Specifications and requirements for in-line inspection of pipelines

Version 2016

Contents

1 Introduction

This document specifies the advised operational and reporting requirements for tools to be used for geometric measurement, mapping, metal loss, crack or other anomaly detection during their passage through pipelines. The tools may pass through the pipeline driven by the flow of a medium or may be towed by a vehicle or cable. The tools may be automatic and self-contained or may be operated from outside the pipeline via a data and power link.

This document has been reviewed and approved by the Pipeline Operator Forum (POF). It is stated however, that neither any of the member companies of the POF nor their representatives can be held responsible for the fitness for purpose, completeness, accuracy and/or application of this document.

A draft version of this document has been sent for comments to in-line-inspection Contractors as listed in Appendix 1. The POF like to thank the Contractors for their constructive feedback.

This document is intended to serve as a generic in-line-inspection specification and therefore cannot cover all pipeline or pipeline operator specific issues. POF members and other users of this specification are therefore free to add or change requirements that should be based on their specific pipeline situation. To support the pipeline operator in specifying/detailing optional items in this document, a guideline with a short description of these items is given in Appendix 2.

Comments on this specification and proposals for updates may be submitted to the Administrator at specifications@pipelineoperators.org with the form which is available on the POF website (www.pipelineoperators.org).

2 Definitions and abbreviations

2.1 General

During the update of this specification, reference to standards such as API 1163 [1] and PDAM[1] [2] have been reviewed and some terminology has been aligned. However, if referenced standards are in conflict with this (POF) specification, this specification prevails.

If the word "shall" is used in this document it indicates a requirement.

If the word "should" is used in this document it indicates a recommendation.

2.2 Definitions

Anomaly/feature definitions are provided in such manner that the ILI vendor can identify them accurately, e.g. general reporting like metal loss and deformation is not sufficiently detailed.

For the purpose of this document, the following definitions apply:

Above Ground Marker:	A device, on the outside of and close to a pipeline, that detects and records the passage of an ILI tool or transmits a signal that is detected and recorded by the tool. Reference magnets can be applied to serve identical purposes.
Anomaly:	An indication, detected by in-line inspection, of an irregularity or deviation from the norm in pipe material, weld material or coating, which may or may not be an actual flaw.
Arc strike [2]:	Localised point(s) of surface melting caused by arcing between a welding electrode or ground and the pipe surface. The defect formed is a surface depression which may be associated with a local increase in hardness.
Blister [2]:	A raised spot on the surface of the pipe caused by expansion of gas in a cavity within the pipe wall.
Buckle [2]:	A local geometric instability causing ovalisation and flattening of the pipe as a result of excessive bending or compression with possibly abrupt changes in the local curvature, which may or may not result in a loss of containment. *Note: Buckle to be defined in detail for reporting as Global, Local or Propagation, see below.*
Buckle arrestor:	A device or element in the pipeline with high wall thickness that will act to stop the advance of a propagating buckle.
Buckle, global or Global buckle [2]:	A Global Buckle will typically involve several pipe joints. It can be horizontal or vertical.
Buckle, local or Local buckle [2]:	A Local Buckle is a mode causing gross deformation of the pipe cross section, also known as pipe wall buckling. Collapse,

[1] PDAM is only used as a reference for definitions

	localised wall wrinkling and kinking are examples of local buckling.
Buckle, propagation or Propagating Buckle [2]:	A Propagating Buckle is the result of a dynamic process whereby a local buckle propagates along the length of the pipeline. A propagating buckle cannot initiate unless a local buckle has occurred.
Casing:	A type of feature consisting of a larger diameter pipe placed concentrically around the pipeline, usually in high stress areas such as road crossings or otherwise protecting the pipe from mechanical damage.
Certainty:	The probability that the characteristics of a reported anomaly are within the stated tolerances.
Characteristic [1]:	A physical descriptor of a pipeline e.g. grade, wall thickness, manufacturing process or type, size, shape of an anomaly.
Client [1]:	An organisation that owns and/or operates the pipeline facilities.
Cluster:	Two or more adjacent anomalies in the wall of a pipeline or component of a pipeline that may interact to weaken the pipeline more than either would individually.
Colony [3]:	A grouping of stress corrosion cracks (cluster) occurring in groups of a few to thousands of cracks within a relative confined area.
Combined features:	Features that appear at the same location but at different (inner and outer) surfaces.
Component [1]:	Any physical part of the pipeline, other than line pipe, including but not limited to valve, weld, tee, flange, fitting, tap, branch connection, outlet, support, anchor, above ground marker, anode, repair, additional metal and wall thickness change.
Contractor [1]:	Any organisation providing ILI services to Clients.
Corrosion:	An (electro)-chemical reaction causing loss of metal.
Corrosion Resistant Alloy (CRA):	An alloy with increased corrosion resistance which may contain metals such as: chrome, cobalt, nickel, iron, titanium, molybdenum.
Corrosion related to CRA:	Corrosion between carbon steel and CRA affecting the interface.
Crack:	A planar, two-dimensional anomaly feature with a high length to width ratio, a sharp root radius and a possible displacement (surface opening) < 0.1 mm of the fracture surfaces.

Crack-like	An anomaly feature similar to a crack with some volume and a displacement (surface opening) between 0.1 and 1.0 mm of the fracture surfaces but that might not have a sharp root radius.
Debris:	Extraneous material in a pipeline.
Deformation:	A plastic change in shape in the steel pipeline. *Note: Deformations are to be reported as e.g. bend, dent, ripple/wrinkle, buckle or ovality, see below.*
Dent:	A local plastic or elastic deformation of the pipe wall resulting in a change of the internal diameter caused by an external force. *Note: Dents to be defined in more detail for reporting as Kinked, Plain or Complex*
Dent, Complex	A dent which causes a smooth change in curvature of the pipe wall that contains an anomaly (such as e.g. gouge, corrosion loss, crack) and/or is associated with an adjacent girth, spiral or seam weld.
Dent, Kinked [2]:	Dent with an abrupt change in the curvature of the pipe wall if any radius of curvature in the dent is ≤ 5 times the wall thickness. This type of dent might also be associated with wall thickness reduction or crack.
Dent, Plain [2]:	A dent which causes a smooth change in curvature of the pipe wall that contains no wall thickness reduction (such as gouge, crack, corrosion) and is not associated with an adjacent girth, spiral or seam weld.
Detection threshold:	Minimum detectable feature dimension at a certain certainty.
Feature:	Component or anomaly in a pipeline detected by in-line inspection.
Geodetic Datum	3D coordinate system. *Note: the World Geodetic System (WGS84) is commonly used, but others include ETRF89, NAD83, NAD27, RGF93 and more.*
Gouge:	A surface damage with elongated grooves or cavities caused by mechanically displaced or removed material from the pipe wall by interference with a foreign object.
Grinding:	Wall thickness reduction by removal of material by hand filing or power disk grinding.
Heat affected zone (HAZ):	The area around a weld where the metallurgy of the metal is altered by the rise in temperature caused by the welding process, but this is distinct from the weld itself. For the purpose of this specification it is considered to be within 2t with a minimum of 20mm.

In-Line Inspection (ILI):	Inspection of a pipeline from the interior of the pipe using an In-Line Inspection tool.
In-Line Inspection (ILI) tool:	Device or vehicle, also known as an intelligent or smart pig that uses a non-destructive testing technique to inspect the pipeline from the inside.
Interaction of anomalies:	Two or more adjacent anomalies in the wall of a pipeline or component of a pipeline that may interact to weaken the pipeline more than either would individually.
Joint:	Single section (also pipe spool) of pipe that is circumferentially welded to form a pipeline.
Lamination [2]:	Internal metal wall separation creating layers generally orientated parallel to the pipe wall.
Lap:	A flap of metal that has been rolled or otherwise worked against the surface of the metal but is not fixed, usually with a trapped residue of oxide or scale beneath it.
Mapping:	Recording of the 3D pipeline route using the inertial navigation system of the ILI tool.
Maximum allowable operating pressure [2]:	The maximum allowable operating pressure (MAOP) is a pressure less than or equal to the design pressure and represents the maximum allowed pressure during normal operation.
Metal loss [2]:	Any volumetric pipe anomaly in which metal has been removed. *Note: Metal loss to be reported as e.g. corrosion, gouging, grinding or mill anomaly*.
Measurement threshold:	The minimum dimension(s) of a feature to make sizing possible.
Mill anomaly:	An anomaly that arises during manufacture of a pipe joint or component. *Note: Mill anomalies to be reported as e.g. lap, sliver, lamination, non-metallic inclusion, grinding roll mark or arc strike*.
Ovality [2]:	Out-of-roundness of the pipe joint, defined in terms of the difference between the maximum and minimum internal diameter of the pipe joint.
Pinhole:	Localized corrosion with surface dimensions smaller than 1t or 10 mm whichever is greater in length and width direction.
Pipeline:	A system of joints and other components used for the transportation of products. A pipeline extends from launcher tool trap to receiver tool trap, including the tool traps, or, if no tool trap is fitted, to the first isolation valve within the

	plant boundaries or a more inward valve if so nominated and designed to a pipeline design code.
Pitting:	Localized corrosion of a metal surface that is confined to small areas and takes the form of cavities called pits, but are larger than pinholes. *Note: The dimensions of pitting are defined in detail further in this document.*
Probability of Detection:	The probability of detection is the probability that a specified feature will be detected by the ILI tool. *Note: The level of probability to be used is defined in detail further in this document.*
Probability of Identification:	The probability that a detected anomaly or feature will be correctly identified.
Processed raw data:	Data gathered from ILI tool sensors and passed through one or several filtering algorithms e.g. corrected for odometer slippage.
Raw data:	Unprocessed data from all sensors attached to the respective inspection tool during a pipeline inspection.
Reference magnet:	A permanent magnet placed on the pipeline with known location and/or coordinates used to correlate the inspection data. See also Above Ground Marker.
Reporting threshold:	A parameter, which defines whether or not an anomaly will be reported.
Ripple/Wrinkle:	A smooth local plastic, mainly circumferential orientated, deformation on the out and/or inside wall of the pipe caused by bending stresses. For a wrinkle, the peak-to-valley distance is greater than a ripple.
Roll mark [2]:	Markings on the pipe surface resulting from the plate or pipe rolling process used for spirally or longitudinally seam welded pipe.
Roof topping/peaking [2]:	Incorrect forming of the plate edges into the pipe curvature during fabrication, resulting in meeting of the edges as a triangular apex with the seam weld projecting beyond the circular contour of the pipe, also called peaking or angular misalignment.
Sizing accuracy:	Sizing accuracy is given by the interval with which a fixed percentage of features will be sized. This fixed percentage is stated as the certainty level.
Sliver [2]:	A thin elongated piece of metal rolled into the surface of the pipe, often metallurgically attached at one end. Sometimes reported as lap or lamination.

Strain	Geometrical, non-dimensional measure of deformation representing the relative displacement between particles in a material body.
Trap, launcher/receiver:	An ancillary item of pipeline equipment, with associated pipe work and valves, for introducing an ILI tool into a pipeline (launcher trap) or removing an ILI tool from a pipeline (receiver trap).
Wall thickness, Measured:	The average of measured, un-corroded wall thickness values that is representative for a whole pipe joint/component.
Wall thickness, Nominal:	The wall thickness required by the specification for the manufacture of the pipe.
Wall thickness, Reference:	The actual undiminished wall thickness surrounding a feature, used as reference for the determination of the feature depth.
Weld:	The area where joining has been realised by welding. This is distinct from the heat-affected zone, but is located within it.
Weld anomaly:	Anomaly in the body or the heat affected zone of a weld.
Weld affected area:	Area on both sides of a weld where ILI measurements are affected by the geometry of the weld. See also "Heat affected zone".

2.3 Abbreviations

For the purpose of this document, the following acronyms apply:

A	A geometrical parameter used to specify the dimension class of metal loss anomalies detected by in-line inspection of a pipeline and further defined in Figure 2.1 of this document.
AGM	Above Ground Marker
CRA	Corrosion Resistant Alloy
d	Depth of metal loss
E	End point of anomaly
EC	Eddy Current
EMAT	Electro Magnetic Acoustic Transducer
ERF	Estimated Repair Factor
GIS	Geographic Information System
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
h	Height or depth of Wrinkle/Ripple/Dent or Roof topping
HAZ	Heat Affected Zone

ILI	In-Line Inspection
IMU	Inertial Mapping Unit
ID	Internal pipe Diameter
l	Length of anomaly/feature dimension in the axial direction and length of cracks in any direction
MAOP	Maximum Allowable Operating Pressure
MOP	Maximum Operating Pressure
MFL	Magnetic Flux Leakage
NDE/NDT	Non-Destructive Examination/Non-Destructive Testing
OD	Outer pipe Diameter
PDAM	Pipeline Defect Assessment Manual
POD	Probability Of Detection
POI	Probability Of Identification
P_{safe}	Safe operation pressure as per calculated defect assessment method
R	Internal pipe Radius
S	Start point of anomaly
SCC	Stress Corrosion Cracking
t	Wall thickness
UT	Ultrasonic Testing
w	Width of anomaly/feature in the circumferential direction and opening dimension for crack-like features
WGS 84	World Geodetic System 1984

2.4 Parameters and interaction of anomalies

2.4.1 Metal loss

The parameters of anomalies are length "l", width "w" and depth "d". The starting point, S, and the dimension of an anomaly are defined as illustrated in *Figure 2.1* looking in the ILI run direction. Start and end points are diagonally in a rectangle enclosing the anomaly. The depth represents the deepest point reported within the rectangle.

