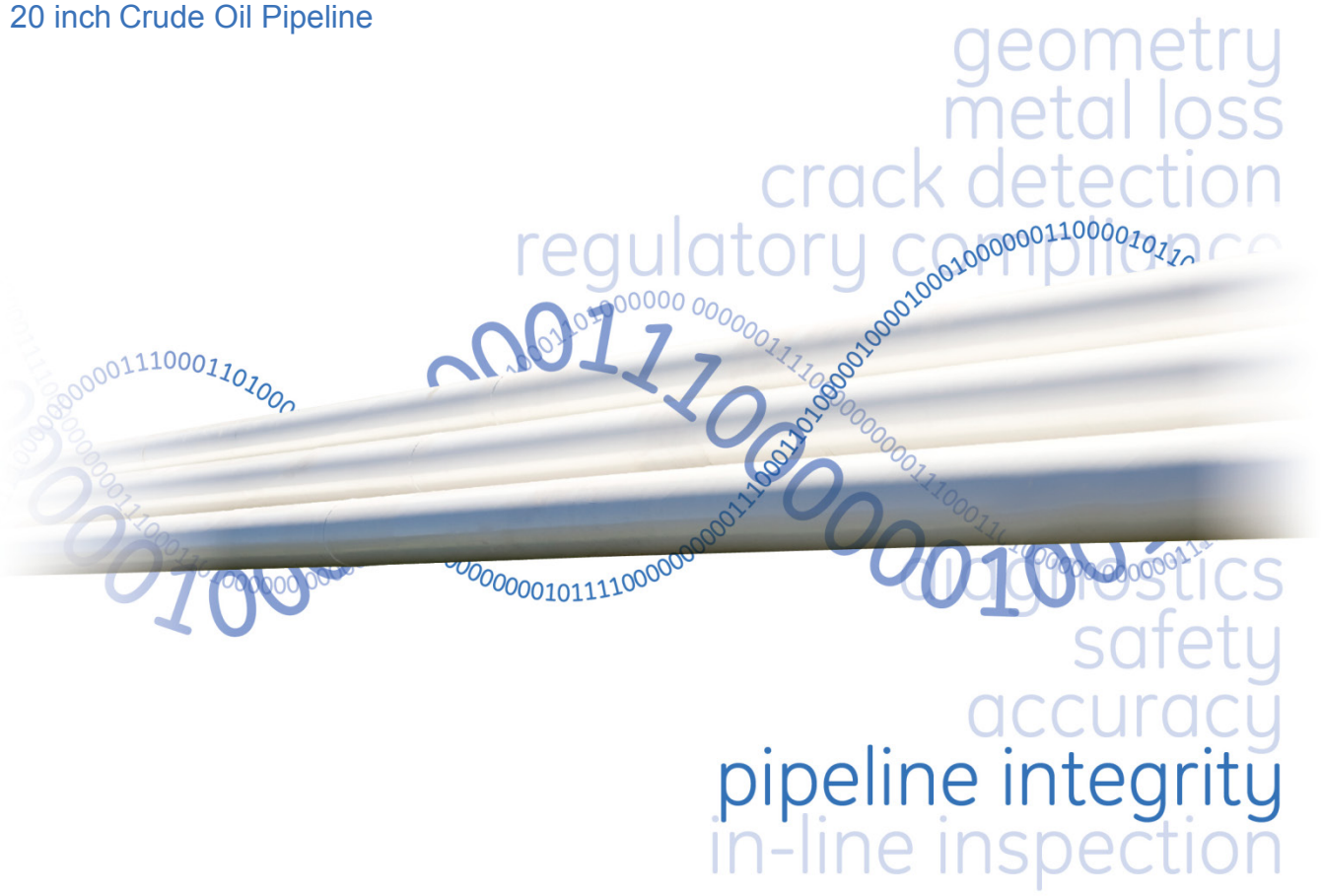
PII Pipeline Solutions
a GE Oil & Gas and Al Shaheen joint venture

MagneScan™ MFL 3
Inspection Report for
20 inch Crude Oil Pipeline



Enbridge Energy Limited Partnership

Line 5: 20" Straits of Mackinac - West Leg
Run Date: 27 August 2013

Contract Number: 436881_20B
Issue 1, 29 November 2013

Executive Summary

A full survey of the Enbridge Energy Limited Partnership Line 5: 20" Straits of Mackinac - West Leg pipeline was successfully completed by PII Pipeline Solutions, a GE Oil & Gas and Al Shaheen joint venture, on the 27th of August 2013. The pipeline survey was performed using the PII Pipeline Solutions Magnetic Flux Leakage (MFL 3) inspection vehicle.

A total of 294 metal loss features have been detected on the inspection survey of which the deepest was 41%. These are distributed throughout the pipeline. Approximately 17% of the total number of spools have metal loss reported within them.

The majority of these are external and have the appearance of mill/manufacturing faults.

In order to improve the depth prediction of features in the line, PII reviewed and manually sized (as needed) all boxed data within Clusters containing:

1. A Box with depth ≥ 45% WT or
2. A Box with a width ≥ 61mm and depth between 20-45% WT.

Note: The girth welds for this inspection have been correlated with the baseline listing provided by Enbridge. Both the girth welds and location references were approved by Enbridge on the 17th of October 2013.

Below are the names, roles and certification levels of the analysis team that participated in this project:

Analyst	Role	Certification Level
Maria Laura Rubinstein	Report Checker	2
Yuyu Tan	QA Checker / Report Author	2
Aniko Stamp	Data Analyst	1

We should hereby like to express our appreciation for the assistance and co-operation which we received from Enbridge Energy Limited Partnership in the course of this project.

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Report Approved by:	**Tanis Lindberg**	**Date:**	**29 November 2013**
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Inspection Summary

This section presents a summary of inspection operation 436881_20B which was conducted for Enbridge Energy Limited Partnership in the Line 5: Straits of Mackinac - West Leg, 20 inch nominal diameter, 4.13 miles, crude oil pipeline.

The pipeline was inspected by the PII Pipeline Solutions Magnetic Flux Leakage (MFL 3) inspection vehicle on the 27th of August 2013.

This was a reinspection of the pipeline with a previous inspection having been carried out by PII Pipeline Solutions in May 2008.

1.1. Metal Loss

A total of 294 metal loss features have been detected on the inspection survey of which the deepest was 41%. These are distributed throughout the pipeline. Approximately 17% of the total number of spools have metal loss reported within them.

The majority of these are external and have the appearance of mill/manufacturing faults.

Mill/manufacturing faults will have been present in the pipeline since it was commissioned. It can be difficult to achieve the normal sizing accuracy for mill/manufacturing faults depending on whether these metal loss features are the result of hot working or cold working of the pipe steel. Consequently, it should be noted that the sizing accuracy specified for corrosion in the Inspection System Performance Specification (Appendix G) contained in the contract may not be applicable to mill/manufacturing faults.

Summaries of all the metal loss features are presented in Section 2.1.

1.2. Pipeline Anomalies

The following is a summary of any pipeline anomalies which have been detected on the inspection survey:

ferrous metal objects:	0
eccentric pipeline casings:	0
dents:	0
girth weld anomalies:	0
shell repairs:	0
patch repaired spools:	0

More information on pipeline anomalies is given in the anomaly reports presented in Sections 2.2.2 to 2.2.6.

1.3. Inspection Quality

Inspection data was obtained for the full length (4.13 miles) of the pipeline.

The quality of the inspection data is satisfactory and this has enabled a comprehensive assessment of the pipeline to be carried out.

1.4. Summary of Pipeline Changes

This pipeline was previously inspected by PII Pipeline Solutions in May 2008. The previous report reference number is 109170_20A.

The following table summarises the differences in the numbers of the reported features between the current inspection and the previous inspection 109170_20A.

Feature Type	109170_20A 2008	436881_20B 2013	Comment
External metal loss	0	0	No changes from the previous inspection.
Internal metal loss	4	0	4 previously reported internal metal loss features are not in the currecnt inspection data due to pipe replacements.
External mill/manufacturing faults	205	194	Due to the benefit of a re-inspection, all external mill/manufacturing faults have been re-assessed and some are not included in the current inspection report as they appear to be part of the seamless pipe pattern.
Internal mill/manufacturing faults	108	100	Due to the benefit of a re-inspection, all internal mill/manufacturing faults have been re-assessed and some are not included in the current inspection report as they appear to be part of the seamless pipe pattern.
Dents	4	0	Due to the benefit of a re-inspection, all dents from the previous inspection report have been re-assessed and they do not carry the signature of a dent signal therefore are not included in the current inspection report.
Girth weld anomalies	0	0	No changes from the previous inspection.
Metal objects	0	0	No changes from the previous inspection.
Eccentric casings	0	0	No changes from the previous inspection.
Shell repairs	0	0	No changes from the previous inspection.
Patch repaired spools	0	0	No changes from the previous inspection.

Pressure Based Pipeline Summary Report

The Pressure Based Pipeline Summary Report provides an overview of the pipeline condition.

2.1. Metal Loss Information

This section provides summaries of all the metal loss features detected along the pipeline in the following formats:

- Pressure Sentenced Plot
- Pressure Based Histograms
- Depth Based Histograms
- Orientation Plot
- Severity Listing

2.1.1. Pressure Sentenced Plot

The pressure sentenced plot shows the relative significance of each detected metal loss feature.

Metal loss features that have been identified as manufacturing faults are not included on the pressure sentenced plot.

The significance of each metal loss feature has been assessed using the pressure sentencing formulae as supplied by the client and defined in the Appendix to the Specification for the Pipeline Inspection Report (Appendix F).

These formulae depend on the following five variables;

two measured by the PII Pipeline Solutions inspection system:

- the predicted peak depth of the metal loss feature, or the area ratio if the metal loss feature consists of two or more metal losses that have been clustered together;

- the predicted axial length of the metal loss feature, or the overall predicted axial length if the metal loss feature consists of two or more metal losses that have been clustered together;

and three specified by the pipeline operator:

- the external pipe radius (r);

- the nominal pipe wall thickness (nwt); and,

- the Specified Minimum Yield Strength (SMYS).

The pressure sentenced plot shows the relative significance of each metal loss feature by plotting the sentenced depth of the metal loss feature against its predicted axial length and by indicating on the graph the appropriate curve that represents an RPR of 1. The curve representing an RPR of 1 will move if any of the values for r, nwt, or SMYS change.

Those metal loss features with RPR values <1 will be plotted above the curve. The lower the value, the higher the significance and the further away from the curve the metal loss feature will be plotted.

The report contains one pressure sentenced plot for each major pipeline segment defined by the pipeline operator. Only those metal loss features within the major segment, and any minor segments within the major segment, are shown on the respective pressure sentenced plot. The RPR unity curve is calculated using the values of r, nwt, and SMYS that have been specified for the major segment by the pipeline operator; these values are also given on each plot.

A pressure sentenced plot will not be provided if the major segment does not contain any metal loss features.

A list of the major segments and the values of nwt and SMYS that apply within each segment are provided in the nominal wall thickness listing presented in Section 2.2.8. The value for r is assumed to be constant throughout the pipeline.

There are two symbols used on the pressure sentenced plot to represent metal loss features. These are:

+	The metal loss feature is within the major segment. That is the spool containing the metal loss feature has pipeline parameters equal to those used to calculate the RPR unity curve.
△	The metal loss feature is within a minor segment. That is the spool containing the metal loss feature has pipeline parameters different to those used to calculate the RPR unity curve.

Each pressure sentenced plot is presented overleaf.

SENTENCED PLOT

Line 5: 20" Straits of Mackinac - West Leg

Major Segment 1

External Diameter 20 in
Wall Thickness 0.812 in
SMYS 35000.0 PSI

R.P.R. = 1.0

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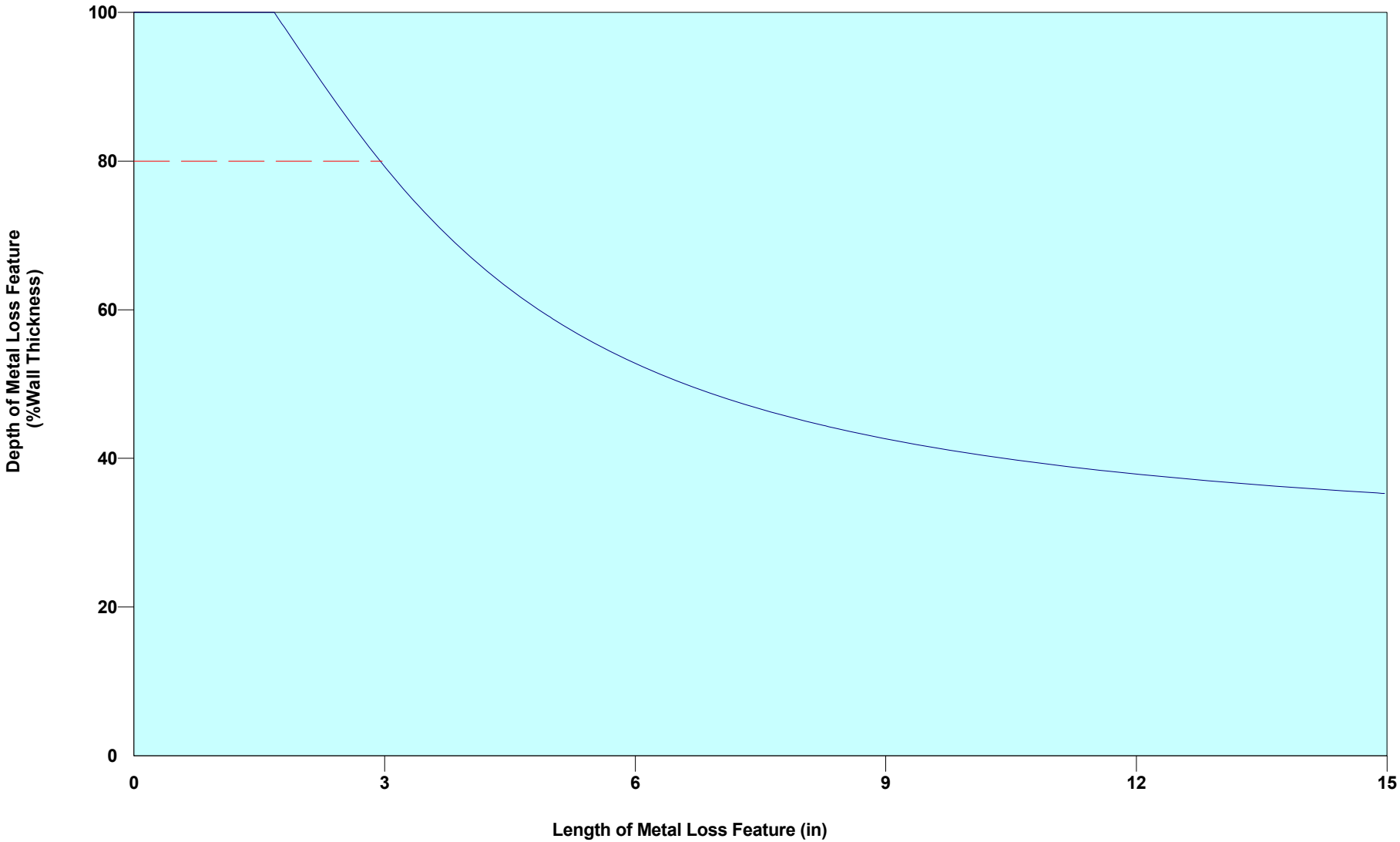

2.1.2. Pressure Based Histograms

The pressure based histograms show the distribution of the most significant metal loss features along the pipeline.

