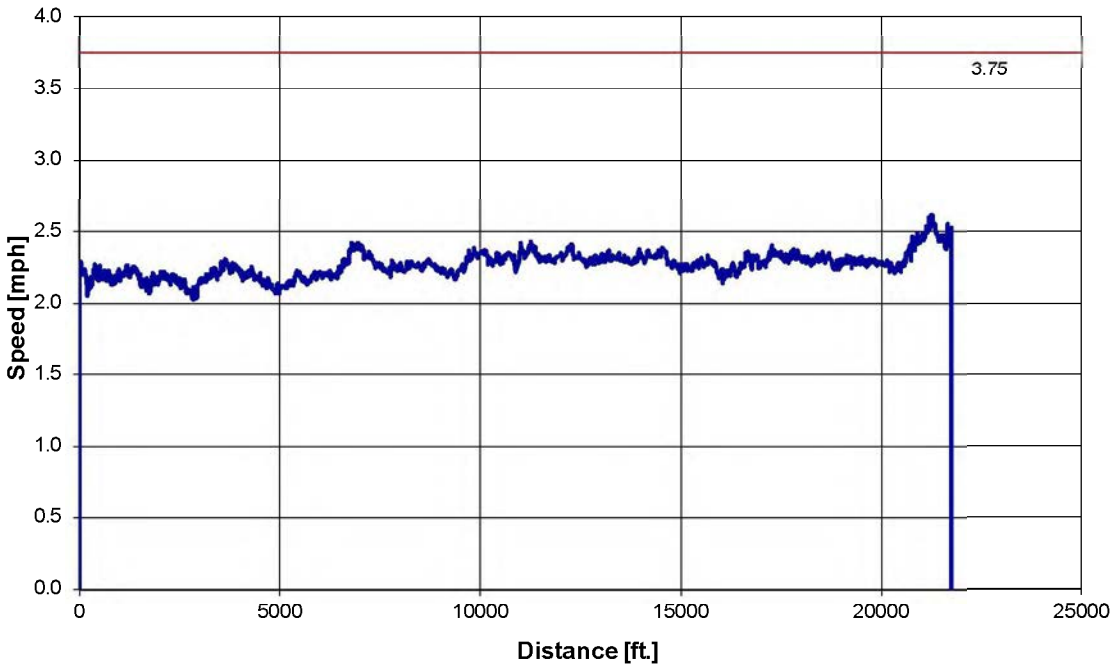


Figure 1 – Speed profile

The speed diagram shows that for the whole distance range the tool speed was below the specified maximum speed of 3.75 mph, i.e. the performance specifications are not affected by the tool speed.

3.2 Temperature Profile

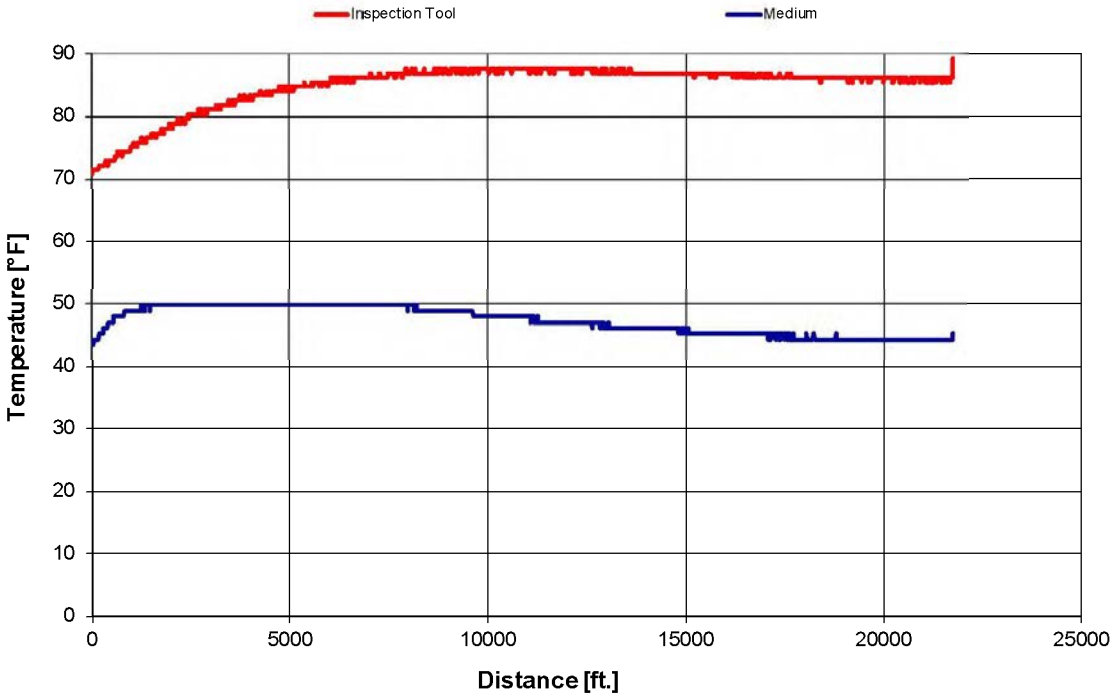


Figure 2 – Temperature profile

3.3 Pressure Profile

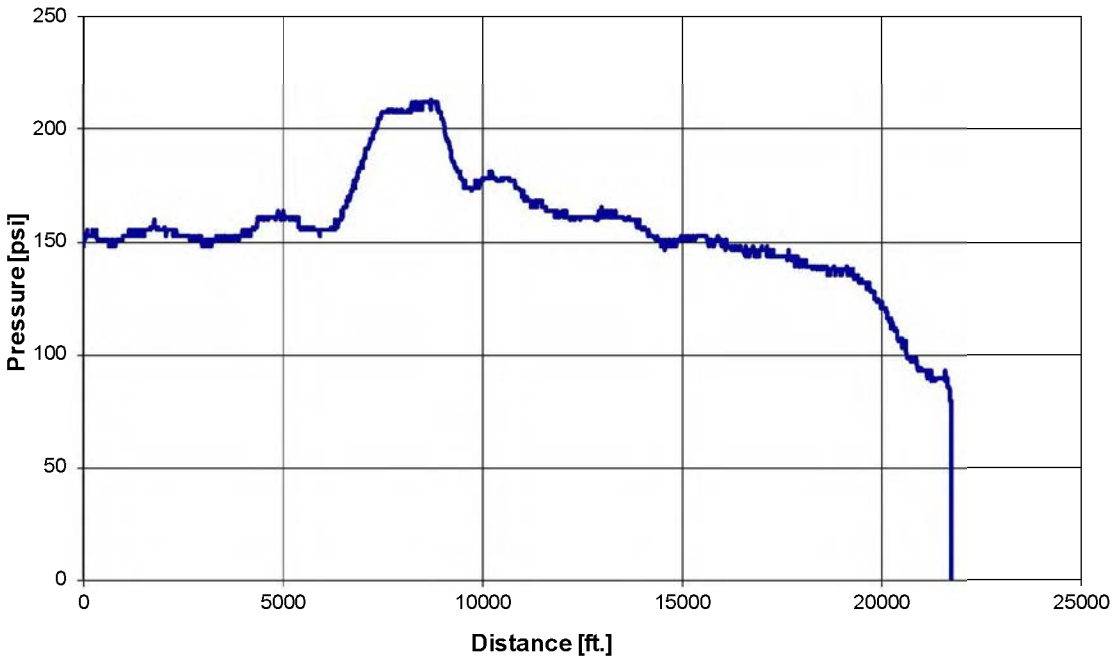


Figure 3 – Pressure profile

3.4 Pendulum Profile

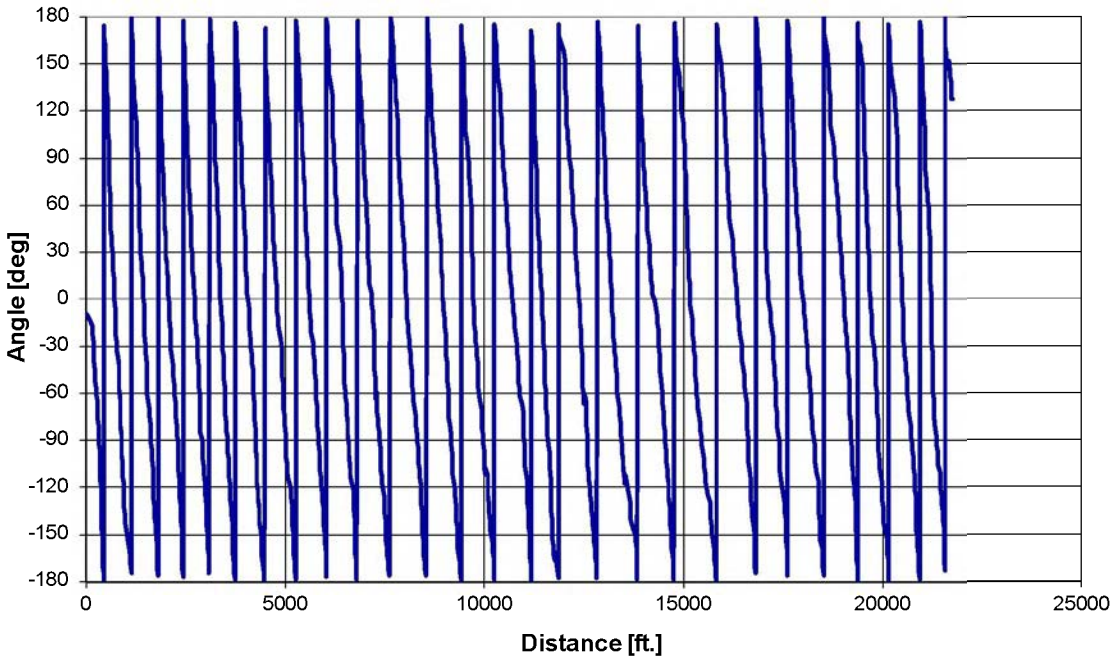


Figure 4 – Pendulum profile

The tool rotation does not affect data analysis because the rotation is recorded by the pendulum and considered during data processing.

4 Data Quality

During the Evo Series 1.0 UCc inspection run, data was recorded by all channels, covering the complete circumference and length of the pipeline (21694.15 ft. according to the odometer reading).

The recorded data quality fulfills the acceptance criteria for a successful run according to POF 2016.

Based on the statistics and results of the data quality assessment it can be concluded that the quality of the recorded data is good, complete and has consistent amplitudes over the total inspection distance.

The total coupling loss over the complete inspection distance is 0 % for the crack signals. There are no sensors with continuous coupling loss over the entire section distance.

The stated performance specifications can be achieved over the entire pipeline length and circumference.

The inspection run is therefore classified as successful.

This survey was accepted for final data analysis.

Copyright © 2018, NDT Global, Issue # 3

5 Summary of Results

5.1 Reporting Criteria

The following criteria[1] were applied to the dimensions of a feature to be included in the listing:

Circumferential crack or crack-like anomaly	Minimum length Minimum depth	1.18 in. 0.04 in.
Installation		All

Table 4 – Reporting criteria

All distances stated in this inspection report and the listing are odometer distances.