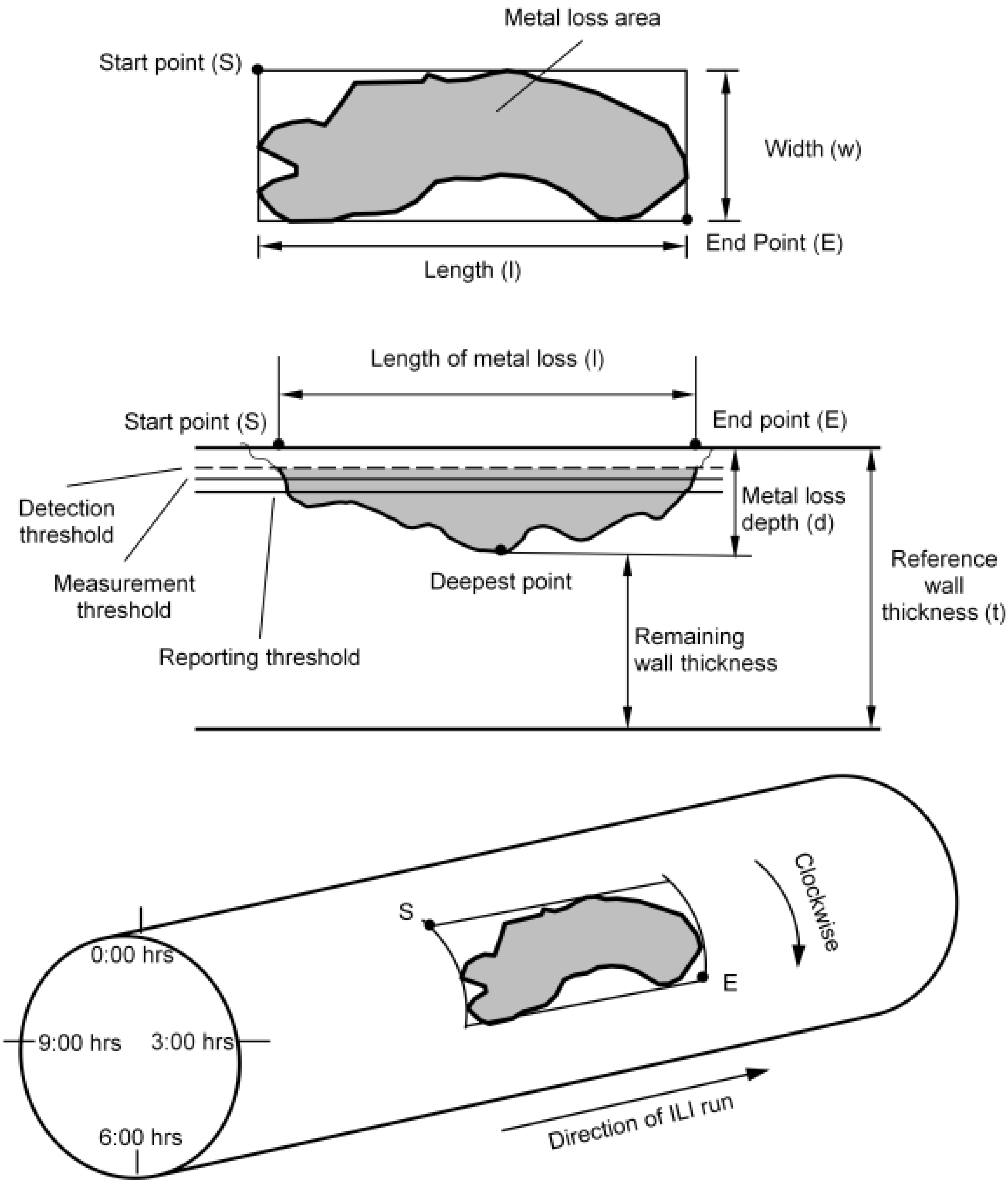


Figure 2.1: Illustration of parameters describing location and dimension of metal loss feature.

The start position of the anomaly has a lower clock position than the end position. Anomalies crossing the 0:00 o'clock position have a higher clock position at the start. Full circumferential anomalies are reported with S at 0:00 o'clock. *Note: highest clock position shall be 11:59.*

Metal loss anomaly classification

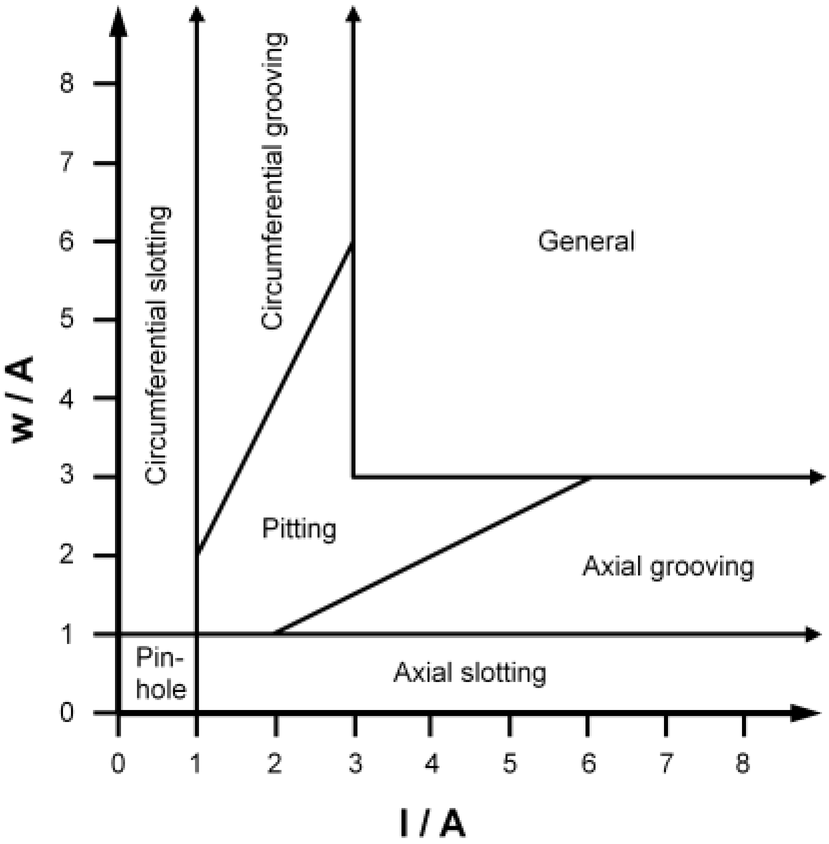
The measurement capabilities of non-destructive examination techniques, in particular the MFL technique, depend on the geometry of the metal loss anomalies. Metal loss anomaly classes have been defined as shown in Figure 2.2 for anomaly reporting purposes. In addition it allows for a proper specification of the measurement capabilities of MFL ILI tools.

Each anomaly class permits a large range of shapes. Within that shape a reference point/size is defined at which the POD for MFL tools is specified, see Table 2.1. An even distribution of length, width and depth shall be assumed for each anomaly dimension class to derive a statistical measurement performance on sizing accuracy.

Table 2.1: Definition of anomaly dimension class and MFL POD reference point/size

Anomaly dimension class	Definition	Reference point/size for the POD in terms of l x w
General:	{[w ≥ 3A] and [l ≥ 3A]}	4A x 4A
Pitting:	{([1A ≤ w < 6A] and [1A ≤ l < 6A] and [0.5 < l/w < 2]) and not ([w ≥ 3A] and [l ≥ 3A])}	2A x 2A
Axial grooving:	{[1A ≤ w < 3A] and [l/w ≥ 2]}	4A x 2A
Circumferential grooving:	{[l/w ≤ 0.5] and [1A ≤ l < 3A]}	2A x 4A
Pinhole:	{[0 mm < w < 1A] and [0 mm < l < 1A}	Minimum dimensions to be further defined by Contractor, see table A3-2
Axial slotting*:	{[0 mm < w < 1A] and [l ≥ 1A]}	2A x ½A
Circumferential slotting*:	{[w ≥ 1A] and [0 mm < l < 1A]}	½A x 2A

* Anomalies with a width < 1mm are defined as crack of crack-like which might or might not be metal loss



The geometrical parameter A is linked to the NDE methods in the following manner:

- If t < 10 mm then A = 10 mm
- If t ≥ 10 mm then A = t

Figure 2.2: Graphical presentation of surface dimensions of metal loss anomalies per dimension class.

2.4.2 Dent

A dent is defined by its type (Kinked, Plain, Smooth), maximum depth (h), width and length, as shown in Figure 2.3. If requested, the maximum strain based on a methodology agreed between Client and Contractor. If the dent results in an ovality of the pipe then a more detailed description and evaluation is required.

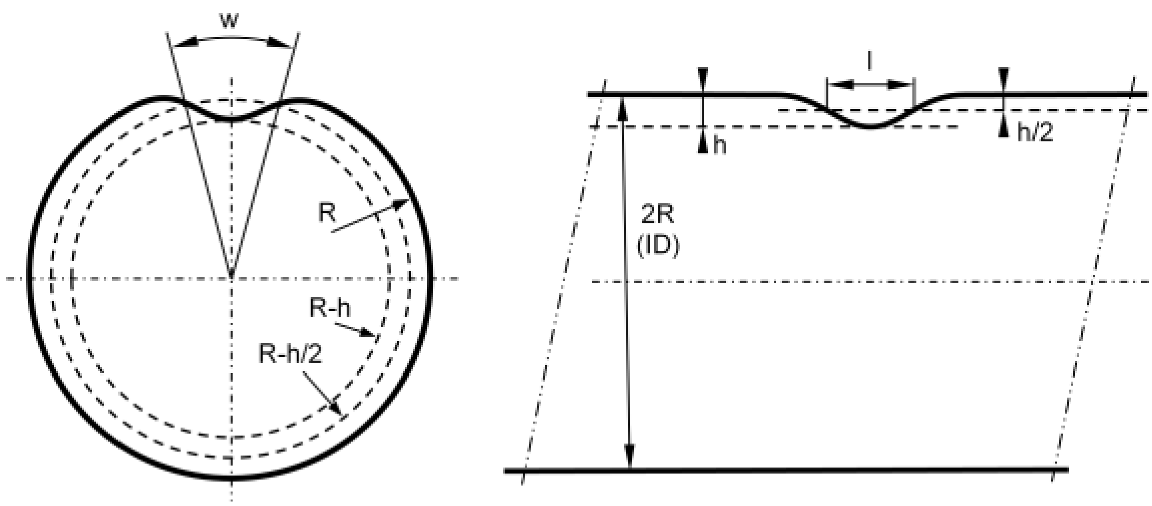


Figure 2.3: Measurement of dent.

The dent is defined as a percentage of the OD where h is measured from either the inside or outside of the pipe:

$$\frac{h}{OD} * 100\%$$

2.4.3 Gouge

As a gouge can take various forms, a schematic drawing is not available. Gouge anomaly dimensions are defined by the rectangle as shown in Figure 2.1, but the Contractor shall classify them as gouges with the angle related to the pipe axis reported as well. If a gouge is associated with a dent, then it shall be reported as a "Smooth or Kinked Dent with Gouge" with separate dimensions of the gouge and dent.

2.4.4 Ovality

Ovality is specified by ID_{max} and ID_{min} as shown in Figure 2.4

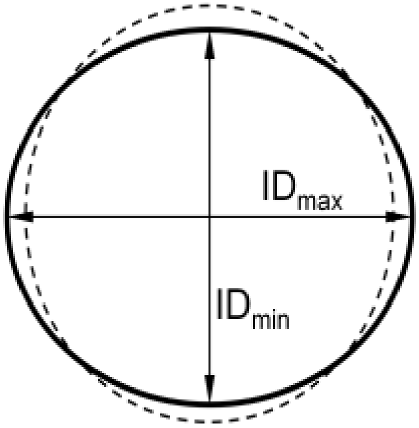


Figure 2.4: Measurement of ovality at one point over distance.

The ovality is defined as the ratio given in the equation below:

$$\frac{ID_{max} - ID_{min}}{\left[\frac{ID_{max}+ID_{min}}{2}\right]}$$

The ovality reported at the joint is based on a statistical approach of the measurements along the joint. It can be the mean ovality or any percentile (90th is common) or the maximum measured, which is to be detailed by the Client in the contract. If not specified otherwise, the maximum shall be reported. *Note: Reporting of ovality dimensions depends on the used formula (code) and it is therefore required that the formula applied is stated in the report.*

2.4.5 Buckle

As a buckle can take various forms, a schematic drawing is not available.