Metal loss features that have been identified as manufacturing faults are not included in the pressure based histograms.

The significance of each metal loss feature has been assessed using the pressure sentencing formulae supplied by the client and defined in the Appendix to the Specification for the Pipeline Inspection Report (Appendix F).

Each pressure based histogram shows the distribution along the pipeline of those metal loss features with RPR values below a chosen pressure sentenced threshold.

Each bar on the histogram represents the number of occurrences within a 50 ft section of the pipeline.

The pressure sentenced thresholds chosen to highlight the most significant metal loss features are as follows:

- all metal loss features with RPR values <1.000
- all metal loss features with RPR values <1.100
- all metal loss features with RPR values <1.200

Summarising from the histograms:

0 metal loss features with RPR values <1.000

0 metal loss features with RPR values <1.100

0 metal loss features with RPR values <1.200

In addition, a single three-dimensional summary histogram is included which shows the distribution along the pipeline of those metal loss features with RPR values below each of the chosen pressure sentenced thresholds.

The pressure based histograms are presented overleaf.

Number of Metal Loss Features

PRESSURE BASED HISTOGRAM

Line 5: 20" Straits of Mackinac - West Leg

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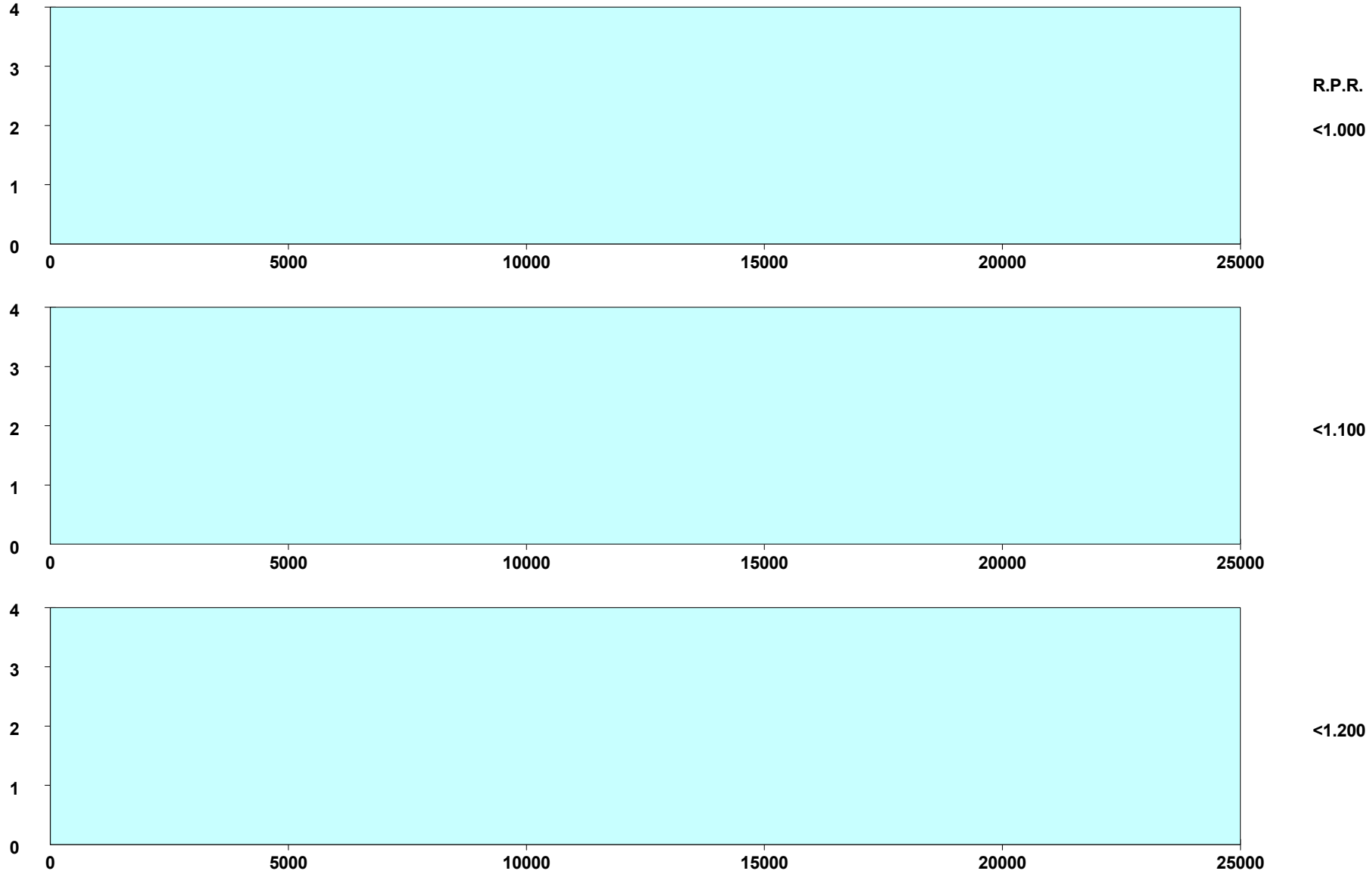
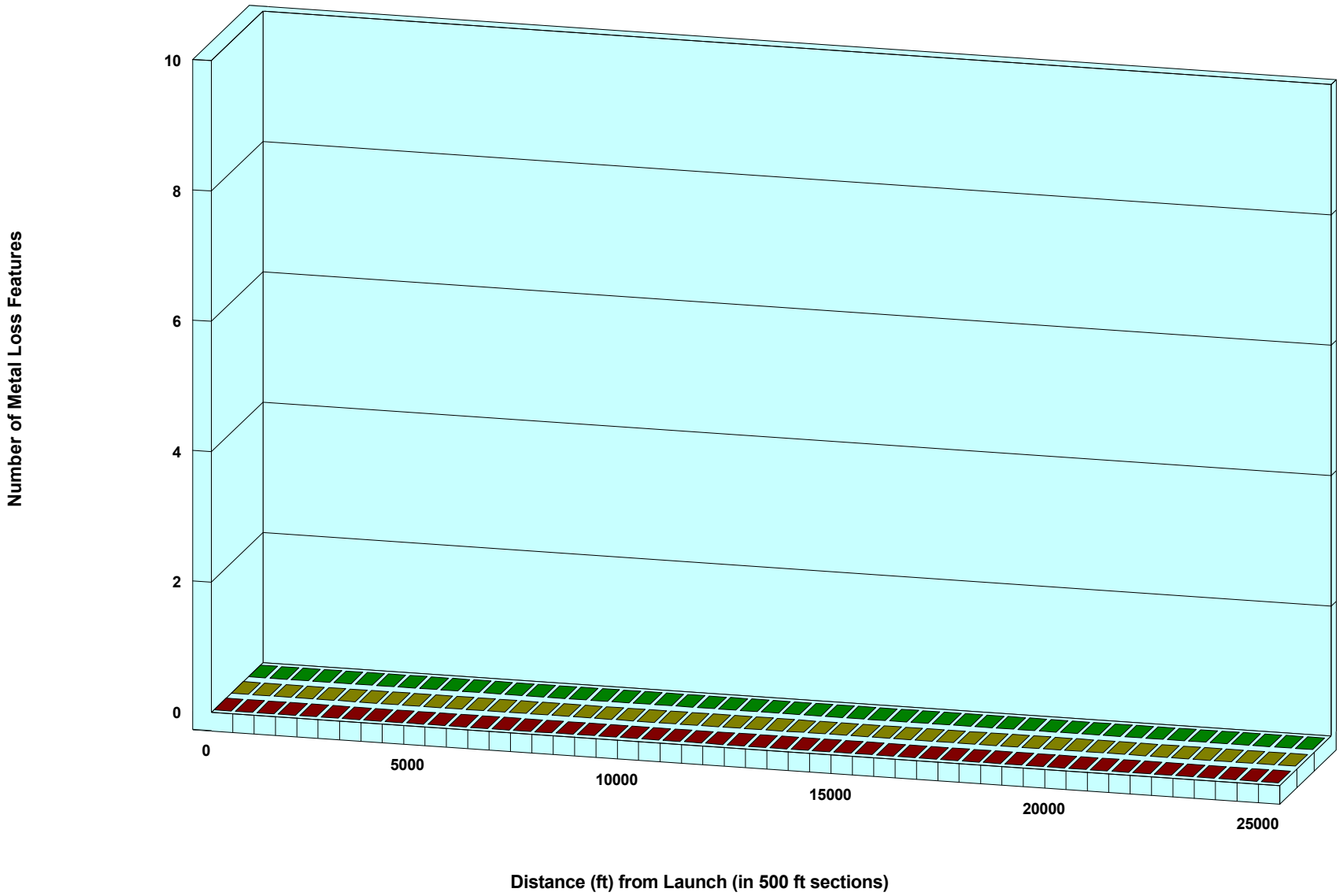


PRESSURE BASED HISTOGRAM

Line 5: 20" Straits of Mackinac - West Leg

R.P.R. < 1.200
R.P.R. < 1.100
R.P.R. < 1.000



2.1.3. Depth Based Histograms

The depth based histograms show the distribution of all detected metal loss features along the pipeline.

Twelve histograms are presented in this section:

- three ungraded metal loss histograms
- eight graded metal loss histograms
- one three-dimensional summary histogram

Ungraded Metal Loss Histograms

The total metal loss histogram shows the distribution of all metal loss features along the pipeline. Each bar on the histogram represents the number of occurrences within a 50 ft section of the pipeline.

The area metal loss histogram shows how much of the pipe surface has been affected by metal loss. Each bar on the histogram represents the total surface area of the metal loss within a 50 ft section of the pipeline. This is expressed as a percentage of the surface area of an undamaged pipe section.

The volume metal loss histogram shows how the volume of metal in the pipeline has been affected by metal loss. Each bar on the histogram represents the total volume of the metal loss features within a 50 ft section of the pipeline. This is expressed as a percentage of the volume of metal in an undamaged pipe section.

Graded Metal Loss Histograms

The metal loss features are graded into eight categories, which are derived from combinations of two length and four predicted peak depth categories.

There is one graded metal loss histogram for each category. Each bar on the histogram represents the number of occurrences within a 50 ft section of the pipeline.

Summarising from the histograms, a total of **294** metal loss features have been identified within the pipeline. These have been graded as follows:

229 metal loss features with predicted axial lengths ≤ 3t.
Of these:

85	have a predicted peak depth of ≤ 20%t.
143	have a predicted peak depth of > 20%t and ≤ 40%t.
1	have a predicted peak depth of > 40%t and ≤ 60%t.
0	have a predicted peak depth of > 60%t.

65 metal loss features with a predicted length > 3t.
Of these:

20	have a predicted peak depth of ≤ 20%t.
45	have a predicted peak depth of > 20%t and ≤ 40%t.
0	have a predicted peak depth of > 40%t and ≤ 60%t.
0	have a predicted peak depth of > 60%t.

Three-Dimensional Summary Histogram

The metal loss features are graded into nine depth categories and displayed on a single three-dimensional histogram. Each bar on the summary histogram represents the number of metal loss occurrences within the appropriate depth category for a specific section of the pipeline.

The histograms are presented on four pages overleaf.

