BAKER HUGHES a GE company

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Effective Date: 12 Apr 2019

Geometry In-Line Inspection Final Report

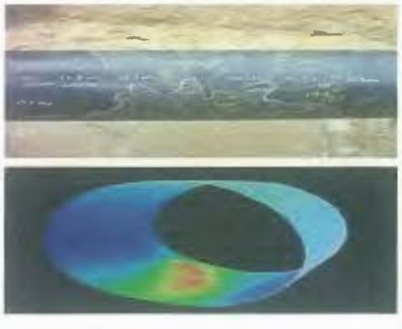
Submitted to:

Client Name	Enbridge Energy, Limited Partnership,
Pipeline Name:	NPS20 Line5 North Straits EAST to Mackinaw
PPS Job #:	451356 20A
GEOPIG™ Geometry In-Line Inspection Type:	High Resolution GEOPIG™/ IMU
Run Date:	Start Date: 2/19/2019 End Date: 2/19/2019
Pull Date:	2/19/2019
Report Date:	4/20/2019

Signature Block	Name	Date	Initial
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*As per ILI PQ-2005 (2010)

Issue Number	Release Date	Issue Date	Description of Changes
451356 20A- Issue 1	4/20/2019	4/20/2019	Initial Issue





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ENBDNR0005735

1.0 Executive Summary

Baker Hughes, a GE Company (BHGE) Pipeline Inspection has successfully completed an Inertial Geometry survey of Enbridge Energy, Limited Partnership, NPS20 Line5 Oil pipeline from North Straits EAST to Mackinaw on 2/19/2019, 4.13mi. The purpose of the inspection was to determine pipeline geometry, which includes plan, profile, weld tally and pipe wall deformations.

The analysis of the caliper data has identified 19 dents greater than 0.5% O.D. and no ovalities greater than 5% O.D in the line. There are no outward wrinkles over 2% O.D. in the line. The largest dent is 0.76in (3.8% O.D.) and located at absolute chainage 8,820.94ft. The anomaly listing is included in Appendix 6.

2 internal diameter restrictions, where the I.D. was less than 90% O.D., were identified during the caliper analysis. The largest internal diameter restriction reached 17.54in (87.7% O.D.) and was located at absolute change 8,821.01ft at dent with heavy wall. The internal diameter restriction listing is included in Appendix 8.

The analysis of the inertial data has identified 20 bends with an angle larger than 1.5 and a radius of curvature less than 100D. No bends are tighter than or equal to 5D. All bends are listed in Appendix 9.

The line was analyzed for pipeline movements between the current inspection and 2003 GEOPIG™ Inspection. The reporting threshold is to report pipeline movements with differential bending strain exceeding 0.1% and spanning over more than one joint. No areas of pipeline movement, except the launcher and receiver replacements, were found meeting the reporting threshold within this line. All areas of bending strain are listed in Appendix 12 and illustrated in plots in Appendix 13.

Enbridge provided updated GPS coordinates in 2016 for 2 locations along the entire line, consisting of the launch and receive valves. Since the 2005 and 2013 GEOPIG™ inspections, both the launch and receive areas of the pipeline have been replaced. This information was integrated with the pipe centerline coordinates obtained from the inertial survey, providing a means for locating pipeline anomalies and a foundation for a Geographic Information System (GIS). A listing of the UTM coordinates based on the NAD83 datum appears in Appendix 4.

One copy of the survey data and the BHGE software for viewing it are stored on the enclosed USB. The complete pipeline tally including girth welds, pipe fittings, wall thickness transitions, bends and anomalies can be displayed in BHGE's software together with the caliper and inertial data. This information is also available in the BHGE 2019 GEOPIG Survey NPS20 Line 5 North Straits EAST - Mackinaw Issue 1.xls file, which is located in the directory "*\BHGE\NPS20_Line5_North_Straits_EAST_Mackinaw*" on the USB.

A copy of Enbridge ILI Minimum Reporting Requirements Guide 8.2 is included in Appendix 16.

