GE
Oil & Gas
PII Pipeline Solutions

CaliPPer™ Inspection Report
for 20 inch Crude Oil Pipeline



Enbridge Energy Limited Partnership

2008 Line 5: Straits of Mackinac-East Leg
Run Date: May 9, 2008

109170_20B
Issue 1, July 2008
Part 1 of 1

imagination at work

July 18, 2008

Enbridge Energy Limited Partnership
Attention: Ms. Martha Vega-Smith
10201 Jasper Avenue
Edmonton, AB
T5J 3N7

RE: FINAL REPORT OF ENBRIDGE ENERGY LIMITED PARTNERSHIP'S 20 INCH CRUDE OIL PIPELINE, LINE 5: STRAITS OF MACKINAC-EAST LEG, INSPECTION COMPLETED MAY 9, 2008

Dear Ms. Vega-Smith,

GE's PII Pipeline Solutions business has completed its in-line inspection of Enbridge Energy Limited Partnership's pipeline. After careful examination of information resulting from the survey, we are very pleased to present you one copy of the enclosed pipeline final report.

Thank you again for choosing GE's PII Pipeline Solutions business.

If you should have any questions or require additional information, please do not hesitate to contact the undersigned at (403) 262-7447.

Sincerely,

GE
Oil & Gas
PII Pipeline Solutions

Neil Makwana,
Pipeline Data Analyst

Kevin Sun,
Analysis Team Leader

*Enclosures, As Noted

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1. Introduction

1. Introduction

The subject of this Final Report is the CaliPPer® inline inspection

of the

20 inch Crude Oil Pipeline
Line 5: Straits of Mackinac-East Leg

on behalf of:

Enbridge Energy Limited Partnership
10201 Jasper Avenue
Edmonton, AB
T5J 3N7

The CaliPPer® run 109170_20B took place on May 9, 2008. The Field Technologist Leader for this run was John Collis. The designated Project Manager in charge of 109170_20B is Rod Trefanenko of GE Oil & Gas PII Pipeline Solutions.

The geometry data recorded during this CaliPPer® run was analyzed by the Data Analysis Department and the results are enclosed in the present Final Report.

Data Analyst:	Jey Gajendiran	L0 Certified
QA Checker:	Neil Makwana	L2 Certified
Report Approved by:	Kevin Sun	Analysis Team Leader

2. Description of the CaliPPer® Tool Used for this Inspection Job

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2.1 General Information about the CaliPPer® System

Dents affect the safe operation of a pipeline as they restrict the flow of the transported medium and tend to induce spot-like formations of sedimentation, turbulence, erosion, corrosion, and hydrates. The pipeline's service life is shortened further by localized excessive mechanical stress.

Geometric deviations can be located and their dimensions determined by means of the CaliPPer® pipeline inspection tool. Its use now forms an integral part in the acceptance of new pipelines and the monitoring of pipelines in operation. The CaliPPer® works during the normal operation of a pipeline and is propelled through the line by the transported medium.

Thanks to the long-standing experience and progressive improvements, the CaliPPer®'s purpose-adapted structure meets even extreme conditions for operation in pipelines. The CaliPPer® is able to pass extreme deformations (up to 25 %) and, thanks to the high sensitivity of the gauging system and the large number of sensing fingers, even the smallest dents can be detected. In order to avoid speed cycling, especially during the inspection run in gas pipelines, the polyurethane cup sleeves are designed for easy running.

For inspection of long-distance pipelines, a large data storage system has been designed for pipelines up to a length of 325 miles. A battery life of 85 and more hours also facilitates operation when the CaliPPer® tool has to wait several days either in the launcher before the start of pumping or at any position in the pipeline due to interruption of pipeline operation.

Preliminary data evaluation and listing of the defects can be made with a notebook PC immediately after the inspection run on site, thus enabling quick decisions for subsequent actions.

The data collected during the inspection run are analyzed by means of evaluation software that shows the graphical representation of the inner pipeline diameter. Normally girth welds, wall thickness changes, and installations, etc. can be seen on the chart in addition to dents and ovalities. Time pulses at 1 – second intervals indicate the speed of the CaliPPer® inside the pipeline. The marker position serves as fixed reference point for flaw detection.

2.2 Design of the CaliPPer®

The CaliPPer® is an intelligent inspection system which serves to measure diameter reductions in pipelines such as dents, ovalities, girth welds, wall thickness changes and to detect T – pieces, valves and other installations.



20" CaliPPer® tool

The **cup sleeves** fill the cross section of the pipeline and enable the CaliPPer® to be transported through the pipeline by the medium.

The **spider** measures the inner pipeline diameter at every pipeline position.
In addition to the measuring data from the spider, the distance data generated by **odometer wheels** is continuously acquired and stored together with the individual diameter values.

The **internal locator unit** transmits electromagnetic signals. This allows the CaliPPer® to be located by an external inspection tool locator.

Rate gyroscopes are used to determine the rate of change in the rotation of the tool. This data in turn is used to categorize and measure bends.

The **recording unit** stores the measured values of the spider, the odometer wheels, gyroscopes and the internal locator unit.

The **pushing table** is used to push the CaliPPer® into the launcher. Additionally, it helps to fix the calibration ring accurately and to protect the spider against mechanical damage.