DEPTH BASED HISTOGRAM - ALL METAL LOSS

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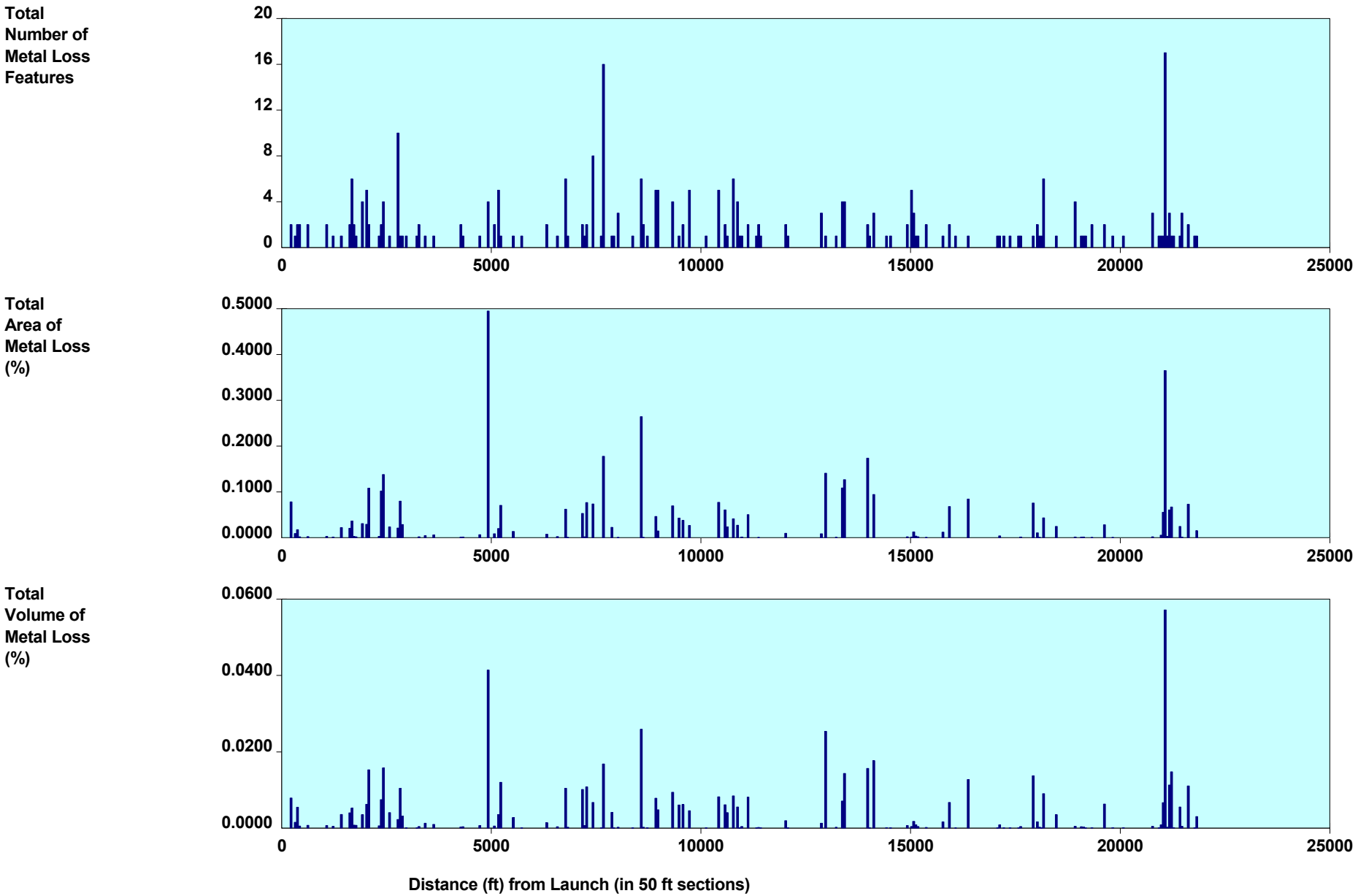
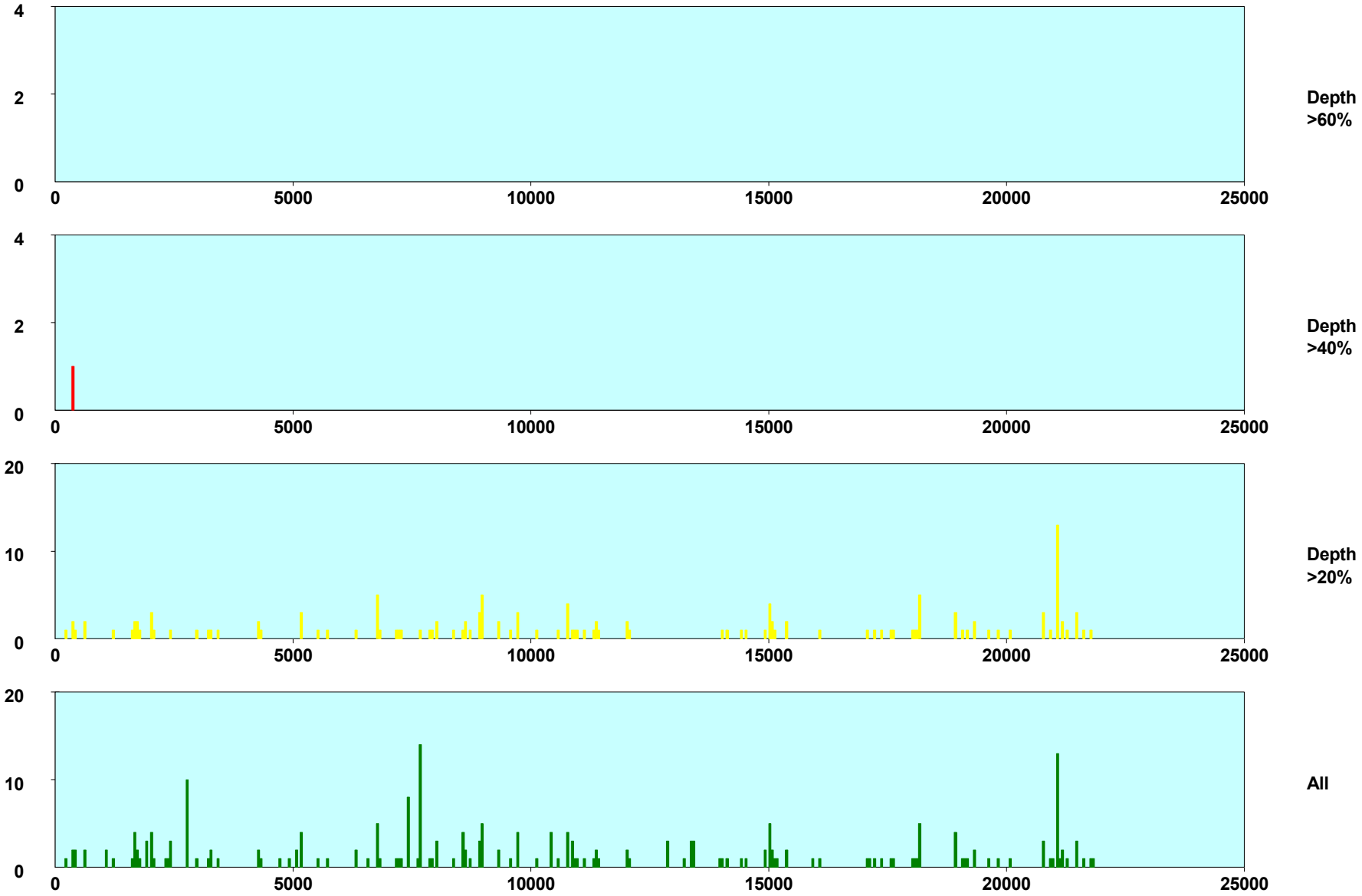


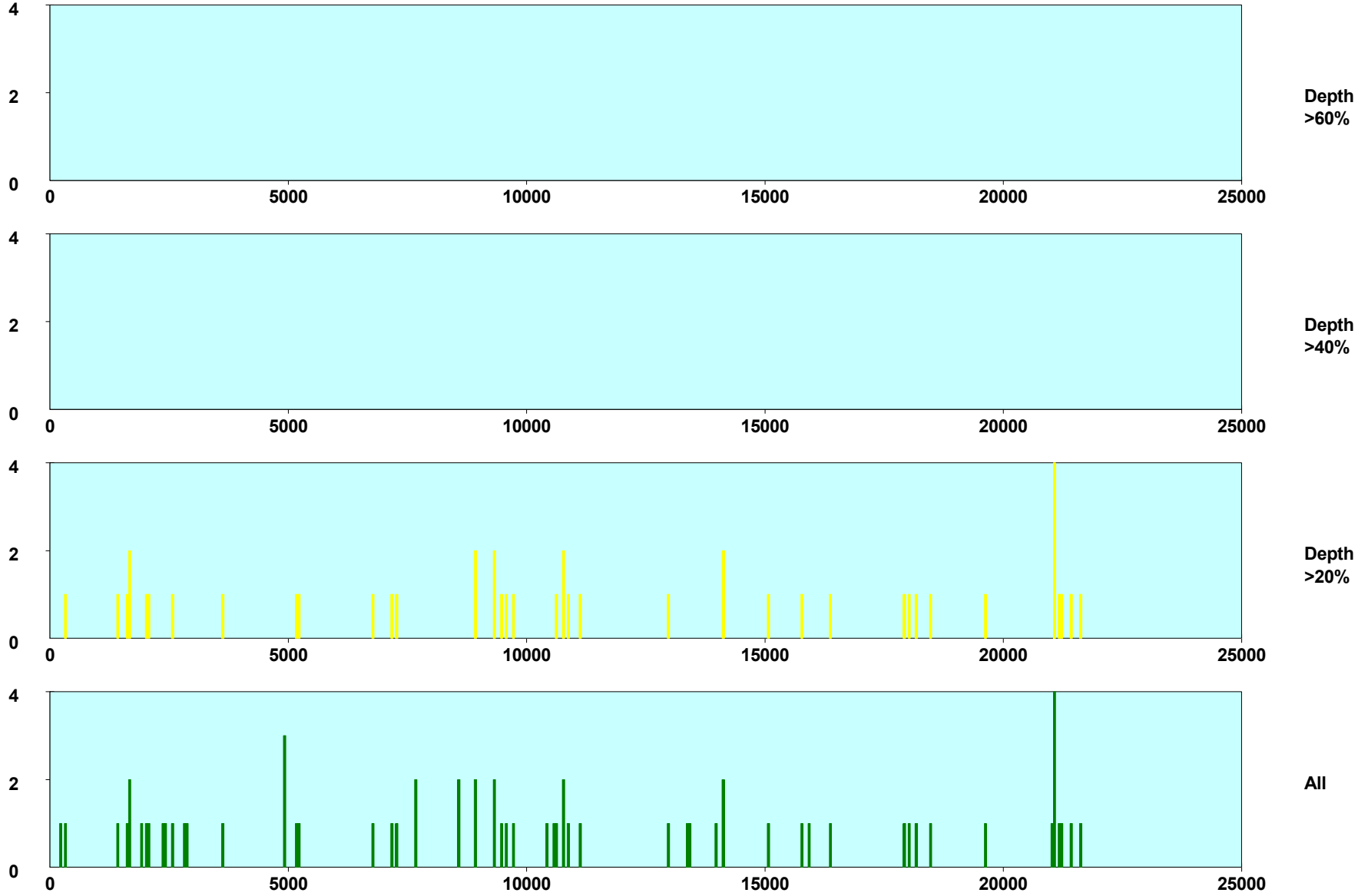
Number of
Metal Loss
Features

DEPTH BASED HISTOGRAM
Axial Length ≤ 3t
Line 5: 20" Straits of Mackinac - West Leg



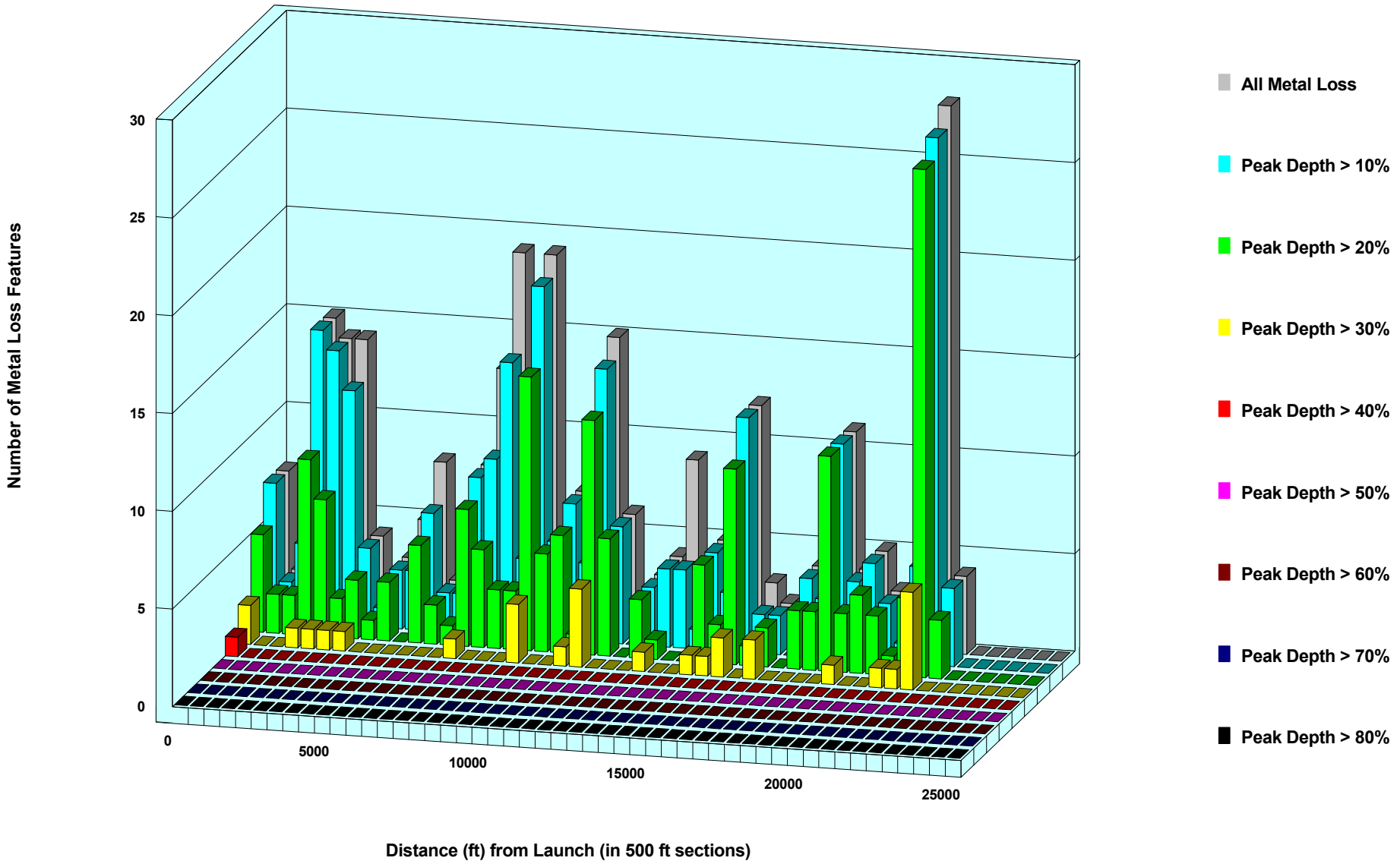
Number of
Metal Loss
Features

DEPTH BASED HISTOGRAM
Axial Length > 3t
Line 5: 20" Straits of Mackinac - West Leg



DEPTH BASED HISTOGRAM

Line 5: 20" Straits of Mackinac - West Leg



2.1.4. Orientation Plot

The orientation plot shows the location and extent of each metal loss feature around the pipe's circumference.

The absolute distance from the launch is plotted against the orientation of the metal loss. The orientation is based on a 12 hour clock as viewed in the direction of product flow; for example, twelve indicates the top of the pipe and six indicates the bottom.

For each metal loss feature a box is drawn on the plot showing the predicted circumferential and axial extent of the metal loss feature. Due to the scale along the distance axis, each metal loss feature appears as a solid vertical line on the plot.

The orientation plot is presented overleaf.

ORIENTATION PLOT

Line 5: 20" Straits of Mackinac - West Leg

Peak Depth ≤ 20%
20% < Peak Depth ≤ 40%
40% < Peak Depth ≤ 60%
Peak Depth > 60%

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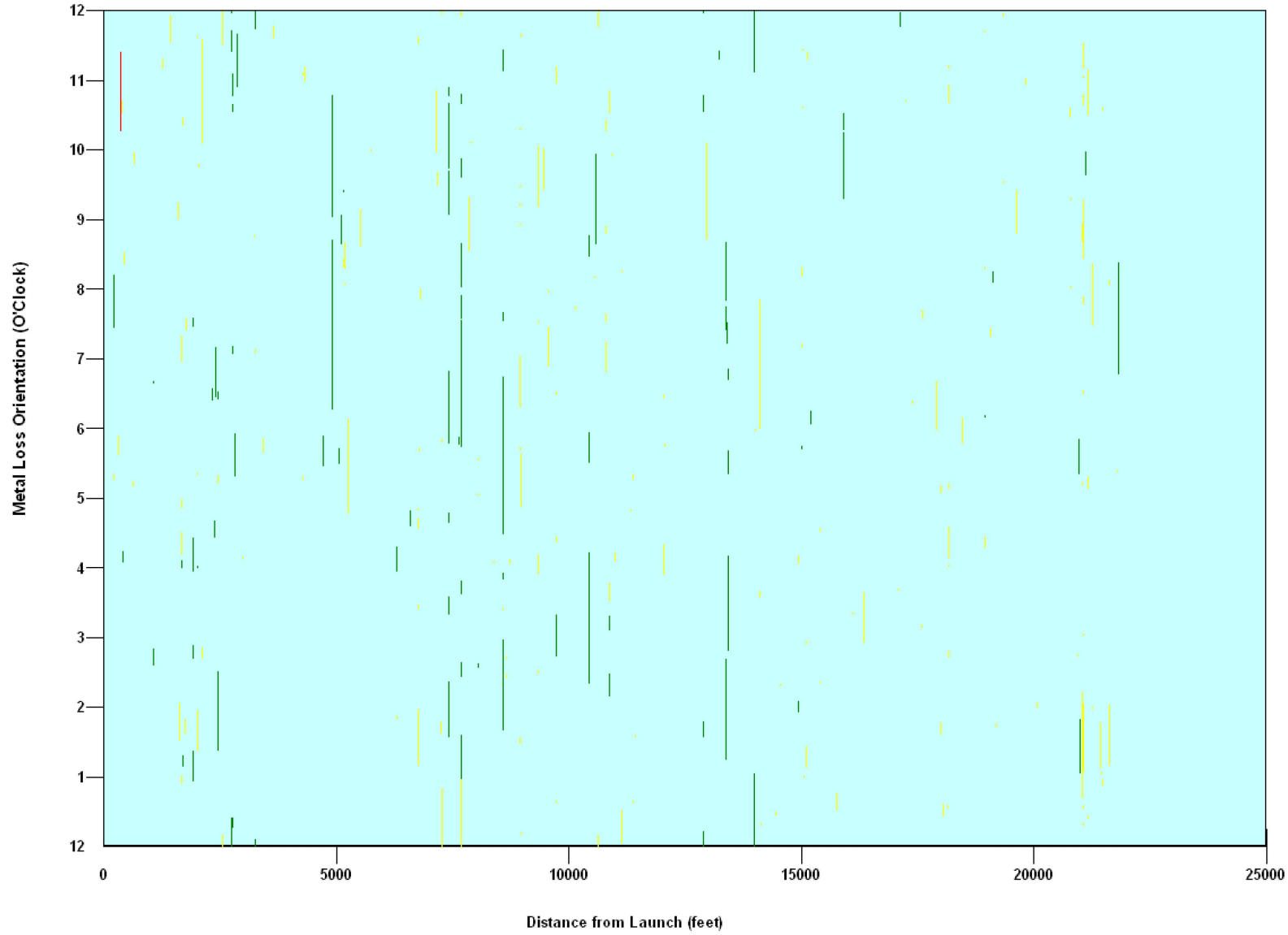

2.1.5. Severity Listing

The severity table identifies those pipe spools which contain the most severe metal loss features, based on pressure sentencing ratio and peak depth.