2.4.6 Ripple/Wrinkle

A ripple/wrinkle is specified by its height and length as shown in Figure 2.5Figure 2.5, Figure 2.6 and Figure 2.7. The maximum values shall be reported and, if requested, also the maximum strain based on a methodology agreed between Client and Contractor.

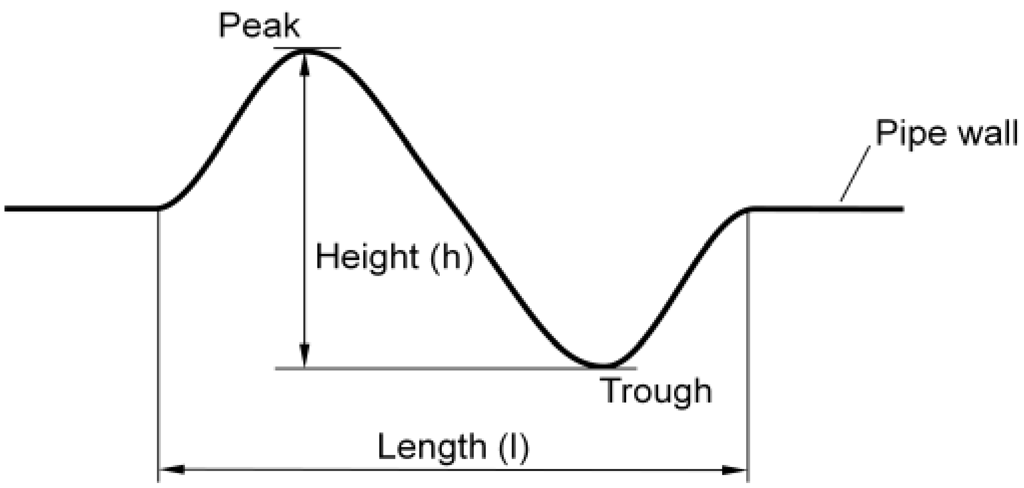


Figure 2.5: Measurement of ripple / wrinkle.

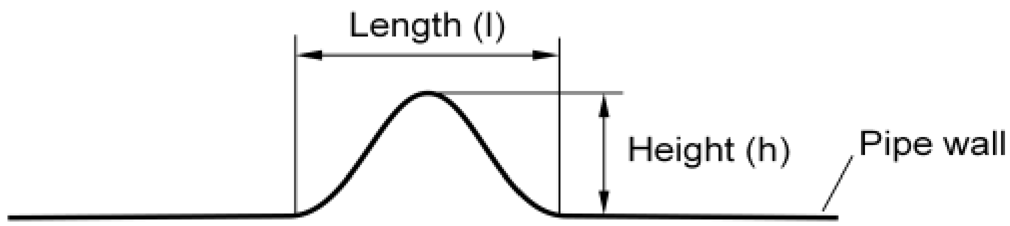


Figure 2.6: Measurement of single ripple/wrinkle.

A ripple/wrinkle is defined by its length (l) and maximum height (h).

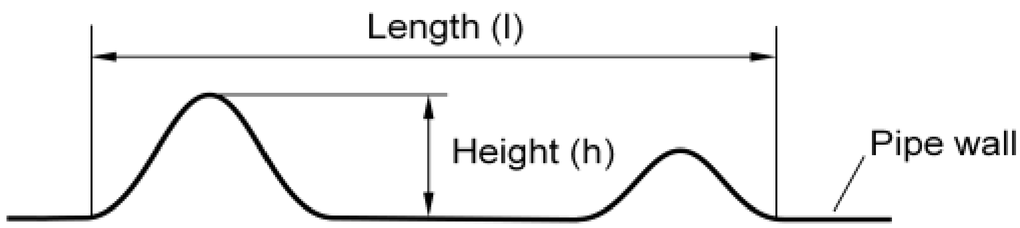


Figure 2.7: Measurement of multiple ripple / wrinkle.

Multiple ripples/wrinkles are defined by the total length (l) and maximum height (h).

2.4.7 Roof topping/peaking

Roof topping/peaking is specified by the angle 2ϴ and height (h), see Figure 2.8.

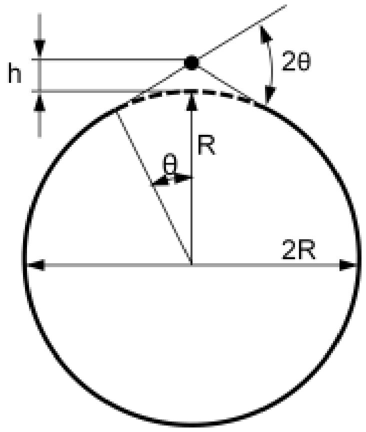


Figure 2.8: Measurement of peaking/roof topping.

Roof topping/peaking is defined by its height h in mm and angle 2ϴ in degrees (°).

2.4.8 Crack and crack-like

A crack or crack-like feature is specified by the length (l, from tip S to tip E), depth (d) and orientation (angle α) to the pipeline axis, see Figure 2.9.

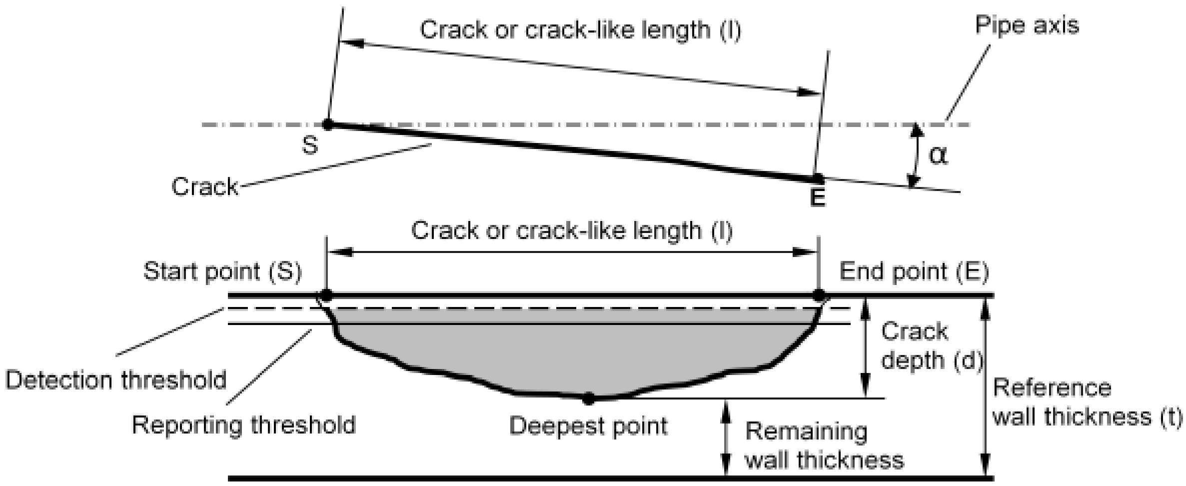


Figure 2.9: Illustration (top view and cross section) of parameters describing location and dimension of crack and crack-like features.

Planar, two-dimensional and elongated pipeline features mechanically splitting the pipe wall into two parts and oriented primarily perpendicular to the pipe surface are referred to as cracks or crack-like anomalies depending on the driving cracking mechanism.

Cracks are typically oriented either axially in the pipe body, or in the longitudinal, spiral, or circumferential weld areas and welds. Independent from the nature of the cracking mechanism, cracks in pipelines are observed as single or colonies.

The parameters of single crack and crack-like anomalies are length "l" and depth "d". Due to its planar, two-dimensional nature a crack or crack-like anomaly shows no width but may show a crack opening depending on the geometry and nature of the crack.

Cracks are regarded to have an opening at the surface < 0.1 mm, crack like defects to have an opening at the surface of 0.1 mm to 1.0 mm.

The capabilities of non-destructive examination techniques to detect, classify and size crack and crack-like anomalies strongly depend on the technology itself and its implementation on the inspection tool. In contrast to metal loss anomalies, no anomaly classes exist for cracks and crack-like anomalies. The Contractor shall provide the tool performance specifications in accordance to section 4.4 and table A5-4 with special emphasis on:

- The POD at 90% as a function of the anomaly dimensions.
- Details on the basis of the performance shall be clearly presented with regards to artificial and/or natural features.

2.4.9 Crack colonies

A crack colony is specified by the length (l), width (w), see Figure 2.10 and depth of the deepest single crack in the colony (see Figure 2.9).

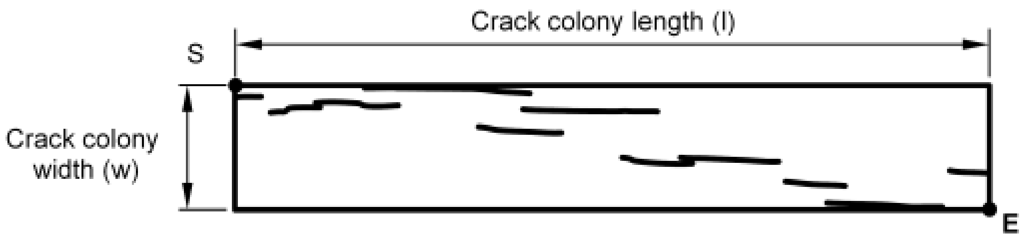


Figure 2.10: Illustration (top view) of parameters describing location and dimensions of crack colonies.

Colonies of cracks can be formed as a result of corrosion (e.g. SCC) and cracks in such a colony might interact depending on their dimensions, separation and density. Interaction rules are applicable for assessment, see 2.6.1.

2.5 Nomenclature of features

Features can be divided into component features and anomaly features.

Features shall be identified in accordance with Appendix 3: Report structure, terminology and abbreviations: Column Feature type.

The type of features shall be further identified in accordance with Appendix 3: Report structure, terminology and abbreviations: Column Feature identification.

2.6 Anomaly assessment

2.6.1 Interaction rules

Clustering of anomalies will be required if defects can interact and thereby pose a greater risk to the pipeline than individually assessed. The applicable assessment method shall define the interaction rules and clustering requirement.

If not specified otherwise by the Client, the latest version of ASME B31G [11] should be used for assessment and interaction rules of metal loss. Possible alternative methods include, but are not limited to:

- API 579/ASME FFS (general, including metal loss and cracking) [9]
- Modified ASME B31 G, (metal loss) [11]
- BS 7910 (general, including metal loss and cracking) [10]
- DNV RP-F101 (metal loss) [12]
- Kastner (only circumferential features) [8]
- CEPA Recommended Practices for Managing Near-neutral pH Stress Corrosion Cracking (only SCC) [3]
- Pipeline Defect Assessment Manual (PDAM) [2].

2.6.2 Indication of anomaly severity (ERF)

To allow the Client to rank the indications of anomalies in the pipeline on the basis of a first pass screening of severity, the Estimated Repair Factor (ERF) can be used. It is noted that for significantly ranked defects a more sophisticated assessment may then be applied.

The ERF is defined as:

$$ERF = MAOP/P_{safe}$$

P_{safe} is the safe working pressure as calculated by the latest version of an appropriate anomaly assessment method as agreed between Client and Contractor. P_{safe} shall be calculated using specific information of the pipeline segment such as the measured wall thickness and appropriate design factor for the area class.

If not specified otherwise by the Client, the latest version of ASME B31G [11] should be used for metal loss features. For possible alternative assessment methods (but not limited to) see section 2.6.1.

Note: The calculation of ERF has been updated from previous versions of this POF specification by replacing MOP with the MAOP. Whereas MOP could be applied as a temporary process restriction, MAOP implies the maximum pressure that could be introduced to the pipeline both at the time of the calculation and for any future operations.

2.7 Resolution of measurement parameters

A list of definitions with resolution and associated units to be used is presented in Table 2.2.

Table 2.2: List of definitions with minimum resolution and associated units to be used.

Definition	SI/metric units	Alternative units
Log distances	0.001 m	0.01 ft
Feature length and width	1 mm	0.01 inch
Feature depth	0.1 mm or 1%	0.01"or 1%
Reference t	0.1 mm or 1%	0.01" or 1%
Orientation	0.5° or 1 minute	1 minute
ERF	0.01	0.01
Magnetic field strength (H)	0.1 kA/m	1 Oe (Oersted)
Magnetic flux density (B)	0.1 T (Tesla)	10^3 G (Gauss)
Axial sampling distance	0.1 mm	0.01 inch
Circumferential sensor spacing	0.1 mm	0.01 inch
Tool speed	0.1 m/s	0.1 ft/sec
Temperature	1 °C	1 °F
Pressure	0.01 MPa/0.1 bar	1 psi
Global Position Coordinates[1)]	0.01 m	10^{-8} ° (Decimal degree)

1) Unless specified otherwise, WGS84 shall be used as the coordinate system

3 Health and safety

Care for health and safety is essential during any stage of any activity. As ILI of pipelines typically involves working with pressurized components and potentially explosive, flammable or hazardous atmosphere, adequate procedures must be in place to prevent any harm to personnel, environment or equipment. It is the responsibility of both Client and Contractor to agree on health and safety requirements and procedures and to check if latest and most stringent versions of (local) HSE requirements are met.

