Specifications and requirements for in-line inspection of pipelines

Standard Practice

POF 100

November 2021

Foreword

This document has been reviewed and approved by the Pipeline Operators Forum (POF) and is based on knowledge and experience available from POF members and others at the date of issue. It is stated however, that neither POF nor its member companies (or their representatives) can be held responsible for the fitness for purpose, completeness, accuracy and/or application of this document.

A draft version of this specification has been sent for review and comments to in-line inspection contractors. The POF would like to thank the Contractors for their constructive feedback.

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).

Changes November 2021

The 2021 version of this document supersedes the 2016 version. The main technical changes are listed in the table below.

This revision also implements the new POF document numbering system.

Topic	Reference	Description
Anomaly-Feature	Whole document	When applicable the word feature has been replaced by anomaly
Definitions	2.2	Some definitions have been updated and new have been added; bend, bulge, defect, hard spot, imperfection and spalling
Abbreviations	2.3	New abbreviations added: ART, FPR, LFM, POF, SMYS, UPT, UTS
Anomaly types	2.4	New anomaly types have been added: lamination, coating disbondment, hard spot and material identification.
Crack and crack-like	2.4, 2.4.8	Updated definition (2.4) and guidance (2.4.8) for these anomaly types.
Dent	2.4.2, 2.4.3, 2.4.8	Term “smooth” dent has been removed and is now considered to be a “plain” dent. Term “complex dent” shall be used if other anomalies are associated with the dent.
Crack and crack-like	2.4, 2.4.8	Updated definitions and description
Failure Pressure Ratio (FPR)	2.6.2, 7.3.8	FPR is also allowed as indication of anomaly severity, though ERF remains the default.
Bend measurement capabilities	2.7, 7.3, A2, A4-10	New information on bend measurement capabilities and reporting
Contractor compliance check	6.1	Added reference to POF-320: “In-line inspection contractor compliance check”
Acceptable data loss	7.1	The formulation for acceptable data loss has been changed
Anomaly reporting threshold	7.2	Anomaly thresholds for preliminary report have been updated.
UPT data report	7.4	Raw data report has been replaced by UPT data report with reference to POF-110: “Specifications and requirements for universal POF Template (UPT) data format for in-line inspection of pipelines”
Run comparison	7.5	Updated guidance with reference to POF-110
Feature type and identification	A2, Table A4-1	Updated table to make distinction between feature type and identification more consistent
Examples	A5, A6, A7 and A.8	Updated examples of pipe tally (A4), list of anomalies (A5), list of clusters (A7) and run comparison (A8)

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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 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 1: Guideline for clients to define specific details of the POF specifications.

2 Definitions and abbreviations

2.1 General

During the update of this specification, standards such as e.g. API 1163 [1], PDAM [2] and CEPA [3] have been reviewed and some definitions have been aligned. The annotation behind the definitions below refer to the standard used. 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 [1]:	An unexamined deviation from the norm in pipe material, coatings, or welds, which may or may not be a defect. See also imperfection, defect, and feature.
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.
Bend:	A change of direction of the pipeline, in either the horizontal or the vertical planes, or in a combination of both. A bend is primarily defined by its angle (in degrees), and its radius (in a multiple of the pipe diameter). It can also be defined by the plane of change of direction (horizontal, vertical, combination of both).
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. A buckle is defined as a deformation with an amplitude greater than 25.4 mm (ref. API 1160). *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, 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.
Bulge:	A local, outward plastic or elastic deformation of the pipe wall resulting in a change of the internal diameter. If this anomaly coincides with any other anomaly and/or is associated with an adjacent weld, then it should be reported to be complex.
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 valves, welds, tees, flanges, fittings, taps, branch connections, outlets, supports, and anchors.
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 with a high length to width ratio, a sharp root radius and no or very small opening of the crack fracture surfaces.
Crack-like:	An anomaly, similar to a crack that may or may not have a sharp root radius and with an opening of the fracture surfaces in the order of 0.1 mm or more.
Debris:	Extraneous material in a pipeline.

Defect [1]:	A physically examined anomaly with dimensions or characteristics that exceed acceptable limits. See also imperfection.
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, inward 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 anomaly dimension at a defined certainty.
Feature [1]:	Any physical object detected by an ILI system. Features may be anomalies, components, nearby metallic objects, welds, appurtenances, or some other item.
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.
Hard spot:	Area in the pipe with a hardness level considerably higher than that of the surrounding metal.
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.
Imperfection [1]:	An anomaly with characteristics that do not exceed acceptable limits. See also defect.
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:	Definition of the 3D pipeline route coordinates using the inertial navigation system of the ILI tool.
Material identification:	Identification of line pipe material (grade) by means of in-line inspection technology
Maximum allowable operating pressure [2]:	Pressure less than or equal to the design pressure that 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 an anomaly to make sizing possible.
Mill anomaly:	An anomaly that arises during manufacture of a pipe joint or component.
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 that a specified anomaly 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 of the wall of the pipe caused by bending stresses.
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:	The interval with which a fixed percentage of anomalies 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.
Spalling [2]:	Severe abrasion which smears the surface of the pipe, producing shallow surface laps. Spalling is caused by mechanical damage and might be associated with denting.
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 an anomaly, used as reference for the determination of the anomaly 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 and acronyms

For the purpose of this document, the following abbreviations and 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
ART	Acoustic Resonance Technology
CRA	Corrosion Resistant Alloy
d	Depth of metal loss or crack
E	End point of anomaly
EC	Eddy Current
EMAT	Electro Magnetic Acoustic Transducer
ERF	Estimated Repair Factor
FPR	Failure Pressure Ratio
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 Measurement Unit
ID	Internal pipe Diameter
LFM	Low Field MFL
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
POF	Pipeline Operators Forum
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
SMYS	Specified Minimum Yield Strength
t	Wall thickness
UPT	Universal POF Template
UT	Ultrasonic Testing
UTS	Ultimate Tensile Strength
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

This section gives an overview of the main (but not all) anomalies that may be present in a pipeline. There is no single ILI technology that is capable of reliably detecting all anomaly types. Selection of ILI technology requires a discussion between Client and Contractor where factors are considered such as relevant threats, their associated anomalies and capabilities and limitations of the various ILI technologies for these anomalies. For example, the orientation of the applied magnetic field in MFL tools can have an important influence on the detection, identification and sizing of anomalies. Also, the expected type of anomaly, like planar, may preclude the use of certain technologies. For further detail, see section 4.1 and other industry standards such as API 1160 [13]. and NACE SP0102 [17].