Metal loss features that have been identified as mill/manufacturing features are not included in the severity table.

The pressure based severity list the twenty-five pipe spools which contain the most severe metal loss feature in each spool and these are listed in severity order, as defined by the calculated Effective Area RPR.

The depth based severity list the twenty-five pipe spools which contain the most severe metal loss features based on peak depth, which are ranked in descending order of severity.

No metal loss features have been detected during this pipeline inspection.

2.2. Pipeline Information

The Pipeline Information section presents summaries of any pipeline anomalies, repairs, location reference points and changes in the nominal pipe wall thickness along the pipeline. The following summaries are provided:

- Velocity Plot
- Metal Object Report
- Eccentric Casing Report
- Dent Report
- Girth Weld Anomaly Report
- Repair Listing
- Location Reference Point Listing
- Nominal Wall Thickness Listing

2.2.1. Velocity Plot

The velocity plot shows the speed of the inspection vehicle during the inspection run.

The red line on the velocity plot indicates the specified maximum velocity for the inspection vehicle. If the vehicle exceeds the specified maximum velocity then the performance of the inspection vehicle may be degraded.

The inspection vehicle did not exceed the specified maximum velocity during the inspection survey.

The inspection vehicle's average velocity during the inspection run was 9.8 ft/s.

The velocity profile plot is presented overleaf.

VELOCITY PLOT

Line 5: 20" Straits of Mackinac - West Leg

Contractual Maximum and Minimum Velocities

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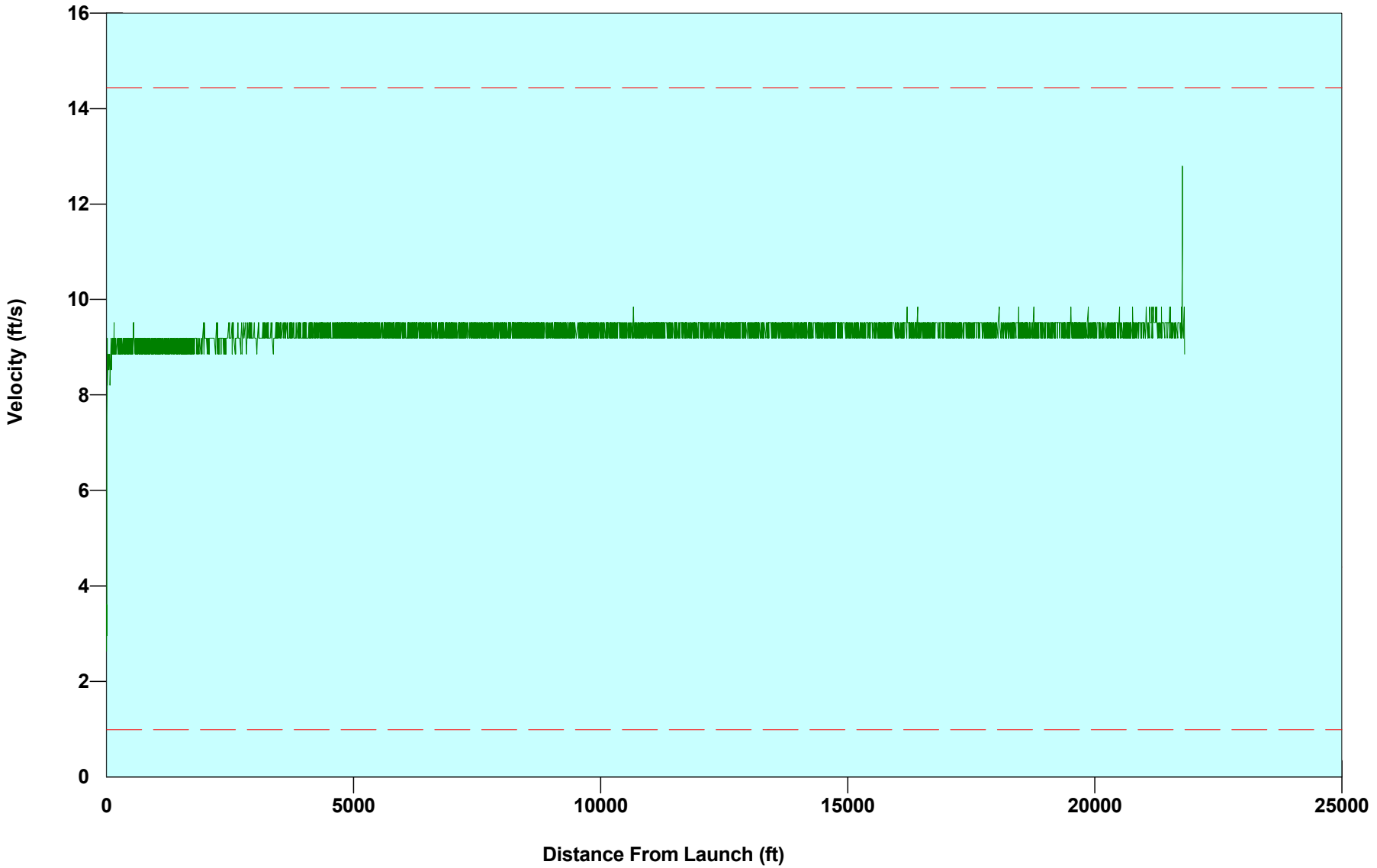


2.2.2. Metal Object Report

The metal object report provides a list of all ferrous metal objects that have been detected along the pipeline.

Metal objects can be potentially hazardous to the pipeline. They can impair the pipeline's protective coating or the cathodic protection system, and over time they can also dent or damage the pipe itself.

Metal objects are classified as close to or touching the pipeline. Those metal objects classified as touching are considered to have damaged the pipeline's protective coating or impaired the cathodic protection system. Metal objects that are considered to be part of the pipeline build, such as supports but excluding attachments, will only be reported if they are touching the pipeline. Pipeline casings that are touching the pipe will be reported in the eccentric pipeline casing report presented in Section 2.2.3.

No metal objects have been detected during this pipeline inspection.

2.2.3. Eccentric Casing Report

The eccentric casing report provides a list of all casings detected along the pipeline which appear to be eccentric to the pipe and may, therefore, have damaged the pipeline's protective coating or impaired the cathodic protection system.

No eccentric casings have been detected during this pipeline inspection.

2.2.4. Dent Report

The dent report provides a list of all dents that have been detected along the pipeline.

The proximity of dents to metal losses, girth welds and seam welds is indicated in the report. If the orientation of a seam weld is unclear in the data then the dent proximity will be marked '***'.

Dents will affect the integrity of the pipeline and are potentially dangerous. It should be noted that a dent associated with metal loss is potentially more significant than a dent alone.

No dents have been detected during this pipeline inspection.

2.2.5. Girth Weld Anomaly Report

The girth weld anomaly report provides a list of all significant girth weld anomalies that have been detected along the pipeline.

Incomplete welds and circumferential cracks within the weld are examples of girth weld anomalies.

No girth weld anomalies have been detected during this pipeline inspection.

2.2.6. Repair Listing

The repair listing provides a list of all fully circumferential repair shells and patch repaired spools that have been detected along the pipeline.

It should be noted that any metal loss detected beneath a repair shell or repair patch will not be included in the inspection analysis.

If a patch repair is detected within the spool then the spool will be reported on this listing as a patch repaired spool. Details of the individual patch repairs within the patch repaired spool will not normally be provided.

The inspection system has detected **no repair shells** and **no patch repaired spools** during this pipeline inspection.

2.2.7. Location Reference Point Listing

This is a list of the line markers (timer boxes), magnets, mainline valves, offtakes and anodes, as appropriate, that have been detected by the inspection system and that can be used to locate features along the pipeline.

Line markers were not used on the inspection survey.

A table listing the location reference points along the pipeline is provided on the accompanying external hard drive.

2.2.8. Nominal Wall Thickness Listing

The nominal wall thickness listing provides a list of the locations along the pipeline where a change in the nominal pipe wall thickness, or other parameter of the pipeline, has been detected by the inspection system. This listing identifies the major and minor pipeline segments used during the analysis of the inspection data.

A pipeline segment is a section of the pipeline where the nominal wall thickness (nwt) and the SMYS are constant.

Pipeline segments can be categorised as either major or minor segments.

A major segment is a pipeline segment that has been defined by the pipeline operator in the table provided in the Company Defined Operating Parameters section of the contract. In this table the pipeline operator specifies the locations of the start and end of the segment and the values of nwt and SMYS that apply within it.

A minor segment is a pipeline segment identified by the inspection system. The minor segment is a section within the major segment where the nominal wall thickness is distinctly different from that detected for the major segment.

In the absence of information from the pipeline operator, the SMYS value for the minor segment will be assumed to be the same as that specified for the major segment in which it is located.

The nominal wall thickness within the minor segment will be estimated from readings obtained from the inspection survey. The estimated nominal wall thickness will be either a wall thickness stated by the pipeline operator as being present in the pipeline, or the nearest American Petroleum Institute (API) nominal wall thickness.

The values of nwt and SMYS specified for each segment are used to calculate the RPR value of each metal loss feature detected within the segment.

A table listing the pipeline segments is provided on the accompanying external hard drive.

2.3. Pipeline Listing

The pipeline listing presents the sequence of girth welds, metal loss features, metal objects, eccentric pipeline casings, dents, girth weld anomalies and repairs detected along the pipeline. Location reference points and changes in the nominal pipe wall thickness are also included in the pipeline listing.

The listing also contains all other pipeline tally information.

There are four types of entry in the pipeline listing. These are:

Girth Welds

Each girth weld entry consists of:

- a girth weld number;
- the relative distance along the pipeline to the girth weld from the previous (upstream) girth weld; and,
- the absolute distance from the start of the pipeline.

Metal Loss Features

Each entry for a metal loss feature consists of:

- the relative distance along the pipeline to the upstream edge of the metal loss feature from the previous (upstream) girth weld;
- the absolute distance along the pipeline to the upstream edge of the metal loss feature;
- ML to denote that the entry refers to a metal loss feature;
- EXT or INT to denote whether the metal loss feature is on the external or internal surface of the pipe. It should be noted that mid-wall metal loss features would be classified as external;
- the predicted peak depth of the metal loss feature;
- the predicted axial length of the metal loss feature;
- the predicted circumferential width of the metal loss feature;
- the orientation of the metal loss feature, as viewed in the direction of flow;
- the nominal wall thickness of the spool;
- the calculated RPR value for the metal loss feature;
- the calculated LAPA RPR value for the metal loss feature;
- a unique Cluster Identifier for the metal loss feature; and,

- those metal loss features which have undergone detailed processing and analysis are indicated by a *. This includes all features reported on inspection sheets.

Please be aware that the RPR values in the Pipeline Listing are allocated to individual features. In the case of future corrosion, increasing depth of individual corrosion features is not the only consideration. Individual features in close proximity may link together through low level corrosion leading to lower net RPR values.

Identified Manufacturing Faults

The entry for an identified manufacturing fault is the same as that for a metal loss feature with the following differences:

- MFG (in place of ML) to denote that the entry refers to an identified manufacturing fault; and,

- there is no calculated RPR value for an identified manufacturing fault.

Pipeline Anomalies and Fittings

Other entries in the pipeline listing relate to pipeline fittings and pipeline anomalies. These entries consist of:

- the relative distance along the pipeline to the fitting or anomaly from the previous (upstream) girth weld;

- the absolute distance along the pipeline to the fitting or anomaly; and,

- a comment describing the fitting or anomaly.

It should be noted that where the orientation of a pipeline fitting has not been specified then the fitting is centred on the 12-00 position.

The pipeline listing is provided on the accompanying external hard drive.

Glossary of Terms

Absolute Distance	The distance from the start of the pipeline to the upstream edge of the metal loss feature.
Axial Length	The predicted axial length of the metal loss feature.
Relative Distance	The distance between the upstream girth weld and the feature under consideration.
ERF	The calculated Estimated Repair Factor value of the metal loss feature.
Ext or Int	Denotes whether the metal loss feature is on the external or internal surface of the pipe. It should be noted that mid-wall metal loss features would be classified as external.
Feature Selection Rule	The number of the selection rule under which the metal loss feature was chosen. The selection rules are specified in the Specification for a Pipeline Inspection Report (Appendix F)
FPR	The calculated Failure Pressure Ratio value of the metal loss feature.
Girth Weld Number	The number of the girth weld at which the pipeline segment begins, as used in the pipeline listing.
Identification	The identification number of the line marker, magnet or anode.
Inspection Sheet Number	The number of the inspection sheet which is summarised by each line in the Summary tables.
Major Segment	A pipeline segment that has been defined by the pipeline operator in the table provided in the Company Defined Operating Parameters section of the contract. In this table the pipeline operator specifies the locations of the start and end of the segment and the values of nwt and SMYS that apply within it.
MAOP	The maximum allowable operating pressure for the pipeline segment, as specified by the pipeline operator.
Minor Segment	A pipeline segment identified by the inspection system. The minor segment is a section within the major segment where the nominal wall thickness is distinctly different from that detected for the major segment.
Nominal Wall Thickness	The pipe wall thickness of the spool containing the metal loss feature.
Orientation	The location of the metal loss feature around the circumference of the pipe, as viewed in the direction of flow.
Peak Depth	The predicted peak depth of the metal loss feature, expressed as a percentage of nominal wall thickness.