The comment of the feature with ID 8966 was changed to “verified: geometric anomaly with minor scrapes (<10% NWT)” compared to issue # 2 (customer internal issue 1.1) of this report, respectively the Excel listing of the inspection results.

[1] Several features with a length below the reporting threshold were entered into the listing.
The specified confidence level is not applicable to features with dimensions below the performance specifications and may therefore be reduced.

Copyright © 2018, NDT Global, Issue # 3

5.2 Results

The following features are entered into the listing:

Feature type	Description	Qty.
Crack-like	Crack-like anomaly in the weld seam, fatigue crack, etc.	2
Geometric anomaly		2
Installation		19
Total		**23**

Table 5 – Overview of the reported features

Linear indication severity of crack field, crack-like, and notch-like anomalies:

Feature type	Depth > saturation limit	Depth 0.08 in. to saturation limit
Crack-like	0	0
Crack field	0	0
Notch-like	0	0
Total	**0**	**0**

Table 6 – Linear indication (crack) severity

Copyright © 2018, NDT Global, Issue # 3

5.2.1 Crack-like Anomalies

In UCc data analysis, it is sometimes difficult to distinguish crack-like or crack field anomalies from notch-like or metal loss anomalies. Therefore, these anomalies were, in a conservative way, classified as crack-like or crack field anomalies. However, it cannot be excluded that they are really manufacturing-related or metal loss anomalies. In this case, a corresponding comment is added in the listing.

Crack-like Anomalies: 2 crack-like anomalies were entered into the listing.

- The crack like anomaly with ID 19367 (Figure 7) has a calculated depth of 63 mil and is located at distance 21010.09 ft. It has the location in wall "ambiguous" and the comment "possible weld anomaly".
- The internal crack like anomaly with ID 5926 (Figure 8) has a calculated depth of 43 mil and is located at distance 5521.02 ft. It has the comment "possible weld anomaly".

Distribution of crack-like anomalies according to their calculated depths:

Depth (mil)	Crack-like anomaly Qty.
< 39	0
39 – 78	2
≥ 79	0
Total	**2**

Table 7 – Distribution of crack-like anomalies according to depth

5.2.2 Geometric Anomalies

2 geometric anomalies were entered into the listing.

- The geometric anomaly with ID 8966 has the comment "verified: geometric anomaly with minor scrapes (<10% NWT)".
  Due to the lift-off of the sensor carrier, detection and distinction of anomalies at geometric anomalies are limited. In case of doubt, they were classified in a conservative way as linear anomalies. An overestimation or underestimation of the depth for these anomalies is not unusual.

The corresponding diagram in chapter 5.4.2 gives an overview of the distribution of the dents in the pipeline.

The following table gives an overview of the wrinkle/buckle severity:

Feature type	Top	Bottom	Max. depth %
Wrinkles/buckles	n/a	n/a	n/a
Wrinkles/buckles across seam welds or girth welds	n/a	n/a	n/a

Table 8 – Wrinkle/buckle severity

5.2.3 Installations

The following features were classified as installations and entered into the listing:

Installation type	Qty.
Valve	2
Flange	1
T-piece	3
Offtake	11
Stopple	2
Total	**19**

Table 9 – Overview of the pipeline installations

Copyright © 2018, NDT Global, Issue # 3

5.2.4 Run Comparison

All features that were entered into the listings of 2017 and/or 2018 were reviewed and compared. The results are summarized below.

The explanation for the variations observed between 2014, 2017 and 2018 is that these features are "borderline features". Borderline features have depth estimations around 39 mil. They could show a calculated depth ≥ 39 mil in one inspection and a calculated depth < 39 mil in another inspection. The differences in depth calculation are caused by the measurement tolerances from the tool and the geometry and dimensions of the feature. The same will apply for features with lengths that are considered borderline, this is around 1.18 in.

5.2.4.1 Features reported in 2018 and in 2017

No crack-like anomalies were entered into the 2017 listing and into the 2018 listing.

5.2.4.2 Features reported in 2018 but not in 2017

2 crack-like anomalies were entered in the 2018 listing but not into the 2017 listing.

	ENBNA14U0 Depth (mil)	ENBNA17U0 Depth (mil)	ENBNA18U0 Depth (mil)
Crack-like anomaly ID 5926	35	24	43
Crack-like anomaly ID 19367	24	79	63

Table 10 – Comparison of thr features reported in 2018 but not in 2017

In all data sets, both anomalies show a circumferential length < 1.18 in. and therefore have dimensions outside the UCc feature specification. They were only detected by sensors in 1 or 2 tracks.

The amplitudes resulting in a calculated depth of 79 mil for the crack-like anomaly with ID 19367 in ENBNA17U0 was measured by 1 sensor. This sensor shows unclear signals in the inspection data.

A further geometric anomaly that is not visible in the 2014 and 2017 inspection data was entered into the listing of 2018. It has the comment "verified: geometric anomaly with minor scrapes (<10% NWT)".

Copyright © 2018, NDT Global, Issue # 3

5.2.4.3 Features reported in 2017 but not in 2018

No crack-like anomalies were entered in the listing of 2017 but not into the listing of 2018.

The 2017 listing contains 13 notch-like anomalies with a calculated depth < 39 mil. All of them are also visible as notch-like anomalies in the 2018 inspection data. They show a calculated depth < 39 mil and were therefore not entered into the listing of 2018.

Copyright © 2018, NDT Global, Issue # 3

5.3 Examples of Features

The following screenshots of the LineExplorer visualization software explain the major information provided by the C-scan and B-scans. In the C-scan screenshots, features are indicated by a red box.
All distances stated are odometer distances.

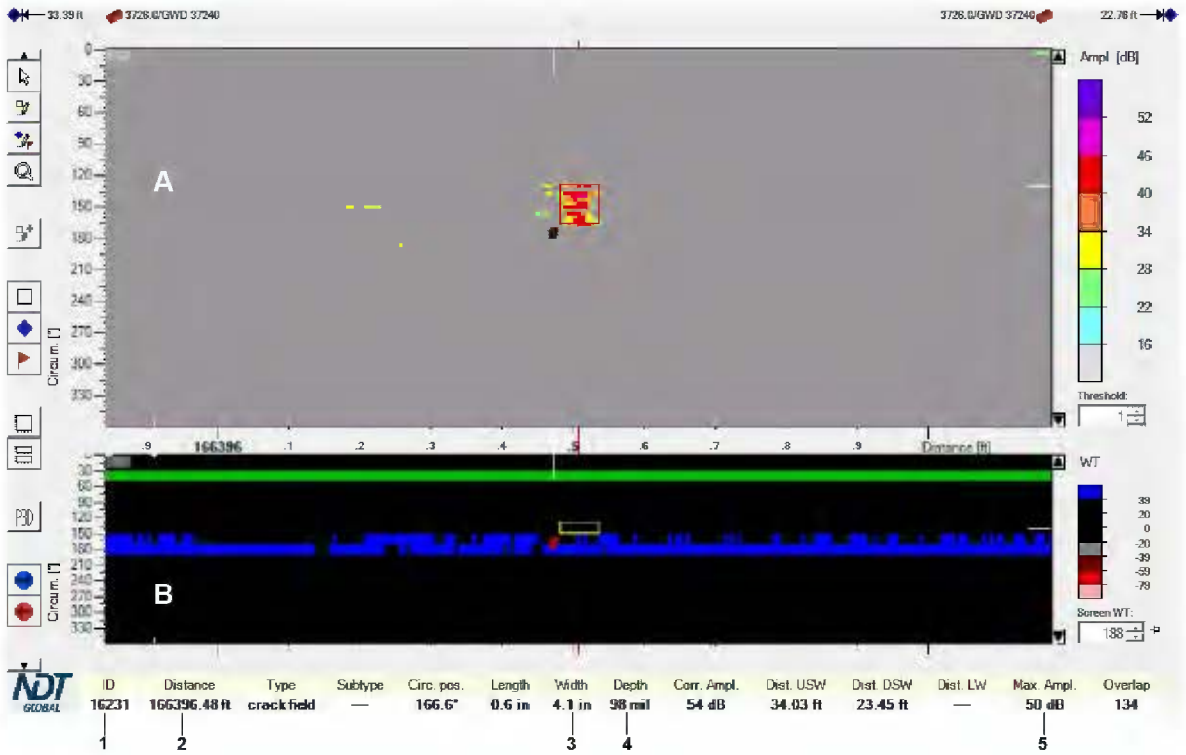


Figure 5 – Information provided in the C-scan demo screenshot

Item	Meaning	Item	Meaning
A	Crack detection C-scan display	1	Feature ID
B	Wall thickness C-scan display	2	Absolute distance of the feature
		3	Circumferential length of the feature
		4	Calculated depth of the feature
		5	Maximum amplitude of the feature

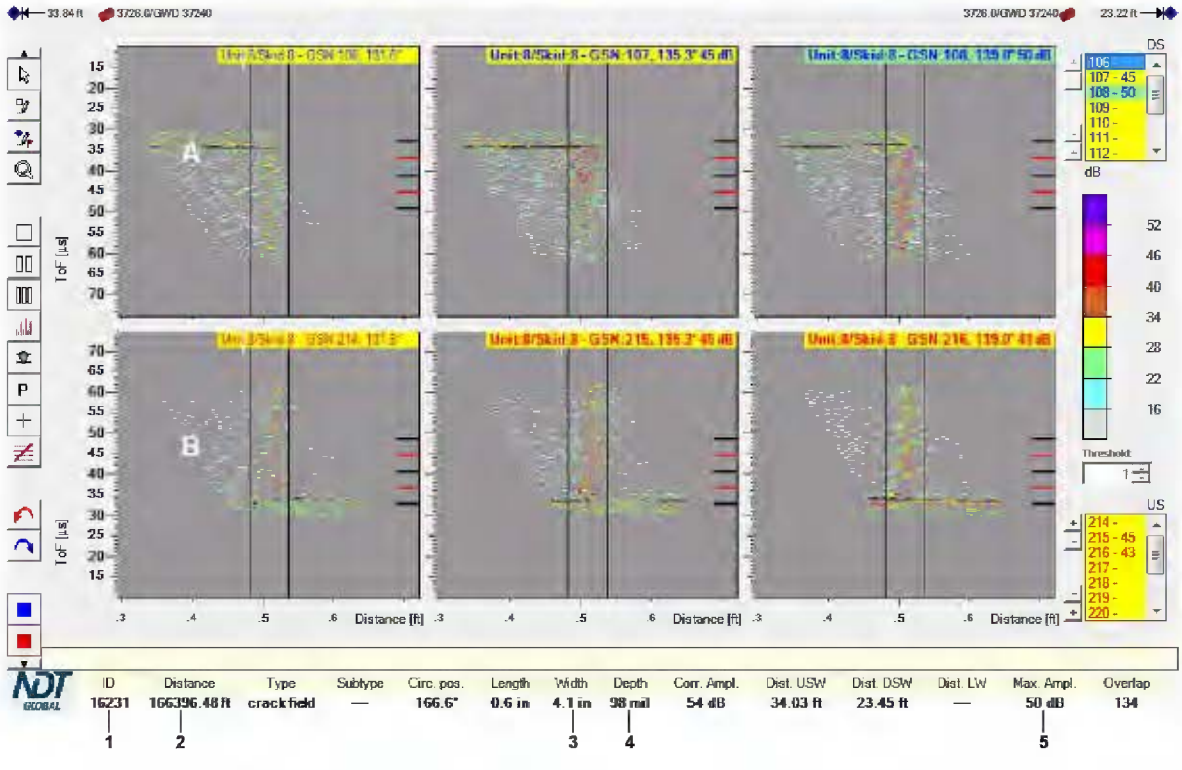


Figure 6 – Information provided in the B-scan demo screenshot

Item	Meaning	Item	Meaning
A	B-scan display of 3 neighboring sensors (downstream sensors)	1	Feature ID
B	B-scan display of 3 neighboring sensors (upstream sensors)	2	Absolute distance of the feature
		3	Circumferential length of the feature
		4	Calculated depth of the feature
		5	Maximum amplitude of the feature

Figure 7 shows the C-scan and B-scans of the crack-like anomaly with ID 19367. It has a calculated depth of 63 mil and is located at distance 21010.09 ft. The anomaly has the location in wall “ambiguous” and the comment “possible weld anomaly”.