ILI operations require a pipeline to be opened and an inspection tool to be loaded/unloaded whereby explosive environments might occur. Special measures to prevent unsafe situations during ILI activities shall be taken.

Regulations have been developed to prevent accidents due to explosive environments. Examples of these regulations are the ATEX guidelines (ATmosphères EXplosive) which is mandatory for activities in the European Union or the IECEx system (*International Electro technical Commission: IEC System for Certification to Standards relating to equipment for use in Explosive Atmospheres*).

Implementation of ATEX, IECEx or an equivalent directive might be mandatory on the basis of national, local legislation or Client policy and if required shall be employed for ILI operations in addition to already applicable standards and procedures.

For use of non-electrical equipment in potentially explosives atmospheres, EN 13463 or an equivalent standard can be applicable.

For use of electrical equipment in potentially explosives atmospheres, EN-IEC 60079-xx (-10, -14, -17) or an equivalent standard can be applicable.

3.1 ATEX

ATEX zone 1 is considered to be applicable for ILI operations. The Client shall specify if ATEX certification is required and if so, the following two directives shall be followed:

- ATEX 114[2], Directive 2014/34/EU of the European Parliament and of the Council of 26 February 2014 on the harmonization of the laws of the Member States relating to equipment and protective systems intended for use in potentially explosive atmospheres.

  For ILI activities in the oil and gas industry it is considered that, unless specific measures are taken, zone 1 (areas with occasional dangerous explosive atmosphere caused by gas, vapour or mist) is typically applicable. Unless the Client specifies otherwise, the ATEX certified ILI tool shall comply with:
  - Group II: Equipment intended for use in explosive atmospheres other than mines
  - Category 2: High protection level for use in zone 1
  - Minimum temperature class T3: Surface temperature of equipment < 200°C (depending on the medium, another temperature class might be required e.g. T4 (<135°C).

  Note: This directive implies that the Contractor has to assess all potential explosion risks of its equipment and has to design the equipment to this directive.

- ATEX 153[2], Organizational requirements for health & safety protection of industrial workers at risk from potentially explosive atmospheres.

[2] Latest or superseding versions of the relevant codes shall be used

ATEX 153 gives organizational and operational requirements for activities in potentially explosive environments. Client and Contractor are to define the operating procedures and work instructions to assure safe work environment. Client is in lead and stays responsible. The operating procedures are considered outside the scope of this document.

Note: This directive requires that the Client assess the zoning of the launch/receive trap workspace through risk assessment and that Client is responsible for ensuring that all equipment introduced into these zones is compliant and QA certified against ATEX 114.

In addition to the ATEX requirements, which are only valid for atmospheric conditions, the Client shall specify, whether the contractor shall ensure safe operation of ILI equipment under explosive conditions for pressures > .11 MPa during receiving and launching of tools.

3.2 IECEx

The IECEx is an alternative code for certification of ILI equipment with equal area of application as ATEX 114, but not further discussed in this specification.

4 Tool specifications

4.1 Introduction

Tool specifications are important for the Client to clearly understand the capabilities and limitations of an ILI tool before selection and use. The purpose of this section is to present a consistent approach for presenting tool specifications and agreed tool specifications shall be part of the contract between Client and Contractor, as further described in chapter 6. Tool specifications typically consist of the combination of tool data sheets and tool performance specification:

- Tool data sheets cover the physical dimensions of the tool and operating conditions the tool can work in
- Performance specifications describe the inspection capabilities and limitations of the inspection technology applied. Tool performance follows the general requirements of API 1163 supported by Contractor quality systems.

The Client should clearly define the goals and objectives of an ILI before tool selection can take place. A key aspect in this process is a proper identification of pipeline threats and anticipated degradation mechanisms. The expected type, size, location and orientation of anomalies are important inputs to tool selection. In many cases tool selection requires a deeper understanding and details of specific tools which can best be obtained in a discussion between Client and Contractor. Factors that may influence tool performance, such as level of cleanliness and pipeline operating conditions need to be considered as well.

Prior to an in-line inspection the following should be in place:

- The Client to communicate the goal and objectives of the ILI to the Contractor
- Tool selection to be discussed and agreed between Client and Contractor
- Contractor to confirm that tool selection is appropriate given the goals and objectives of the ILI.

4.2 Tool data sheets

Tool data sheets provide information to allow Client to understand the limitations of service and suitability for use in pipeline system. Typically separate tool data sheets exist for each diameter and inspection technology combination.

They shall clearly present:

- Tool identification
- Tool specifications
- Safety
- Operating conditions/parameters
- Pipeline restrictions
- Launcher and Receiver trap details.

Detailed tool data sheet requirements are included in Appendix 4.

4.3 Tool class history

In order to achieve a high probability of first run success (Ref. POF document "Guidance on achieving ILI First Run Success" [5]), it is important that the Client clearly understands the operating history of the tool class and its level of operational testing. Before the ILI contract is confirmed and unless otherwise agreed, Client may request any or all of the following information:

- Technology readiness of tool class hardware for operating conditions using the following grades:
  1. Newly designed component with limited testing
  2. Limited field operation (< 20 runs or < 500 km distance)
  3. Multiple uses with clear history of components and subsequent changes
- Provide a unique tool reference number and applicable data sheet.

Design changes to tool components or modules that may affect level of readiness shall be clearly communicated to Client both at time of placing order and for any subsequent change made by Contractor.

4.4 Tool performance specification

Tool performance specifications shall define the ability of the ILI system to detect, locate, identify, and size pipeline features, components and anomalies. It is typically linked to the inspection technology applied in the tool (e.g. UT, MFL, EC, EMAT or mapping).

4.4.1 General

Tool performance specifications shall comply with requirements given in API 1163 [1], chapter 6. The following general requirements are given for tool performance specifications:

- The Probability Of Detection, POD (a), is the probability that a feature with size a will be detected by the ILI tool. Two feature sizes are frequently extracted from the POD information: $a_{90/50}$ (a_{90}) is the feature size at which the average POD is 90% and $a_{90/95}$ is the feature size at which the lower 95% confidence limit of the POD is 90%, see also Figure 4.1. In the tool performance specification it shall be clearly specified what POD value is given. It is recommended to specify the $POD_{90/95}$ value
- The Probability of Identification, POI, is the probability that a feature is correctly identified by the ILI tool. The type or types of anomalies, components, and characteristics that are to be detected, identified, and sized by the ILI system shall be clearly indicated. Identification of each feature type shall be reported as specified in Appendix 5, Table A5-1
- The measurement specifications for detection and sizing of the various anomalies and pipeline location shall be reported as specified in Appendix 5, Tables A5-2 to A5-8 where they apply. The Client might request to complete the alternative Table A5-3a in favour of Tables A5-2 and A5-3
- Performance specification shall clearly state the level of analysis that is required to support the level of specification
- Where a higher level of performance is based on more detailed analysis, the additional performance level and commercial basis for additional analysis shall be clearly stated and agreed by Client and Contractor
- If different technologies (e.g. MFL, UT, EC or EMAT) are combined into one tool, then the specifications shall be provided as if the technologies were applied in a separate tool and additionally a table with the specifications of the multi-technology tool shall be provided.

The performance specification shall define and document the essential variables. In general two types of essential variables should be considered for ILI tool performance: i) pipeline design and operational characteristics, ii) inspection tool design and physical characteristics. More detailed requirements on the essential variables are to be included in the performance specifications as listed in Appendix 5.

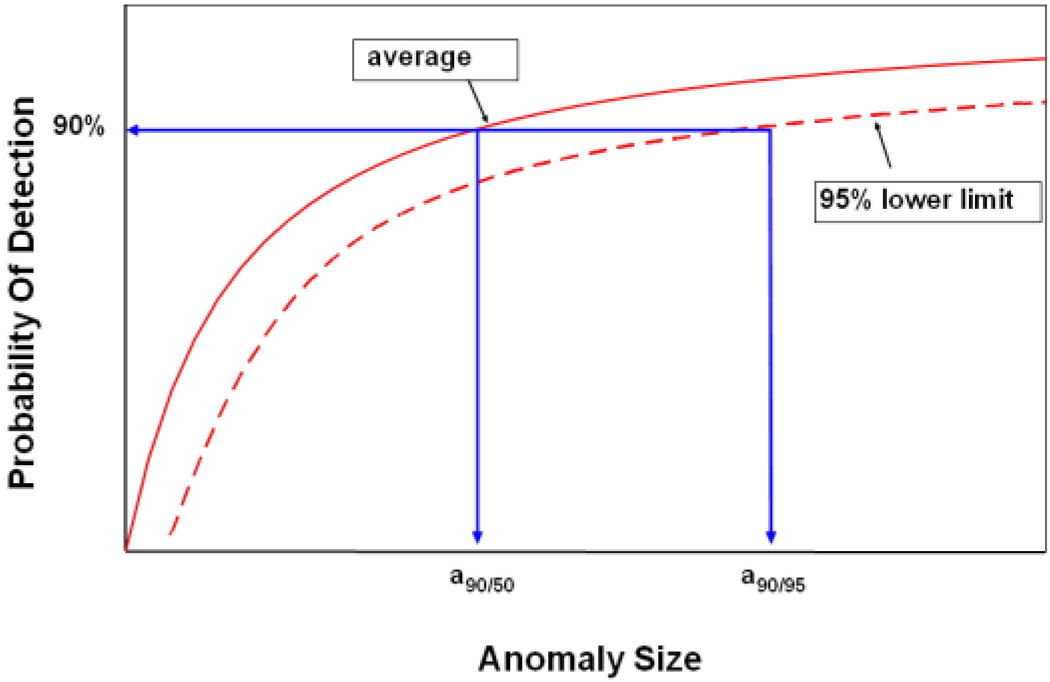


Figure 4.1: Typical example of the average and lower limit POD curve as function of anomaly size with indication of the definitions of $a_{90/50}$ (a_{90}) and $a_{90/95}$

4.4.2 Basis of performance

The basis on which performance specification is made shall be clearly stated for each feature type using the following:

- Modelling only
- Limited pull through tests and modelling (where effects of essential variables have not been fully tested by pull through runs and features used are predominantly manufactured)
- Extensive pull through tests covering range of speed and wall thickness using a combination of manufactured and natural features
- Limited field verification with less than 20 operational runs
- Extensive field verification results reviewed on an annual basis.

Where multiple methods are used, the Contractor shall clarify what has been used. Details of manufactured and/or natural features shall be clearly presented.

4.4.3 Exclusions and limitations

Physical and operational factors or conditions that limit the detection thresholds, PODs, POIs, and sizing accuracies shall be identified in the performance specification. It shall be clearly stated what the acceptable limits are for, but not limited to, e.g. tool speed and pipe wall thickness, see also Appendix 5.

4.4.4 Access to supporting performance information

Contractor shall provide access to information in support of stated tool performance specification on request of Client.

The ILI tool testing information of the contractor shall be auditable and contain information regarding the calibration procedure and latest calibration record of the tool. The procedure should give insight in, but not limited to: used calibration features, line pipe material, wall thickness and manufacturing process, tool velocity, date and frequency of calibration. For magnetic tools the calibration information will include the tool speed and the measured magnetic field strength value with the position where it was measured. In addition the Contractor shall supply a definition of which sizing model and revision was used.

How and where the information is to be provided is to be agreed between Contractor and Client. It is the responsibility of the Contractor to check that the tool and the calibration methods are valid and adapted to the Client's objectives.

4.5 Tool performance verification

A Client may choose to verify tool performance through formal testing or field verification.

In case formal testing is carried out, the report should at least contain the following information:

- Details of runs and essential variables tested
- Details of features
- Comparison of stated performance with actual reported features.

Regarding field verification more guidance can be found in POF document "Guidance on Field Verification Procedures for In-Line-Inspection" and API 1163 [1] (chapter 8 and Annex C). In case field verification is performed the following requirements apply:

- To ensure meaningful data is collected from the field, Client should facilitate access for Contractor to verify field measurement
- Client shall provide Contractor with field verification data (dig data)
- Contractor shall use field verification data to confirm tool performance.

4.6 Changes to tool specification or performance specification sheets

Changes to tool and performance specifications shall be tracked in Contractor Quality Assurance system. Each revision shall have date and issue number.

Where a change could affect earlier pipeline integrity assessment, Client shall be notified of change and potential implications. This typically applies when performance specification for certain features is reduced based on new information or additional testing. Any requirement for reassessment of features as a result of change shall be agreed between Client and Contractor.

5 Personnel qualification

The personnel operating the ILI systems and the personnel handling, analyzing and reporting the inspection results shall be qualified and certified according to ANSI/ASNT-ILI-PQ-2005 (reapproved 2010) [4] or later version/superseding document.

Unless the Client specifies otherwise, key personnel shall meet the following minimum qualifications, ref. ANSI/ASNT-ILI-PQ-2005 [4]:

- Team leader during ILI field activities: Level II Tool Operator for the applicable technology
- Data analysis and reporting Lead: Level II Data Analyst for the applicable technology
- Review of final Client report: Level III Data Analyst for the applicable technology. The review should include (but not limited to) e.g. a quality check of data analysis and reported results.