Recorder unit and internal locator unit are contained in pressure-proof steel bodies.

2.3 Technical Data of the CaliPPer®

Nominal Tool Size:	20"
Total Length:	4.92 feet
Weight:	154.32 lbs
Minimum Bend Radius:	1.5D / 90°
Maximum Pipeline Pressure:	1102.94 psi
Medium Temperature Range:	32°F to 140°F
Type and Capacity of Data Storage:	solid state, 2000 MB
Number of Sensing Fingers:	18
Number of Sensing Wheels per Finger:	2
Diameter of Calibration Ring:	19.61 "
Number and Nom. Diameter of Odometer Wheels:	2 x 2.41 "
Odometer Samples per Revolution:	24
Internal Locator Unit Fitted:	Yes

2.4 Defect Detection Capabilities

20" CaliPPer® Defect Detection Capabilities

Evaluation threshold is generally 2%.

Wall Thickness Changes or **Girth Weld Roots** within round pipes	Sensitivity	0.50 %
	Accuracy	±0.20 %
Dents	Sensitivity	0.80 %
	Accuracy ID_{red} < 10%	±0.60 %
	Accuracy ID_{red} > 10%	±0.80 %
Ovalities	Sensitivity	0.80 %
	Accuracy ID_{red} < 5%	±0.60 %
	Accuracy ID_{red} 5%–10%	±1.20 %
	Accuracy ID_{red} >10%	±1.60 %
Location Accuracy	±0.66 feet related to reference girth weld or approx. ±1% related to reference point	
Tool Speed Limit	0.45 mph – 11.18 mph	

2.5 Bend Classification

Bend Radius

Radius Range	Radius Class Reported
Less than 1.5D	<1.5D *
Less than 3.0D	1.5D
Less than 5.0D	3.0D
Less than 7.0D	5.0D
Less than 10D	7.0D
Less than 13D	10.0D
Greater than 13D	Field Bend

* *Further investigation required prior to further pigging operations*

Bend Angle

The standard reporting threshold is every bend over 5 degrees. All bends are rounded to the nearest 5 degrees unless otherwise requested by the client.

3. Survey Procedures

3. Survey Procedures

3.1 Pipeline Data

Pipeline Outer Diameter:	20"
Pipe Wall Thickness:	0.81"
Recorded Pipeline Length:	4.13 miles
Pipeline Product:	Crude Oil

3.2 CaliPPer® Preparation

In the PII Pipeline Solutions business workshop, all sensing fingers were calibrated individually. A calibration of the whole measuring spider was performed. The electronic components were checked both by a system test and a functional test.

After having arrived on site, all electronic components were checked both by a system test and a recording test. A new calibration was performed and the calibration data were transferred to a notebook. A calibration curve was created accordingly.

3.3 CaliPPer® Run

The following table provides more detailed information on the run of this CaliPPer® inspection:

CaliPPer® Run Name:	109170_20B
CaliPPer® Departure:	May 9, 2008, 8:36
CaliPPer® Arrival:	May 9, 2008, 9:18
Chart Length:	1982439 samples
Amount of Recorded Data:	155 MB
Average Speed of the CaliPPer®:	5.59 mph

Before starting the survey run, the CaliPPer® was activated in front of the launcher. In this state the CaliPPer® was pushed into the launcher.

During the starting and receiving procedures the actual position of the CaliPPer® was monitored by the CaliPPer® technician using the CaliPPer® locator system.

The propelling medium used for the CaliPPer® run was Crude Oil.

3.4 CaliPPer® Handling after the Run

After initial tool clean-up, the CaliPPer® was connected to a notebook. A status check of the electronic units was performed. The status data and the collected measured data of the CaliPPer® were transferred to the notebook hard disk. The quality of the data was assessed.

3.5 Preliminary Interpretation on Site

For preliminary interpretation, the evaluation software searched for ID reductions over 5% of OD for dents and 5% of OD for ovalities.

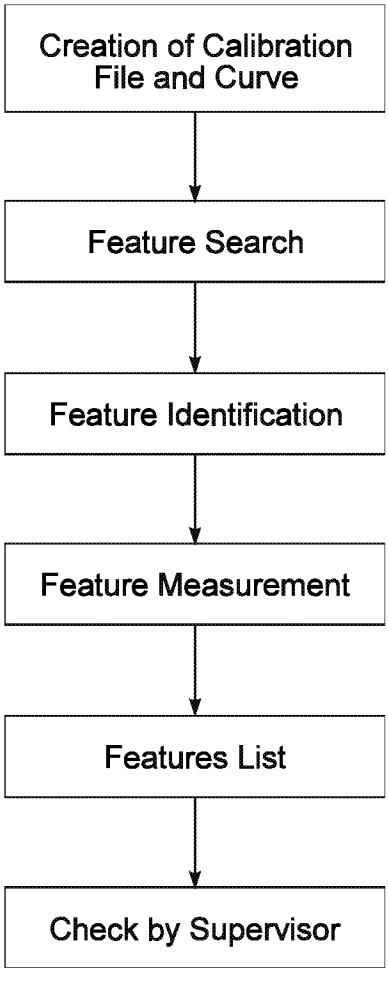
4. Evaluation of the Collected CaliPPer® Data

4. Evaluation of the Collected CaliPPer® Data

4.1 Evaluation Procedure

The CaliPPer® data collected during the inspection run were systematically evaluated in the PII Pipeline Solutions business Calgary Interpretation Department. The individual results are enclosed in the Features List. Please refer to Chapter 6 for the "Features List".