Pi	The internal design pressure for the pipeline segment, as specified by the pipeline operator.
Predicted Dimensions	The predicted dimensions of a metal loss feature are: **Axial length:** The dimension along the pipe and parallel to the pipe axis; **Circumferential width:** The dimension around the pipe and perpendicular to the pipe axis; **Peak depth:** The depth of the metal loss feature expressed as a percentage of nominal wall thickness.
Pressure Ratio	The Estimated Repair Factor (ERF), Failure Pressure Ratio (FPR) or Rupture Pressure Ratio (RPR) calculated for the metal loss feature. This value was calculated using the formulae defined in the Specification for a Pipeline Inspection Report contained in the contract; a copy of which is given in Appendix F.
Primary Reference	A pipeline fitting or marker from which the metal loss feature can be easily located. More than one reference point may be provided on an inspection sheet.
Reference Girth Weld	The girth weld located at the upstream end of the spool containing the metal loss feature.
RPR	The calculated Rupture Pressure Ratio value of the metal loss feature.
Segment Number	Denotes whether the segment is a major or minor segment. A number (n) indicates that the segment is part of the nth major segment defined by the pipeline operator. A number (n/m) indicates that the segment is the mth minor segment within the nth major segment.
Selection Rule	The selection rule under which the most severe metal loss feature within the pipe spool is rated.
Strip Map Number	The drawing number, where available, of the pipeline strip map on which the metal loss feature is located.
Type	Denotes whether the metal loss feature is on the internal or external surface of the pipe. It should be noted that mid-wall metal loss features would be classified as external.
Upstream Girth Weld Number	The girth weld number of the girth weld located at the upstream end of the pipe spool.

Appendix A. Locating Metal Loss Features And Pipeline Anomalies

Locating metal loss features or pipeline anomalies is a difficult task, which can cost the pipeline operator valuable time and resources. Therefore, it is important that appropriate techniques are used at each stage in locating these features.

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

A1. Reference Points

Wherever possible, the position of metal loss features and pipeline anomalies is related to reference points that can be easily identified and located from the surface.

Reference points are either pipeline fittings, such as mainline valves, offtakes, anodes or side bends, or artificial reference points, such as magnets or line markers; these will have been placed on or near the pipeline at the time of the inspection.

At least one reference point is provided for each metal loss feature reported on the inspection sheets. If the reference point is more than 1600 feet from the metal loss feature then a second reference point will usually be provided.

Two reference points are provided for each pipeline anomaly. These reference points are extracted automatically from the pipeline listing and are limited to mainline valves and line markers.

A2. Location of Features

The location of the feature can be carried out in two stages; locating the spool that contains the metal loss feature or pipeline anomaly; then locating the feature within that spool.

To locate the spool containing the feature, the distance from the reference point to the girth weld at the upstream end of the spool is provided.

To locate the feature within the spool, the distance from the upstream girth weld to the feature and the location of the feature around the circumference of the pipe, as viewed in the direction of flow, are provided. Girth weld anomalies will be located within the upstream girth weld.

These distances are given to an accuracy of ±1%. It is recommended that electronic distance measuring equipment (EDM) is used to measure out these distances accurately.

A3. Identification of Features

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

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

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

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

NOTE: Features that are wholly contained within the pipe wall, such as voids, slag inclusions, or non-magnetic alloys, may have been classified as external metal loss, however these anomalies are quite rare.

A4. Contacting PII Pipeline Solutions

PII Pipeline Solutions aims to provide its clients with a quality service. If you cannot locate a metal loss feature from the information provided on the inspection sheet or if the metal loss is very different from the description given on the inspection sheet, then please do not hesitate to contact the project manager at PII Pipeline Solutions.

PII Pipeline Solutions Telephone Numbers:

Project Manager:	Tanis Lindberg 780-448-6021 ext.56017
Telephone:	403-262-7447 (CANADA)
Facsimile:	403-237-9693 (CANADA)
Address:	PII Canada Ltd. (Calgary) 4908 - 52nd Street S.E. Calgary Alberta T2B 3R2 CANADA

Appendix B. Guidance Notes for Recording Excavation of Metal Loss Features

Contents

Illustrations

B1. Introduction

To help maintain and improve the defect sizing accuracy from these high resolution inspection systems it is extremely valuable to have feedback from defect excavations.

Reliable and accurate information from site investigations can be used to monitor actual defect dimensions against the dimensions reported from the inspection survey. This site data can then be used to improve defect sizing methods which brings benefit to all users of the inspection service.

We would ask pipeline operators wherever possible to feed any available comparison data from excavations back to us to help improve our service even more. For guidance, the most useful format for this data is as shown in the sample Damage Record Form in figure 5. This shows feature dimensions and location information.

We would like to express our appreciation to those who have provided this data in the past.

B2. Preparing Pipe Surface For Inspection And Recording

B2.1 Surface Preparation

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

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

(a) Solvent cleaning.

(b) Chemical cleaning.

(c) Wire brushing.

(d) Grit blasting.

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

B3. External Metal Loss Area Mapping

B3.1 Rubbing and Photographic Methods

The preferred method of mapping is by taking a simple rubbing. This is achieved by placing a sheet of paper over the feature, holding the paper firmly in place with, for example, small magnets and rubbing the long edge of a wax crayon over the surface of the paper. The edges of the feature will be delineated and if required, can be highlighted by careful manipulation of the crayon.

The following parameters should be annotated on the paper:

(a) Feature identity (e.g. PII Report Number and Feature Number).

(b) Direction of flow.

(c) Orientation of the feature.

(d) Distance of the feature from the nearest girth weld.

Refer to Figure 1 for an example of a mapped area using the rubbing technique.

The rubbing technique has a definite advantage over photographic recording methods in that it is possible to record all subsequent measurements directly on the rubbing in the appropriate location e.g. each individual pit depth in multiple pitting. Refer to Figure 1 for the example.

Photographic recording can be used but unless a 'polaroid' type film is used it can be a lengthy process before a result is obtained.

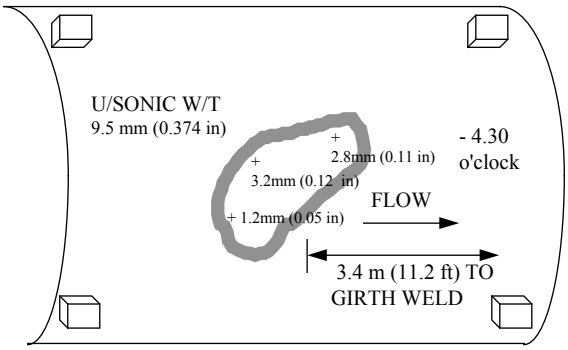


Figure 1: Example of Rubbing

B4. External Metal Loss Depth Recording

The most effective method for recording external metal loss depth is by using a depth micrometer in conjunction with a large bridging bar. Refer to Figure 2 for a typical arrangement.

It is recommended that the micrometer anvil be ground to a taper with a tip diameter of approximately 0.04 inches. This will enable entry into the small diameter pitting and concave surfaces found at the bottom of most metal loss features.

A pit gauge is not recommended because of its potential inaccuracy of up to 0.08 inches. A depth micrometer has a resolution of better than 0.002 inches.

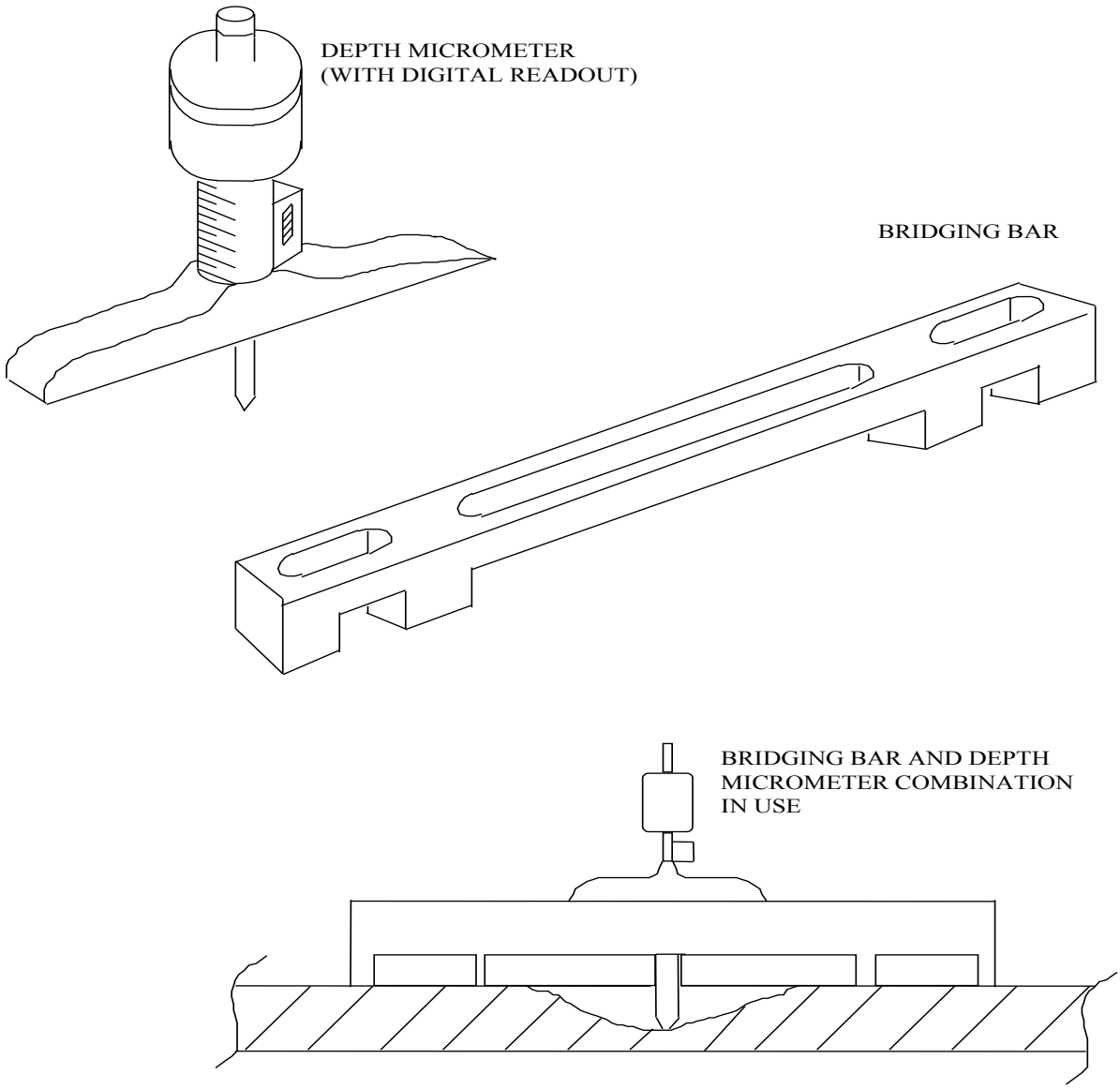


Figure 2: Typical Micrometer and Bridging Bar Arrangement

B5. Wall Thickness And Remaining Ligament Thickness Recording

Pipe wall thicknesses and remaining ligament thicknesses of internal damage can be measured to an accuracy of ±0.002 inches using standard ultrasonic wall thicknesses meters and suitable couplant.

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

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

B6. Locating And Quantifying Internal Metal Loss In Gas Pipelines Using X-Radiography

B6.1 Introduction

Locating a small area of internal metal loss is occasionally difficult using manual ultrasonic techniques. In these instances it is usually preferable to obtain an X-ray of the suspect area to locate the feature. Although time consuming the X-ray technique does have the advantage of providing a permanent record of the feature, and obtaining full inspection coverage.

Gamma radiography is not recommended since this technique is relatively insensitive to metal loss. Depending on wall thickness and the diameter of the pipe a sensitivity of approximately 10% of wall thickness can be achieved using gamma-ray techniques whereas X-ray techniques can achieve a sensitivity of better than 2% of wall thickness.

B6.2 Technique for Quantifying Internal Metal Loss

The following procedure for quantifying metal loss using X-radiograph has been devised and proved successful by PII Pipeline Solutions. Refer to Figure 3.

(1) Locate area of metal loss using ultrasonic or Double Wall Single Image (DWSI) X-ray techniques.

(2) Place plate of known thickness over the metal loss area or deepest part of the metal loss. The plate thickness must be equal to or greater than the damage through-wall thickness.

(3) Place an ultrasonic step wedge on the pipe surface the adjacent to the metal loss but on sound pipe.

(4) Carry out DWSI X-radiography aiming for a density of approximately 3 on the parent plate.

(5) Using a densitometer on the radiograph compare the density of the darkest part in the metal loss plus plate with that on the step wedge and note the step thickness.

(6) Subtract the step thickness from the plate thickness to give the through-wall depth of the metal loss.

NOTE: It has been shown that slag or air are equally transparent to X-ray when using the energies applied to steel pipelines where the density is equal to that of the metal loss.