An overview of personnel qualifications that will be deployed for the ILI tool run, data analysis and final report review shall be submitted to the Client. The personnel qualifications shall be auditable.

6 ILI preparation and contracting

6.1 ILI preparation

The POF document "Guidance on achieving ILI First Run Success" [4] stresses the importance of the preparation and contracting phases to meet all the objectives of the inspection. The preparation phase is described in length in this document, which includes some check lists in Appendix B.

6.2 Contracting

This POF document is intended to serve as a generic ILI specification where details and deviations for ILI runs still need to be defined to serve Client's specific issues. Such details and deviations (Appendix 2 provides guidance), should be agreed between Client and Contractor and stated in the ILI contract.

The contract between the Client and the Contractor shall, as a minimum include the following items:

- Organization: The organization shall be defined between Client and Contractor, in terms of human and materials resources, communication, schedule of the operations, run conditions, procedures, roles and responsibilities, actions in the event of an emergency etc. The POF document "In-Line-Inspection Check Lists" [6] provides guidance
- Specific details: Details and deviations from the POF document "Specifications and requirements for in-line inspection of pipelines" (this document, if applicable)
- Run preparation: The Client should supply the Contractor with details of the pipeline(s) to be inspected. The POF document "ILI Pipeline Questionnaire" [7] provides guidance
- Operations: The operations shall be defined in terms of pipeline technical data, tool specifications, characteristics and performances, criteria for cleaning and run validation
- Results: The results shall be reported as per chapter 7. If requested by the Client, a revised version of the final report shall be issued in case of proven discrepancies between reported information and verifications.

The requirements herein may be changed at Client's request. Some points may depend on the configuration of the network to be inspected, the Contractor, the technology used, the internal (Client) policies and practices and local regulations.

It can be considered that, for specific applications, specifications and/or defect geometries, dedicated tool calibration can be performed (e.g. with spare project pipes), followed by a modified interpretation/sizing model.

7 Reporting

Reporting is an essential part of the inspection process and depending on the time and information required by the Client, various types of reports can be issued, see below. If the Contractor finds an anomaly during the inspection and/or evaluation of the ILI data which could be an immediate threat to the integrity of the pipeline, he has the duty to report this to the Client without delay.

If not agreed otherwise between Client and Contractor, reporting is based on at least two separate documents:

- Operations report
- Final report.

In addition to the above mentioned reports, one or more of the following reports can be requested and agreed between Client and Contractor:

- Preliminary report
- Raw data report
- Multiple run comparison report
- Additional reporting.

All documents and all lists (e.g. pipe tally, list of anomalies, etc.) will contain the following general information:

- Identification of the Contractor and Client
- Identification of the pipeline
- Product
- Outside or nominal diameter
- Length
- Construction year
- ILI technology/technologies
- Inspection date/Reference.

7.1 Operations report

The operations report should summarize important operational information such that the Client is informed on the success of the inspection and quality of data collected and should include information on run preparation, running of tool, run quality including pipeline cleanliness to verify if targets are achieved. If data quality is not as required for a successful pipeline feature evaluation, a re-run (if possible) can be considered. This report follows good practices regarding ILI activities as described in the POF document "Guidance on achieving ILI First Run Success" [5].

The operations report shall be sent in electronic form to the Client before demobilization of the tool and ultimately within 2 days of the ILI run, unless agreed otherwise. The demobilization of tool and crew shall be agreed between Client and Contractor based on the operations report results using the criteria below.

The operations report shall contain, unless agreed otherwise:

- Any reported safety observation (e.g. near miss)
- A description of the operations (cleaning, gauging, dummy tool run, ILI tool run) including run conditions

- Used tool(s) identification (serial number) with tool(s) data sheet and calibration
- AGM statistics (if applicable)
- Cleaning results and comparison to criteria
- Gauging/dummy tool run results and comparison to criteria
- Details of ILI run(s):
  - Time and date of tool launching and receiving
  - Travelling time
  - Min/max tool velocity, and tool velocity plot over the length of the pipeline
  - Min/max pressure
  - For MFL tools: min/max magnetization level, and a plot of the magnetic field strength in kA/m over the length of the pipeline measured at the inner surface of the pipe
  - Condition of tool(s) after receipt e.g. damaged sensors
  - Data loss statistics from faulty sensors and in case of UT echo loss statistics
  - Data recording and quality within contract specifications
- The suitability of the recorded data to allow a successful evaluation.

,The formulation for acceptable data loss shall be, unless specified otherwise:

- Continuous loss of data less or equal to 0.5 % of pipeline length
- Discontinuous loss of data less or equal to 3% of pipeline length
- Continuous loss of data from less than 4 adjacent sensors or 25 mm circumference (whichever is smallest).
- The criteria apply to each section of the pipeline i.e. each diameter, wall thickness and pipe manufacturing process.
- If data loss exceeds one of the criteria above, this shall be discussed between Client and Contractor to reveal the cause and decide on follow-up actions which might be:
  - A re-run of the tool
  - Check if the data loss has an effect on anomaly detection and sizing capability of the ILI tool.

The tool operational data statement shall indicate whether the tool has performed according to specifications and shall detail all locations of data loss and where the measurement specifications are not met. When the specifications are not met (e.g. due to speed excursions, sensor/data loss), the number and total length of the sections shall be reported with possible changes of accuracies and certainties of the reported results.

7.2 Preliminary report

A preliminary report is a list of features, including by their dig sheets. The reporting format is as per the list of anomalies in the final report. The preliminary report shall be delivered if requested by the Client or if the Contractor finds an anomaly (or anomalies) during the analysis of the ILI data which might be (are) an integrity threat to the pipeline.

The preliminary report aims at summarizing the most important features (individual and clustered) based on Client criteria as defined in the contract, in order to guarantee a safe pipeline operation. Unless agreed otherwise, typical reporting should include:

- Features with an ERF ≥ 0.8
- Metal loss features ≥ 50%

- Dents, Wrinkles/Buckles ≥5%
- Cracks with depth ≥ 4.0 mm.

Actual data quality shall be confirmed in terms of:

- Reporting threshold
- Method of analysis
- POD, POI, Sizing accuracy.

The preliminary report shall be sent in electronic form to the Client within 4 weeks of the ILI run, unless agreed otherwise.

7.3 Final report

Standard criteria for the final report are given in this chapter, but can be changed if agreed between Client and Contractor.

The final inspection report (hard and electronic copy) of either a single or combined ILI tool run shall contain the information as described in this chapter and be submitted within 8 weeks of the ILI run, unless agreed otherwise.

The reporting thresholds shall (if not specified otherwise) be:

- For MFL tools: Metal loss with a depth ≥ 10% t for welded pipe and ≥15% for SMLS pipe
- For UT and other tools: Metal loss with a depth ≥ 1.0 mm
- Cracks with a length ≥ 25 mm
- Dents, ripples/wrinkles with a height/depth ≥ 1% ID
- Ovalities ≥ 5% ID.

7.3.1 Pipe tally

The pipe tally shall be a listing of all pipeline component features and anomaly features and should be reported in accordance with a typical report structure as given in Appendix 6 (including terminology, see Appendix 3 "Feature identification"). The Client can specify the pipe tally to specific requirements, e.g. add or delete specific columns.

The pipe tally shall be compatible with standard files such as CSV, ODS or another agreed format.

7.3.2 List of anomalies, clusters, data loss and other lists

Unless specified otherwise by the Client, the following lists shall be provided:

- List of anomalies:
  The list of anomalies shall contain the anomalies which are clustered if required by the interaction rules (according to chapter 2.6.1), with dimensions above the reporting threshold at POD=90% or above a reporting threshold as specified by the Client (including terminology, see Appendix 3). For a typical example see Appendix 7. *Note: if no defect interaction rule is applied, then this list can be waived in favour of the "List of individual anomalies", see below.*
- List of clusters:
  The list of clusters (according to chapter 2.6.1) shall contain the clusters and the individual anomalies that are part of the cluster. It shall be clearly indicated what anomalies form a certain cluster. For a typical example see Appendix 8.
- List of individual anomalies:

The list of individual (all) anomalies shall be a listing of all anomalies without applying a defect interaction rule and with dimensions above the detection threshold at POD=90% or above a reporting threshold as specified by the Client.

- List of data loss:
  The list of data loss shall be a listing of all locations with data loss indicating the cause of data loss. *(Note:* as *data loss might be caused by e.g. a dent or debris whereby an anomaly can be missed such a location shall be carefully checked).*
- Other lists:
  If requested by the client a list with specific, to be indicated, items.

On the Client's request also the location of the deepest point in the metal loss area or clustered area shall be reported.

Unidentified/unknown features with strong signal shall be reported as "unknown" with, in commentary, an indication of the signal level.

The list of anomalies shall be compatible with standard files such as CSV, ODS or another agreed format.

7.3.3 List of components

The list of components shall be a listing of all feature types as listed in Appendix 3, except welds and anomalies. The list of components shall contain the same fields as the pipe tally.

The list of components shall be compatible with standard files such as CSV, ODS or another agreed format.

7.3.4 Summary and statistical data

The summary and statistical information as stated below should be agreed between Client and Contractor.

7.3.4.1 Metal loss

If a metal loss tool was run, the summary report for metal loss shall contain a listing of:

- Total number of anomalies
- Number of internal anomalies
- Number of external anomalies
- Number of anomalies for each metal loss anomaly class
- Number of anomalies per depth range of 10% (lower limit included)
- If applicable, number of anomalies per ERF range of 0.1, starting from 0.6 (lower limit included).

The following plots shall be provided:

- If applicable, sentenced plot including ERF=1 curve of anomaly length against metal-loss feature depth showing all anomalies for each representative wall thickness
- Orientation plot of all anomalies over the full pipeline length
- Orientation plot of all internal anomalies over the full pipeline length
- Orientation plot of all external anomalies over the full pipeline length
- Orientation plot of all anomalies as function of relative distance to the closest girth weld.

7.3.4.2 Cracks, crack-like and crack colonies

If a crack detection tool was run, the summary report for cracks, crack-like and crack colonies shall contain a listing of:

- Total number of anomalies per type and orientation to pipe axis
- Number of internal anomalies per type and orientation to pipe axis
- Number of external anomalies per type and orientation to pipe axis
- Number of anomalies per type per depth range of 2 mm and orientation to pipe axis (lower limit included).

The following plots shall be provided:

- Number of anomalies over the pipeline length
- Circumferentially orientated anomalies as function of relative distance to the closest girth weld
- Longitudinally orientated anomalies as a function of relative distance to the seam weld over the pipeline length.

7.3.4.3 Local and global geometry features

If a geometry tool was run, the summary report of geometry tool shall contain a listing of:

- Total number of dents, ripples/wrinkles, buckles
- Total number of ovalities
- Total number of joints with ovality
- Total number of other localized deformation/geometry anomalies
- Number of dents, ripples/wrinkles, buckles per depth range of 1%
- Number of ovalities per ratio range of 1%
- Number of joints with ovality per ratio range of 1%
- Orientation plot of all dents, ripples/wrinkles, buckles over the pipeline length
- Orientation plot of all ovalities over the pipeline length.

7.3.4.4 Other types of features (e.g. illegal taps)

If a tool capable of detecting other feature types was run, on request of the Client, the summary report for these features shall contain a listing of:

- Total number of features per type
- Number of internal features per type
- Number of external features per type
- Number of features per type per depth range of 10% (lower limit included).

The following plots shall be provided:

- Number of features over the pipeline length
- Orientation plot of all anomalies as function of relative distance to the closest girth weld
- Relative distance plot of all anomalies to the seam weld over the pipeline length.

The lists and plots as defined above can be completed at Client's request.

7.3.5 Performance

The final report shall contain:

- Completed tables A3-1 to A3-8 as per the Contract
- Completed tables A3-1 to A3-8 with actual run performance data depending on run conditions, tool functioning, pipeline cleanliness, etc.

Actual performance data must be given for each pipeline section where it is constant. These sections will be clearly identified.

7.3.6 Dig sheet

The purpose of the dig sheet is to provide the Client with all the information useful to carry out the field verification of a chosen feature.

Unless agreed otherwise, dig sheets shall be included in the final report.

Dig sheets shall contain the following information:

- Length of pipe joint and (when present) orientation of longitudinal or spiral seam at start and end of every joint
- Length and longitudinal or spiral seam orientation of the 3 upstream and 3 downstream neighbouring pipe joints
- Log distance of anomaly
- Wall thickness of the pipe joints (up to the 3 upstream and 3 downstream joints)
- Log distance of closest features like magnet markers, fixtures, steel casings, tees, valves, etc.
- Distance of upstream girth weld to nearest, second and third upstream marker
- Distance of upstream girth weld to nearest, second and third downstream marker
- Distance of anomaly to upstream girth weld
- Distance of anomaly to downstream girth weld
- Orientation of anomaly
- Geographical coordinates of an anomaly if a mapping unit was applied, including the Geodetic Datum Standard used. Unless specified otherwise, WGS84 shall be used
- Anomaly description and dimensions
- Internal/external/mid-wall indication.