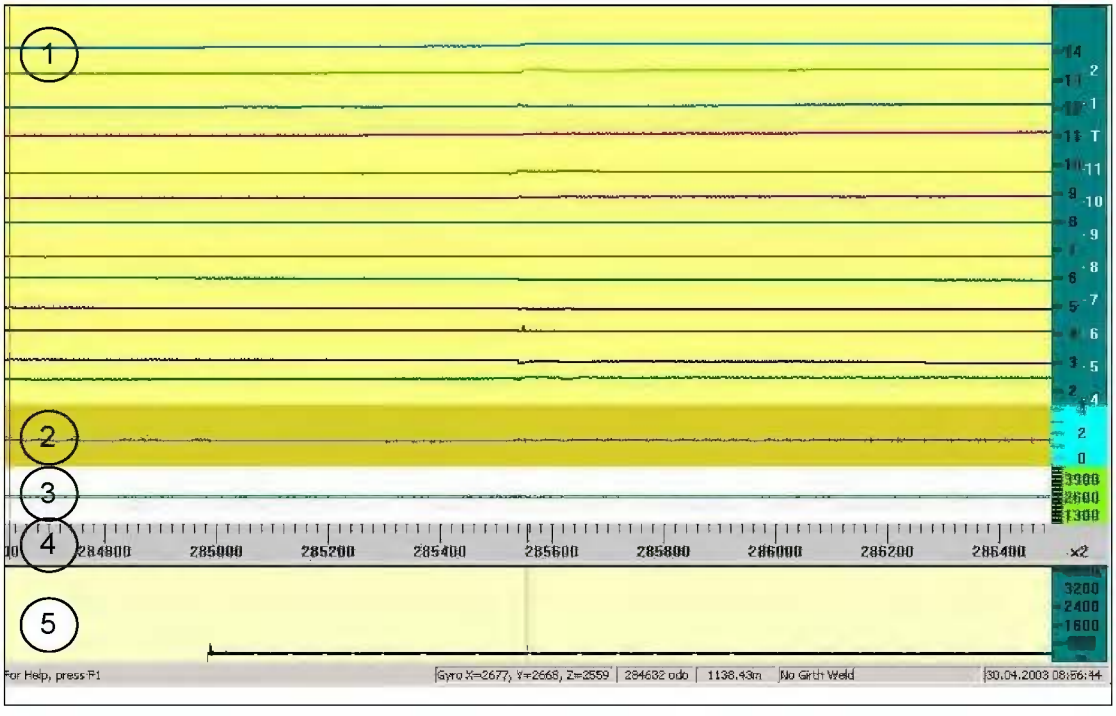
In order to achieve the required quality of the inspection results, the evaluation of the collected CaliPPer® data was performed during the following six phases:



Evaluation Procedure

4.2 Presentation of Measured Data

The CalView program is used for the graphical representation and interpretation of the collected CaliPPer® data. The following figure shows an example of CaliPPer® data representation:



Presentation of CaliPPer® Chart

(1) : Digital spider value shows the change of the inner diameter

(2) : Speed of the tool

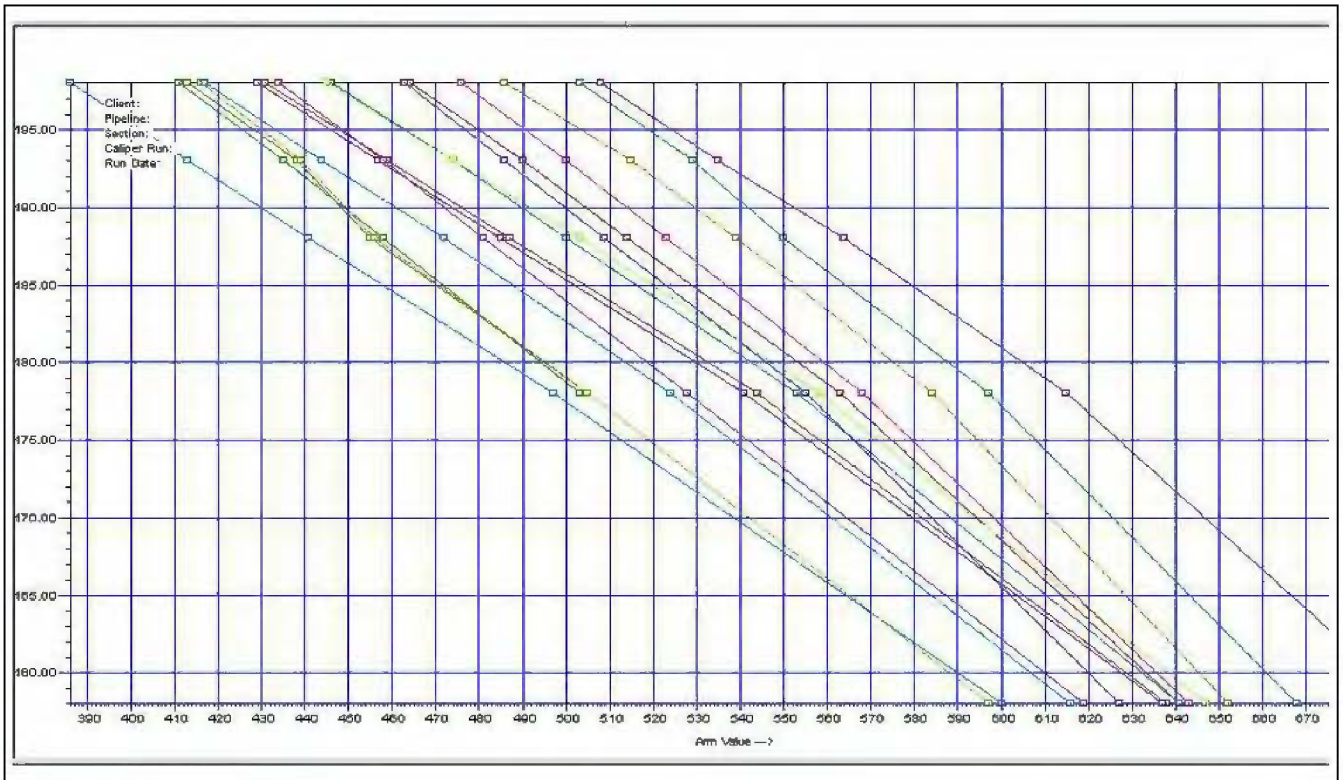
(3) : Raw gyro data

(4) : Distance ruler

(5) : Line log

4.3 Calibration and Computation of ID Reduction

The tool is calibrated by using a calibration ring and simulating deformities with small slabs of material. With the help of this calibration, the measurements of the CaliPPer® are correlated to the actual ID reductions. The following figure gives an example of a calibration.



CaliPPer® Calibration Chart

The evaluation program uses the calibration results to generate the Calibration Curve.

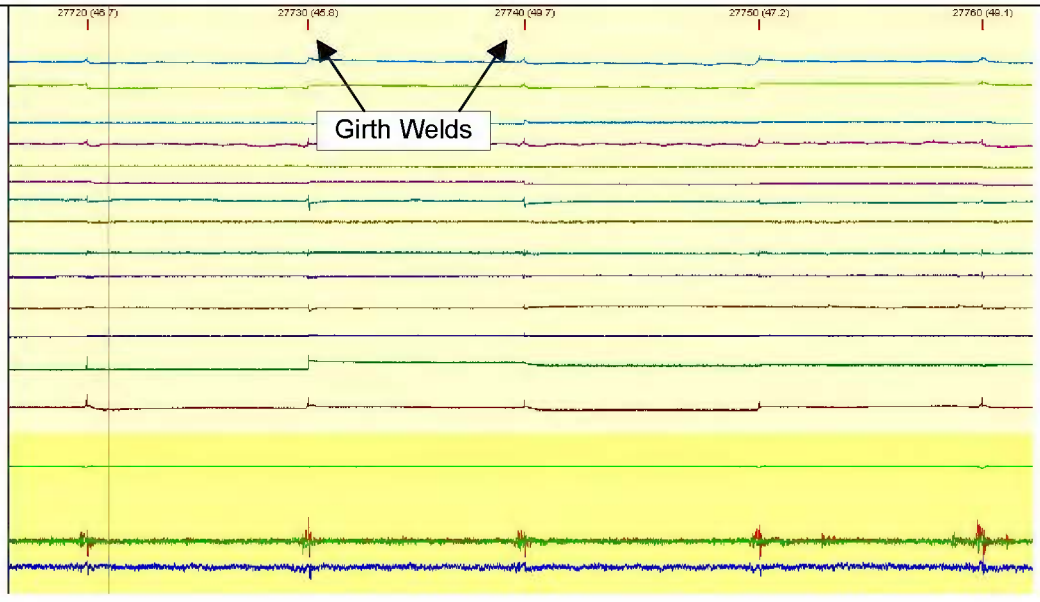
4.4 Evaluation Criteria

The criteria for features to be entered into the Features List were applied as follows:

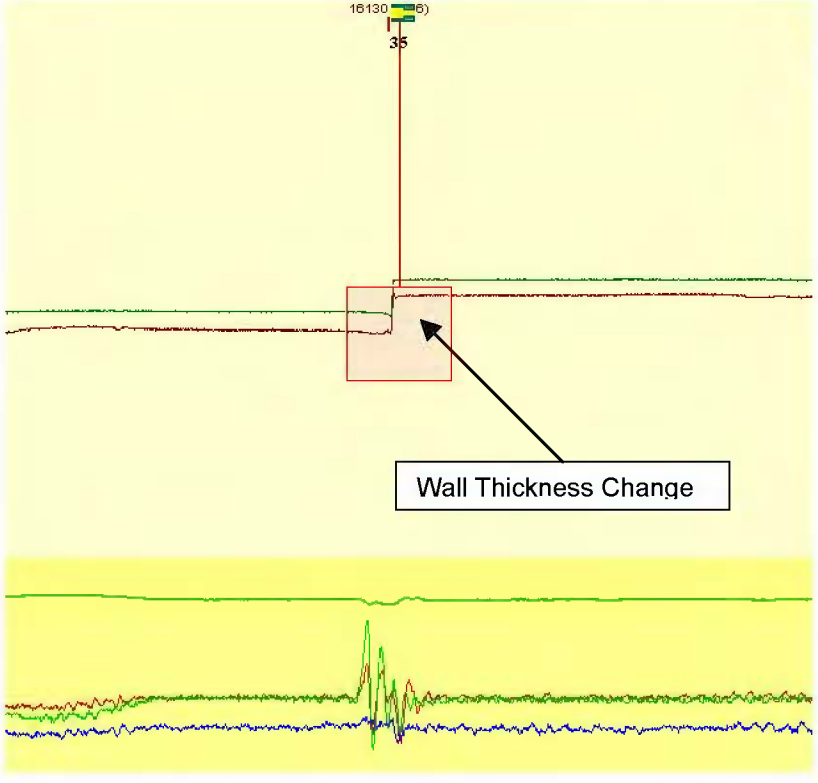
- Dent: 2% of OD
- Ovality: 5% of OD
- Girth Weld: 5% of OD
- ID Reduction: 2% of OD