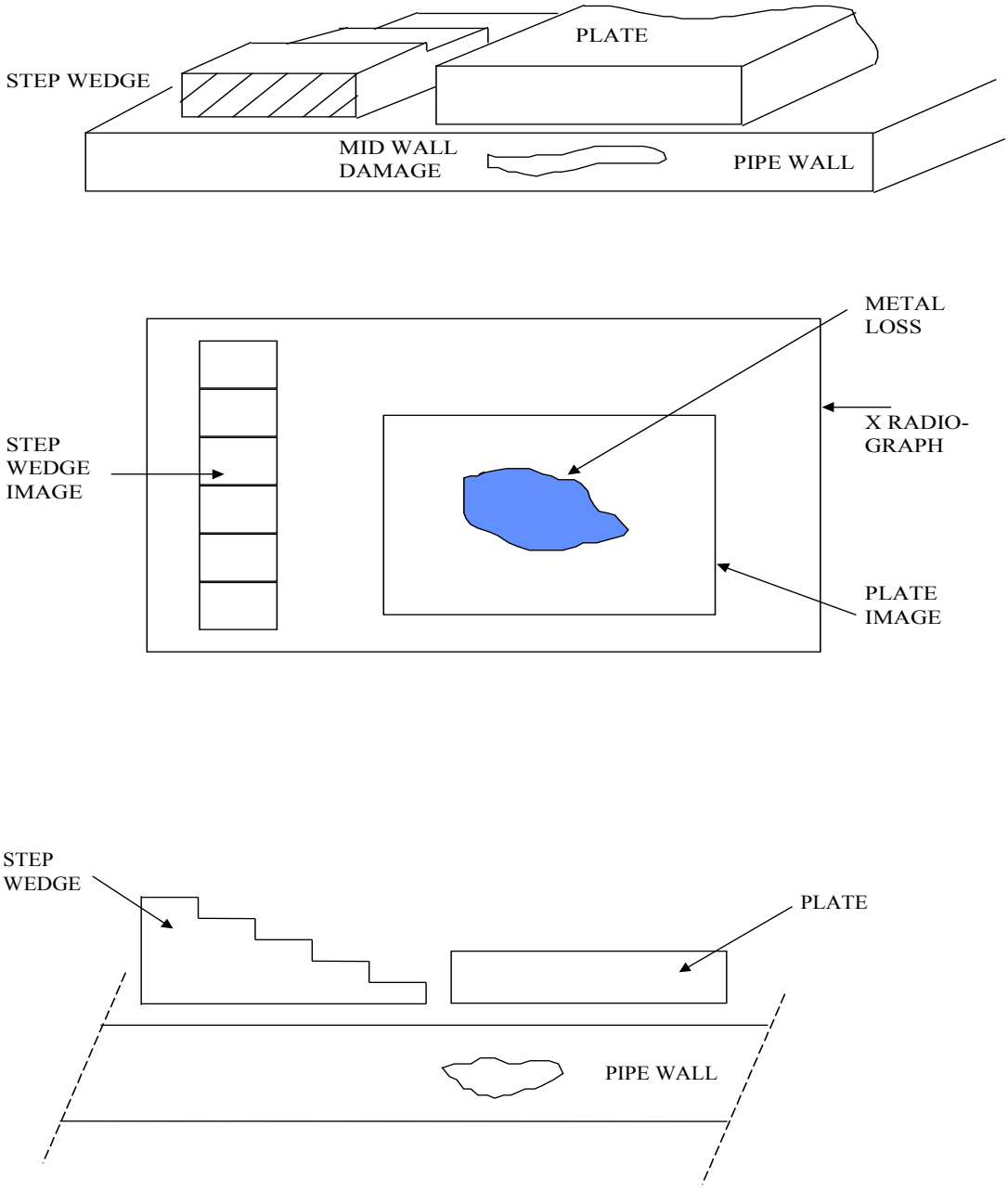


Figure 3: Typical Arrangement for X-ray Technique

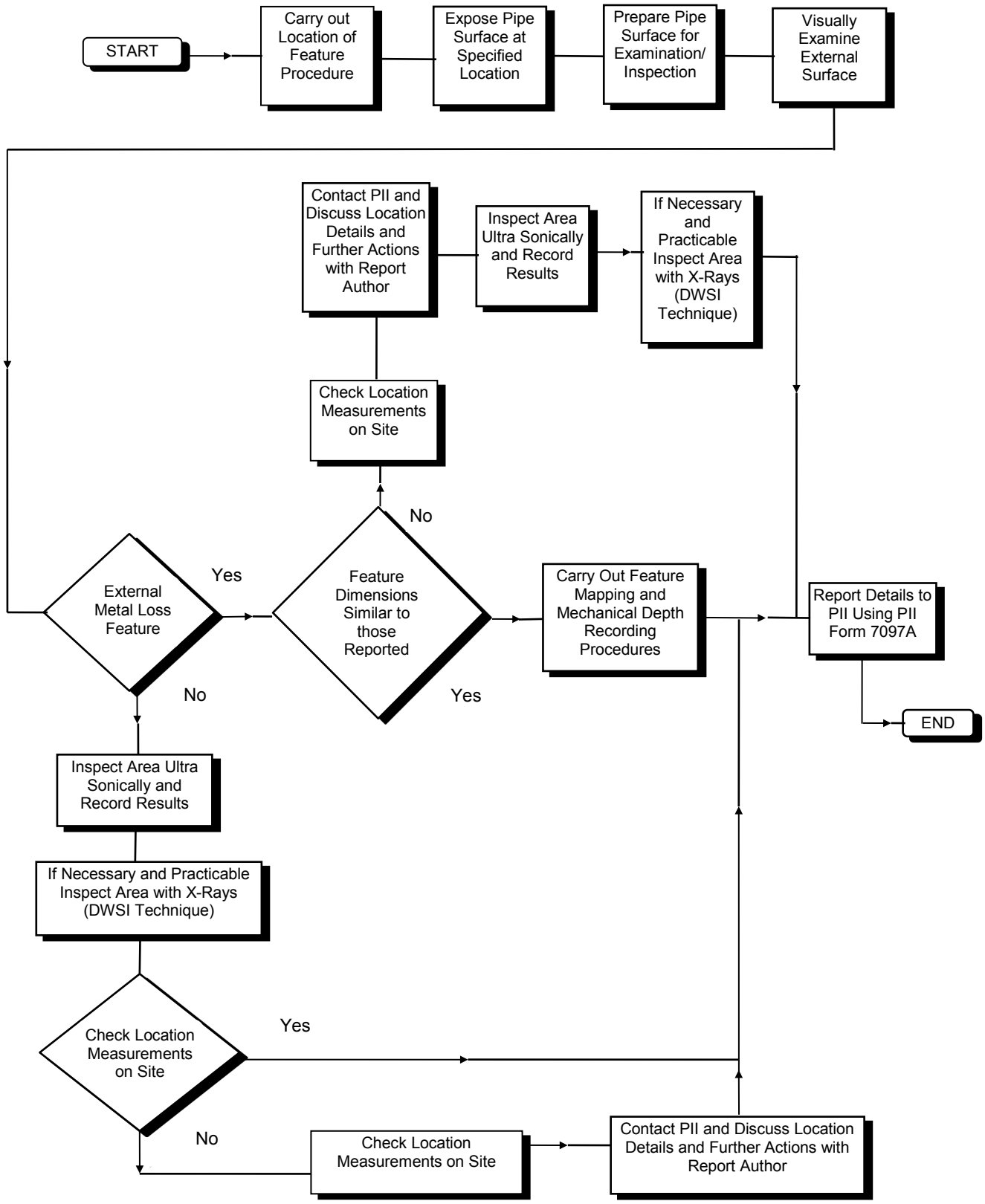


Figure 4: Procedure for Inspecting and Recording Reported Metal Loss Features - Simplified Flow Diagram

PIPELINE DAMAGE RECORD

7097A
Oct 18/93

1. LOCATION OF DAMAGE

PIPELINE START: .....Somewhere Launch..... END: .....Somewhere Receive.....

FEATURE IDENTITY (PII) - REPORT NUMBER: ..SR 192..... INSP SHEET NO: ....3.....

FEATURE TYPE: General Corrosion ☒ Isolated Pit ☐ Gouge ☐ Manufacturing (Mill) ☐

Other: .....

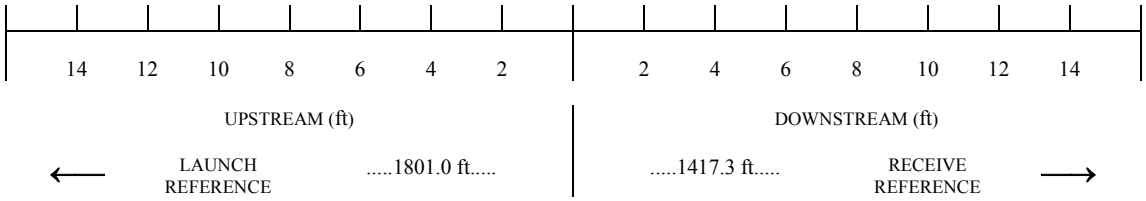
MEASURED WALL THICKNESS: .....0.361in.....

2. FEATURE DIMENSIONS

PII FEATURE NO.	EXACT POSITION UPSTREAM OR DOWNSTREAM OF REF. GIRTH WELD (ft)	ORIENTATION (o'clock)	AXIAL LENGTH (in)	CIRC'L WIDTH (in)	DEPTH	
					AVERAGE in% WT	PEAK in% WT
3/1	4.25 ft down	4.45	2.6	3.2		0.13
3/2	5.10 ft down	4.45	4.1	5.0		0.15
3/3	7.5 ft down	2.45	0.8	0.9		0.28

3. PLAN DIAGRAM OF SPOOL

CLOCK POSITION	REF GIRTH WELD
6 BOTTOM	.....
7	.....
8	.....
9	.....
10	.....
11	.....
12 TOP	.....
1	.....
2	.....3/3.....
3	.....+.....
4	.....3/1.....3/2.....
5	.....+.....+.....
6 BOTTOM	.....



NOTE: FOR COMPLEX FEATURES PLEASE ATTACH A 'RUBBING' OR SKETCH WITH DIMENSIONS AND DEPTHS IDENTIFIED.

RUBBING ATTACHED ☐ SKETCH ATTACHED ☐

DATA OF SITE INSPECTION: ..... SIGNATURE: .....

Figure 5: Example of completed Pipeline Damage Record Form (7097A)

PIPELINE DAMAGE RECORD

7097A
Oct 18/93

1. LOCATION OF DAMAGE

PIPELINE START: ..... END: .....

FEATURE IDENTITY (PII) - REPORT NUMBER: ..... INSP SHEET NO: .....

FEATURE TYPE: General Corrosion ☐ Isolated Pit ☐ Gauge ☐ Manufacturing (Mill) ☐

Other: .....

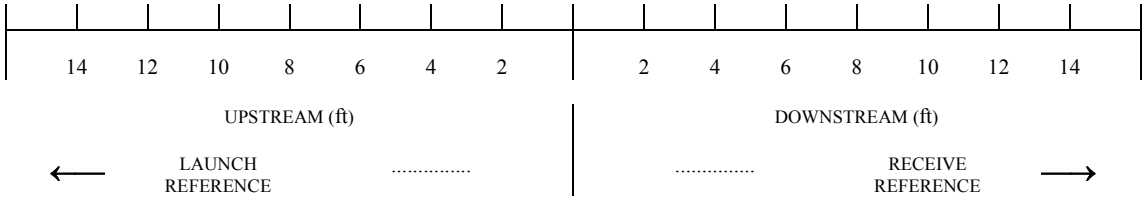
MEASURED WALL THICKNESS: .....

2. FEATURE DIMENSIONS

PII FEATURE NO.	EXACT POSITION UPSTREAM OR DOWNSTREAM OF REF. GIRTH WELD (ft)	ORIENTATION (o'clock)	AXIAL LENGTH (in)	CIRC'L WIDTH (in)	DEPTH	
					AVERAGE in% WT	PEAK in% WT

3. PLAN DIAGRAM OF SPOOL

CLOCK POSITION	REF GIRTH WELD
6 BOTTOM	.....
7	.....
8	.....
9	.....
10	.....
11	.....
12 TOP	.....
1	.....
2	.....
3	.....
4	.....
5	.....
6 BOTTOM	.....



NOTE: FOR COMPLEX FEATURES PLEASE ATTACH A 'RUBBING' OR SKETCH WITH DIMENSIONS AND DEPTHS IDENTIFIED.

RUBBING ATTACHED ☐ SKETCH ATTACHED ☐

DATA OF SITE INSPECTION: ..... SIGNATURE: .....

Appendix C. Operational Details

Contract Number	436881_20B
Operator	Enbridge Energy Limited Partnership
Launch Site	Straits of Mackinac - West Leg
Receive Site	
Inspection Run	
Date of Operation	27 August 2013
Duration of Run	0 hours 39 minutes
Data Recorded	0.00 miles to 4.13 miles
Inspection Modules	MV: 620 T2: 679 BV: 636 REC: 45
Processor Pack	020 PK/19

Appendix D. Pipeline Details

Contract Number	436881_20B
Date of Pipeline Commission	1953
Pipeline Outside Diameter	20 inches nominal
Product	Crude Oil
Pipeline Length (Client Data)	4.15 miles
Pipeline Length (PII Data)	4.13 miles
API Grade	B
Predominant Pipe Type	Seamless
Previous PII Inspection	109170_20A (MFL - May 2008)

The nominal wall thickness listing, presented in Section 2.2.8, provides a list of the major and minor pipeline segments.

The listing identifies the locations of the start and end of each segment and the values of the nominal wall thickness (nwt) and the SMYS that apply within it.

Appendix E. Additional Services

As a complement to the inspection service PII Pipeline Solutions can offer the following:

- Assessment

  This involves an Integrity Assessment which relates the severity of any defects reported by the inspection to the required future operating conditions of the pipeline. At PII Pipeline Solutions we have a dedicated team of engineers who have:

  - successfully conducted over 60 commercial consultancies for major oil and gas companies world-wide;
  - pioneered new integrity assessment methods now accepted by Regulatory Authorities (which have been included in pipeline codes); and
  - initiated and conducted extensive pipeline research.

- Repair

  Specialist repair services can be provided based on proven technologies established to support British Gas' 11000 miles pipeline transmission system. The repair team have extensive experience of operating a pipeline repair service, including work for many clients in Europe and the Middle East.

Appendix F. Pipeline Inspection Report Specification

The contents of the pipeline inspection report and the selection rules for selecting individual metal loss features for detailed analysis and reporting are specified in the Specification for the Pipeline Inspection Report, a copy of which is provided overleaf.

SCHEDULE 5 (Enbridge Version)

PIPELINE INSPECTION REPORT

MAGNESCAN™

For the Pipeline the subject of this Contract the Pipeline Inspection Report shall comprise:

1. **Preliminary Assessment Report**

2. **Metal Loss Feature Report**

    2.1 Inspection Sheets
    2.2 Colour Plots of data
    For a number of the worst metal loss features; manually analyzed and selected against pre-defined selection rules.

3. **Pipeline Summary Report**

    (a) Metal Loss Information

    3.1 Sentenced Plots
    3.2 Pressure Based Histograms
    3.3 Depth Based Histograms
    3.4 Orientation Plot
    3.5 Severity Table

    (b) Pipeline Information

    3.6 Velocity Plot
    3.7 Metal Object Report
    3.8 Eccentric Casing Report
    3.9 Dent Report
    3.10 Girth Weld Anomaly Report
    3.11 Repair Listing
    3.12 Location Reference Points Listing
    3.13 Nominal Wall Thickness Listing

    (c) Summary

    3.14 Pipeline Listing

4. **PipeImage™ Inspection Data Software**

In addition to detailing the Report, this Schedule also contains:

APPENDIX 1 – Definition of Terms

APPENDIX 2 – Interaction Rules

APPENDIX 3 – Software Licensing

1. Preliminary Assessment Report

At the Company's request, a Preliminary Assessment Report will not be provided. Instead, during the course of data analysis, the Contractor will notify the Company of any feature assessed to be greater than 50% on an as discovered basis.

The Contractor will ensure that accurate feature location information is supplied when informing the Company of any feature of concern.

2. Metal Loss Feature Report

The Contractor will provide for each Component Line, a Metal Loss Feature Report comprising up to a maximum of fifteen (15) Inspection Sheets describing the severity, type, size and location of individual Metal Loss Features, all in accordance with those parameters set out in the Inspection Performance Specification.

If due to high levels of metal loss in the Pipeline the Company requires Inspection Sheets in excess of said maximum the Company may select additional Metal Loss Features and the Contractor shall report on such Metal Loss Features at additional charge.