7.3.7 Software and signal

In addition to the hard copy (if applicable), a user friendly software package shall be provided to enable review and assessment of the data collected by the inspection tool.

This software shall enable the Client to carry out the following tasks:

- Viewing of signal for each tool which was run, with possibility to modify gain, scale, etc.
- Preparing dig sheet for each anomaly (including dents, combined features, etc.)
- Plotting graphs and histograms
- Computing ERF (input data, models)
- Accessing detailed profile data for dents.

7.3.8 Anomaly ranking method for ERF

If requested by the Client, the Estimated Repair Factor for anomalies shall be reported on the basis of the assessment method indicated in Chapter 2.6.2 and input data shall be clearly stated in the final report.

ERF shall be reported for each individual feature. When clustering is applied, specific ERF for clusters shall be provided by the Contractor.

7.3.9 Detection of markers

AGMs or permanent markers that have been positively identified during the ILI run shall be indicated in the pipe tally. In addition, in the final inspection report the total number of installed AGMs and the number of identified AGMs shall be reported.

7.3.10 Personnel qualification

An overview of key personnel qualification level that has been deployed for the ILI tool run, data analysis, reporting and final report review shall be reported.

7.4 Raw data report

On request of the Client the raw data or processed raw data from an ILI run or a specific pipeline section shall be provided. The format of the data depends on the type of tool applied and is to be agreed between Client and Contractor and shall be defined in the inspection contract.

7.5 Multiple run comparisons report

If requested by the Client, anomaly data from two or more successive ILI runs carried out on the same pipeline, shall be compared individually and clustered. Aim is to detect discrepancies between reported anomalies of successive runs like new or missed features, corrosion growth, etc.

The run comparison report shall contain a table with matching and non-matching features per joint and include the results of these matching in terms of location, sizing and evolution. For a typical example see Appendix 9.

If the same Contractor is chosen for two successive inspection runs, the Client may request:

- A signal to signal comparison analysis between the two inspections
- A 2nd report based on the raw data of the previous inspection, but processed with the new algorithm.

The final run comparison report shall include the "Final report" (section 7.3) requirements and in addition:

- A comparison in terms of quality, velocity, performance and accuracy (tool rotation, velocity, acceleration, behaviour anomalies, magnetization level, …)
- A comparison of used tools (performance, characteristics, number, type and distance between sensors, acquisition frequency, environment, magnetization, …)
- A comparison of analysis and reporting parameters (e.g. but not limited to algorithms, thresholds, assessment code, interacting rules, …)

7.6 Experience report

The experience report summarizes the operation. Good practices as well as possible improvements are reported. Special attention is paid to

- Project planning
- Interaction between interfaces
- Logistics on site
- Coordination with other operations
- Data quality
- Dig up results

The report will contribute to improved future operations.

7.7 Additional reporting

On request of the client an additional report might be requested including separate reports for each technology used in combination runs, Integrity assessment reports, etc.

8 References

1. Anon, "In-Line Inspection Systems Qualification", API 1163, American Petroleum Institute, 2nd Ed., April 2013.
2. Cosham, A. and Hopkin, P., "Pipeline Defect Assessment Manual (PDAM)", A Joint Industry Project, Penspen, 2013.
3. Anon, "Recommended Practices For Managing Near-Neutral Ph Stress Corrosion Cracking" 3rd Ed., Canadian Energy Pipeline Association (CEPA), May 2015.
4. Anon, "In-line Inspection Personnel Qualification and Certification" ANSI/ASNT-ILI-PQ-2005, American Society for Nondestructive Testing. 2010.
5. Anon, "Guidance on Achieving ILI First Run Success", Pipeline Operators Forum, December 2012.
6. Anon, "In-line Inspection Check Lists", Pipeline Operators Forum, December 2012.
7. Anon, "ILI Pipeline Questionnaire", Pipeline Operators Forum, December 2012.
8. Kastner, W., Rohrich, E., Schmitt, W. and Steinbuch, R., "Critical Crack Sizes in Ductile Piping", Int. J. Press. Ves. Piping 9 (3) 197–219, 1981.
9. Anon, "Fitness-For-Service", API 579-1/ASME FFS-1, American Petroleum Institute, 2016.
10. Anon, "Guide to Methods for Assessing the Acceptability of Flaws in Metallic Structures", BS 7910, British Standards Institution, 2013.
11. Anon, "Manual for Determining the Remaining Strength of Corroded Pipelines", ASME B31G, American Society for Mechanical Engineers, 2012.
12. Anon, "Corroded Pipelines", DNV-RP-F101, Det Norske Veritas, January 2015.

Appendix 1: ILI companies that provided comments to the draft version of these specifications

COMPANY	COUNTRY	WEBSITE
3P Services	Germany	www.3p-services.com
A. Hak Industrial Services	Netherlands	www.a-hak-is.com
Baker Hughes	USA	www.bakerhughes.com
General Electric (PII)	USA	www.geoilandgas.com/pii
NDT Global	Ireland	http://www.ndt-global.com
Pipe Survey International	Netherlands	www.pipesurveyinternational.com
PipeWay	Brazil	www.pipeway.com
Rosen	Switzerland	www.rosen-group.com
T.D. Williamson	USA	www.tdwilliamson.com
Quest Integrity	USA	www.questintegrity.com

Appendix 2: Guideline to clients for defining specific details of the POF specifications

Introduction

The POF document "Specifications and requirements for in-line inspection of pipelines" gives an outline of advised specifications for In-line-inspection (ILI) of pipelines. The Client should adapt certain specifications to reflect Client's specific requirements. For certain aspects of the inspection and/or reporting requirements, some options and default values are already considered, but the document gives the opportunity to define specific items. This guideline is intended to support the Client by listing the considered optional items in the specifications based on the expected integrity threats of the pipeline to be inspected. The items should be defined prior to sending the specifications to the ILI company and agreement of the contract.

In addition, in this guideline also some notes and advised specifications are given (*printed in Italic*), like the minimum requirements that are regarded essential for a successful ILI run.

Chapter 2.4.2 - Dent
The Client should agree with Contractor the methodology if strain based assessment is required and of minimum planar size accuracies of dents expected to be reported for technology selection.

Chapter 2.4.4 - Ovality
Default reporting is the maximum ovality measured. If another value shall be reported, this is to be indicated.

Chapter 2.4.6 - Ripple/Wrinkle
Maximum values shall be reported. If additionally also the maximum strain should be reported, the methodology shall be agreed between Client and Contractor.

Chapter 2.6.1- Interaction rules
ASME B31G methodology is specified as the default assessment method, but another methodology can be specified and agreed if required.

Chapter 2.6.2- Indication of anomaly severity (ERF)
The ASME B31G methodology is specified as the default assessment method for the ERF calculation, but another methodology can be specified if required.

Chapter 2.7 Resolution of measurement parameters
The Client shall specify if SI, metric or alternative units shall be used.

Chapter 2.7 – Coordinates for mapping work.
It is important for the client to specify the final coordinates required from the mapping data. Considerations will include using the latest geodetic system to ensure 'future proofing' of data, but also to ensure the data will match any existing mapping system used (which may in fact not be the latest system).

Chapter 0 - Health and Safety
Health and safety requirements to be agreed between Client and Contractor, including Client' policy on ATEX, IECEx or equivalent directive.

Chapter 3.1 – ATEX
Client shall specify if ATEX certification is required and if so, assess the zone classification.
Client shall specify, whether the Contractor shall ensure safe operation of ILI equipment under explosive conditions for pressures > .11 MPa during receiving and launching of tools.

Chapter 4.3
Client may request for information on tool readiness.

Chapter 4.4.1 - General
Client may request to complete the alternative table A5-3a in favour of tables A5-2 and A5-3.
If a higher level of performance is based on more detailed analysis, the additional performance level and commercial basis shall be agreed.

Chapter 4.4.4 Access to supporting performance information
If access on information in support of stated tool performance specification is requested, details on how and where shall to be agreed.

Chapter 4.6 - Changes to tool specification or performance specification sheets
Any requirement for reassessment of features as a result of tool specification changes shall be agreed (if required).

Chapter 0 - Personnel qualification
Default requirements for qualifications of key personnel are given but can be specified otherwise by the Client.

Chapter 6.2 - Contracting
Various contracting details should be specified.

Chapter 0 - Reporting
Two reports are indicated as standard (default). Additional reporting should be requested and agreed.

Chapter 7.1 - Operations report
Default time for reporting is within 2 days. Change of reporting time should be agreed.
Default content report is listed, modifications to be agreed.
Default values for acceptable data loss are given, modifications to be agreed.

Chapter 7.2 - Preliminary report
Default time for reporting is within 4 weeks. Change of reporting time should be agreed.
Default content report is listed, modifications to be agreed.
Typical reporting criteria are given, modifications to be agreed.

Chapter 7.3 - Final report
Default time for reporting is within 8 weeks. Change of reporting time should be agreed.
Default content report is listed, modifications to be agreed.
Default reporting thresholds are listed, modifications to be agreed.

In chapter 7.3.1 to 7.3.10 typical reporting options are listed and should be used as default. Modifications to be agreed.

Chapter 7.4 - RAW data report
If requested by Client, the raw data or processed raw data shall be provided by agreement.

Chapter 7.5- Multiple run comparisons report
If requested by Client, anomaly data from two or more runs shall be compared. A typical reporting structure is given, modifications to be agreed.

Chapter 7.6- Additional reporting
Any additional desired reporting should be requested and agreed upon by Client and Contractor.

Appendix 5 - Tool technology performance specifications
It is requested that the ILI company provides information on anomaly detection and sizing and other measurement capabilities of their tool. Below some typical values that can support the Client in his review of the proposed specifications.

<u>POD of detected anomalies</u>
The POD of a tool is normally taken at 90% and is based on anomalies with reference dimensions as given in the tables of appendix 5.

The typical minimal detectable depth of a high resolution MFL tool for general corrosion is 10% t and for pitting defects it is 15% t both with a POD of 90%. For seamless pipes and other category defects other values can apply.

The typical minimal detectable defect depth of a UT tool is 1 to 1.5 mm with a POD of 90%.

<u>Depth, length and width sizing accuracies</u>
The accuracy depends on the anomaly dimension class:
Typical for (high resolution) MFL tools: depth 10-15% t, length and width accuracy 10-20 mm
Typical for UT tools: depth 0.3 – 0.5 mm, length and width accuracy 10 mm
For anomaly depth, length and width sizing accuracy, the typical certainty level is 80%.

<u>Accuracy of distance and orientation (clock position) of features:</u>
Typical accuracy of distance to/from marker: 0.25% of distance
Typical accuracy of distance to closest weld: 0.15 m
Typical accuracy of circumferential position: 10°.

<u>Certainty and accuracy of sizing deformations by geometry tool:</u>
The certainties and accuracies of reported dents and ovalities shall be defined.
Typical certainties and accuracies are:
Ovalities: ID reduction, accuracy 1% of pipeline ID with certainty = 90%
Length, accuracy 10% of pipeline ID with certainty = 90%.
Dents: Depth, accuracy 1% of pipeline ID with certainty = 90%
Length, accuracy 10% pipeline ID with certainty = 90%
Width, accuracy 10% pipeline ID with certainty = 90%.

Mapping: The accuracy of mapping is dependent on a variety of factors. Some of the main ones include the quality/technology of the IMU, the accelerometers, the odometer, the AGM's clock matching that of the inspection tool, the AGM's and also spacing of the accuracy with which the position of AGM is determined. Manufacturers and service providers will have varying technologies that provide varying accuracies.

It is generally thought that the accuracy of an IMU varies over distance travel, but the accuracy degrades over time, so it is important to consider the speed of the product in the pipe during the mapping inspection run. It is therefore important to specify maximum and minimum flow rates during mapping surveys.

AGM's are used to correct the IMU's 'drift' over time (and hence distance). The closer the AGM spacing, the more accurate the final coordinates will be. Many mapping runs use a 1 mile or 2 kilometre spacing, but for very or extremely high accuracy work 1 kilometre or even 500m spacing can be used.

AGM's should not be placed where the pipe is too deep for the inspection tool to be detected by the AGM.

Below are some reference documents that relate to magnetic properties for MFL inspection:

- *In "Magnetisation as a key parameter of magnetic flux leakage pigs for pipeline inspection" by H.J.M. Jansen, P.B.J. van de Camp and M. Geerdink (Insight Vol. 36, September 1994) it is concluded that MFL pigs are least sensitive to error sources (e.g. residual stresses, pressure, remnant magnetization) if the magnetic induction in the pipe wall > 1.8T. The magnetic field strength required to obtain such an induced magnetisation level depends on the type of material, wall thickness, pig speed etc.*
- *NACE International Publication 35100: "In-Line Non-destructive Inspection of Pipelines gives the following typical specifications for high-resolution MFL tools:*
  Minimum magnetic field strength: 10 to 12 kA/m (3 to 3.7 kA/ft)
  Minimum magnetic flux density: 1.7 T.