4.5 Feature Identification

The following examples show typical pipe features.

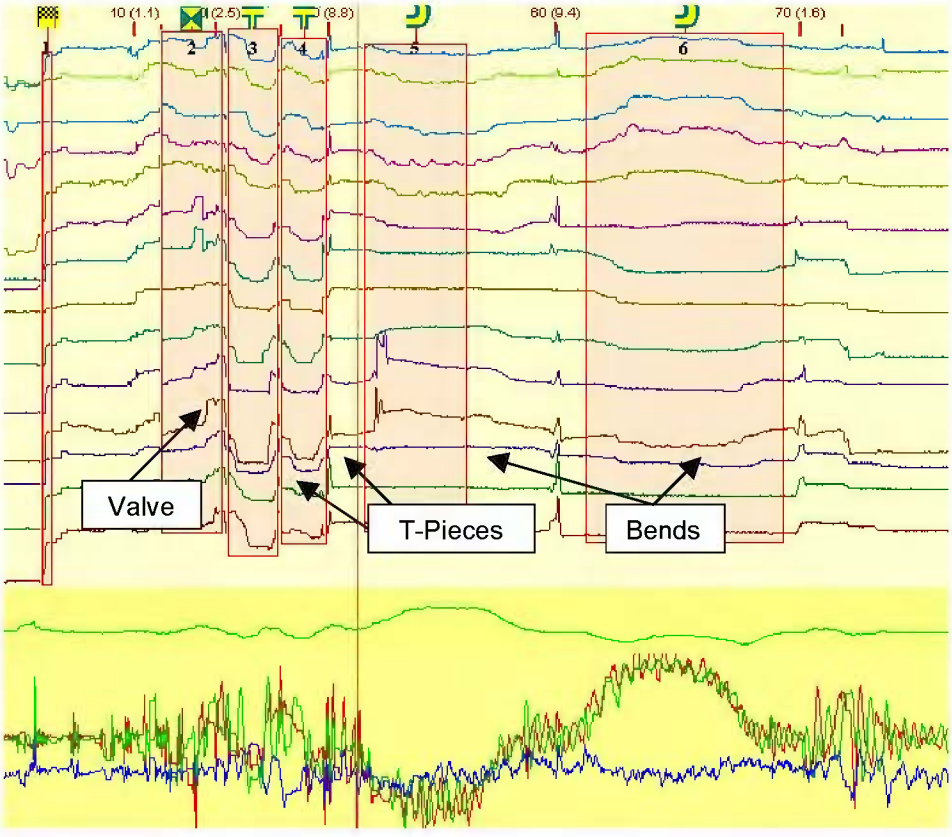


Girth Welds

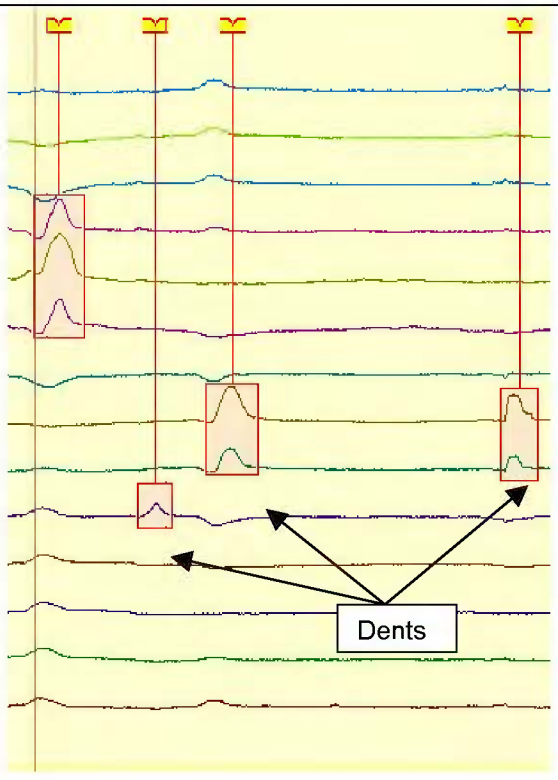


Wall Thickness Change

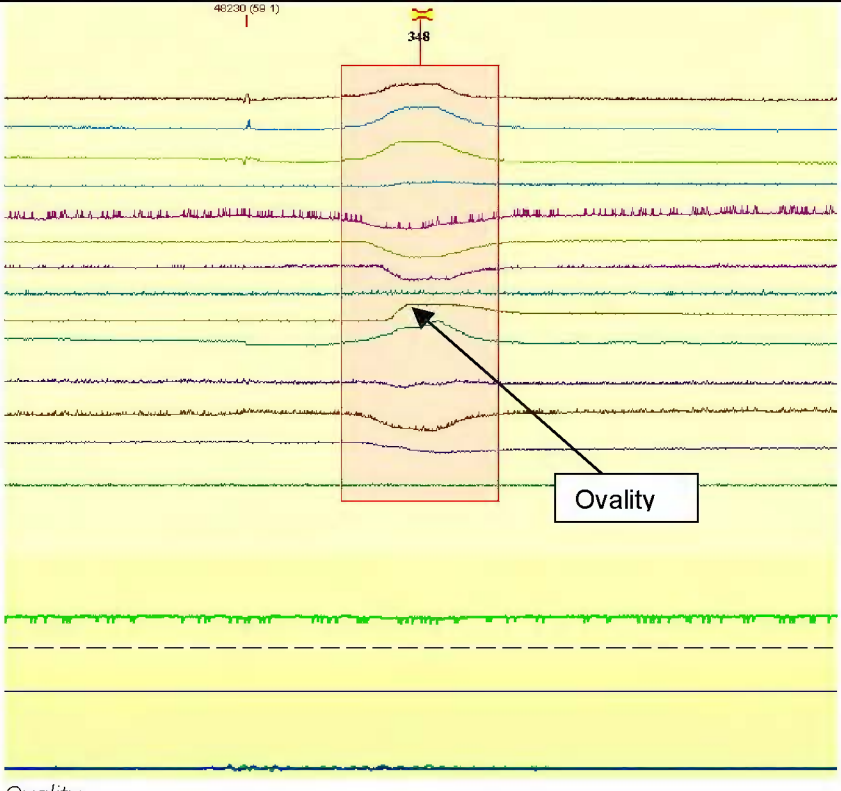
The CaliPPer tool does not have sensors to detect wall thickness of pipes. Instead, it measures the internal diameters and infers the wall thickness change by calculating the difference of internal diameters between the upstream and downstream pipes.



Valve Station

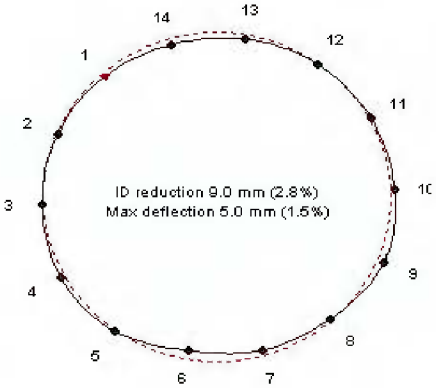


Dent



Ovality

Cross-Sectional View



Ovality is generally characterized by ID reduction on the top and bottom of the pipe, along with ID expansion on the sides. This is calculated by dividing the difference of the Maximum and Minimum Diameters by the Nominal Outer Diameter.

5. Discussion of Results

5. Discussion of Results

The CaliPPer® data recorded during this inspection clearly depict the present geometrical condition of the pipeline.

The following table gives an overview of the features detected by the CaliPPer® tool:

Feature Type	Quantity
Bend	11
Wall Thickness Change	6
Flange	2
Launcher	1
Receiver	1
T-Piece	3
Valve	2

Please note:

- All statements regarding valves and other pipeline installations are given in accordance with the results of the preliminary interpretation on site.
- When excavating a dent or ovality, the external load imposed on the pipeline will be eliminated. This allows elastic relaxation of the dent or ovality. Therefore the remaining deformation of such defects can be significantly smaller than the value measured by the CaliPPer®.
- Due to the mechanical over-reaction of the spider in the installation areas, the indications of some girth welds and sharp edges are exaggerated.
- The absolute distance depicted in the mechanical indication results and the feature listing are from the center of features to the run start. The relative distance depicted in the mechanical indication results and the feature listing are from the center of features to the upstream girth weld.