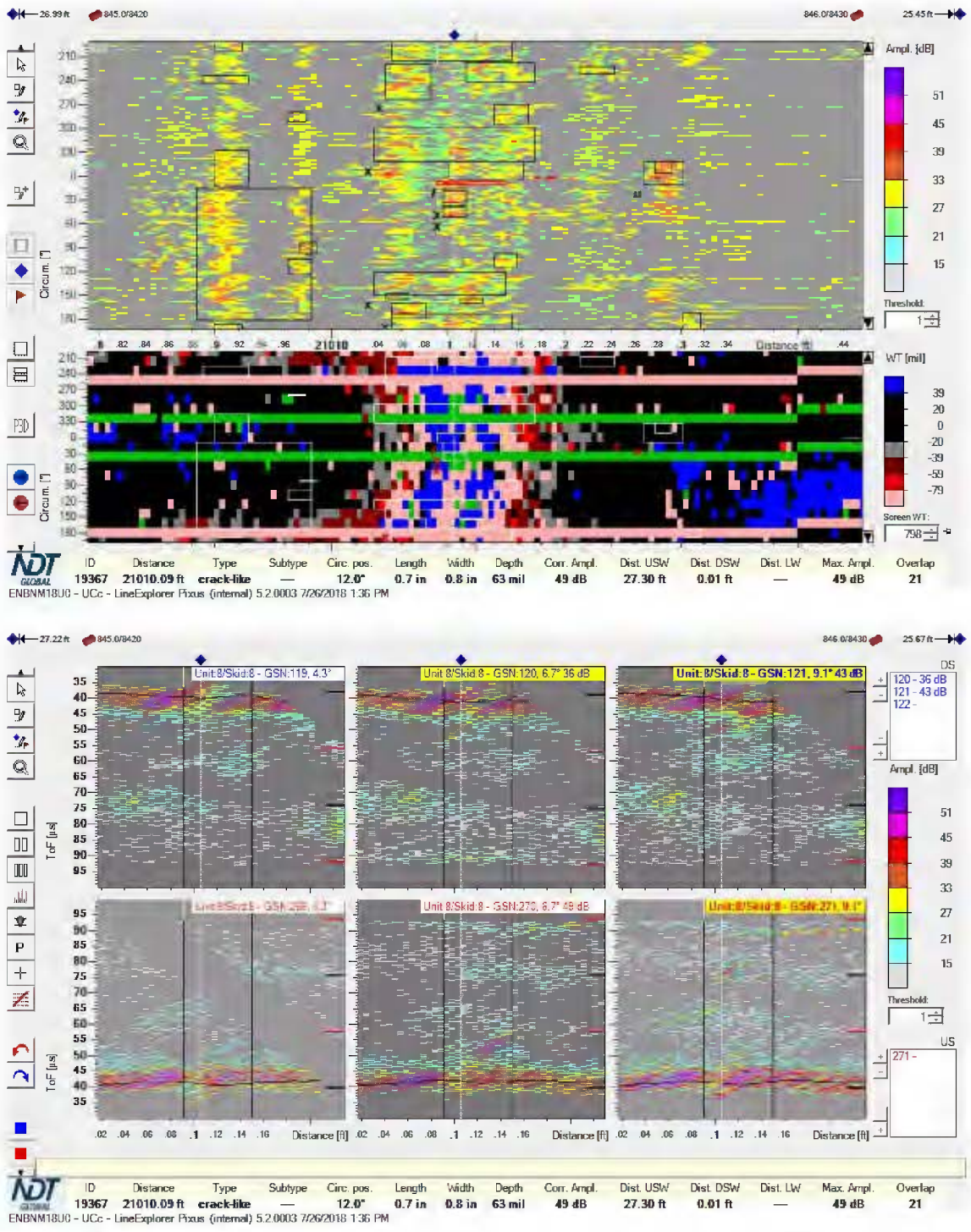


Figure 7 – Top: C-scan, bottom: B-scans of a crack-like anomaly (ID 19367)

Figure 8 shows the C-scan and B-scans of the internal crack-like anomaly with ID 5926. It has a calculated depth of 43 mil and is located at distance 5521.02 ft. The anomaly has the comment “possible weld anomaly”.

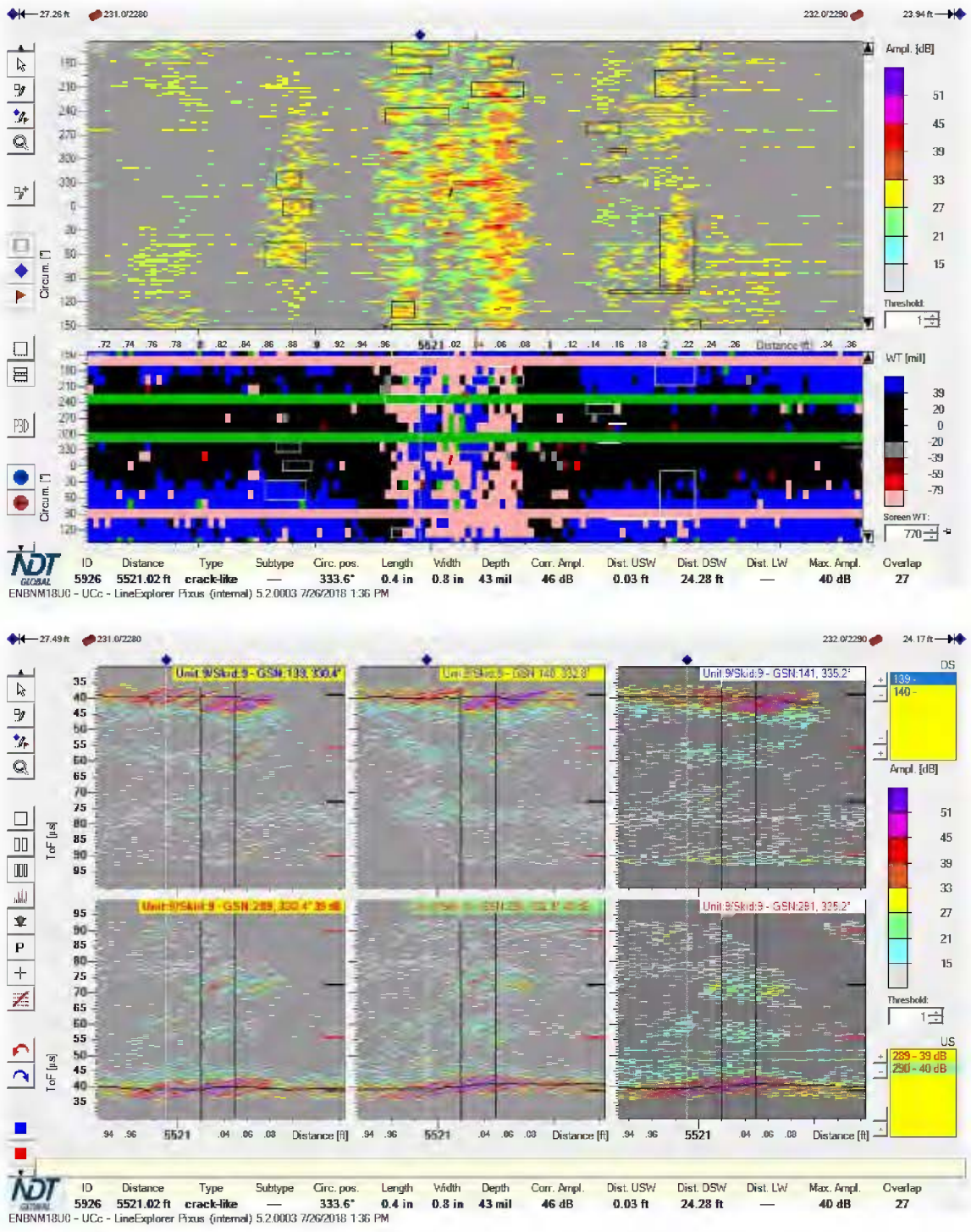


Figure 8 – Top: C-scan, bottom: B-scans of a crack-like anomaly (ID 5926)

5.4 Charts

5.4.1 Distribution of Crack-like Anomalies

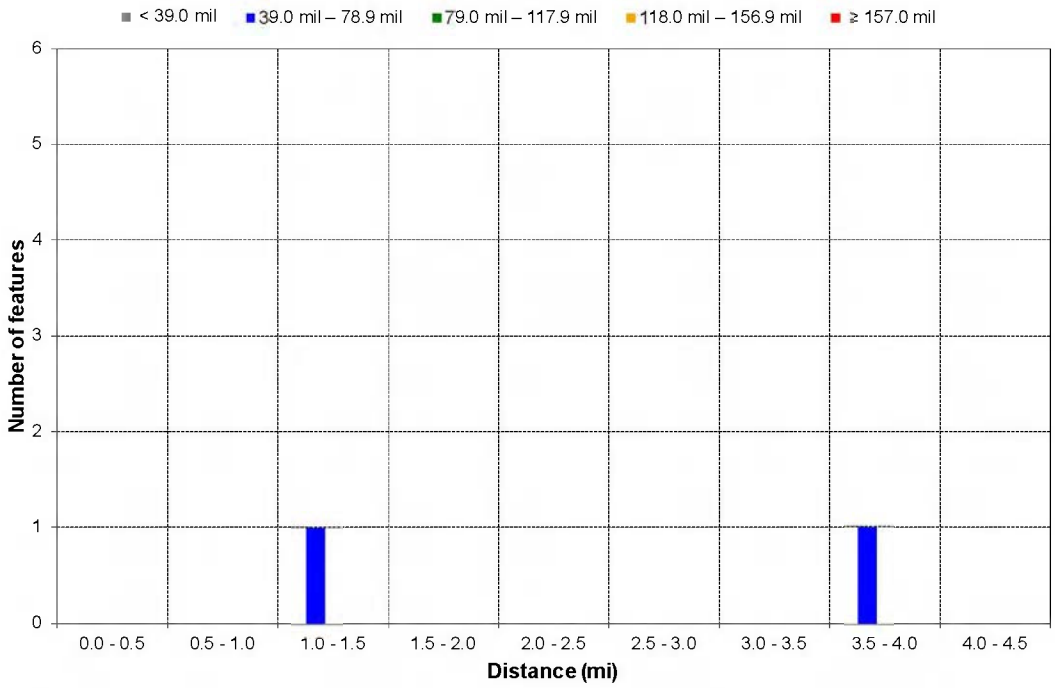


Figure 9 – Distribution of crack-like anomalies according to depth – number vs. distance