<u>Mapping tool specifications</u>

Geographical locations shall be reported in GPS coordinates by default, but another method can be specified if required.

Appendix 3: Report structure, terminology and acronyms

Column title	Unit	Prescribed terminology	Acronym	Explanatory note
Log distance	m	-		Starting point: trap valve
Abs up weld dist.	m	-		Absolute distance to upstream weld
L joint	m	-		Joint length to downstream weld
Feature type	-	- Above Ground Marker	AGM	
		- Additional metal/material	ADME	Further identified below
		- Anode	ANOD	
		- Anomaly	ANOM	Further identified below
		- Buckle arrestor begin/-end	BUAB/BUAE	
		- Casing begin/-end	CASB/CASE	
		- Change in wall thickness	CHWT	
		- CP connection	CPCO	
		- External support	ESUP	
		- Ground anchor	ANCH	
		- Off take	OFFT	
		- Other	OTHE	
		- Pipeline fixture	PFIX	
		- Reference magnet	MGNT	
		- Repair	REPA	Further identified below
		- Tee	TEE	
		- Valve	VALV	
		- Weld	WELD	Further identified below
Feature identification	-	Additional metal/material:		
		- Debris	DEBR	
		- Touching metal to metal	TMTM	
		- Other	OTHE	
		Anomaly:		
		- Arc strike	ARCS	
		- Artificial defect	ARTD	
		- Blister	BLIS	
		- Buckle Global	BUCG	
		- Buckle Local	BUCL	
		- Buckle Propagation	BUCP	
		- Corrosion	CORR	
		- Corrosion cluster	COCL	
		- Corrosion related to CRA	COCR	
		- Crack	CRAC	
		- Crack cluster	CRCL	
		- Dent complex	DENC	
		- Dent kinked	DENK	
		- Dent plain	DENP	
		- Gouge	GOUG	
		- Gouge cluster	GOCL	
		- Grinding	GRIN	
		- Girth weld crack	GWCR	
		- Girth weld anomaly	GWAN	
		- Longitudinal weld crack	LWCR	
		- Longitudinal weld anomaly	LWAN	
		- Mill anomaly Grinding	MGRI	
		- Mill anomaly Lamination	MLAM	
		- Mill anomaly Lap	MLAP	
		- Mill anomaly Non-Metallic Inclusion	MNOI	

		- Mill anomaly cluster - Ovality - Ripple/Wrinkle - Roof Topping - SCC - Spiral weld crack - Spiral weld anomaly <u>Repair:</u> - Welded sleeve begin/-end - Composite sleeve begin/-end - Weld deposit begin/-end - Coating begin/-end - Crack arrestor begin/end - Other begin/-end <u>Weld:</u> - - Bend begin/-end - Change in diameter - Change in wall thickness - Adjacent tapering - Longitudinal seam - Spiral seam - Not identifiable seam - Seamless	MACL OVAL RIWR ROTP SCC SWCR SWAN WSLB/WSLE CSLB/CSLE WDPB/WDPE COTB/COTE CRAB/CRAE OTHB/OTHE BENB/BENE CHDI CHWT ADTA LOSE SPSE NISE SMLS	No abbreviation for all welds different from welds below Applicable for: Pipe – pipe unequal WT
Feature class		- Axial Grooving - Axial Slotting - Circumferential Grooving - Circumferential Slotting - General - Pinhole - Pitting	AXGR AXSL CIGR CISL GENE PINH PITT	See Fig. 2.2 See Fig. 2.2 See Fig. 2.2 See Fig. 2.2 See Fig. 2.2 See Fig. 2.2 See Fig. 2.2
Clock position	h: min			See Fig. 2.1
Nominal t	mm			Nominal wall thickness of every joint
Reference t	mm			The actual not diminished wall thickness surrounding a feature
Length	mm			Anomaly length in axial direction
Width	mm			Anomaly width in circumferential direction
d (peak)	% or mm			If MFL: depth in % of ref t or nominal t*. If other technology in mm from ref t or nominal t*. *if ref. t is not available
d (mean)	% or mm			
Surface location		- Internal - External - Mid wall - Not applicable	INT EXT MID N/A	Location of anomaly on the pipeline: internal, external, mid wall or Not Applicable
ERF				
Comments	-	-		-

Appendix 4: Detailed tool data sheet requirements

Provide where appropriate following data.

Tool identification:

Tool type and model number
Unique reference number and date

Tool specifications:

Total Length:
Weight:
Number of Modules:
Maximum inspection range:
Maximum inspection time:
Inspection duration constraints: length of pipeline that can be inspected in one run due to e.g. wear of components, data storage limits or battery life:
Wall thickness range for full specification at minimum speed:
Wall thickness range for full specification at maximum speed:
Speed control range (if available):
Number and type of primary sensors:
Number and type of secondary (e.g. ID/OD) sensors:
Number of calliper/geometry sensors (if applicable):
Nominal circumferential centre to centre distance of primary sensors:
Longitudinal sampling distance: (specify values for either time or distance based):
Feature Location Accuracy - Axial
Feature Location Accuracy - Circumferential
Optimum tool speed Range:
One- or bi-directional design:

MFL specific:

- Direction of magnetization (axial/circumferential, helical) and polarity of magnetic field
- Required minimal magnetic field strength H in kA/m at the inner surface of the pipe to meet the given POD and sizing accuracy
- Type of magnet: (brushes, flaps, wear plates, wear knobs, wheels, ...).

Maximum circumferential secondary sensor spacing (i.e. circumferential centre to centre distance).

UT specific:

- Dimensions of UT transducers and diameter of crystal
- Frequency of UT signal
- Stand-off distance of UT transducers
- Diameter of UT beam at the inner pipe surface and outer pipe surface. The diameter of sound beam is defined by the diameter where the sound beam pressure is 6dB below the pressure at the centre of the beam
- Maximum tolerable attenuation in liquid and metal to receive sufficient response.

UT crack detection (in addition to UT specific)

- Angle of UT signal in steel
- Direction of angle of UT signal relative to pipe axis (longitudinal direction is 0°, circumferential is 90°).

Phased Array UT (in addition to UT crack detection)

- Number and dimensions of active elements within each transducer
- Range of angles of UT signal that can be generated in pipe wall.

EMAT UT:

- Type, mode and frequency of ultrasonic signal generated.

Safety:

ATEX and/or IECEx certification:
Type of batteries:
Magnetization hazard alert:
Pressurized containers alert:

Operating Parameters:

Maximum Operating Pressure:
Minimum Operating Pressure:
Temperature range:
Speed range for full performance specification:
Acceptable (proven) pipeline media (e.g. H2S, saline water, chemicals):
Excluded pipeline media:

Pipeline Parameters:

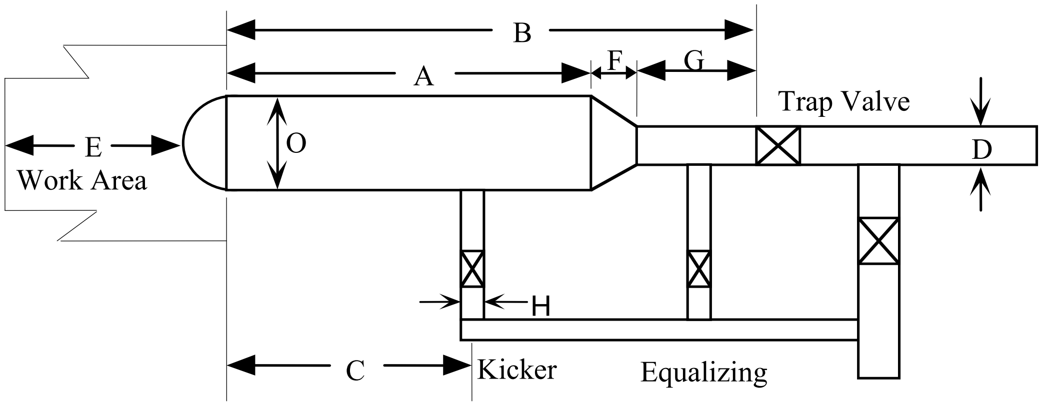
Maximum nominal bore:
Minimal nominal bore:
Minimum pipeline bend radius:
Minimal internal diameter in bend:
Maximum diameter barred:
Maximum diameter unbarred:
Minimum full bore adjacent tees:
Minimum full bore adjacent tees - Centreline separation:
Gauge plate diameter:
Back to Back bend capability:

Valves

Minimum ball valve bore:
Minimum gate valve bore:
Maximum void length:
Maximum Local Restriction:

Launcher and Receiver trap details

Launch and receive requirements including handling for vertical and horizontal traps:
Please provide a drawing with dimensions or complete the table below.



Trap Details		Launcher Dimensions (mm)	Receiver Dimensions (mm)
8.1.1 A	Closure to reducer		
B	Closure to trap valve		
C	Closure to bridle CL		
D	Pipeline internal diameter		
O	Overbore internal diameter		
E	Axial clearance		
F	Reducer length		
G	Reducer to valve		
H	Bridle		

Appendix 5: Tool technology performance specifications

Tool technology performance specifications shall define the ability of the ILI system to detect, locate, identify, and size pipeline features, components and anomalies. It is typically linked to the inspection technology applied in the tool e.g. High resolution MFL, standard MFL, Ultrasonic pitting detection tool, Ultrasonic wall thickness measuring tool etc.

The tool performance specifications as listed in this appendix shall be given. The influence of the operating or pipeline variables on the performance specifications shall be clearly indicated via e.g. correction factors or additional tables.

Essential variables that might influence the specifications and possibly require additional specifications are e.g. (but not limited to) listed below:

General specifications:

- Tool inspection technology
- Tool speed range
- Maximum axial sampling interval
- Maximum circumferential primary sensor spacing (i.e. circumferential centre to centre distance)
- Influence of line pipe manufacturing process (e.g. SAW, HFW, Seamless, etc)
- Influence of the location of the anomaly with respect to girth weld and/or seam weld; i.e. the ability to detect and size anomalies in and near weld and HAZ
- Influence of curvature of the pipeline, i.e. minimal bend radius.

MFL specific:

- Direction of magnetisation (axial/circumferential/ spiral) and polarity of magnetic field
- Required minimal magnetic field strength H in kA/m at the inner surface of the pipe to meet the given POD and sizing accuracy
- Maximum circumferential secondary sensor spacing (i.e. circumferential centre to centre distance).

UT specific:

- Dimensions of UT transducers and diameter of crystal
- Frequency of UT signal
- Stand-off distance of UT transducers
- Diameter of UT beam at the inner pipe surface and outer pipe surface. The diameter of sound beam to be defined by the dimension where the sound beam pressure is 6dB below the pressure in the centre of the beam.
- Maximum tolerable attenuation in liquid and metal to receive sufficient response.

UT crack detection (in addition to UT specific)

- Angle of UT signal in steel
- Direction of angle of UT signal relative to pipe axis (longitudinal direction is 0°, circumferential is 90°).

Phased Array UT (in addition to UT crack detection)

- Number and dimensions of active elements within each transducer
- Range of angles of UT signal that is generated in pipe wall.

EMAT UT:

- Type, mode and frequency of ultrasonic signal generated.

Table A5-1: Identification of features

Feature	Yes POI>90%	No POI<50%	May be 50%<=POI<=90%
Int./ext./mid wall discrimination			
Additional metal/material:			
- debris, magnetic			
- debris, non-magnetic			
- touching metal to metal			
- Other			
Anode			
Anomaly:			
- arc strike			
- artificial defect			
- blister			
- buckle global			
- buckle local			
- buckle propagation			
- corrosion			
- corrosion cluster			
- corrosion related to CRA			
- crack			
- crack cluster			
- dent kinked			
- dent plain			
- dent smooth			
- gouge			
- gouge cluster			
- grinding			
- girth weld crack			
- girth weld anomaly			
- longitudinal weld crack			
- longitudinal weld anomaly			
- mill anomaly - grinding			
- mill anomaly lamination			
- mill anomaly lap			

- mill anomaly non-metallic inclusion			
- mill anomaly cluster			
- ovality			
- ripple/wrinkle			
- SCC			
- spalling			
- spiral weld crack			
- spiral weld anomaly			
Eccentric pipeline casing			
Change in wall thickness			
CP connection/anode			
External support			
Ground anchor			
Off take			
Pipeline fixture			
Reference magnet			
Repair:			
- welded sleeve begin/end			
- composite sleeve begin/end			
- weld deposit begin/end			
- coating begin/end			
- crack arrestor begin/end			
Tee			
Valve			
Weld:			
- bend			
- diameter change			
- wall thickness change (pipe/pipe connection)			
- adjacent tapering			
- longitudinal weld			
- spiral weld			
- not identifiable seam			
- seamless			

Table A5-2: MFL detection and sizing accuracy for metal loss anomalies

	General metal-loss	Pitting	Axial grooving	Circumf. grooving	Pinhole	Axial slotting	Circumf. Slotting
Depth at POD=90%					N/A see below		
Depth sizing accuracy at 90% certainty							
Width sizing accuracy at 90% certainty							
Length sizing accuracy at 90% certainty							
Minimum pinhole diameter at POD=90% if depth=50%t						n.a.	
Minimum pinhole diameter at POD=90% if depth=20%t						n.a.	