2.0 Inspection Summary

2.1 Operational Details

BHGE Pipeline Inspection has mobilized equipment and a qualified crew to perform in-line inspections of the following system:

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BHGE Job Number	451356 20A Issue1
Pipeline Operator	Enbridge Energy, Limited Partnership,
Segment Name	NPS20 Line5 North Straits East - Mackinaw
Launch Site	Ignace, Michigan
Receive Site	Mackinaw City, Michigan
Pipeline Nominal Diameter	20"
Product	Oil
Section Length	4.13mi
Date of GEOPIG Inspection	February 19, 2019
Duration of GEOPIG Inspection	47 minutes
Field Project Manager	Jeff Lee

Table 1. Operational Details

Pre-launch inspections procedures to the GEOPIG™ were performed at the BHGE (Location) office. After passing all of the BHGE pre-run inspection procedures, the tool was launched at 09:34 EDT on 2/19/2019. The tool entered the receive site at 10:21 EDT the same day. The tool was received clean with no apparent damage. The data was downloaded off-site and later analyzed. 100% valid caliper, IMU and odometer data was collected during the run.

2.2 Reporting threshold

The reporting criteria are to report

- Dents greater than or equal to 0.5% of nominal O.D. of the pipeline;
- Outward wrinkles greater than or equal to 2% O.D.
- Ovalities greater than or equal to 5% O.D.
- Areas of pipeline movement with bending strain difference exceeding 0.1% and spanning more than 1 pipe joint.

The anomaly size definition varies by feature type and is provided in Section 2.3. Details of the reporting specifications and features definition can be found in Enbridge's Inline Inspection Reporting Profile standard Version 8.2 included in Appendix 16.

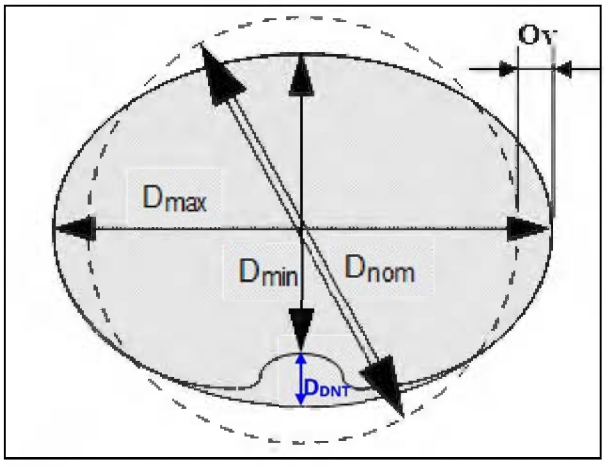
2.3 Pipewall Anomaly Calculation

The caliper information is processed to provide the internal shape and diameter of the pipeline. The anomaly size D (depth) is calculated as follows:

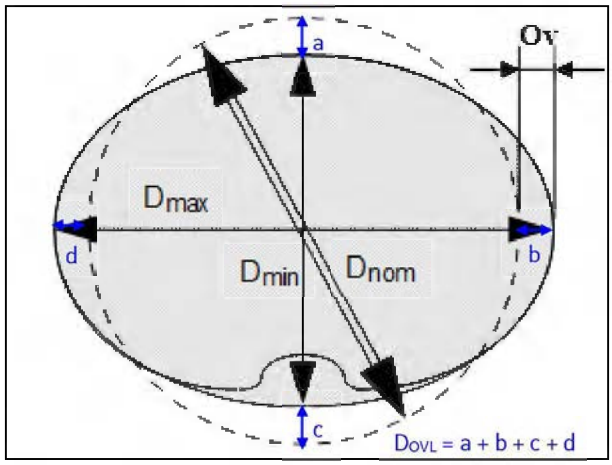
For dents: $\mathbf{D_{DNT} = D_{Rstr} - 2*O_V}$ without ovality $D_{Rstr} = D_{Nom} - D_{Min}$

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$$O_V = (D_{Max} - D_{Nom})/2$$



For Ovality: $D_{OVL} = D_{Max} - D_{Min}$ CSA Z662



where:

D_{Rstr} - total diameter restriction
O_V - pipe ovality
D_{Nom} - inner nominal pipe diameter
D_{Min} - inner pipe diameter at the feature
D_{Max} - inner pipe diameter 90° from the feature

The dent length and width are calculated as the axial distance and the circumferential distance between points of zero radial deflection respectively. The ovality length and width are calculated as the axial distance and the circumferential distance over which the feature depth exceeds 50% of its peak value respectively. A dent with the width larger than its length is called an inward wrinkle. The outward wrinkle is characterized by a local increase of pipe diameter.