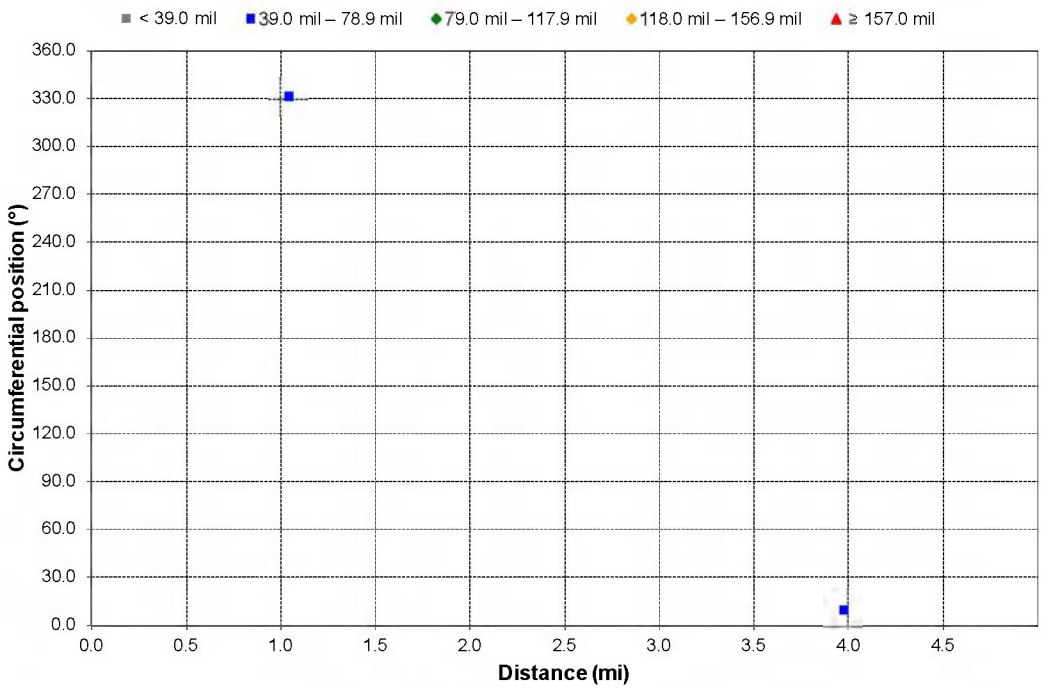


Figure 10 – Circumferential distribution of crack-like anomalies according to depth

5.4.2 Distribution of Geometric Anomalies

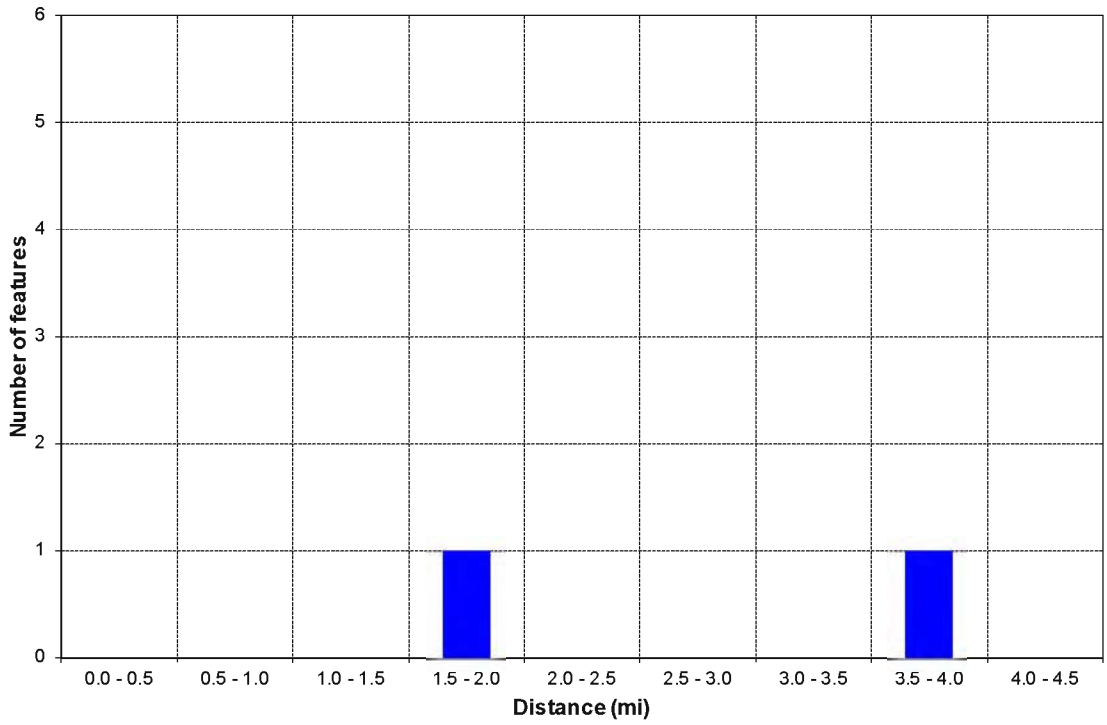


Figure 11 – Distribution of geometric anomalies – number vs. distance

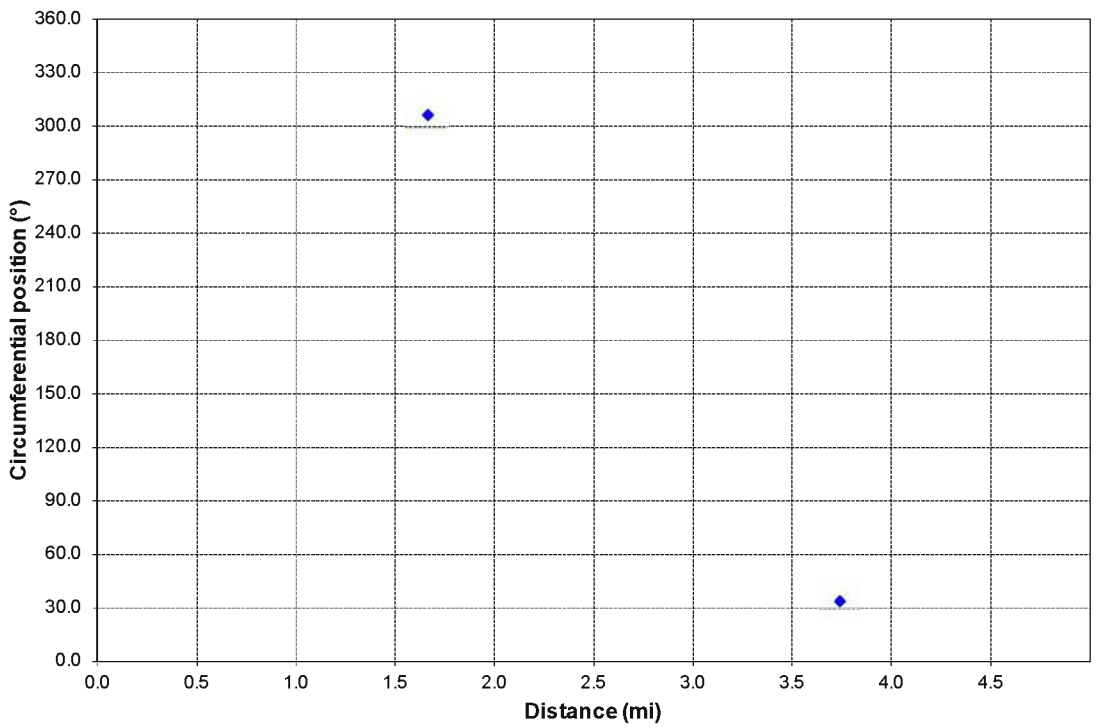


Figure 12 – Circumferential distribution of geometric anomalies

5.4.3 Distribution of Wall Thickness

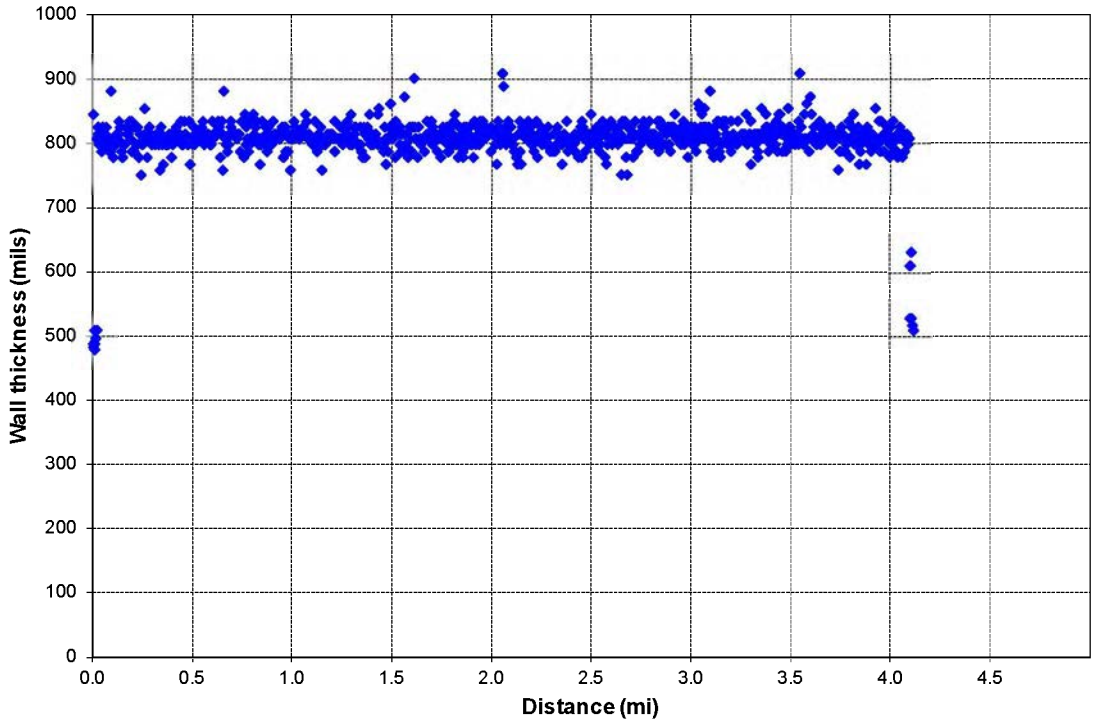


Figure 13 – Wall thickness distribution of the pipe joints

Part 2: Listing

Contents

1 Key to the Listing

1.1 Generic Attributes
1.2 Metal Loss Attributes
1.3 Crack Attributes
1.4 Geometry Attributes
1.5 Strain Attributes

Copyright © 2018, NDT Global, Issue # 3

1 Key to the Listing

For the listing itself, please refer to the spreadsheet in the corresponding Excel file.