Table A5-3: Metal loss detection and sizing accuracy for technologies other than MFL.

Detection but no sizing at POD=90%	Minimum diameter	
	Minimum depth	
Detection and sizing at POD=90%	Minimum diameter	
	Minimum depth	
Depth sizing accuracy at 90% certainty		
Length sizing accuracy at 90% certainty		
Width accuracy at 90% certainty		
Accuracy of wall thickness measurement at 90% certainty		

Table A5-3a: Detection and sizing of internal and external metal loss, regardless of technology. One table for each wall thickness must be filled out. Note: this table might be requested by the Client as an alternative for tables A5-2 and A5-3.

Wall Thickness xx-xx mm, POD/POI =90%							
Technique	Speed interval for stated detection limit and accuracy, m/s	Minimum defect size, Internal			Minimum defect size, External		
		Depth, mm	Length, mm	Width, mm	Depth, mm	Length, mm	Width, mm
Technique 1							
Technique 2							
Resulting tool performance							

Table A5-4: Detection and sizing accuracy for cracks or crack-like anomalies.

	Axial crack Pipe body/weld	Axial crack colony Pipe body	Circumferential crack Pipe body/weld	Spiral crack Pipe body/weld
Depth at POD=90% of crack with L=25 mm				
Minimum crack opening (mm)				
Depth sizing accuracy at 90% certainty				
Length sizing accuracy at 90% certainty				
Orientation limits (in degrees) for detectability				

Table A5-5: Detection and sizing accuracy for dents, ovalities, ripples/wrinkles, buckles

	Dent	Ovality
Height/Depth POD=90%		n.a.
Height/Depth sizing accuracy at 90% certainty		n.a.
Width sizing accuracy at 90% certainty		n.a.
Length sizing accuracy at 90% certainty		
Ovality at POD=90%	n.a.	

Table A5-6: Detection and sizing accuracy in 90˚ bends.

Minimal bend radius for detection of metal loss anomalies as given in Table A5-2, A5-3, A5-3a	OD*
Minimal bend radius for sizing accuracy for metal loss anomalies as given in Table A5-2, A5-3, A5-3a	OD*
Minimal bend radius for detection of crack or crack-like anomalies as given in Table A5-4	OD*
Minimal bend radius for sizing accuracy of crack or crack-like anomalies as given in Table A5-4	OD*

* If the bend radius in the pipeline is smaller than given in the table, then applicable specifications for that bend radius shall additionally be provided in the form of Tables A5-2, A5-3, A5-3a or A5-4.

Table A5-7: Location accuracy of features.

Accuracy of distance to upstream girth weld at 90% certainty	
Accuracy of distance from trap valve at 90% certainty	
Accuracy of circumferential position at 90% certainty	

Table A5-8: Mapping tool accuracy and horizontal and vertical accuracy of pipeline location as function of marker distance and certainty.

Accelerometer accuracy (micro g)		
Gyroscope accuracy (°/h)		
Horizontal accuracy (m) at 90% certainty	Vertical accuracy (m) at 90% certainty	Marker distance (m) (add rows to table if required)
0.5	0.5	
1.0	1.0	
2.0	2.0	

The values to be entered in this table depend on the accuracy of the individual company's technology and their way of operating their system as a whole. It is generally thought that the accuracy of an IMU varies over distance travelled, but the accuracy degrades over time, so it is important to consider the speed of the product in the pipe during the mapping inspection run. It is therefore important to specify, in consultation with the Contractor, the maximum and minimum flow rates during mapping surveys as well as spacing of AGMs. Very slow rates will reduce accuracy.

AGM's are used to correct the IMU's 'drift' over time (and hence distance). The closer the AGM spacing, the more accurate the final coordinates will be. Many 'standard' mapping runs use a 1 mile or 2 kilometre spacing, but for very or extremely high accuracy work 1 kilometre or even 500m spacing can be used.

Appendix 6: Typical example of Pipe tally*

	GPS coordinates			Feature type and ID			Reference joint						Joint global geometry		Feature location on joint			Anomly sizing and further information										
																		Deformations			Cracks and metal losses							
Log distance [m]	latitude	longitude	altitude [m]	Feature type	Feature identification	Comment / Cluster ID	Girth weld Nr	Joint manufacturing type	Joint / component length [m]	Internal diameter [mm]	Nominal thickness [mm]	Measured/reference thickness [mm]	Ovality [%]	Bend Y/N	Abs. Dist. to upstream weld [m]	Clock position seam weld / anomaly	Surface location	Inward/outward	Depth / height [%.D or mm]	Size (length x width) [mm]	Mean depth [%.t or mm]	Max. depth [%.t or mm]	Length [mm]	Width [mm]	Anomaly dimension classification	ERF (metal losses)	Reference table for performance	Comments
-1.136				Weld			10	Seamless	2.272	508	14	14.2																
0				Valve		Starting point: City									1.136													
1.136				Weld	Change wall thickness		20	Seamless	8.001	508	12	12.3	0.8														A3-5	
9.137				Weld			30	Long seam	12.001	508	12	12.1	0.4			8:04											A3-5	
21.138				Weld	Change wall thickness	Adjacent tapering	40	Spiral seam	12.001	508	8	8.4	0.2			4:42											A3-5	
23.139				Anomaly	Corrosion	Abnormal signal						8.4			2.001	10:32	Ext				18%	25%	126	42	GENE	Not calculated	A3-2	
30.143				Above ground marker	Marker	AGM 1									9.005													
33.141				Weld			50	Long seam	11.003	508	8	8.3	1.2			7:26											A3-5	
35.001				Anomaly	Dent, Kinked	Mechanical damage						8.3			12.860	0:22	Ext	Inw	2.7%	45x78	12%	21%	31	67	GENE	Not calculated	A3-2	
35.801				Anomaly	Gouge Cluster	GOCL-01						8.3			2.800	0:10	Ext				8%	15%	38	20	AXGR	Not calculated	A3-2	
44.144				Weld	Bend begin	Adjacent tapering	60	Long seam	2.004	508	12	12.2	0.9	Y		1:38												Installation S-449
44.999				Anomly	Corrosion Cluster	COCL-01						12.1		Y	0.855	8:36	Ext				32%	32%	42	25	PITT	Not calculated	A3-2	
46.148				Weld	Bend end	Adjacent tapering	70	Long seam	11.145	508	8	8.4	0.8			11:10												Installation S-449
47.151				Anomaly	Mill anomaly Cluster	MACL-01						8.4			1.003	8:53	Int				17%	36%	159	120	GENE	Not calculated	A3-2	
57.293				Weld			80	Long seam	10.999	508	8	8.5	0.9			7:12											A3-5	

* Columns can be added or deleted, e.g. depending on the ILI tool technology/technologies applied and/or on request of the Client.

Appendix 7: Typical example List of anomalies*

Log distance [m]	GPS coordinates			Feature type and ID			Reference joint						Joint global geometry		Feature location on joint			Anomaly sizing and further information									Reference table for performance	Comments
																		Deformations			Cracks and metal losses							
	latitude	longitude	altitude [m]	Feature type	Feature identification	Comment / Cluster ID	Girth weld Nr	Joint manufacturing type	Joint / component length [m]	Internal diameter [mm]	Nominal thickness [mm]	Measured/reference thickness [mm]	Ovality [%]	Bend Y/N	Abs. Dist. to upstream weld [m]	Clock position seam / anomaly	Surface location	Inward/outward	Depth / height [%.D or mm]	Size (length x width) [mm]	Mean depth [%.t or mm]	Max. depth [%.t or mm]	Length [mm]	Width [mm]	Anomaly dimension classification	ERF (metal losses)		
23.139				Anomaly	Corrosion	Abnormal signal						8.4			2.001	10:32	Ext				18%	25%	126	42	GENE	Not calculated	A3-2	
35.001				Anomaly	Dent, Kinked	Mechanical damage						8.3			12.860	0:22	Ext	Inw	2.7%	45x78	12%	21%	31	67	GENE	Not calculated	A3-2	
35.801				Anomaly	Gouge Cluster	GOCL-01						8.3			2.800	0:10	Ext				8%	15%	38	20	AXGR	Not calculated	A3-2	
44.999				Anomaly	Corrosion Cluster	COCL-01						12.1		Y	0.855	8:36	Ext				32%	32%	42	25	PITT	Not calculated	A3-2	
47.151				Anomaly	Mill anomaly Cluster	MACL-01						8.4			1.003	8:53	Int				17%	36%	159	120	GENE	Not calculated	A3-2	

* Columns can be added or deleted, e.g. depending on the ILI tool technology/technologies applied and/or on request of the Client.

Appendix 8: Typical example List of clusters*

	GPS coordinates			Feature type and ID			Reference joint						Joint gobal geometry		Feature location on joint			Anomly sizing and further information										
																		Deformations			Cracks and metal losses							
Log distance [m]	latitude	longitude	altitude [m]	Feature type	Feature identification	Comment / Cluster ID	Girth weld Nr	Joint manufacturing type	Joint / component length [m]	Diameter [mm]	Nominal thickness [mm]	Measured/reference thickness [mm]	Ovality [%]	Bend Y/N	Abs. Dist. to upstream weld [m]	Clock position seam / anomaly	Surface location	Inward/Outward	Depth / height [%.D or mm]	Size (lenght x width) [mm]	Mean depth [%.t or mm]	Max. depth [%.t or mm]	Length [mm]	Width [mm]	Anomaly dimension classification	ERF (metal losses)	Reference table for performance	Comments
35.801				Anomaly	Gouge Cluster	GOCL-01						8,3			2.8	0:10	Ext				8%	15%	38	20	AXGR	Not calculated	A3-2	
35.801					Gouge	GOCL-01.01						8.3			2.8	0:10	Ext				7%	12%	30	11	AXGR	Not calculated	A3-2	24° angle
35.811					Gouge	GOCL_01.02						8.3			2.8	0:14	Ext				5%	15%	28	12	AXGR	Not calculated	A3-2	35° angle
44.999				Anomly	Corrosion Cluster	COCL-01						12.1			0.855	8:36	Ext				32%	32%	42	25	PITT	Not calculated	A3-2	
44.999					Corrosion	COCL-01-01						12.1			0.855	8:36	Ext				24%	24%	12	12	PITT	Not calculated	A3-2	
45.015					Coprrosion	COCL-01-02						12.1			0.871	8:43	Ext				36%	36%	26	20	PITT	Not calculated	A3-2	
47.151				Anomaly	Mill anomaly Cluster	MACL-01						8.4			1.003	8:53	Int				17%	36%	159	120	GENE	Not calculated	A3-2	
47.151					Grinding	MACL-01-01						8.4			1.003	9:16	Int				14%	36%	64	70	GENE	Not calculated	A3-2	
47.221					Non-metallic inclusion	MACL-01-02						8.4			1.073	9:42	Int				12%	12%	10	12	PITT	Not calculated	A3-2	
47.232					Lamination	MACL-01-03						8.4			1.084	8:53	Mid				11%	24%	78	55	GENE	Not calculated	A3-2	

* Columns can be added or deleted, e.g. depending on the ILI tool technology/technologies applied and/or on request of the Client.

Appendix 9: Typical example Run comparison overview*

DATA RUN 1 (yyyy-mm-dd)															DATA RUN 2 (yyyy-mm-dd)															Difference				Comment
Log distance [m]	Latitude	Longitude	Altitude	Girth weld number	Joint / component length [m]	Wall thickness [mm]	Abs. dist. feature to upstream weld [m]	Feature	Clock position	Length [mm]	Width [mm]	Depth %	Int / Ext	…	Log distance [m]	Latitude	Longitude	Altitude	Girth weld number	Joint / component length [m]	Wall thickness [mm]	Abs. dist. feature to upstream weld [m]	Feature	Clock position	Length [mm]	Width [mm]	Depth %	Int / Ext	…	Δ Length [mm]	Δ Width [mm]	Δ Depth %	…	
10,250.250				7500	14.651	10.0		weld							10,250.000				7500	14.811	10.5		weld											Weld matched
10,256.630						10.0		corrosion	6:00	35	40	12	Int		10,257.000								corrosion	5:42	120	80	18	Int		85	40	6		Corrosion matched
															10,262.650								corrosion	4:12	15	10	5	Int						New corrosion
10,263.305						10.0		grinding	11:04	120	80	8	Ext		10,263.500								corrosion	11:00	140	90	12	Ext		20	10	4		Identification correction: grinding to corrosion
10,264.910				7510	15.100	10.0		weld							10,264.818				7510	15.080	10.5		weld											Weld matched
10,280.008				7520	15.000	10.0		weld							10,279.898				7520	3.110	10.5		weld											Weld matched
															10,283.000				7522	7.000	12.5		weld											New weld
															10,290.064				7524	4.905	10.5		weld											New weld
10,294.800				7530	14.805	10.0		weld							10,294.900				7530	14.805	10.5		weld											Weld matched

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