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.

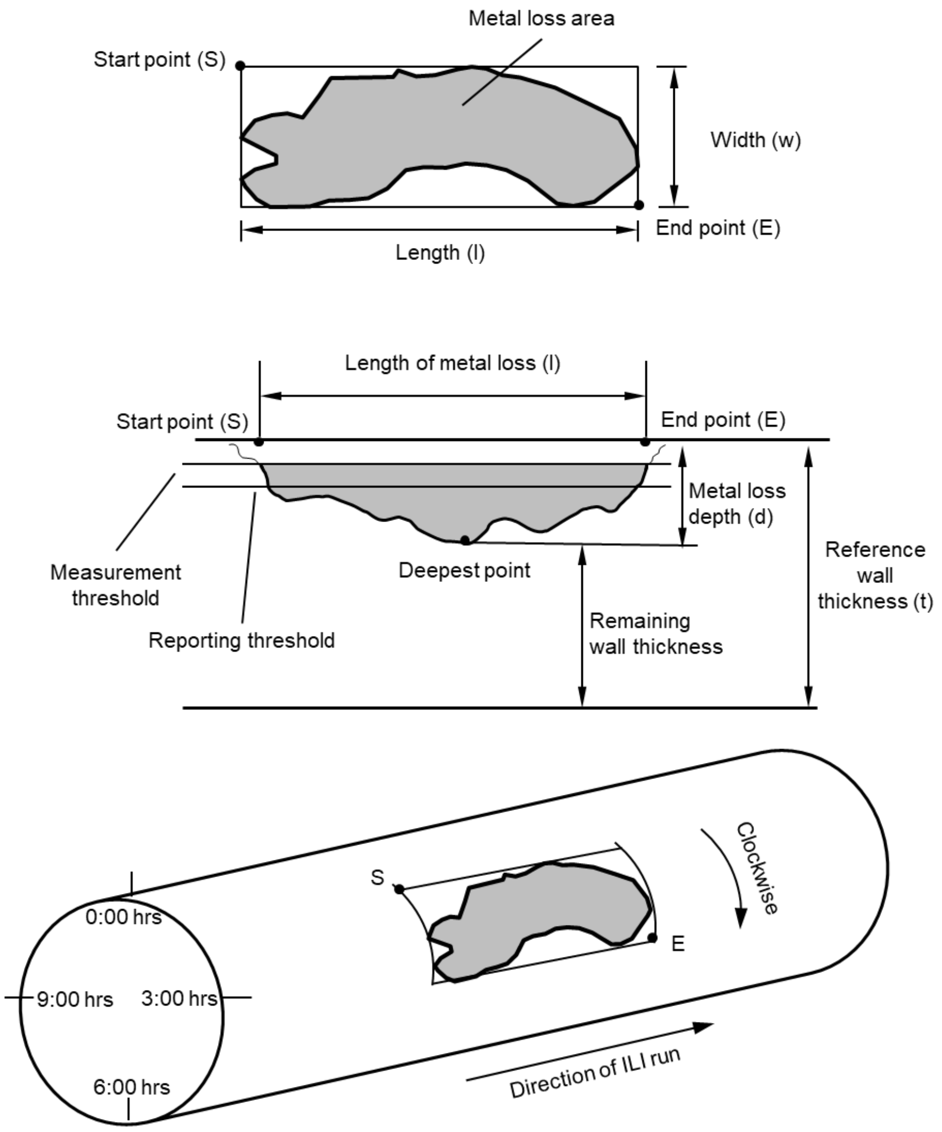


Figure 2.1: Illustration of parameters describing location and dimension of metal loss anomaly.

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 and a remark can be added to the comment field. *Note: highest clock position shall be 11:59.*

Metal loss anomaly classification

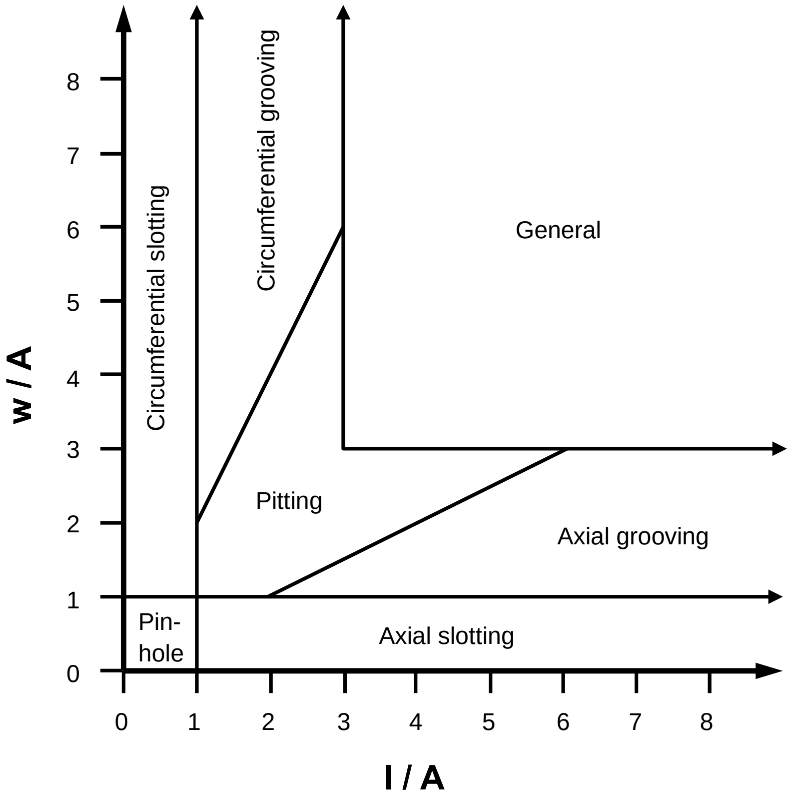
The measurement capabilities of non-destructive examination techniques, in particular the MFL technique, depend on the geometry of the metal loss anomalies. Metal loss anomaly classes have been defined as shown in Figure 2.2 for anomaly reporting purposes. In addition, it allows for a proper specification 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 A4 - 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

* Slotting anomalies might be classified as 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.