The listing consists of the following columns:

1.1 Generic Attributes

Upstream girth weld	Upstream girth weld of the joint containing the start of the feature. For geometry features: the upstream girth weld of the joint containing the MSP of the feature.
Absolute distance (ft.)	Distance of the beginning of the feature to the reference distance 0 ft., based on the odometer reading.
Joint length (ft.)	Length of the pipe joint, measured from the middle of the girth weld to the middle of the girth weld.
Nominal pipe size (in.)	Diameter of pipeline, as provided by Enbridge Pipelines
Nominal wall thickness (mm)	Nominal wall thickness of the joint, as provided by Enbridge Pipelines.
Actual measured local wall thickness (in.)	Local wall thickness measured in the vicinity of the feature by NDT Global's inspection tool. For UCc not available.
Average wall thickness (in.)	The most frequently measured wall thickness in a pipe joint.
Seam weld type detected	Type of seam weld used to fabricate the joint. **Note:** This is not the weld type used to attach 2 separate joints. ERW/FW electric resistance weld or flash weld. SAW submerged arc weld. DSAW double submerged arc weld. SPIRAL spiral weld. SMLS seamless weld. UNKN weld type could not be determined.

Copyright © 2018, NDT Global, Issue # 3

Seam weld orientation start detected (°)	Circumferential orientation of the seam weld at the US girth weld (clockwise from top looking downstream), as detected by NDT Global's inspection tool. For UCc not available.
Seam weld orientation end detected (°)	Circumferential orientation of the seam weld at the DS girth weld (clockwise from top looking downstream), as detected by NDT Global's inspection tool. For UCc not available.
Seam weld orientation start provided (°)	Circumferential orientation of the seam weld at the US girth weld (clockwise from top looking downstream), as provided by Enbridge Pipelines.
Seam weld orientation end provided (°)	Circumferential orientation of the seam weld at the DS girth weld (clockwise from top looking downstream), as provided by Enbridge Pipelines.
Pipe grade provided	Pipe grade, as provided by Enbridge Pipelines.
Joint insulated	Identifies whether or not the joint containing is electrically insulated.
Feature ID	Unique feature identifier, as provided by NDT Global.
Sleeve/Casing ID	Unique identifier of a sleeve or casing
Feature type	Possible feature types are: • crack-like • crack field (group of several crack-like features, e.g. SCC = stress corrosion cracking) • notch-like (gouging, scratches, etc.) • metal loss (general corrosion, pitting, channeling, etc.) • manufacturing-related (lamination, inclusion, blister, etc.) • dent • geometry (dent, ovality, wrinkle, bend, internal diameter reduction, etc.) • casing eccentric (area where casing is touching the pipe) • casing start / casing end • sleeve start / sleeve end • installation (flange, T-piece, valve, offtake, etc.)
Feature comment	• Additional information on the feature, if necessary.
Relative distance start (ft.)	Start distance of the feature from the US girth weld.

Copyright © 2018, NDT Global, Issue # 3

Relative distance end (ft.)	End distance of the feature from the US girth weld.
Relative distance centre (ft.)	Distance of the feature box from the US girth weld. This attribute only applies to geometric anomalies detected by technologies other than a caliper.
MSP relative distance (ft.)	Distance of the feature's most severe point (MSP) from the US girth weld.
Orientation start (°)	Circumferential position of the leading edge of the feature (clockwise from top looking downstream).
Orientation end (°)	Circumferential position of the trailing edge of the feature (clockwise from top looking downstream).
Orientation centre (°)	Circumferential position of the centre of the feature box (clockwise from top looking downstream). This attribute only applies to geometric anomalies detected by technologies other than a caliper.
MSP orientation (°)	Circumferential position of the feature's most severe point (clockwise from top looking downstream).
Length (in.)	Axial length of the feature box. For UCc technologies only: For the feature types crack-like, crack field, and notch-like anomalies, this corresponds to the anomaly width.
Width (in.)	Circumferential width of the feature box. For UCc technologies only: For the feature types crack-like, crack field, and notch-like anomalies, this corresponds to the anomaly length.
Depth (in.)	Maximum depth of the feature
Depth percent nominal	Depth of feature in percent of nominal wall thickness.
Depth percent local	Depth of feature in percent of local wall thickness.
Radial position	Radial position of the feature: Internal Feature was detected on the internal surface only. External Feature was detected on the external surface only. Internal and External: One or several features were detected on both the internal and external surfaces at the same location. Mid-wall Feature was detected within the pipe wall.

Copyright © 2018, NDT Global, Issue # 3

	Not decidable Position of the feature could not reliably determined.
Relative position to girth weld	Across girth weld Feature is across the girth weld. For UM technologies only: Adjacent to weld Feature is within 25 mm from the centreline of the girth weld. In weld Feature is within girth weld. Not associated Feature is more than 25 mm from the centreline of the girth weld. For UC technologies only: Adjacent to weld Feature is between 50 mm and 400 mm from the centreline of the girth weld. In weld Feature is within 50 mm from the centreline of the girth weld. Not associated Feature is more than 400 mm from the centreline of the girth weld.
Relative position to seam weld	Across seam weld Feature is across the seam weld. In weld Feature is within seam weld. Not decidable Unable to determine the relative position of the feature to the seam weld. For UM technologies only: Adjacent to weld Feature is within 25 mm from the centreline of the seam weld. For UC technologies only: Adjacent to weld Feature is within 20 mm from the centreline of the seam weld. Base metal Feature is more than 20 mm from the centreline of the seam weld.
Bulging	Indicates whether or not a lamination has caused an extreme bulge.
Intermittent	Indicates whether or not a lamination is non continuous.
Sloping	Indicates whether or not a continuous lamination slopes as it approaches both the inner and outer surfaces.
Surface breaking	Indicates whether or not a lamination extends to either the internal or external surface of the pipe.
Variable depth	Indicates whether or not there are multiple laminations that vary in depth.
IMU reported latitude (°)	IMU reported latitude of the feature.

Copyright © 2018, NDT Global, Issue # 3

IMU reported longitude (°)	IMU reported longitude of the feature.
IMU reported elevation (m)	IMU reported elevation of the feature.
Under sleeve	Indicates whether the feature is fully covered by a sleeve, or not.
Degraded data	Y Signal loss or degraded data due to overspeed, sensor failure, debris, coupling loss, electronic failure, etc. N No signal loss or degraded data.
Interacting with deformation	Feature is interacting with a deformation (Y), or not (N).
Interacting with crack	Feature is interacting with a crack (Y), or not (N).
Interacting with metal loss	Feature is interacting with a metal loss (Y), or not (N).
Interacting with manufacturing defects	Feature is interacting with a manufacturing-related defect (Y), or not (N).
Length accuracy (in.)	Tool resolution for the detection of the feature.
Depth accuracy (in.)	Tool accuracy for the detection of the feature.

Table 10 – Generic attributes

1.2 Metal Loss Attributes

Feature morphology	The dimensional classes as defined by API 1163.
Depth UTWM WT (in.)	Maximum depth of the feature based on UTWM WT.
Depth percent UTWM WT	Maximum depth of the feature based on Nominal WT.
Effective length (in.)	Effective axial length of the feature determined using the RSTRENG method.
Effective length nominal WT (in.)	Effective axial length of the feature determined using the RSTRENG method based on Nominal WT.

Copyright © 2018, NDT Global, Issue # 3

Effective length UTWM WT (in.)	Effective axial length of the feature determined using the RSTRENG method based on UTWM WT.
Effective depth (in.)	Effective depth of the feature determined using the RSTRENG method.
Effective depth nominal WT (in.)	Effective depth of the feature determined using the RSTRENG method based on Nominal WT.
Effective depth UTWM WT (in.)	Effective depth of the feature determined using the RSTRENG method based on UTWM WT.
Effective Area Failure Pressure (psi)	Calculated failure pressure of a metal loss feature using the effective area method.
Effective Area Failure Pressure Nominal WT (psi)	Calculated failure pressure of a metal loss feature using the effective area method based on Nominal WT.
Effective Area Failure Pressure UTWM WT (psi)	Calculated failure pressure of a metal loss feature using the effective area method based on UTWM WT.
MB31G Failure Pressure UTWM WT (psi)	Calculated failure pressure of a metal loss feature using Modified B31G
Effective Area RPR	Rupture Pressure Ratio (RPR) of the feature using the RTSTRENG method and river bottom profile.
Effective Area RPR Nominal WT	Rupture pressure ratio of the feature, calculated using the RSTRENG method, through assessment of river bottom profile based on Nominal WT.
Effective Area RPR UTWM WT	Rupture pressure ratio of the feature, calculated using the RSTRENG method, through assessment of river bottom profile based on UTWM WT.
MB31G RPR	Rupture Pressure Ratio (RPR) of the feature using Modified B31G.
Interacting with close metal loss	Indicates whether or not a metal loss feature is within 15.24 m (50 feet) of a detected metal object.
Proximity	Indicates if a detected ferrous metal object or casing is close to or touching the pipeline, based upon the magnetic signal.
Echo loss	Echo occurred at feature (Y), or not (N).
Echo loss rules	Rule type which triggered the echo loss flag during analysis.

Copyright © 2018, NDT Global, Issue # 3

Remaining wall thickness (in.)	Remaining wall thickness at most severe point of the feature (local wall thickness minus feature depth).

Table 11 – Metal loss attributes

1.3 Crack Attributes

Longest interacting length (in.)	The longest length of linked cracks in a crack field (or the longest crack indication if there are no interacting indications); For UCc not available.
Depth range lower bound (in.)	Lower bound of the estimated crack depth range of the feature.
Depth range upper bound (in.)	Upper bound of the estimated crack depth range of the feature.
Single crack	The crack-like feature is a single crack (Y) or intermittent cracks (N).
Sensor lift off	The ability to detect, identify, or size the feature was reduced by a prominent girth weld root (Y), or not (N).
CW sensors	Number of clockwise sensors detecting a signal from the crack feature. For UCc, this corresponds to the number of downstream sensors.
CCW sensors	Number of counter-clockwise sensors detecting a signal from the crack feature. For UCc, this corresponds to the number of upstream sensors.
Width accuracy (in.)	Tool resolution for the detection of the feature.
Minimum detected length (in.)	Minimum feature length detectable by Evo Series 1.0 UCc. For UCc, this corresponds to the circumferential length of a feature.
Tool velocity (ft./s)	Velocity of Evo Series 1.0 UCc when passing the feature.
Name of previous inspection	Run ID of the previous run.