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3.0 Survey Results

The inertial survey provides pipeline plan, profile and bending strain, allowing one to locate the pipeline in the GPS mapping projection, and to detect pipeline movement between runs. The positional information is derived from the onboard strapdown inertial unit, the odometer readings and the GPS coordinates of selected tie points obtained from a GPS survey.

The caliper survey provides the information on the internal diameter and shape of the pipe, allowing for detection and measurement of pipe wall anomalies (dents, ovalities and wrinkles), wall thickness changes, valves, tees and girth welds.

3.1 Chainage

The chainage is the distance measured by the tool's odometers along the pipeline and is denoted as SCh (slack chainage) on the plots. It starts from 19.07ft at the pig launch trap and ends at 21,783.27ft in the receive trap. The horizontal chainage is also available, and it represents the true horizontal distance of the surveyed pipeline.

The tool's chainage was correlated with Enbridge Energy, Limited Partnership,'s chainage by matching these chainages at wall thickness transitions. The list of tie points that were used appears in Appendix 5.

3.2 GPS Tie Points

Enbridge provided updated GPS coordinates in 2016 for 2 locations along the entire line, consisting of the launch and receive valves. Since the 2005 and 2013 GEOPIG™ inspections, both the launch and receive areas of the pipeline have been replaced. This information was integrated with the pipe centerline coordinates obtained from the inertial survey, providing a means for locating pipeline anomalies and a foundation for a Geographic Information System (GIS). A listing of the UTM coordinates based on the NAD83 datum appears in Appendix 4.

3.3 Pipe Anomalies

The caliper data was used for detecting and sizing diameter restrictions and pipe wall anomalies, such as ovalities, dents and wrinkles. The anomaly size definition is provided in Section 5.4.

The analysis of the caliper data has identified 19 dents greater than 0.5% O.D. and no ovalities greater than 5% O.D in the line. There are no outward wrinkles over 2% O.D. in the line. The largest dent is 0.76in (3.8% O.D.) and located at absolute chainage 8,820.94ft. The anomaly listing is included in Appendix 6.

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Deformations		Dents				Ovalities	Inward Wrinkles	Outward Wrinkles
		All	≥ 6%	Top of Pipe	On GWD			
Total Number		19	0	17	0	0	0	0
Largest	Size (%OD)	3.78		3.78				
	Absolute Distance (m)	8,820.94		8,820.94				

Geometry Feature Severity

Feature Type	Top	Bottom	Max Depth %	
Geometry Feature depth d ≥5%	0	0		
Geometry Feature associated with stress risers or welds	0	0		

Wrinkle/Buckle Severity

Feature Type	Top	Bottom	Max Depth %
Wrinkles/Buckles	0	0	
Wrinkles/Buckles across seam welds or girth welds	0	0	

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The following plots show the distribution and orientation of dents along the pipeline.

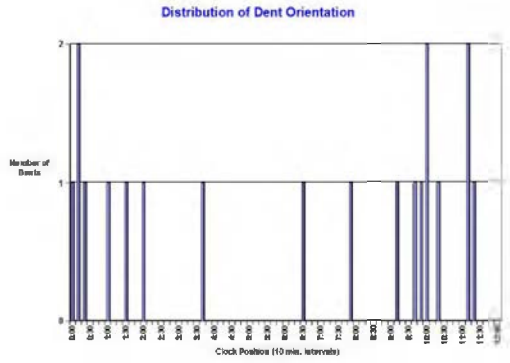


Figure 1.