2.1 Inspection Sheets

(a) Inspection Sheets will be prepared employing detailed examination and analysis techniques, for those sentenced metal loss features (or identified Manufacturing Faults) selected for detailed reporting using the Selection Rules listed below. The information contained within a typical Inspection Sheet is as follows:

(i) **Metal Loss Feature Description**

1. Internal/external characterization
2. Orientation of Metal Loss Feature viewed in the direction of the flow
3. Axial length, circumferential width, peak and where appropriate, average depth of the Metal Loss Feature, to the accuracy specified in the Inspection Performance Specification
4. Indication of Pressure Sentenced Ratio
5. Selection Rule Number
6. Nominal wall thickness of the pipe spool as advised by the Company
7. Distance from start of the Component Line to the Metal Loss Feature (absolute distance)
8. Comment of the general nature of the Metal Loss Feature and the existence of any nearby metal loss

(ii) **Metal Loss Feature Location**

1. Relevant strip map number, if available
2. Definition of at least one primary reference point on the Component Line which can be used to locate the Metal Loss Feature
3. Definition of the reference girth weld as the nearest upstream girth weld to the Metal Loss Feature
4. Distance between the reference girth weld and the primary reference points to the accuracy specified in the Inspection Performance Specification
5. Distance between the Metal Loss Feature and the reference girth weld (relative distance) to the accuracy specified in the Inspection Performance Specification
6. Length of the spool containing the Metal Loss Feature, the length of the two adjacent spools both upstream and downstream from the Metal Loss Feature spool and if visible, the orientation of the seam welds in each of the spools

(b) Selection Rules, for detailed reporting of Metal Loss Features on Inspection Sheets, will be selected according to the following:

Rule 1 - The 3 (three) most significant Metal Loss Features with Pressure Sentenced Ratio less than 1.0
Rule 2 - Metal Loss Features with peak depth greater than 80% wall penetration (0.8t)
Rule 3 - Metal Loss Features with a Pressure Sentenced Ratio less than 0.8
Rule 4 - Metal Loss Features with a Pressure Sentenced Ratio between 0.8 and 1.0
Rule 5 - Metal Loss Features with a Pressure Sentenced Ratio less than 1.05 (providing always that such Metal Loss Features are above the Inspection reporting parameters set out in the Inspection Performance Specification)
Rule 6 - Metal Loss Features with a peak depth greater than 60% wall penetration (0.6t)
Rule 7 - Metal Loss Features with a peak depth greater than 40% wall penetration (0.4t)
Rule 8 - Metal Loss Features with a peak depth greater than 20% wall penetration (0.2t)
Rule 9 - Metal Loss Features with a peak depth greater than 10% wall penetration (0.1t) and whose length is greater than 3 times the wall thickness

Some of the Metal Loss Features reported may fall below the Inspection Performance Specification and therefore the Inspection Performance Specification may not apply to the sizing of such Metal Loss Features.

(c) Initially reporting of Metal Loss Features will be limited to not more than 1 (one) per pipe spool. If due to low numbers of corroded pipe spools, the specified maximum number of Metal Loss Features to be separately reported upon has not been achieved for each Component Line then the one Metal Loss Feature per pipe per spool rule will be relaxed. The Selection Rules will then be reactivated such that so far as is possible, the balance of the Metal Loss Features up to the maximum specified are selected for inclusion on Individual Inspection Sheets.

(d) If due to low levels of detected metal loss within the Pipeline, the maximum number of Metal Loss Features to be separately reported upon for each Component Line has not been achieved subsequent to the reporting of Rule 10 Features, then those Manufacturing Faults identified in the Pipeline Listing shall be selected for reporting. This shall be on a one per pipe spool basis. The Inspection Performance Specification may not apply to the sizing of such Manufacturing Faults.

(e) In the event that subsequent to (b), (c) and (d) above, the maximum number of Inspection Sheets to be provided for each Component Line has not been achieved, the Contractor shall have no obligation to report further save that where no Metal Loss Features or Manufacturing Faults are selected under the Selection Rules, the Contractor shall select one (1) low level metal loss instance for reporting. The Inspection Performance Specification may not apply to the sizing of such low level metal losses.

2.2 Colour Plots

Accompanying each Inspection Sheet are two pictorial representations of the magnetic response derived from the Metal Loss Feature.

In both cases the pictorial representations of Metal Loss Feature are as viewed from outside the pipe with the upstream end being on the left. The vertical (y) axis is annotated with o'clock orientation as viewed in the direction of flow (at the time of the inspection). The horizontal (x) axis is annotated with the absolute distance measured from the launch.

The Overview Plot (monochrome) shows the magnetic response of the full circumference of the pipe for a length of approximately one spool to give the context of the Metal Loss Feature reported on the Inspection Sheet. To assist the Company in identifying the areas of metal loss it is shaded as if illuminated from the left side of the plot.

The Detailed Contour Plot (colour) is approximately centered on the Metal Loss and identifies the relative magnitudes of the magnetic responses in this area. The magnitude of the magnetic responses is represented by designated colours, with common magnitudes having common colours. Due to the behaviour of this magnetic response, the plot will not normally, provide a true representation of the physical profile of the Metal Loss Feature. The aspect ratio and zoom will be chosen to produce an appropriate image with the Metal Loss Feature being displayed to a higher magnification than in the Overview Plot.

3. Pipeline Summary Report

The Pipeline Summary Report provides an overview of the detected metal loss and other pipeline anomalies within each Component Line. Metal Loss Features, which during the process of selection have undergone detailed processing and analysis will be highlighted on the Pipeline Listing and the sizing accuracy specified in the Inspection Performance Specification will apply to all such Metal Loss Features (excluding identified Manufacturing Faults).

Otherwise than aforesaid, the processes used to size the Metal Loss Features in the Pipeline Summary Report do not include the detailed examination and analysis

employed when reporting Metal Loss Features on Inspection Sheets and hence, the sizing accuracy contained in the Inspection Performance Specification does not apply to the Pipeline Summary Report.

The Pipeline Summary Report shall comprise the following:

(A) Metal Loss Information:

3.1 Sentenced Plots
3.2 Pressure Based Histograms
3.3 Depth Based Histograms
3.4 Orientation Plot
3.5 Severity Table

(B) Pipeline Information:

3.6 Velocity Plot
3.7 Metal Object Report
3.8 Eccentric Casing Report
3.9 Dent Report
3.10 Girth Weld Anomaly Report
3.11 Repair Listing
3.12 Location Reference Points Listing
3.13 Nominal Wall Thickness Listing

(C) Summary

3.14 Pipeline Listing

3.1 Sentenced Plots

A Sentenced Plot will be produced for each Major Segment of each Component Line (as detailed by the Company). This will show sentenced depth versus length for all detected Metal Loss Features (excluding identified Manufacturing Faults) and includes the curve for a Pressure Sentenced Ratio of unity also defined in the Appendix. Metal Loss Features detected in Minor Segments identified within the Major Segment of any Component Line will be represented separately on the Sentenced Plot.

3.2 Pressure Based Histograms

A histogram will be provided indicating the number of occurrences of Pressure Sentenced Metal Loss Features (excluding identified Manufacturing Faults) per unit distance against absolute distance along each Component Line. Such Pressure Sentenced Metal Loss Features will be graded into bands according to severity. Additionally, a three-dimensional histogram will be provided showing the metal loss distribution for each of the pre-selected graded bands along each Component Line

3.3 Depth Based Histograms

The Depth Based Histograms show the number of occurrences of detected Metal Loss Features and identified Manufacturing Faults against absolute distance along each Component Line, presented in the following formats:

(i) All detected Metal Loss Features against absolute distance along each Component Line.

(ii) Total area of metal loss expressed as a percentage of surface area of Component Line against absolute distance.

(iii) Total volume of metal loss expressed as a percentage of pipe wall volume, against absolute distance.

(iv) Short Metal Loss Features i.e. Metal Loss Features with axial length < 3t graded into bands according to peak depth.

(v) Long Metal Loss Features i.e. Metal Loss Features with axial length > 3t graded into bands according to peak depth.

(vi) The distribution of detected metal loss graded into bands according to peak depth. This will be provided on a three dimensional histogram.

3.4 Orientation Plot

This plot shows all the instances of Metal Loss Features and identified Manufacturing Faults detected over the total length of each Component Line and indicates the orientation of the metal loss viewed in the direction of flow, against the absolute distance along the Component Line. The Orientation Plot is colour coded to show the depth grading of the Metal Loss Feature as reported in the Depth Based Histogram. Internal/external distribution can be viewed on the Orientation Plot contained in PipeImage™ Inspection Data Software.

3.5 Severity Table

The Severity Table comprises a list of pipe spools indicating the Pressure Sentenced Ratio, peak depth and axial length of the most severe Metal Loss Feature (excluding identified Manufacturing Faults) within each spool. These Metal Loss Features are selected in accordance with the Selection Rules detailed in Paragraph 2.1.(b) and listed in descending order of severity.

The Severity Table includes all pipe spools containing a Metal Loss Feature with Pressure Sentenced Ratio less than or equal to unity.

In the event that there are less than 25 (twenty five) pipe spools containing a Metal Loss Feature with Pressure Sentenced Ratio equal to or less than unity, the balance up to 25 shall be made up of the most severe of the remaining pipe spools.

The Severity Table shall contain the following:

(a) Pressure Sentenced Ratio of the Metal Loss Feature calculated in accordance with the Appendix

(b) Peak Depth and axial length of the Metal Loss Feature

(c) Weld number of nearest upstream girth weld

(d) Distance from the start of the Component Line (absolute distance)

(e) Orientation of the Metal Loss Feature viewed in the direction of the flow

3.6 Velocity Plot

This plot indicates the Inspection Vehicle velocity against absolute distance along the Component Line

3.7 Metal Object Report

The following information will be provided for all ferrous metal objects detected in proximity to a Component Line:

(a) Number of nearest upstream girth weld from the metal object

(b) Distance of metal object from the nearest upstream girth weld (relative distance) to the accuracy set out in the Inspection Performance Specification

(c) Distance of metal object from the start of the Component Line (absolute distance)

(d) Proximity classification (i.e. close or touching). Those metal objects classified as ‘touching’ may in the Contractor’s opinion, have interfered with the coating or cathodic protection of the Component Line

(e) Orientation of detected metal object viewed in the direction of the flow

(f) Identification of nearest upstream location reference point

(g) Distance of upstream location reference point from nearest upstream girth weld to the accuracy set out in the Inspection Performance Specification

(h) Identification of nearest downstream location reference point

(i) Distance of downstream location reference point from nearest upstream girth weld to the accuracy set out in the Inspection Performance Specification

3.8 Eccentric Casing Report

Where a casing is considered by the Contractor to be so eccentric as to affect the carrier protective coating or the cathodic protection system the following information will be provided:

(a) Number of nearest upstream girth weld from the start of the casing

(b) Distance from nearest upstream girth weld to upstream end of casing (relative distance) to the accuracy set out in the Inspection Performance Specification

(c) Distance from the start of the Component Line to the upstream end of the casing (absolute distance)

(d) Category of position (i.e. start, end or intermediate)

- upstream end
- downstream end
- ends of unconnected spools making up the casing, if appropriate

(e) Comment as to whether the point of minimum separation of the casing so affected is 'close' or 'touching'

(f) Comment as to whether corrosion has been detected within the casing

(g) Length of casing (relative distance from start of casing)

(h) Comment on the identity of the casing and a statement as to whether the affected casing is associated with a road/railway crossing.

(i) Orientation of the point of minimum separation between the casing and the carrier pipe

3.9 Dent Report

All dents detected by the Inspection System will be reported upon in the following format:

(a) Number of nearest upstream girth weld from dent

(b) Distance of dent from nearest upstream girth weld (relative distance) to the accuracy set out in the Inspection Performance Specification

(c) Distance of dent from the start of the Component Line (absolute distance)

(d) Indication of presence of associated metal loss

(e) Indication of presence of associated girth weld

(f) Indication of presence of associated seam weld

(g) Orientation of dent viewed in the direction of the flow

(h) Identification of nearest upstream location reference point

(i) Distance of upstream location reference point from nearest upstream girth weld to the accuracy set out in the Inspection Performance Specification

(j) Identification of nearest downstream location reference point

(k) Distance of downstream location reference point from nearest upstream girth weld to the accuracy specified in the Inspection Performance Specification

3.10 Girth weld Anomaly Report

The following information shall be provided for all girth weld anomalies detected by the Inspection System:

(a) The number of the girth weld in which the anomaly occurs

(b) Distance of girth weld from the start of the Component Line (absolute distance)

(c) Indication of the type of girth weld anomaly (e.g. crack, incomplete weld, dressing repairs etc.

(d) Estimated circumferential extent of the girth weld anomaly

(e) Orientation of detected girth weld anomaly viewed in the direction of the flow

(f) Identification of nearest upstream location reference point

(g) Distance of upstream location reference point from the nearest upstream girth weld to the accuracy specified in the Inspection Performance Specification

(h) Identification of nearest downstream location reference point

(i) Distance of downstream location reference point from nearest upstream girth weld to the accuracy specified in the Inspection Performance Specification

3.11 Repair Listing

The following information shall be provided for all repair shells (i.e. full circumferential, snug fitting, welded or epoxy filled, or repair clamps) or spools containing repair patches detected by the Inspection System:-

(a) Number of nearest upstream girth weld from the start of the repair shell or the spool containing the repair patch(es)

(b) Distance from nearest upstream girth weld to upstream end of repair shell (relative distance) to the accuracy specified in the Inspection Performance Specification

(c) Distance from the start of the Component Line to the upstream end of the repair shell or the spool containing the repair patch(es) (absolute distance)

(d) Comment as to whether the repair is a shell or a patch-repair spool

(e) Length of repair shell

NB: Metal loss detected under repair shells and repair patches shall not be included in the reports, which comprise the Pipeline Summary Report.

3.12 Location Reference Point Listing

To assist in the location of features the Contractor shall detail the location of reference points such as timer boxes, magnets and/or anodes, valves and major offtakes (i.e. offtakes >50% of Component Line nominal bore), and shall provide the following information:

(a) Number of nearest upstream girth weld from reference point

(b) Distance of reference point from nearest upstream girth weld (relative distance)

(c) Distance of reference point from the start of the Component Line (absolute distance)

(d) Indication of the presence of a reference point

(e) Magnet/timerbox/anode identification number

(f) Mile Post value for location points as supplied by the Company

Additionally, the Contractor shall provide a separate listing containing the reference point identification number from the above listing against which a description of the above ground geographical location of each such reference point shall be provided, when available.

3.13 Nominal Wall Thickness Listing

All pipe spool nominal wall thickness changes detected by the Inspection System will be reported in the following format:

(a) The number of the girth weld at which the change in the pipe spool nominal wall thickness occurs

(b) Distance of the girth weld from the start of the Component Line (absolute distance)

(c) Distance from the girth weld to the next identified pipe spool nominal wall thickness change (length)

(d) Nominal wall thickness of the spools downstream from the girth weld

(e) Segment Number which also gives an indication as to whether the spools are in Major or Minor Segments

(f) SMYS value as supplied by the Company

3.14 Pipeline Listing

The Pipeline Listing will provide a comprehensive overview of all detected features along the length of the pipeline, including girth welds, fittings, metal loss features, identified manufacturing faults, metal objects, casings, dents, girth weld anomalies, repair shells, location reference points, and nominal wall thickness changes. This will include the following information:

(a) Girth weld number

(b) Distance from the nearest upstream girth weld (relative distance) to the current listing item (provided such information can be reliably identified)

(c) Distance from the start of the Component Line to the current listing item (absolute distance)

(d) Description of the current listing item

(e) Peak depth of Metal Loss Feature or Manufacturing Fault

(f) Axial length of Metal Loss Feature or Manufacturing Fault

(g) Pressure sentenced ratio of the Metal Loss Feature calculated in accordance with the Appendix

(h) Orientation of detected Metal Loss Feature, Manufacturing Fault, metal object, dent, girth weld anomaly or major offtake viewed in the direction of the flow. For welds this will show orientation of seam weld (when visible) or start and end orientation of spiral weld on the downstream spool.