If a metal loss anomaly is associated with a dent, then it shall be reported as a complex dent with separate dimensions of the metal loss anomaly and dent.

2.4.2 Dent

A dent is defined by its type (Kinked, Plain, Complex), maximum depth (h), width (w) and length (l), as shown in Figure 2.3. If requested, the maximum strain based on a methodology agreed between Client and Contractor shall be reported. If the dent results in an ovality of the pipe then a more detailed description and evaluation is required. If the Contractor has more information about the dent, e.g. that it is re-rounded or cycled, this can be reported through the specific anomaly type and/or in the comment field.

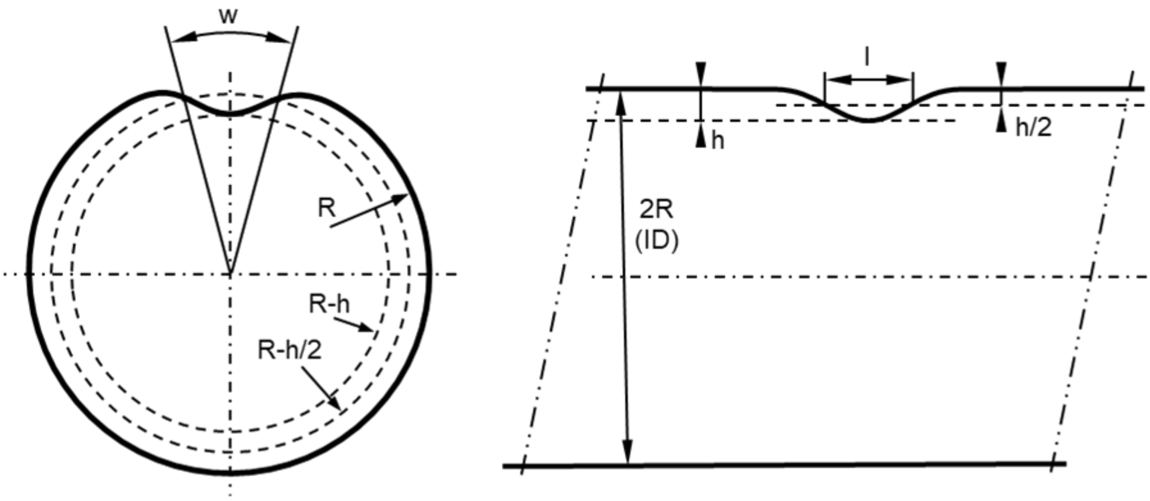


Figure 2.3: Measurement of dent.

The dent can be defined by absolute depth or as a percentage of the pipeline diameter. The value of diameter shall be the OD, unless agreed differently between Client and Contractor:

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

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 complex dent 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

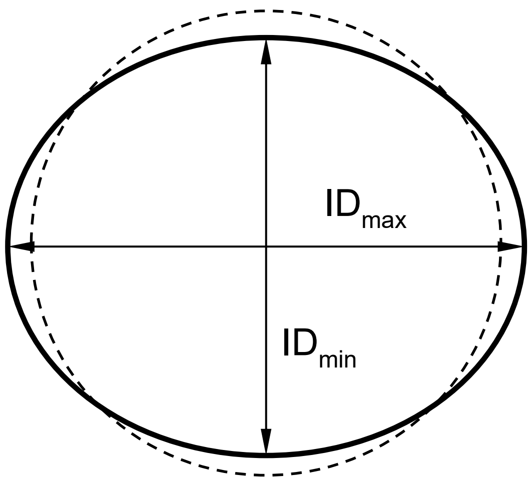


Figure 2.4: Measurement of ovality at one point over distance.

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

$$\frac{ID_{max} - ID_{min}}{\left[\frac{ID_{max}+ID_{min}}{2}\right]} * 100\%$$

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.

Notes:

- *If not specified otherwise, the maximum shall be reported*
- *If agreed between Client and Contractor, the ovality can be based on the OD.*
- *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 2.5, Figure 2.6. Multiple ripples/wrinkles are defined by the total length (l) and maximum height (h), see 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.

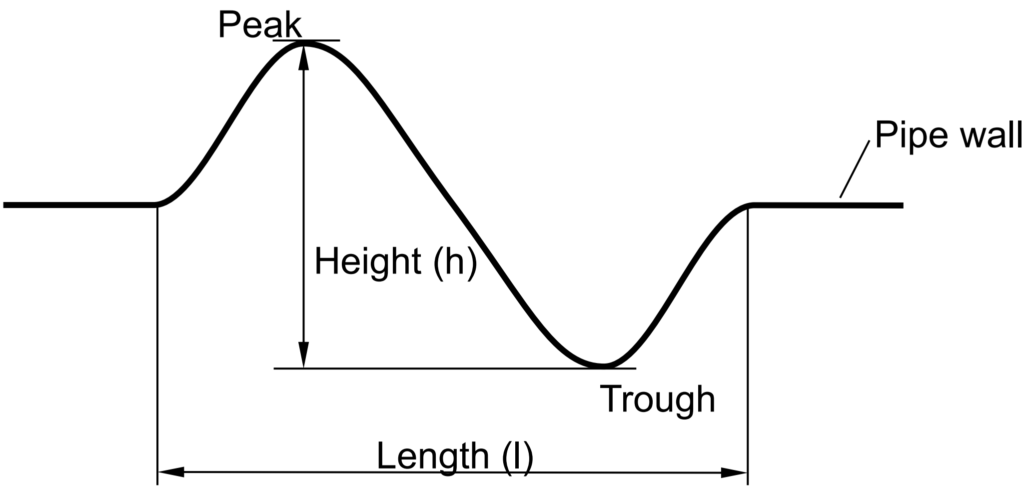


Figure 2.5: Measurement of ripple / wrinkle.