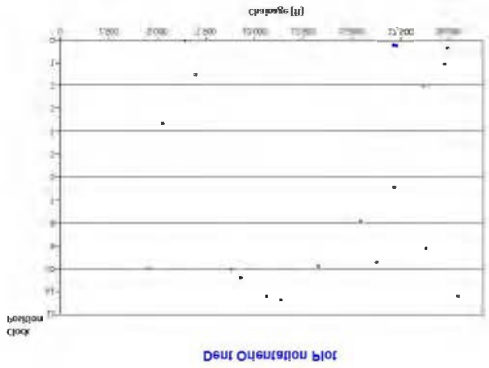


Figure 2.

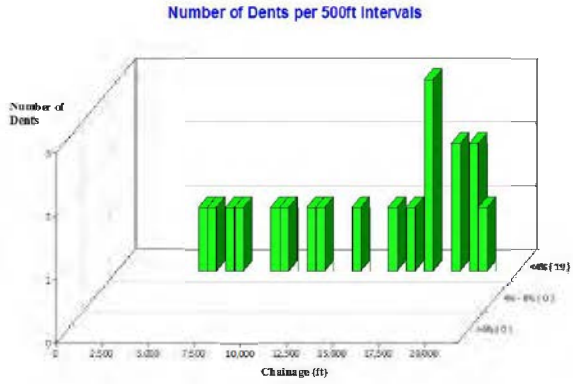


Figure 3.

Appendix 7 contains inspection sheets for the largest dent. There are three inspection sheets per anomaly: a dig sheet showing the position of the feature in a pipe joint together with the adjacent joints, a plot of pipeline

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plan and profile between the nearest u/s and d/s reference points, and a plot showing 3 views of the anomaly: 3-D view, pipe cross-section and diameter profile. The 3-D view scale is exaggerated 3 times. The pipe diameter profile consists of 25 lines showing the pipe internal diameter at different clock positions measured by the 25 pairs of opposing caliper arms. The clock positions of these caliper arms are color coded according to the spectrum displayed on the left side of the plot.

6 internal diameter restrictions, where the I.D. was less than 92% O.D., were identified during the caliper analysis. The largest internal diameter restriction reached 356mm (87.6% O.D.) and was located at absolute chainage 37,136.20m at tee with heavy wall and ovality. The internal diameter restriction listing is included in Appendix 8.

3.4 Bends

The analysis of the inertial data has identified 20 bends with an angle larger than 1.5 and a radius of curvature less than 100D. No bends are tighter than or equal to 5D. All bends are listed in Appendix 9.

3.5 Pipeline Movement

The line was analyzed for pipeline movements between the current inspection and 2003 GEOPIG™ Inspection. The reporting threshold is to report pipeline movements with differential bending strain exceeding 0.1% and spanning over more than one joint. No areas of pipeline movement, except the launcher and receiver replacements, were found meeting the reporting threshold within this line. All areas of bending strain are listed in Appendix 12 and illustrated in plots in Appendix 13.

Pipe Movement

Feature Type	No. of Features	Vertical Movement (ft)	Horizontal Movement (ft)	GW	Distance (ft)	Comments
Pipe Movement	2	N/A	N/A	N/A	N/A	Launch and receive areas replaced since 2005
Largest Movement (excluding replacements & re-routes)	N/A	N/A	N/A	N/A	N/A	N/A
	N/A	N/A	N/A	N/A	N/A	N/A

Strain Severity

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Feature Type	No. of Features	Largest Peak Strain Vertical %	Largest Peak Strain Horizontal %	Largest Peak Strain Total%	GW	Distance (m)	Comments
Strain	2	N/A	N/A	N/A	N/A	N/A	Launch and receive areas replaced since 2005
Largest Bending Strain	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	N/A	N/A	N/A	N/A	N/A	N/A	N/A

3.6 Pipe Tally

The pipe internal diameter measured by the calipers is used for calculation of pipe wall thickness assuming a constant pipe O.D. The wall thickness transitions were correlated with the listing supplied by Enbridge Energy, Limited Partnership,, and is attached in Appendix 10. The list of valves and fittings are included in Appendix 11.