6. Feature List

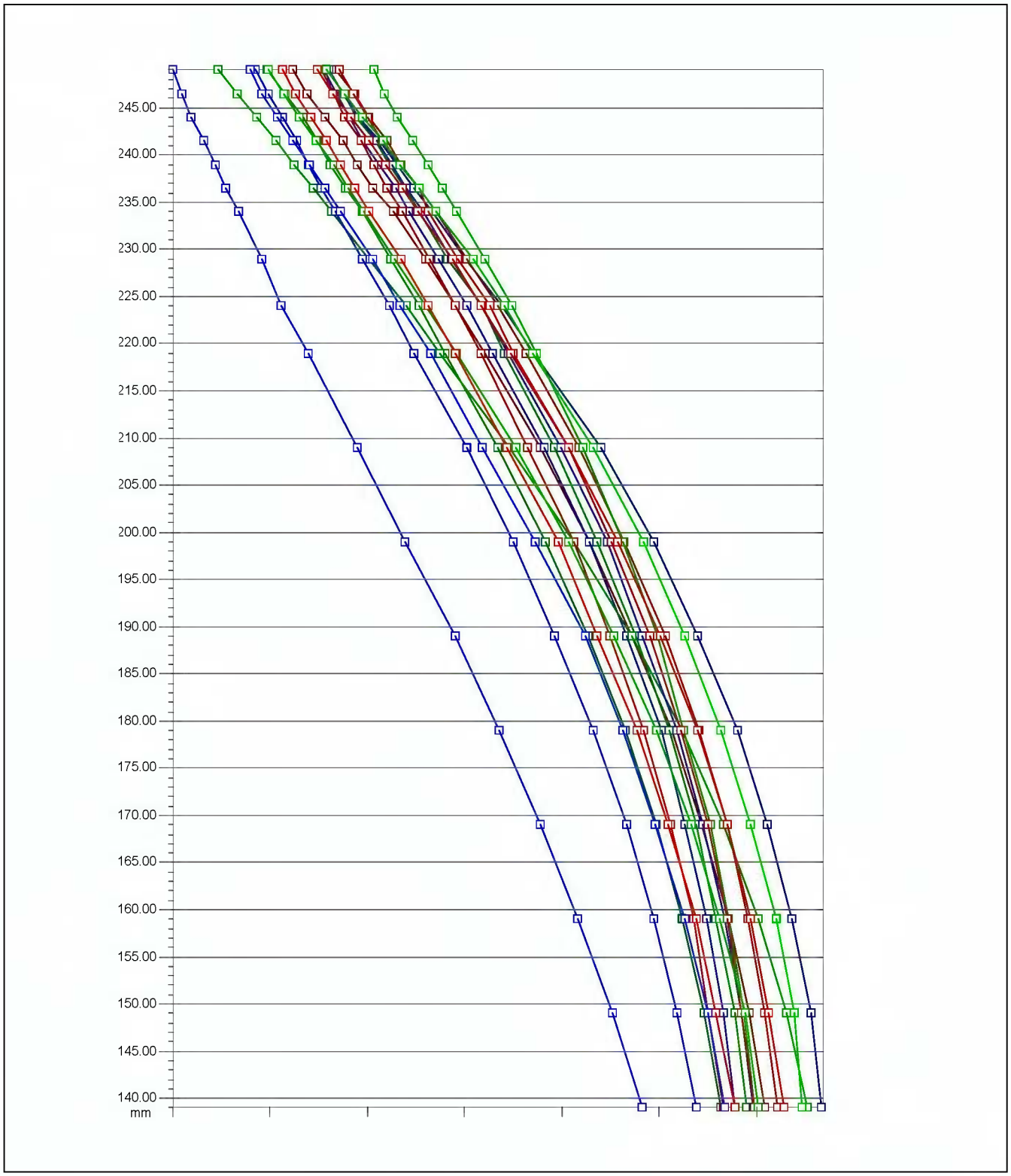
6. Features List

Pipe no.	Length [ft]	Feat no.	Odometer	Abs. Distance [ft]	Rel. Distance [ft]	Feature	Bend Radius	Bend Angle	Ovality [%]	ID Reduction [%]	ID Reduction [in]	Length [in]	Width [in]	Minimum ID [in]	Orientation	Comments
1	2.40	1	18	0.20	0.02	Launcher								18.36		Straits of Mackinac (East Leg)
5	25.30	2	1004	10.98	8.38	Bend	Field Bend	15°						18.33	Down Turn	
5	25.30	3	1193	13.05	10.44	T-Piece								18.12		Offtake @ 12:00
20	21.30	4	4348	47.55	10.28	Bend	Field Bend	25°						18.36	Up Turn	
30	3.70	5	5534	60.52	1.94	Valve								18.73		BALL VALVE
70	2.40	6	6096	66.67	1.17	T-Piece								18.49		16 IN OFFTAKE-FORGED @ 9:00
95	1.30	7	7963	87.08	0.63	Flange								18.21		JOINT-INSULATED
340	27.50	8	60324	659.71	15.85	Bend	Field Bend	20°						18.34	Right Turn	
4400	16.50	9	992188	10850.70	0.22	Wall Thickness Change					-0.230			18.08		
4450	26.50	10	1002362	10961.96	0.20	Wall Thickness Change					0.110			18.03		
5790	25.30	11	1319512	14430.36	0.22	Wall Thickness Change					Below sensitivity			18.13		
6420	17.50	12	1463158	16001.29	0.59	Wall Thickness Change					Below sensitivity			18.10		
8310	20.60	13	1889076	20659.19	0.42	Wall Thickness Change					-0.150			18.02		