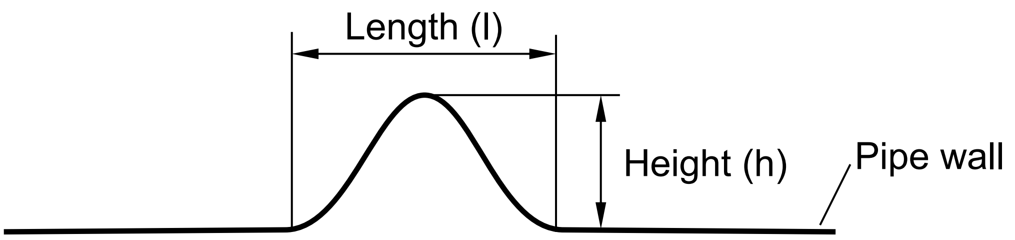


Figure 2.6: Measurement of single ripple/wrinkle.

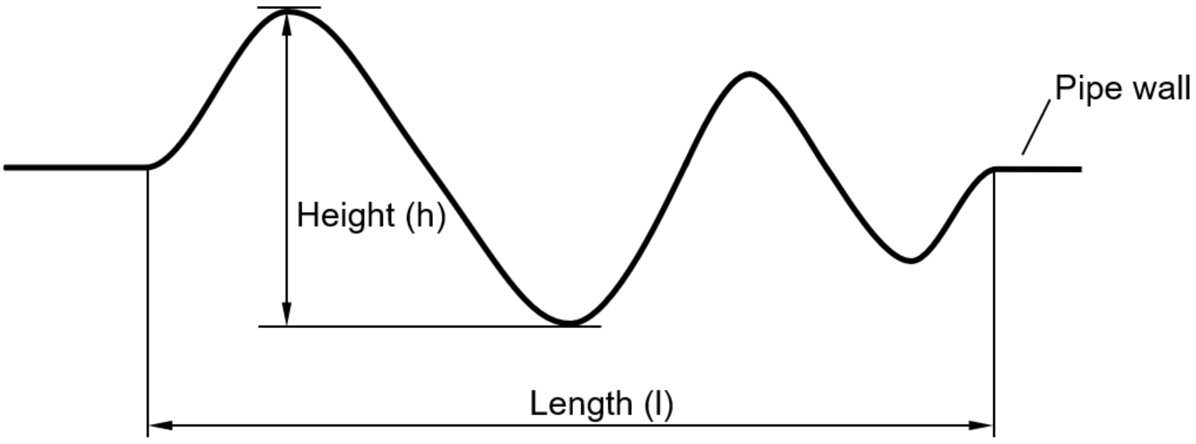


Figure 2.7: Measurement of more complex, single sided multiple ripples / wrinkles,

2.4.7 Roof topping/peaking

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

Note: Inward peaking may also occur. In that case, the definition of ϴ in the figure below can be different and shall be discussed between Client and Contractor.

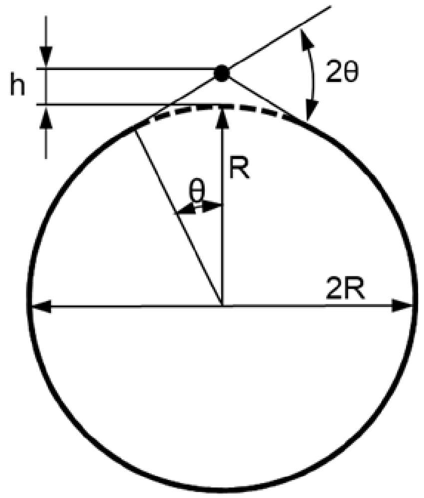


Figure 2.8: Measurement of peaking/roof topping.

2.4.8 Crack and crack-like

A crack or crack-like anomaly 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.

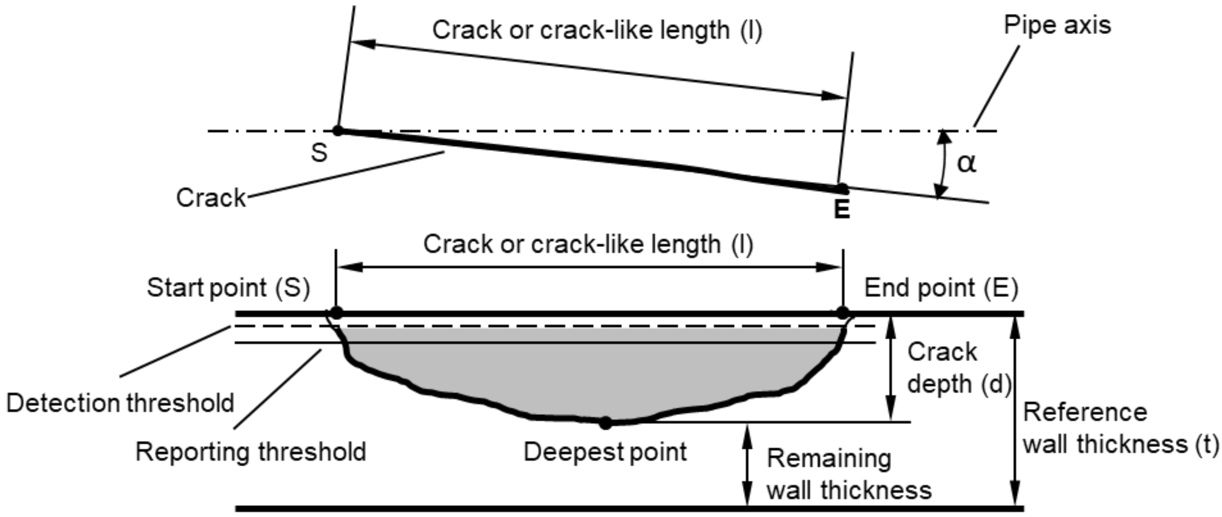


Figure 2.9: Illustration (top view and cross section) of parameters describing location and dimension of crack and crack-like anomalies.