The GEOPIG™ has also detected all the girth welds in the pipeline. They are listed in the worksheet "Weld Log", which contains the information on the length and start chainage of each pipe joint. The weld log combined with all the other features in the pipeline (valves, tees, wall thickness transitions, anomalies and bends) are listed in the worksheet "Pipe Tally". A one-page sample of the pipe tally listing is included in Appendix 14.

All the listings included in Appendices 4 to 12 as well as the full pipe tally are available in electronic form in the MS Excel spreadsheet "BHGE GEOPIG Survey 2019 NPS20 Line5 North Straits EAST to Mackinaw Issue 1.xls".

3.7 Plan and Profile

The first plot in Appendix 15 shows the plan, profile, pig velocity, internal diameter, and valves of the entire pipeline. The remaining 6 plots show the pipeline plan, profile, internal diameter and location of selected features, such as valves, AGM locations, anomalies, and wall thickness transitions at 4,000ft per page.

4.0 BHGE Software Installation

The report is accompanied by a USB containing the BHGE display software and the data from the present survey. The data can be viewed using the GEMINIView™ and GeoDisplay programs running in Microsoft Windows operating system. GEMINIView™ is used to display the 3-D view of the pipe and the inner pipe wall shape measured by the calipers. GeoDisplay is used for displaying the inertial, odometer, weld, caliper and other databases (if available).

The directory structure on the USB is as follows:

\BHGE\NPS20_Line5_North Straits EAST to Mackinaw\2019_GEOPIG, which contains:

- Several subdirectories with the data from the run

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- Environment file:BHGE_2019_GEOPIG_NPS20_Line5_North Straits EAST to Mackinaw_Issue1.env with the information on the location of the data files from the run. (%RootDir% specifies the path, and %BaseName% - the name)

\BHGE\BHGE_Software	with the software stored on two subdirectories:
\GEMINIView	with the GEMINIView program (GEMINIVIEW.EXE)
\GD	with the GeoDisplay program (GDPR.EXE)

The entire content of the USB can be copied to a network drive, or a local hard drive for faster access of the data and the ability to save configuration files with customized displays. The programs can also be stored on the local hard drive while the data is accessed from the USB or a network drive. In this case, only the *\BHGE_Software* subdirectory needs to be copied on the local hard drive.

4.1 GEMINIView

To setup the GEMINIView™ program for the first time on a computer:

- Run the setup.exe program in the *BHGE\BHGE_Software\GEMINIView directory*

To launch the GEMINIView™ program:

- Double click on *GEMINIView_3.21.0.0.exe*

Jobs can then be loaded using the *File -> Open* menu

4.2 GeoDisplay

The simplest way to launch GeoDisplay from the USB is to double click on the application program (GDPR.EXE) using Windows Explorer.

The recommended way to launch GeoDisplay is to copy the "Geodisplay-NPS20_Line5_ North Straits EAST to Mackinaw_Issue1" icon onto the computer desktop using the procedure outlined below. It is assumed that the subdirectory *\BHGE\BHGE_Software* is stored on the C: drive, and the data directory, \BHGE\NPS20_Line5_North Straits EAST to Mackinaw is on the *D:* drive. However, the proper drive letters for the USB, network or hard drive corresponding to the actual location of those directories have to be used.

1. Go to the directory *C:\BHGE\BHGE_Software\GD* using windows explorer and drag the shortcut icon "Geodisplay NPS20_Line5_North Straits EAST to Mackinaw"to the desktop.

2. Right click on this new icon and left click on *Properties.*

3. Click on the *Shortcut* tab and make sure the "Target" and "Start in" are set to *C:\BHGE\BHGE_Software|GD\GDPR.exe* and *D:\BHGE\NPS20_Line5_North Straits EAST to Mackinaw* respectively.

4. Click on the *General* tab and uncheck the "Read-only" box.

5. To start the program, double click on the icon.

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