Copyright © 2018, NDT Global, Issue # 3

Previous inspection feature type	Feature type at this location reported in the previous report.
Previous inspection depth range lower bound (in.)	Lower bound of the estimated crack depth range of the feature in the previous report.
Previous inspection depth range upper bound (in.)	Upper bound of the estimated crack depth range of the feature in the previous report.

Table 12 – Crack attributes

1.4 Geometry Attributes

Dent depth B (in.)	Depth of dent-like geometry feature, including the effects of pipe ovality.
Depth percent dent	Depth of geometry feature at the MSP, excluding the effects of pipe ovality.
Depth percent B	Depth of geometry feature at the MSP, including the effects of pipe ovality.
Ovality	Out-of-roundness relative to the nominal circular shape of the pipe.
US_LAX00 (in.)	The US axial distance from the MSP of the geometry feature to the point of 0 % of the peak depth.
US_LAX05 (in.)	The US axial distance from the MSP of the geometry feature to the point of 5 % of the peak depth.
US_LAX50 (in.)	The US axial distance from the MSP of the geometry feature to the point of the 50 % peak depth.
DS_LAX00 (in.)	The DS axial distance from the MSP of the geometry feature to the point of 0 % of the peak depth.
DS_LAX05 (in.)	The DS axial distance from the MSP of the geometry feature to the point of 5 % of the peak depth.
DS_LAX50 (in.)	The DS axial distance from the MSP of the geometry feature to the point of the 50 % peak depth.

Copyright © 2018, NDT Global, Issue # 3

CW_LTR00 (in.)	The clockwise transverse distance from the MSP of the geometry feature to the point of 0 % of the peak depth.
CW_LTR05 (in.)	The clockwise transverse distance from the MSP of the geometry feature to the point of 5 % of the peak depth.
CW_LTR50 (in.)	The clockwise transverse distance from the MSP of the geometry feature to the point of the 50 % peak depth.
CW_LTR00 (in.)	The clockwise transverse distance from the MSP of the geometry feature to the point of 0 % of the peak depth.
CW_LTR05 (in.)	The clockwise transverse distance from the MSP of the geometry feature to the point of 5 % of the peak depth.
CW_LTR50 (in.)	The clockwise transverse distance from the MSP of the geometry feature to the point of the 50 % peak depth.
Minimum distance of MSP to GW (in.)	The minimum distance of the geometry feature's MSP to the nearest girth weld.
Minimum distance of MSP to LSW (in.)	The minimum distance of the geometry feature's MSP to the nearest seam weld.
Internal pipe pressure at deformation (psi)	The internal pipe pressure at the location of the geometry feature.
Nominal ID (in.)	The nominal measured inner diameter of the joint containing the feature.
Minimum ID (in.)	The minimum measured inner diameter of the pipe at the location of the MSP.
Maximum ID (in.)	The maximum measured inner diameter of the pipe at the location of the MSP.
Associated with girth weld	The geometry feature is located at a girth weld (Y), or not (N).
Associated with seam weld	The geometry feature is located at a seam weld (Y), or not (N).
Topside	Y The MSP of the feature is on the topside, between 240° and 120°. N The MSP of the feature is on the bottom side, between 120° and 240°.

Copyright © 2018, NDT Global, Issue # 3

Off axis	The longitudinal axis of the dent is more than 15° from the longitudinal axis of the pipeline (Y), or equal or less than 15° (N).
MultiApex dent	The dent has more than one apex point (Y), or not (N).
Dent in close proximity	Y One or more topside dent MSPs (or feature box centres) are within 3 m (10 ft.) in axial direction and 60° in circumferential direction. Y Two or more bottom side MSPs (or feature box centres) are within 1.5 m (5ft.) in axial direction and 60° in circumferential direction. N None of the above conditions applies.
Bend angle (°)	Maximum angle of the bend.
Bend azimuth angle (°)	The angle of the direction change, looking down onto the pipeline.
Bend azimuth change direction	The bend moves right (Right) or left (Left), looking down onto the pipeline.
Bend pitch angle (°)	The angle of the tilt change.
Bend pitch direction	The bend moves up (Up) or down (Down).
Bend radius (OD)	Minimum radius of the curvature of the bend, on the plane of the bend angle.

Table 13 – Geometry attributes

1.5 Strain Attributes

Strain value at largest difference horizontal	The horizontal component of the absolute bending strain at the peak total differential bending strain location.
Strain value at largest difference vertical	The vertical component of the absolute bending strain at the peak total differential bending strain location.

Strain value at largest difference total	The combined vertical and horizontal component of the absolute bending strain at the peak total differential bending strain location.
Largest strain difference horizontal	The horizontal component of the total differential bending strain between the current and the baseline inspection.
Largest strain difference vertical	The vertical component of the total differential bending strain between the current and the baseline inspection.
Largest strain difference total	The combined vertical and horizontal component of the total differential bending strain between the current and the baseline inspection.
Pipeline movement direction horizontal	The direction of the maximum horizontal location difference between the current and baseline inspections within the start and end of the chainage range.
Pipeline movement direction vertical	The direction of the maximum vertical location difference between the current and baseline inspections within the start and end of the chainage range.
Pipeline movement horizontal (ft.)	The maximum horizontal difference between the current and the baseline inspection within the start and end chainage range.
Pipeline movement vertical (ft.)	The maximum vertical difference between the current and the baseline inspection within the start and end chainage range.

Table 14 – Strain attributes

Copyright © 2018, NDT Global, Issue # 3

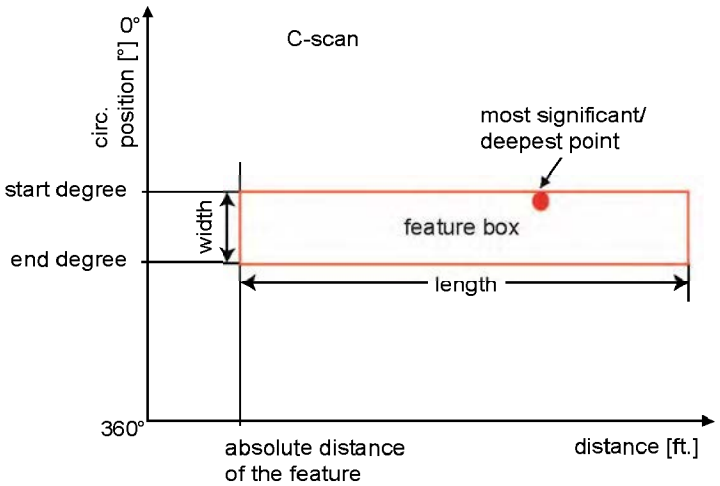


Figure 14 – Illustration of box coordinates

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 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 performance 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.

Copyright © 2018, NDT Global, Issue # 3

Part 3: Appendix

Contents

1 Tool Specifications 3

2 Performance Specification Evo Series 1.0 and LineExplorer UCc 4

2.1 Introduction 4
2.2 Detection Capabilities 4
2.3 Depth Sizing Accuracy 5
2.4 Length Sizing Accuracy 5
2.5 Location Accuracy 6
2.6 Probability of Identification (POI) 6
2.7 Constraints and Definitions 9
2.7.1 Validity 9
2.7.2 Circumferential Orientation of Feature 10
2.7.3 Radial Orientation of Feature 10
2.7.4 Surface Connection & Mid-wall Flaws 10
2.7.5 Length 11
2.7.6 Wall Position 11
2.7.7 Seamless Pipe 11
2.7.8 Longitudinal/Spiral Weld Location 12
2.7.9 Girth Weld Location 13
2.7.10 Bends and Deformations 13
2.7.11 Speed Excursions 13
2.7.12 Medium Properties 13
2.7.13 Reported Anomaly Depth 13
2.7.14 Reporting of Circumferential Location 14
2.7.15 Reference Wall Thickness 14

3 Data Evaluation Procedure 15

4 Ultrasonic Crack Inspection Technology 17

5 Glossary 18

Copyright © 2018, NDT Global, Issue # 3

6 Abbreviations 22

7 ILI PQ Certifications 24

7.1 Tool Operator 24

7.2 Data Analysis Project Leader 25

7.3 Global Manager Data Analysis 26

Copyright © 2018, NDT Global, Issue # 3

1 Tool Specifications

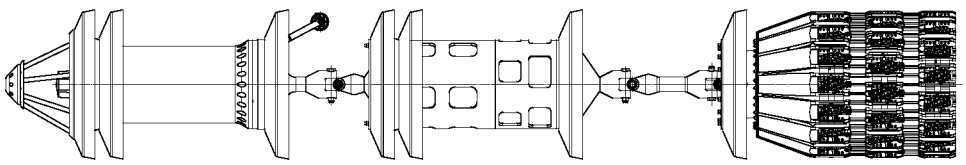


Figure 15 – Schematics of the 20" NDT Evo Series 1.0 UCc

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

	Unit	Value
Mechanical properties		
Nominal pipe size	in.	20
Minimum ID straight pipe	in.	17.01
Minimum ID bend	in.	17.99
Tool length	ft.	11.68
Tool weight	lbs	1102
Minimum bend radius	D	3/90°
Number of tool bodies		3
Operating conditions		
Temperature range	°F	14 – 122
Maximum pressure during inspection	psi	1740
Maximum tool speed	mph	3.75
Measurement properties		
Axial sampling distance	in.	0.06
Circumferential sensor spacing	in.	0.39
Maximum operating time	h	32
Distance at specified maximum tool speed	mi.	120
Maximum wall thickness	in.	0.79
Number of crack detection sensors		300
Number of reference wall thickness sensors for UC/UCc		20

Table 16 – Tool specifications

Copyright © 2018, NDT Global, Issue # 3

2 Performance Specification Evo Series 1.0 and LineExplorer UCc

2.1 Introduction

This section describes the performance specification of NDT Global's Evo Series 1.0 UCc and LineExplorer UCc tools. It is in accordance with requirements stated in the latest versions of "Specifications and requirements for in-line inspection of pipelines" by Pipeline Operators Forum (POF) 2016 and "In-line Inspection Systems Qualification", Standard 1163, 2nd edition by the American Petroleum Institute. The given values have been derived from NDT Global's testing program, consisting of small scale lab testing, full scale tests utilizing extensive loop testing, and field verification information from actual in-line inspections.

2.2 Detection Capabilities

Minimum dimension for circumferential cracks, crack-like anomalies, and linear indications at a POD ≥ 90 %					
Axial resolution		1.5 mm	0.12 in.	0.75 mm	0.06 in.
Circ. resolution		10.0 mm	0.39 in.	10.0 mm	0.39 in.
In base material[1] &	Depth	1.0 mm	0.04 in.	1.0 mm	0.04 in.
At weld/HAZ[2]	Length	30.0 mm	1.18 in.	30.0 mm	1.18 in.
in weld	Depth	2.0 mm	0.08 in.	2.0 mm	0.08 in.
	Length	30.0 mm	1.18 in.	30.0 mm	1.18 in.
Minimum crack opening		0.0 mm	0.00 in.	0.0 mm	0.00 in.
Reporting	Reporting threshold may differ from minimum feature dimension and is individually specified for each inspection				

Table 17 – POD for circumferential cracks, crack-like anomalies, and linear indications

[1] Base material: non heat affected zone or welded area of spool
[2] At weld: Weld area, with filler material of welding process and melted material

Copyright © 2018, NDT Global, Issue # 3

2.3 Depth Sizing Accuracy

Depth sizing accuracy and reporting of circumferential cracks, crack-like anomalies, and linear indications		
Depth	1 ... < 4 mm	0.04 ... < 0.16 in.
Accuracy at 80 % certainty	±1.0 mm	±0.04 in.
Reported as	Absolute value	Absolute value
Depth	≥ 4.0 mm	≥ 0.16 in.
Certainty of correct sizing	80 %	80 %
Reported as	≥ 4.0 mm	≥ 0.16 in.