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 in colonies.

If a crack or crack-like anomaly is associated with a dent, then it shall be reported as a complex dent with separate dimensions of the crack and dent.

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.

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. For instance, electromagnetic technologies such as MFL require a certain minimum crack opening (typically ~0.1 mm) or volume for detection while this is much less the case for ultrasonic technologies.

The Contractor shall provide the tool performance specifications in accordance with section 4.4 and Table A4 - 5 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 anomalies.

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).

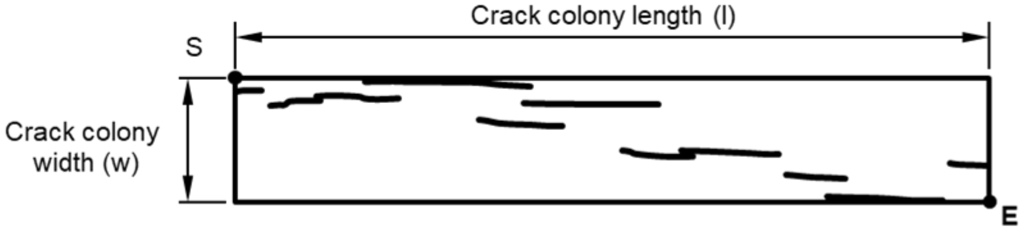


Figure 2.10: Illustration (top view) of parameters describing location and dimensions of crack colonies.

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.

2.4.10 Laminations

Planar, two-dimensional and elongated pipeline anomalies mechanically splitting the pipe wall into two parts and oriented primarily parallel to the pipe surface are referred to as laminations. In analogy to metal loss and as shown in Figure 2.11, a lamination is defined by location, its width and length and the minimum distance from the ID of the pipe. Depending on the ILI tool capabilities a possible slope of the lamination with respect to the longitudinal pipe axis can be reported. If the lamination is identified as being surface breaking to the ID or OD of the pipe, a more detailed description and evaluation based on a methodology agreed between Client and Contractor is required.

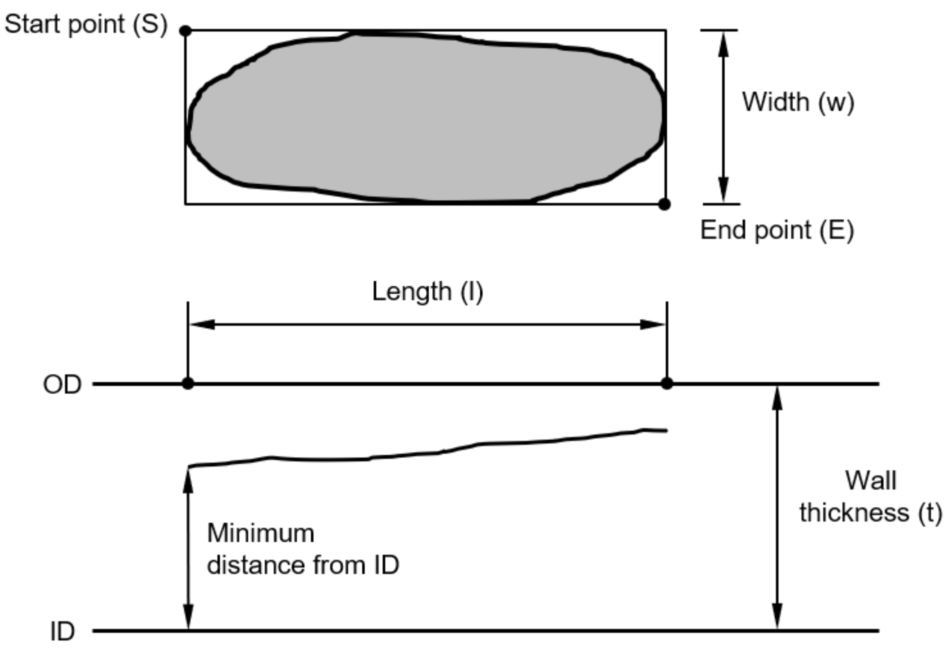


Figure 2.11: Measurement of laminations.

2.4.11 Coating disbondment

Areas of detached, missing or insufficiently bonded external pipe coating are designated as areas of coating disbondment. Such areas are best described by its location in analogy to metal loss, their width (w) and length (l), see Figure 2.12. Depending on the ILI tool capabilities and Client requirements, discrimination of different coating types and missing or insufficient adherence of coating to the pipe steel may be part of tool data evaluation and reporting. A methodology between Client and Contractor is required to allow for a common understanding and interpretation of the results.

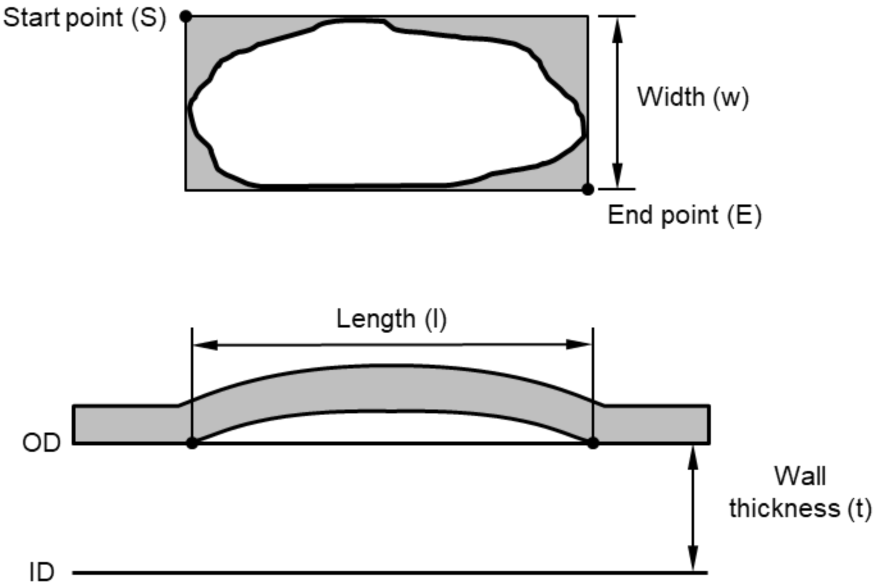


Figure 2.12: Measurement of coating disbondment.