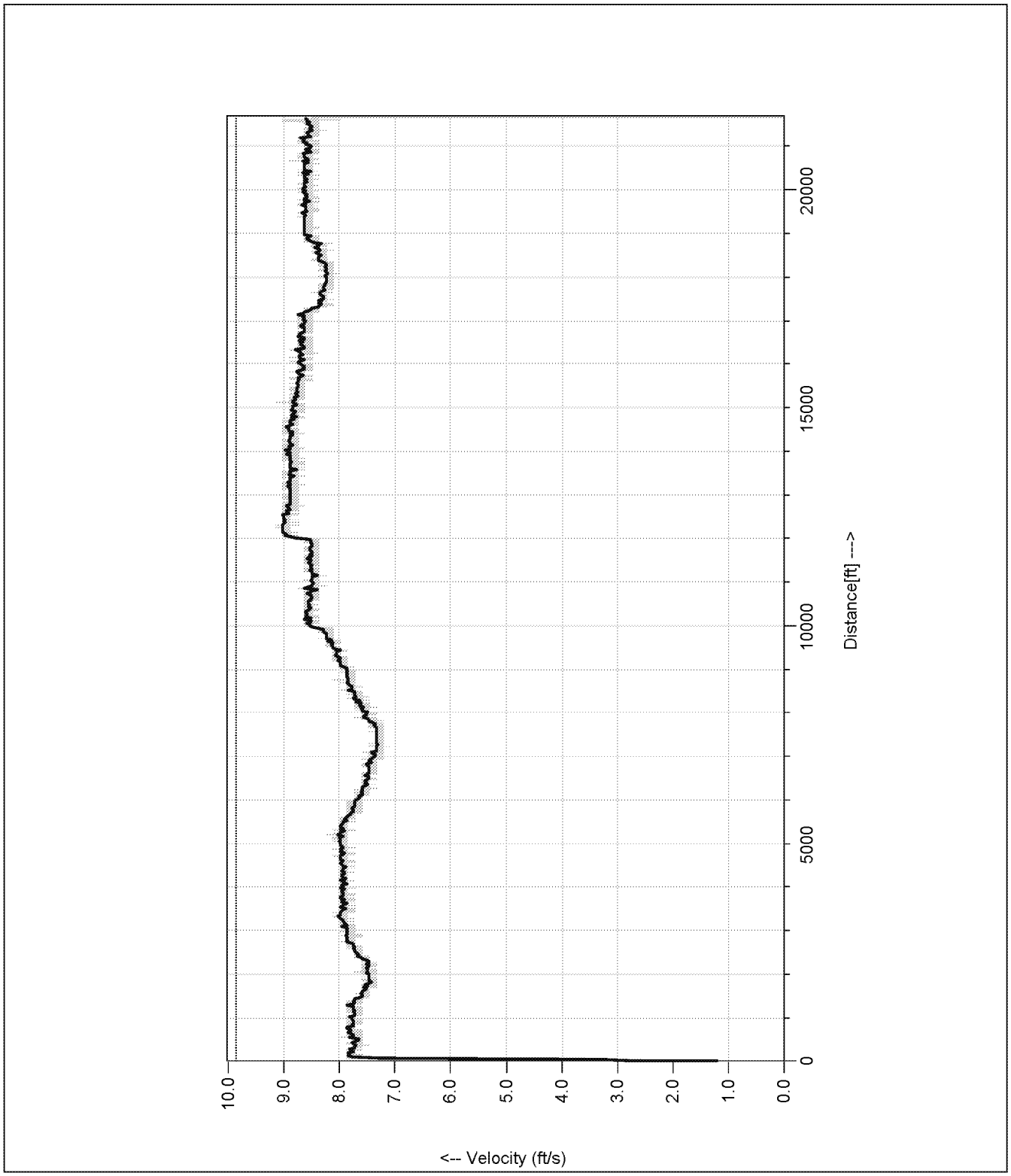
Pipe no.	Length [ft]	Feat no.	Odometer	Abs. Distance [ft]	Rel. Distance [ft]	Feature	Bend Radius	Bend Angle	Ovality [%]	ID Reduction [%]	ID Reduction [in]	Length [in]	Width [in]	Minimum ID [in]	Orientation	Comments
8320	27.90	14	1890952	20679.70	0.34	Wall Thickness Change					0.150			18.18		
8350	25.50	15	1897229	20748.35	8.09	Bend	Field Bend	10°						18.33	Up Turn	
8380	24.90	16	1905086	20834.27	15.86	Bend	Field Bend	5°						18.27	Down Turn	
8490	28.10	17	1931117	21118.95	13.39	Bend	Field Bend	20°						18.32	Right Turn	
8500	26.30	18	1933517	21145.20	11.58	Bend	Field Bend	15°						18.25	Right Turn	
8510	26.80	19	1936096	21173.40	13.53	Bend	Field Bend	25°						18.37	Right Turn	
8520	26.70	20	1938293	21197.43	10.74	Bend	Field Bend	20°						18.29	Right Turn	
8675	1.10	21	1971914	21565.11	0.65	Flange								17.95		JOINT-INSULATED
8700	2.60	22	1974670	21595.25	1.20	T-Piece								18.18		16 IN OFFTAKE-FORGED @ 9:00
8720	3.00	23	1975215	21601.21	1.52	Valve								18.27		BALL VALVE
8750	21.90	24	1976164	21611.59	8.86	Bend	Field Bend	10°						18.38	Up Turn	
8770	24.90	25	1979314	21646.04	11.51	Bend	Field Bend	10°						18.26	Down Turn	
8780	2.90	26	1980799	21662.28	2.88	Receiver								17.96		Straits of Mackinac (East Leg)

7. Calibration Curve and Speed Graph

Calibration Curve



Speed Graph


0
5000
10000
15000
20000
Distance[ft] --->
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
<-- Velocity (ft/s)