Table 18 – Depth sizing accuracy and reporting for circumferential cracks, crack-like anomalies, and linear indications

2.4 Length Sizing Accuracy

Length sizing accuracy of circumferential cracks, crack-like anomalies, and linear indications		
Accuracy at 90 % certainty	±15 mm	±0.59 in.

Table 19 – Length sizing accuracy for circumferential cracks, crack-like anomalies, and linear indications

Copyright © 2018, NDT Global, Issue # 3

2.5 Location Accuracy

Location accuracy of circumferential cracks, crack-like anomalies, and linear indications		
Axial		
Accuracy to closest reference weld at 90 % certainty	±100 mm	±3.94 in.
Circumferential		
Nominal pipe size Accuracy at 90 % certainty	≥ 508 mm ±5°	≥ 20 in. ±5°
Nominal pipe size Accuracy at 90 % certainty	< 508 mm ±10°	< 20 in. ±10°

Table 20 – Location accuracy of detectable features

2.6 Probability of Identification (POI)

Note: The indicated probabilities are estimated unless covered by the tool's performance specifications regarding detection and sizing.

Feature - Probability of Identification	**Yes** **POI > 90 %**	**No** **POI < 50 %**	**Maybe** **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		

Copyright © 2018, NDT Global, Issue # 3

Feature - Probability of Identification	Yes POI > 90 %	No POI < 50 %	Maybe 50 % ≤ POI ≤ 90 %
Buckle			x
corrosion		x	
corrosion cluster		x	
(circumferential) crack[1],[2]	x		
dent[3]			x
dent with metal loss		x	
gouging[4]			x
dent with crack			x
grinding		x	
girth weld crack (circumferential)	x		
girth weld anomaly			x
Hydrogen Induced Cracking (HIC)	x		
lamination			x
linear indications	x		
longitudinal weld crack		x	
longitudinal weld anomaly		x	
ovality		x	
pipe mill anomaly			x
pipe mill anomaly cluster			x
Stress Corrosion Cracking, circ. (SCC)	x		
spalling			x

1 Axial crack-like anomalies will be identified by Evo Series UC 1.0 and LineExplorer UC.
2 Crack anomalies are classified as “crack-like” or “crack field”.
3 Shape of dent may affect measurement capabilities.
4 Orientation of gouge within specified circumferential direction.

Copyright © 2018, NDT Global, Issue # 3

Feature - Probability of Identification	Yes POI > 90 %	No POI < 50 %	Maybe 50 % ≤ POI ≤ 90 %
spiral weld crack (parallel to weld)		x	
spiral weld anomaly		x	
wrinkle			x
Crack arrestor		x	
Eccentric pipe casing		x	
Change in wall thickness	x		
CP connection			x
External support (welded)			x
Ground anchor		x	
Offtake[1]			x
Pipeline fixture	x		
Reference magnet		x	
Repair			
welded sleeve repair[2] (Type B sleeve)			x
composite sleeve repair		x	
weld deposit			x
coating		x	
Tee	x		
Valve	x		
Weld			
bend[3]			x

1 Larger than 30 mm (1.18 in.)
2 If welded to the pipe
3 Bend radius < 5D/90°

Copyright © 2018, NDT Global, Issue # 3

Feature - Probability of Identification	Yes POI > 90 %	No POI < 50 %	Maybe 50 % ≤ POI ≤ 90 %
diameter change		x	
wall thickness change (pipe/pipe connection)	x		
adjacent tapering	x		
longitudinal weld[1]		x	
spiral weld			x
not identifiable seam			x
seamless			x

Table 21 – Probability of identification for different installations and feature types

2.7 Constraints and Definitions

2.7.1 Validity

The performance specification is valid for intelligent in-line inspections (ILI) with essential variables, as defined in API 1163, 2nd ed., within specified limitations in straight and clean pipe. Individual application range for each essential variable (e.g. speed, temperature, medium properties, tool rotation) are either defined in the individual tool data sheets or this section. Constraints for seamless and spirally welded pipes are shown below.

[1] (D)SAW; if ERW weld is trimmed, detectable only if there are marks.

Copyright © 2018, NDT Global, Issue # 3

2.7.2 Circumferential Orientation of Feature

The specified maximum misalignment of a feature from circumferential direction is limited to $\alpha < \pm 10°$. Figure 16 depicts a general schematic drawing.

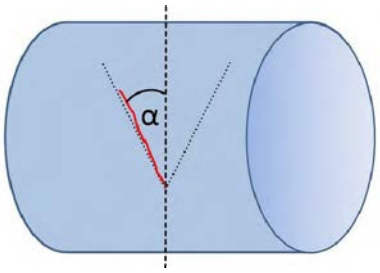


Figure 16 – Schematic drawing of crack in spool with definition of angle α

2.7.3 Radial Orientation of Feature

The specified maximum misalignment of feature orientation from radial direction for detection is defined as $\beta < 45°$. Figure 17 depicts a general schematic drawing.

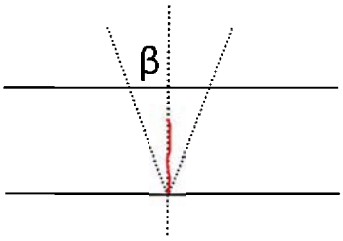


Figure 17 – Schematic drawing of cross section with crack and definition of angle β

2.7.4 Surface Connection & Mid-wall Flaws[1]

The specified maximum gap between feature tip and internal/external pipe surface for detection is limited to 2 mm (0.08 in.). Figure 18 depicts a general schematic drawing.

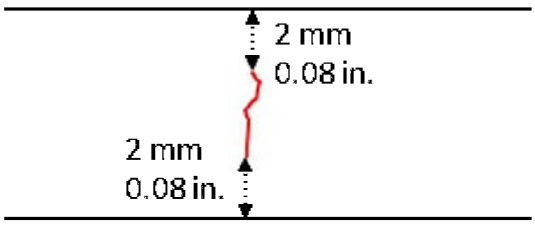


Figure 18 – Schematic drawing of mid-wall feature

[1] Depth sizing accuracy might be reduced for not surface connected anomalies

Copyright © 2018, NDT Global, Issue # 3

2.7.5 Length

The length of a crack or crack field is defined as the maximum interlinking circumferential length of crack(s) with a minimum depth of 1 mm (0.04 in.).

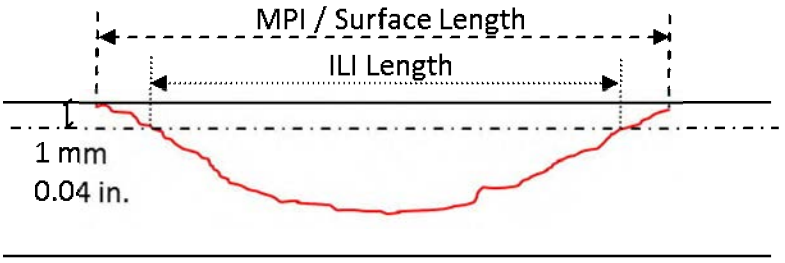


Figure 19 – Schematic cross section drawing of crack anomaly with magnetic particle/surface indication and ILI reporting length

2.7.6 Wall Position

Based on the time of flight of the reflection anomalies are identified as internal, external or mid-wall.

2.7.7 Seamless Pipe

Seamless pipes often show strong wall thickness variation of > ±10 % of nominal wall thickness.
These variations might influence performance specification or reporting threshold.
Pipe manufacturing tolerances may exceed reporting thresholds.

Copyright © 2018, NDT Global, Issue # 3

2.7.8 Longitudinal/Spiral Weld Location

NDT Global discriminates up to 3 different locations for anomalies per spool, as shown in Figure 20.

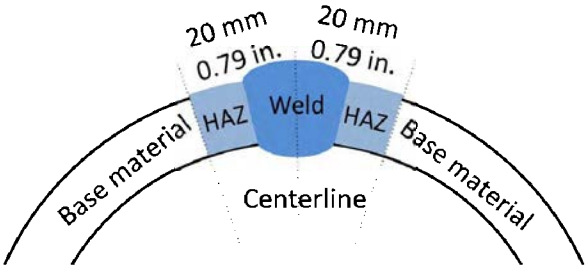


Figure 20 – Schematic cross-sectional drawing of longitudinal seam and HAZ zone

2.7.8.1 In Weld

The "In Weld" area, is the melted welding zone, e.g. with filler material and will often have additional material and overall thickness when compared to the base material of the spool.

2.7.8.2 Heat Affected Zone (HAZ) or At Weld

The Heat Affected Zone is defined as the area affected by the welding process, typically 20 mm (0.79 in.) from centerline of weld in both directions.

2.7.8.3 Base Material

The base material is unaffected by the welding process of spool.

2.7.9 Girth Weld Location

An area upstream and downstream of the girth weld of ±50 mm (1.97 in.) from the centerline of the weld may reduce performance specification due to the welding process and ILI tool sensor lift-off.

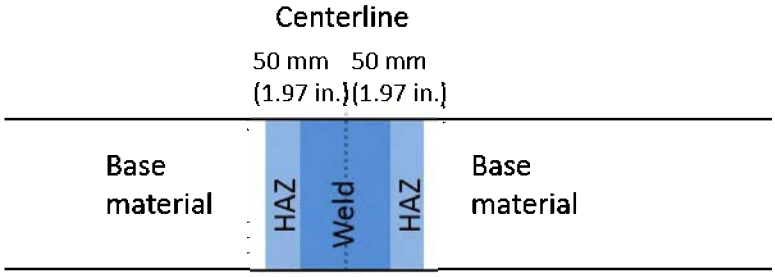


Figure 21 – Schematic drawing of girth weld, HAZ and affected area due to lift-off

2.7.10 Bends and Deformations

The performance specification may be reduced in bends (field bends, miter bends, factory bends), dents, and other deformations.

2.7.11 Speed Excursions

The ILI tool speed is one essential variable (API 1163). Speed excursions are defined as ILI data recorded in areas above predefined maximum tool velocity. The performance specification may be reduced.
A detailed probability of detection values, minimum feature dimensions and sizing accuracies within areas of speed excursions are available upon request.

2.7.12 Medium Properties

The medium properties are essential variables (API 1163) for ultrasonic inspections. Variation of medium properties from those expected may affect the quality of data. Properties of the medium are defined in corresponding tool data sheet. The speed of sound for standard inspections should be within 1100 m/s (2460 mph) to 1500 m/s (3355 mph). Other media/values require pre-run investigation.