2.4.12 Hard spot

A hard spot is a local area in the pipe wall with a hardness level considerably higher than that of the surrounding metal, usually due to localised quenching during rolling of the steel plate, change in chemistry or possibly gouging. These hard spots may be detected with a dedicated electromagnetic inspection technology. The dimensions can be treated the same as metal loss (see Figure 2.1), whereby an increase of 50 Vickers hardness (HV) compared to the typical baseline pipe material hardness marks the boundaries of the spot. The parameters of anomalies are length (l), width (w), start point (S) and end point (E) as for metal loss but in place of depth, the maximum Vickers hardness (HV) should be stated. If agreed between Client and Contractor, the boundary value (50 HV) of the hard spot can be changed or reported in a different measurement unit (e.g. Brinell HBW or Rockwell HRC).

2.4.13 Material identification

Electromagnetic technologies, such as low field magnetic flux leakage, may be used to identify the grade of pipe material and thereby the SMYS/UTS of each spool.

2.5 Nomenclature of features

Features can be further divided into, among others, components and anomalies.

Features shall be identified in accordance with Appendix 2: Report structure, terminology and abbreviations.

The type of features shall be further identified in accordance with Appendix 2: Report structure, terminology and abbreviations: Row Feature identification.

2.6 Anomaly assessment

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:

- Pipeline Defect Assessment Manual (PDAM) [2]
- CEPA Recommended Practices for Managing Near-neutral pH Stress Corrosion Cracking (only SCC) [3]
- API 579/ASME FFS (general, including metal loss and cracking) [9]
- BS 7910 (general, including metal loss and cracking) [10]
- Modified ASME B31 G, (metal loss) [11]
- DNV-RP-F101 (metal loss) 12]
- API RP 1183 (dents) [14]
- API RP 1176 (cracking) [16]

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.

2.6.2 Indication of anomaly severity

To allow the Client to rank anomalies in the pipeline, a first pass screening of anomaly severity can be used. The Estimated Repair Factor (ERF) is considered to be the default methodology. On request of the Client, the Failure Pressure Ratio (FPR) can be chosen, which is described in API 1160 [13].

It is noted that for significantly ranked defects a more sophisticated assessment may then be applied.

2.6.3 Estimated Repair Factor (ERF)

The ERF is defined as:

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

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.

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%
Measured wall thickness (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)
Bend angle	1 degree	n/a
Bend radius	0.1 multiple of OD	n/a

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[1], 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.

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

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

  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 > 0.11 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.

Tool data sheet requirements are included in Appendix 3: Detailed tool data sheet requirements.

4.3 Tool class history

In order to achieve a high probability of first run success (Ref. POF 300 [6]), 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 Performance specification

The performance specifications shall define the ability of the ILI system to detect, locate, identify, and size pipeline features. It is typically linked to the inspection technology applied in the tool.

4.4.1 General

The 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 system. 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 4: Tool technology performance specifications, Table A4 - 1.
- The measurement specifications for detection and sizing of the various anomalies and pipeline location shall be reported as specified in Appendix 4: Tool technology performance specifications, Table A4 - 2 to Table A4 - 9 where they apply. The Client might request to complete the alternative Table A4 - 4 in favour of Table A4 - 2 and Table A4 - 3.
- The 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 with UT) are combined into one tool, then the performance specification 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 4: Tool technology performance specifications.

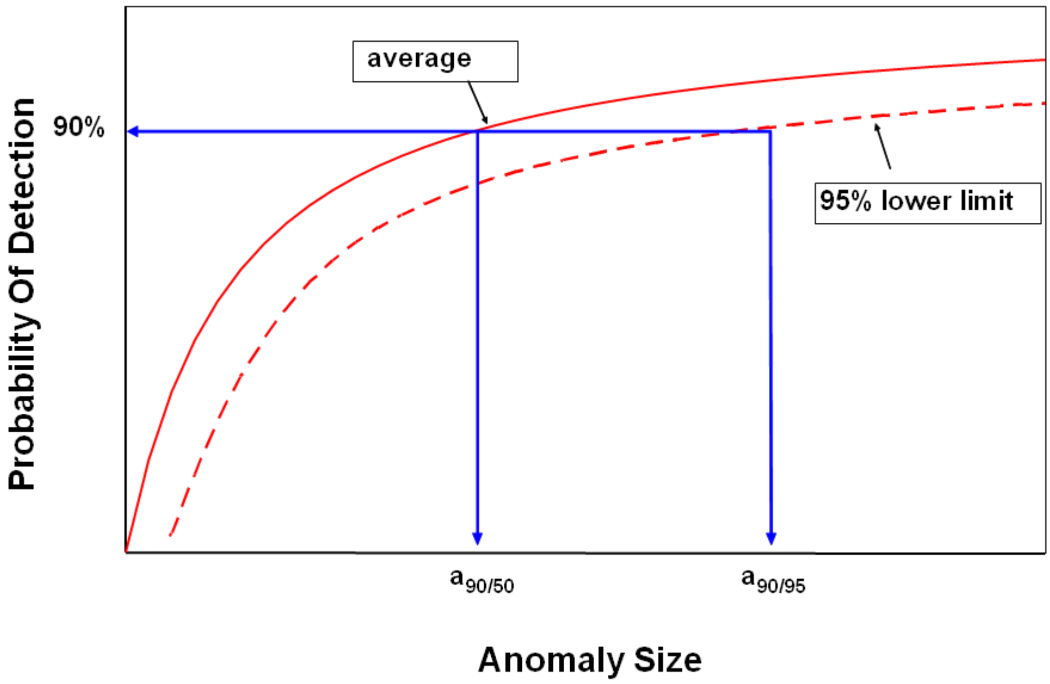


Figure 4.1: Typical example of the average and lower limit POD curve as function of anomaly size with indication of the definitions of $a_{90/50}$ (a_{90}) and $a_{90/95}$

4.4.2 Basis of performance

The basis on which performance specification is made shall be clearly stated for each anomaly 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 anomalies used are predominantly manufactured)
- Extensive pull through tests covering range of speed and wall thickness using a combination of manufactured and natural anomalies
- 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 anomalies 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 4: Tool technology performance specifications.