4. PipeImage™ Inspection Data Software

4.1 The PipeImage™ Inspection Data Software will be supplied on CD-ROM and will include all the information contained within the Pipeline Inspection Report.

4.2 PipeImage™ Inspection Data Software provides the following user features:

(i) Data Display
- Menu driven command interface in Windows environment
- Icon driven pipeline data navigation and report generation
- Graphical Mainview report window
- Graphical display of inspection data in multiple formats including “Grey Scale”
- Pipeline overview window
- Pipeline zoom and pan
- Graphical representation of feature boxes and clusters
- User defined annotation of areas of features and other interest

(ii) Pipeline Listing
- User defined reports
- Pipeline feature search and go to
- Data filtering and sorting
- Interactive listings and graphical reports

(iii) Reporting
- Sentenced Plots
- Re-sentencing with variable pipeline and pressure parameters
- Pressure and Depth Based Histogram
- Metal Loss Plot
- Velocity Plot
- Inspection/Dig sheet generation
- Report Browser Utility

(iv) Utilities
- PipeImage™ Inspection Data Software -set up program
- Data export tool
- Online Help
- Suitable for installation on a network

4.3 The Contractor hereby grants to the Company the perpetual right to use the PipeImage™ Inspection Data Software save that all patent, copyright and other intellectual property rights embodied in the PipeImage™ Inspection Data Software shall remain vested in the Contractor. The Company hereby agrees that it shall not cause or permit the reverse engineering, disassembly or de-compilation of the PipeImage™ Inspection Data Software and shall keep confidential information relating to the processes and/or programs employed in the aforementioned software

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APPENDIX 1

MAGNESCAN™ - PIPELINE INSPECTION REPORT

1. Definition of Terms

1.1 Metal Loss Feature

The term Metal Loss Feature is used to describe an occurrence of metal loss detected by the Inspection System. Where an occurrence of metal loss has been recognized to be “distinct”, a box will be drawn around the Metal Loss Feature, which will be used to describe the boundary of the metal loss by its axial length and circumferential width. For isolated Metal Loss Features “distinct” means that the metal loss levels surrounding the box are below the reporting levels set out in the Inspection Performance Specification. For more complex areas of metal loss where pitting occurs within an area of general metal loss “distinct” shall mean that the metal loss level surrounding the box is significantly lower than that of the box.

Within areas of Pipeline where general corrosion has been detected, background metal loss below the reporting threshold of the Inspection System is commonly found to surround the boxed Metal Loss Feature. To ensure that the Company is made aware of all Metal Loss Features, which could pose a threat to the integrity of the Pipeline, the Contractor adopts a conservative approach to such areas of general corrosion by the application of signal clustering rules. Where the Contractor considers two or more boxed Metal Loss Features in close proximity may reasonably be joined by background metal loss, these will be combined and classified as a “cluster”. The dimensions of the resulting cluster will be described by the peak depth, axial length and circumferential width.

1.2 Manufacturing Fault

A Manufacturing Fault is an occurrence of metal loss detected by the Inspection System, which has been assessed as having been caused during the manufacture of the line pipe/Component Line prior to commissioning/hydrostatic testing. It will be either,

(a) a single isolated box, or
(b) a cluster

The profile and surface texture of some Manufacturing Faults may make it difficult during analysis of the inspection data, to distinguish between a Manufacturing Fault and metal loss caused for example by corrosion. However, such faults should have been subject to the hydrostatic test during commissioning of the Pipeline and therefore should pose no threat to the integrity of the Pipeline.

1.3 Interaction Rules

The Interaction Rules are intended to represent the physical interaction between areas of metal loss (boxes). The Interaction Rules to be used in the compilation of the Pipeline Inspection Report are as follows;

Feature boxes, regardless of reported depth, will "interact" if they are separated by no more than 6 wall-thicknesses (6t) both axially and circumferentially. Each set of interacting boxes will be "clustered".

1.4 Pressure Sentenced Ratio

The Pressure Sentenced Ratio expresses the severity of the Metal Loss Feature. This is calculated below as RPR085. The more severe the Metal Loss Feature, the lower the Pressure Sentenced Ratio.

$S =$ Hoop stress level at failure

$$A = \frac{L^2}{Dt}$$

If the value of A is greater than 50

$$M_{085} = 3.3 + 0.032A$$

If the value of A is less than or equal to 50

$$M_{085} = \sqrt{1 + 0.6275A - 0.003375A^2}$$

$$T = \frac{1 - \frac{0.85d_{\%}}{100}}{1 - \frac{0.85d_{\%}}{100M_{085}}}$$

$$S = F_{stress}T$$

$$\text{RPR085} = \frac{S}{SMYS}$$

d	=	Sentenced Depth = Peak depth of the cluster.
t	=	Nominal wall thickness of pipe for each Component Line Major segment as defined in Paragraph 1.5 (page 4 of 4).
L	=	Axial length of the Cluster. Note the individual metal loss boxes will have been clustered according to the specified Interaction Rules of Appendix 2.
D	=	Nominal outside diameter of the pipe.

1.5 Company Defined Operating Parameters

Pressure Sentenced calculations may be varied for each identifiable segment of a Component Line to suit different operating parameters as required. The Company shall define such Major Segments and the appropriate operating parameters in the table below prior to Contract signature or as soon as possible thereafter.

In the event that the operating parameters have not been so defined by the Company, the Contractor shall perform Pressure Sentenced calculations using the following default parameters:

(a) The design pressure and MAOP will be assumed to be the same pressure and the same pressure will apply to all Major Segments. This provides for a conservative evaluation of any Metal Loss Feature in relation to Pipeline safety.

(b) The wall thickness in Major and Minor Segments (t and t' respectively) will be derived from the inspection data and where appropriate cross checked against previous inspection data or other data provided by the Company.

Component Line

Major Segment	START	FINISH	P_i kpa/psi	t mm/ins	SMYS Kpa/psi	MAOP kpa/psi	Minor Segment t' mm/ins
1	Launch to						
2							
3							
4							
5		Receive to					

P_i = Internal Design Pressure
t = Nominal Wall Thickness of Pipe (Major Segment)
MAOP = Maximum Allowable Operating Pressure or Company chosen Operating Pressure
SMYS = Specified Minimum Yield Stress
t' = Nominal Wall Thickness of Pipe within a Minor Segment where it is known to vary from t (e.g. road, river crossings etc.)

Those Major Segments of the Component Line listed by the Company above will be subdivided into Minor Segments in the event that the Contractor identifies areas of the Major Segment containing line pipe with Nominal Wall Thickness which varies significantly to that stated by the Company (e.g. road or river crossings, repair sections etc.).

For Minor Segments, the Contractor shall use either the appropriate Minor Segment wall thickness (t') supplied in the table above or the appropriate API wall thickness that is most consistent with the inspection data.

In the absence of any other information from the Company (strip maps, pipe listings etc.), the Contractor shall assume the Major Segment pressure parameters (P_i, MAOP) for the Minor Segments.

Pressure Sentenced Calculations shall be produced for each Metal Loss Feature in such Minor Segments on this basis.

This additional information relating to the wall thickness in Minor Segments shall be provided in the Nominal Wall Thickness Listing. Detailed sentenced plot data for Minor segments will be presented in the PipeImage™ Inspection Data Software report only.

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APPENDIX 2

MAGNESCAN™ - PIPELINE INSPECTION REPORT

Interaction Rules

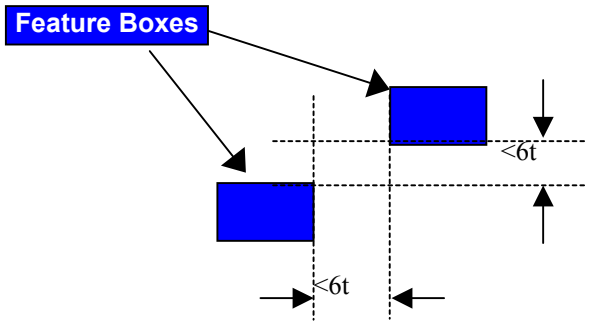
The Interaction Rules are intended to represent the physical interaction between areas of metal loss (boxes). The Interaction Rules to be used in the compilation of the Pipeline Inspection Report are as follows:

(i) Feature boxes will "interact" if their axial separation and their circumferential separation are both no more than 6 wall-thicknesses (6t).

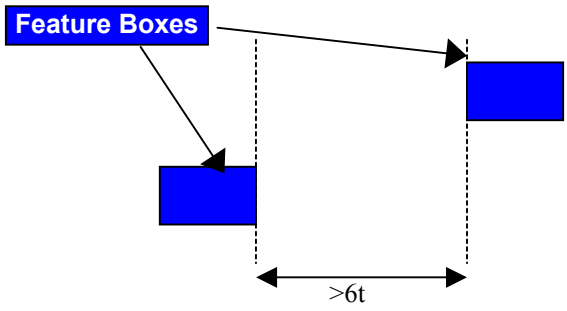
(ii) A set of interacting boxes will form a "cluster"

An example is as follows:

Example of Feature Boxes that Interact



Example of Feature Boxes that Do Not Interact



Feature Boxes must be within 6 Wall Thicknesses (6t) in both directions.

A cluster of pits situated across a girth weld shall be considered to be continuous (i.e. girth welds do not prevent interaction).

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APPENDIX 3

MAGNESCAN™ - PIPELINE INSPECTION REPORT

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Appendix G. Inspection System Performance Specification

The pipeline inspection system employed by PII Pipeline Solutions has been designed to carry out a genuine high resolution pipeline inspection.

The performance capabilities of the inspection system are defined in the Inspection System Performance Specification, a copy of which is provided overleaf:

SCHEDULE 5

THE INSPECTION PERFORMANCE SPECIFICATION

1. Introduction

The Contractor's Inspection Vehicles have been specifically designed to ensure high resolution inspection of the full circumferential extent of the Pipeline and the detection of metal loss occurrences therein.

Inspection data obtained during the Inspection Vehicle run(s) in the Pipeline is subjected to a two stage processing and analysis procedure.

During Stage 1, preliminary processing and analysis is performed using the Contractor's automatic data analysis facilities. All Metal Loss Features detected by the Inspection System irrespective of depth or surface dimension are automatically sized and are reported together with Pipeline Anomalies and Pipeline Fittings, in the Pipeline Summary Report detailed in Schedule 5. The analysis systems employed during this stage are specifically designed such that all Metal Loss Features which may be of concern to the integrity of the Pipeline are highlighted and are selected for more detailed processing and analysis, subject to the maximum number of Features specified in Schedule 5.

During Stage 2, the most significant Metal Loss Features identified in Stage 1 are selected using the priority rules detailed in Schedule 5, for more detailed processing and analysis and reported on Individual Inspection Sheets. Those Metal Loss Features that have undergone such detailed processing and analysis shall be sized to the accuracy detailed in section 4 below.

The Contractor's Inspection Vehicles together with the aforementioned data processing and analysis comprise the Contractor's Inspection System.

2. Detection Capability

The capability of the Contractor's Inspection System, which applies irrespective of the type of pipeline construction (i.e. seamless, seamwelded, spiral etc.), is such that the following types of feature present in the pipeline can be detected:

(a) Metal loss

(i) associated with corrosion, including
- such metal loss in the vicinity of girth welds
- such metal loss associated with dents
- such metal loss situated beneath casings

(ii) associated with gouging

All such metal loss of depth and surface dimension greater than the minimum required for accurate sizing as detailed in Table 1 shall be detected. Metal loss below such depth and surface dimension can be detected. However, the probability of detection is reduced as the depth and surface dimension of the feature is reduced.

(b) Metal loss situated beneath repair clamps

(c) Metal loss associated with manufacturing faults

(d) Welds - girth, seam and spiral

(e) Girth weld anomalies including circumferential cracks within girth welds

(f) Dents

(g) Manufacturing/mill type defects

(h) Construction damage

(i) Changes in nominal pipe wall thickness

(j) Pipeline fixtures and fittings including:
- (i) Tees
- (ii) Offtakes
- (iii) Valves
- (iv) Bends
- (v) Anodes
- (vi) Buckle Arrestors
- (vii) External Supports
- (viii) Ground Anchors
- (ix) Repair Shells
- (x) CP Connections - ferro-magnetic type

(k) Ferrous metal objects in close proximity to the pipeline considered likely to affect the carrier protective coating or cathodic protection system.

(l) Casings, including eccentric casings where the degree of eccentricity is considered likely to affect the carrier protective coating or cathodic protection system.

(m) Reference marker magnets

3. Location Accuracy

3.1 All those features detailed in section 2 detected by the Inspection System shall be located to the accuracy detailed in Table 1.

4. Sizing Accuracy

4.1 Those Metal Loss Features as detailed in section 2.(a) detected by the Inspection System and which have been selected for reporting on Individual Inspection Sheets shall subject to section 4.2, be sized to the accuracy detailed in Table 1 attached hereto.

4.2 It should be noted that the sizing accuracy is dependent upon several factors such as pipeline cleanliness, pipe construction methods, product flow conditions etc. These factors have been taken into account by the Contractor when designing the Inspection System. However it has been found impractical to compensate fully for the extremes which have been noticed in practice and as a result the accuracy with which Metal Loss Features can be detected and sized can vary from point to point along a pipeline. The Contractor's experience of operating on-line Inspection Systems show that the sizing accuracy detailed in Table 1 is attained for greater than 80% of Metal Loss Features reported.

TABLE 1 DETECTION, SIZING AND LOCATION ACCURACY (10/20)

	METAL LOSS CATEGORY		
	PITTING <(3t X 3t)*	**GENERAL >(3t x 3t)***	**GOUGING**
Minimum Depth for Accurate Sizing	If surface dimension is > 0.275" x 0.275" or 0.4t x 0.4t (whichever greater): 0.2t	0.1t	If width > 0.5t or 0.275" (whichever greater): 0.2t If width > 3t: 0.lt
Sizing Accuracy (Depth)	±0.1t	±0.1t	±0.1t
Sizing Accuracy (Length)	±0.4"	±0.8"	±0.8"
Sizing Accuracy (Width)	±0.8"	±0.8"	±0.8"
Location Accuracy (Axial)	±8" between the feature and the reference girth weld and ±1% of stated distance between reference girth weld and identified location reference		
Location Accuracy (Circumferential)	±7.5 degrees which for ease of reference is stated to the nearest half hour clock position		

t = nominal wall thickness

* Metal loss is characterized by the minimum rectangle of dimensions, circumferential width (W) and axial length (L) that contains the surface area of pipe affected by metal loss.

Pipeline Anomalies (i.e. Dents, Weld Anomalies, Eccentric Casings, and Metal Objects) and Pipeline Fittings (i.e. Valves, Offtakes, etc.) shall also be located to the accuracy stated above.