2.7.13 Reported Anomaly Depth

Extra material e.g. in welds is not considered for depth calculation and reporting.

Copyright © 2018, NDT Global, Issue # 3

2.7.14 Reporting of Circumferential Location

Specified accuracies for circumferential position of features are not applicable in riser or other vertical sections of line.

2.7.15 Reference Wall Thickness

The reference wall thickness is defined as wall thickness in sound pipe.

NDT Global reserves the right to introduce modifications and changes without prior notice.

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.

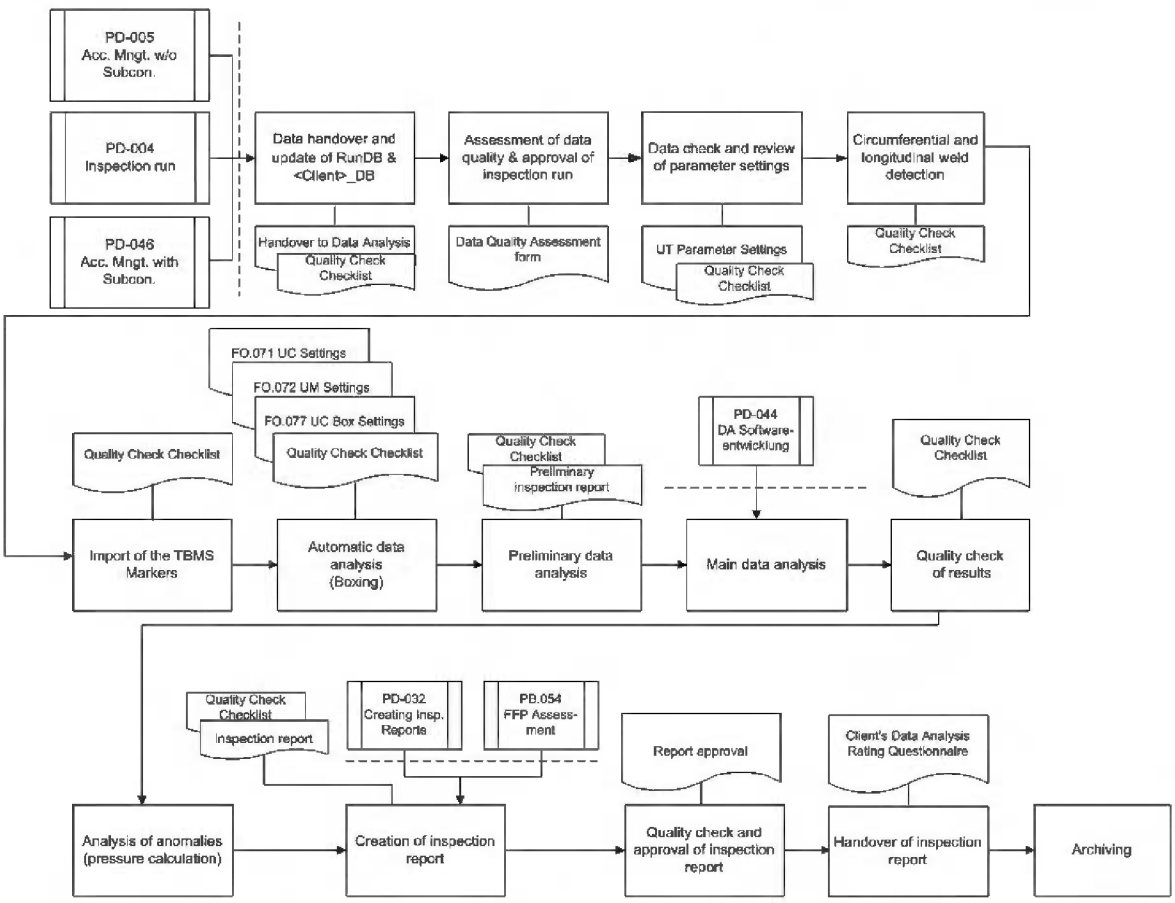


Figure 22 – Data Evaluation Procedure and Quality Management

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, listing and detailed feature descriptions.

Copyright © 2018, NDT Global, Issue # 3

4 Ultrasonic Crack 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.

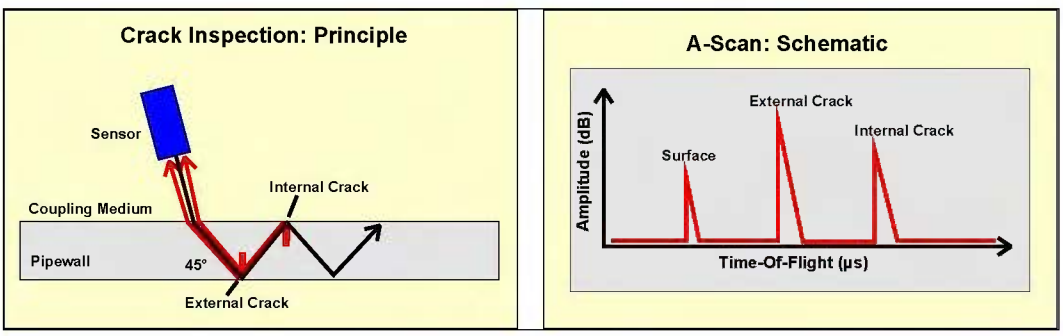


Figure 23 – Principle of ultrasonic crack inspection

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").

Copyright © 2018, NDT Global, Issue # 3

5 Glossary

Items are based on: “Specifications and requirements for in-line inspection of pipelines”, Version 2016, by POF. Items with asterisks have been supplied by NDT Global.

Term	Definition
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.

Copyright © 2018, NDT Global, Issue # 3

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.
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.
Grinding*	A special type of a manufacturing-related feature which emerges when different wall thicknesses are manually levelled by hand filing or power disk grinding. In the NDT Data Analysis in general, the term “grinding” is used for such features located at a girth weld. In most cases, grindings are applied to the complete circumference of the girth weld (see also “manufacturing-related”).
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	Comment in the Spreadsheets when several anomalies are believed to be separated by base material into different anomaly components (not one solid area of metal loss or lamination).

Copyright © 2018, NDT Global, Issue # 3

Lamination	Imperfection or discontinuity with a layered separation that may extend parallel or angular to the pipe wall surface.
Main spot*	The deepest point of a feature will be represented by a separate, smaller feature box. Such a “main spot” defines one or more distinctive and/or deep parts in corrosion areas. The size of the main spot depends on the local profile of the metal loss in the deep areas. Main spots are entered into the result lists but not considered in the statistics or pressure-based assessments.
Manufacturing-related* (man.-rel.)	Features that have indications similar to metal loss and are not related to the corrosion process. Manufacturing-related features may occur in every part of a pipe joint (girth weld and base material). In most cases, they do not extend over the entire circumference of the girth weld (see also “grinding”).
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.
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.
Nominal wall thickness	The wall thickness required by the specification for the manufacture of the pipe.
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.

Copyright © 2018, NDT Global, Issue # 3

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	Comment in the Spreadsheets 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.
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.
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).

Table 22 – Glossary

Copyright © 2018, NDT Global, Issue # 3

6 Abbreviations

Items are based on: “Specifications and requirements for in-line inspection of pipelines”, Version 2016, by POF.

Abbreviation	Definition
AGM	Above Ground Marker
EA	Effective Area
DGS	Ultrasonic echo comparison method based on Distance, Gain, Size
DOC	Depth of Cover
DOP	Dilution of Precision due to satellite geometry
DSAW	Double Submerged Arc Welding
EC	Eddy Current
EE	Entry Echo
EMAT	Electro-Magnetic Acoustic Transducer
ERF	Estimated Repair Factor
ERW	Electric Resistance Welded
GIS	Geographic Information System
GPS	Global Positioning System
HIC	Hydrogen Induced Cracking
ILI	In-Line Inspection
IMU	Inertial Measurement Unit
INS	Inertial Navigation System
MAOP	Maximum Allowable Operating Pressure
Man.-rel.	Manufacturing-related
MFL	Magnetic Flux Leakage
MOP	Maximum Operating Pressure
MPI	Magnetic Particle Inspection
NPS	Nominal Pipe Size
OD	Outer Diameter
PI	Points of Inflection

Copyright © 2018, NDT Global, Issue # 3

POD	Probability of Detection
POI	Probability of Identification
RPR	Rupture Pressure Ratio
RWE	Rear Wall Echo
SAW	Sub-merged Arc Welding
SCC	Stress Corrosion Cracking
SMLS	Seamless
SMYS	Specified Minimum Yield Strength for the pipe steel
TOFD	Time-of-Flight Diffraction method
UT	Ultrasonic Technology (or Ultrasonic Testing)
UTM	Universal Transverse Mercator
WT	Wall Thickness

Table 23 – Abbreviations

Copyright © 2018, NDT Global, Issue # 3

7 ILI PQ Certifications

7.1 Tool Operator

The Tool Operator has been certified according to the ILI PQ Personnel Qualification standard.

INSPECTION INTELLIGENCE NDT GLOBAL

This is to certify that

Evan Irvine

has successfully completed the certification requirements according to the NDT Written Practice for Training and Qualification, in compliance with ANSI/ASNT ILI PQ-2010, and is hereby qualified as

LEVEL III Tool Operator

for Ultrasonic Compression and Shear Wave Technology

Date of issue: April 27th, 2018
Valid until: April 26th, 2021

Stutensee, April 27th, 2018

Stephen Gaida
CEO Canada

Florian Schmalenberg
Maintenance & Support Manager

ENBDNR0005631

7.2 Data Analysis Project Leader

The Data Analysis Project Leader has been certified according to the ILI PQ Personnel Qualification standard and has provided the final review of the analysis of the inspection.

INSPECTION INTELLIGENCE NDT GLOBAL

This is to certify that

Achim Notheisen

has successfully completed the certification requirements according to the NDT Written Practice for Training and Qualification, in compliance with ANSI/ASNT ILI PQ-2010, and is hereby qualified as

LEVEL III Data Analyst

for Ultrasonic Shear Wave Technology

Date of issue: April 13th, 2018
Valid until: April 12th, 2021

Stutensee, April 13th, 2018

Garrett Fitzsimons
Vice President Data Services

Rogelio Jesus Guajardo Rodriguez
Global Manager Data Analysis UC

ENBDNR0005633

7.3 Global Manager Data Analysis

The Global Manager Data Analysis has been certified according to the ILI PQ Personnel Qualification standard and has reviewed and approved this report.

INSPECTION INTELLIGENCE NDT GLOBAL

This is to certify that

Rogelio Jesus Guajardo Rodriguez

has successfully completed the certification requirements according to the NDT Written Practice for Training and Qualification, in compliance with ANSI/ASNT ILI PQ-2010, and is hereby qualified as

LEVEL III Data Analyst

for Ultrasonic Shear Wave Technology

Date of issue: May 28th, 2018
Valid until: May 27th, 2021

Stutensee, May 28th, 2018

Garrett Fitzsimons
Vice President Data Services

Chris MacNulty
Head of Talent Development

ENBDNR0005635