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: calibration anomalies used, 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 Performance verification

A Client may choose to verify the performance specification 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 anomalies
- Comparison of stated performance with actual reported anomalies.

Regarding field verification more guidance can be found in POF 310 [18] 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 performance specification.

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 anomalies is reduced based on new information or additional testing. Any requirement for reassessment of anomalies 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, analysing and reporting the inspection results shall be qualified and certified according to ASNT-ILI-PQ [4] or later version/superseding document.

Unless the Client specifies otherwise, key personnel shall meet the following minimum qualifications, ref. ASNT-ILI-PQ [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

Before entering into an ILI contract with a Contractor, it is recommended to check if the candidate Contractor can provide tools, technologies and services in compliance with industry accepted standards. POF 320 [5] is a guide that can be used for this purpose.

POF 300 [6], 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, and some check lists are available in POF 302 [7].

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 1: Guideline for clients to define specific details of the POF specifications), 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. POF 302 [7] provides guidance
- Specific details: Details and deviations from POF 100 (this document, if applicable)
- Run preparation: The Client should supply the Contractor with details of the pipeline(s) to be inspected. The ILI pipeline questionnaire in POF 301 [8] 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, as described in 4.5.

The requirements herein may be changed at request of the Client or the Contractor. 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, Contractor shall 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
- UPT data report
- Multiple run comparison report
- Experience 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 POF 300 [6].

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
    - Recording length of the pipeline
    - 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 or when sensors cannot measure properly (e.g. back wall echo loss in case of UT or excessive sensor lift-off in case of MFL)
    - 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:

- Accumulated loss of data from all primary sensors simultaneously less or equal to 0.5 % of pipeline length.
- Accumulated loss of data from individual primary sensors less or equal to 3% of pipeline surface area.
- Accumulated loss of data from adjacent primary sensors, covering more than 25 mm circumference less or equal to 10% of pipeline length.

Primary sensors are those sensors that provide the main input for the detection and sizing of anomalies. If ID/OD discrimination is not performed with primary sensors, then the above acceptable data loss criteria also apply to the ID/OD sensors

The criteria apply to each section of the pipeline separately, 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) a re-run of the tool or b) check if the data loss has a considerable 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 on detection thresholds, sizing accuracies and certainties of the reported results.

7.2 Preliminary report

A preliminary report contains a list of anomalies, including the associated 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 anomalies during the analysis of the ILI data which might be an integrity threat to the pipeline.

The preliminary report aims at summarizing the most important anomalies (individual and clustered) or which need immediate response per applied regulations, based on Client criteria as defined in the contract, in order to guarantee a safe pipeline operation. Unless agreed otherwise, typical reporting should include:

- Unclustered anomalies with an ERF ≥ 1.0
- Metal loss anomalies ≥ 50%
- Dents, Wrinkles/Buckles ≥5% OD
- Dents, complex or dents kinked
- Cracks/Crack-like features with depth exceeding 4.0 mm or 50% of the wall thickness whichever is smallest.

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 (as 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 agreed 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% OD
- Ovalities ≥ 5% ID
- Bend angle > 5°.

7.3.1 Pipe tally

The pipe tally shall be a listing of all pipeline features and should be reported in accordance with a typical report structure as given in Appendix 5: Pipe tally example* (including terminology, see Appendix 2: Report structure, terminology and abbreviations: "Feature identification"). The Client and Contractor can agree on specific requirements to the pipe tally, 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 2: Report structure, terminology and abbreviations). In this list of anomalies shall be indicated which of those are clustered anomalies. For a typical example see Appendix 6: List of anomalies example*. *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 which anomalies form a certain cluster, see Appendix 7: List of clusters example*
- List of individual anomalies:
  The list of individual 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 and agreed upon by the Contractor, 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 "other" 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 component types as listed in Appendix 2: Report structure, terminology and abbreviations. 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 anomalies depth showing all anomalies for each representative wall thickness
- Calculated safe working pressure of all anomalies as function of log distance
- 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 Crack detection

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 anomalies

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
- Distribution of all ovalities over the pipeline length.

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

If a tool that is capable of detecting other feature types was run, on request of the Client and agreed by the Contractor, 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.

7.3.5 Performance

The final report shall contain:

- Completed Table A4-1 to Table A4-10 as per the Contract
- Completed Table A4-1 to Table A4-10 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 anomaly.

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 Data viewing software

In addition to the final report, 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 / FPR

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. The ERF is considered to be the default method, but on request of the Client, the Failure Pressure ratio can be used. Input data and method used (ERF / FPR) shall be clearly stated in the final report.

ERF / FPR shall be reported for each individual anomaly. When clustering is applied, specific ERF / FPR 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 UPT data report

In order to ease multiple runs comparison, the extended data format called Universal POF Template (UPT) has been specified in POF 110 [15].

On request of the Client the run data shall be provided in UPT format. It is recommended to request this for any inspection, even if a run comparison is not specifically required, in order to be able to do it against a future run.

7.5 Multiple run comparisons report

On request of the Client, anomaly data from two or more successive ILI runs carried out on the same pipeline, shall be compared. This can be completed using either individual anomaly or clustered anomaly data. Aim is to detect discrepancies between reported anomalies of successive runs like new or missed features, corrosion growth, etc. If UPT data is available for both runs, the Client will provide UPT data of the previous run to the Contractor in order to make the run comparison using those UPT inspection data. This run comparison based on UPT data is expected to be more precise than the standard boxes/clusters comparison. 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 8: Run comparison example*.

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 sizing 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, …)
- A description of how the comparison was performed; i.e. more information on how individual defect and population growth have been determined.

7.6 Experience report

The experience report summarizes the operation and cooperation. 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. American Petroleum Institute, *In-Line Inspection Systems Qualification*, API STD 1163, Second Edition, April 2013, reaffirmed August 2018.
2. Penspen, *The Pipeline Defect Assessment Manual (Edition 2)*, October 2016.
3. Canadian Energy Pipeline Association (CEPA), *Recommended Practices for Managing Near-Neutral pH Stress Corrosion Cracking,* 3rd Ed., May 2015.
4. American Society for Nondestructive Testing, *In-line Inspection Personnel Qualification and Certification Standard*, ASNT ILI-PQ, 2017.
5. Pipeline Operators Forum, *In-line inspection contractor compliance check*, POF 320, 2021
6. Pipeline Operators Forum, *Achieving successful In-Line Inspection*, POF 300, 2021.
7. Pipeline Operators Forum, *In-line inspection check lists*, POF 302, 2021.
8. Pipeline Operators Forum, *ILI pipeline questionnaire*, POF 301, 2021.
9. American Petroleum Institute, *Fitness-For-Service*, API 579-1/ASME FFS-1, 2016.
10. British Standards Institution, *Guide to Methods for Assessing the Acceptability of Flaws in Metallic Structures*, BS 7910, 2019.
11. American Society for Mechanical Engineers, *Manual for Determining the Remaining Strength of Corroded Pipelines*, ASME B31G, 2012, reaffirmed 2017.
12. Det Norske Veritas, *Corroded Pipelines*, DNV-RP-F101, September 2021.
13. American Petroleum Institute, *Managing System Integrity for Hazardous Liquid Pipelines*, API RP 1160, Third Edition, February 2019.
14. American Petroleum Institute, *Assessment and Management of Pipeline Dents*, API RP 1183, First Edition, November 2020.
15. Pipeline Operators Forum, *Specifications and requirements for Universal POF Template (UPT) data format for in-line inspection of pipelines*, POF 110, 2021.
16. American Petroleum Institute, *Recommended Practice for Assessment and Management of Cracking in Pipelines*, API RP 1176, First Edition, July 2016.
17. NACE International, *In-Line Inspection of Pipelines*, NACE SP0102-2017.
18. Pipeline Operators Forum, *Guidance on Field Verification Procedures for In-Line Inspection*, POF 310, 2021.

Appendix 1: Guideline for clients to define specific details of the POF specifications

Introduction

POF 100 *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 Contractor 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

- A dent can be defined by absolute depth or as a percentage of pipeline diameter. The value of diameter shall be the OD, unless agreed differently between Client and Contractor.
- 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

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 0 – Coordinates for mapping work.

It is important for the client to specify the Global Position 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 3 - 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 > 0.11 MPa during receiving and launching of tools.

Chapter 4.3 – Tool class history
Client may request for information on tool readiness.

Chapter 4.4.1 - General
Client may request to complete the alternative Table A4 - 4 in favour of Table A4 - 2 and Table A4 - 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 be agreed.

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

Chapter 5 - 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 7 - 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.

Chapter 7.3.1 to 7.3.10
Typical reporting options are listed and should be used as default. Modifications to be agreed.

Chapter 7.5 - 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 7.7- Additional reporting
Any additional desired reporting should be requested and agreed upon by Client and Contractor.

Appendix 4: 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 4: Tool technology performance specifications.

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 90%.

<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 20 – 30 mm with certainty = 90%.
Dents: Depth, accuracy 1% of pipeline ID with certainty = 90%
Length, accuracy 10 - 20 mm with certainty = 90%
Width, accuracy 20 – 30 mm 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 km spacing, but for very or extremely high accuracy work 1 km 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.

Bend reporting:
Depending on the technologies which will be deployed, bends can or cannot be detected, and can or cannot be sized. In some instances, sizing can be done only by specifying ranges and not actual angle or radius. Client request should therefore be discussed with the ILI company prior to contracting.

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 (previous version of 2012): "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.

Appendix 2: Report structure, terminology and abbreviations

Column title	Unit	Prescribed terminology	Abbreviation	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	-	- Additional metal/material - Anomaly - Component - Marker - Other - Repair - Weld	ADME ANOM COMP MARK OTHE REPA WELD	Further identified below Further identified below Further identified below Further identified below E.g. for unknown features Further identified below Further identified below
Feature identification	-	Additional metal/material: - Debris - Touching metal to metal - Close metal object Anomaly: - Arc strike - Artificial defect - Blister - Buckle Global begin/end - Buckle Local - Bulge - Coating disbondment - Corrosion - Corrosion cluster - Corrosion related to CRA - Crack - Crack-like - Crack cluster - Dent complex - Dent cycled - Dent kinked - Dent plain - Dent re-rounded - Gouge - Gouge cluster - Grinding - Girth weld crack - Girth weld anomaly - Hard spot - Lamination - Lamination surface breaking - Longitudinal weld crack - Longitudinal weld anomaly - Mill anomaly - Mill anomaly cluster - Ovality - Ripple/Wrinkle - Roof topping - SCC - Spalling - Spiral weld crack - Spiral weld anomaly	 DEBR TMTM CLMO ARCS ARTD BLIS BUCB/BUCE BUCL BULG COAD CORR COCL COCR CRAC CRAL CRCL DENC DENY DENK DENP DENR GOUG GOCL GRIN GWCR GWAN HSPT LAMI LAMS LWCR LWAN MIAN MACL OVAL RIWR ROTP SCC SPAL SWCR SWAN	

Column title	Unit	Prescribed terminology	Abbreviation	Explanatory note
		Component: - Anode - Casing begin/-end - CP connection - External support - Flange - Ground anchor - Off take - Pipeline fixture - Tee - Valve Marker: - Above Ground Marker - Reference magnet Repair: - Welded sleeve begin/-end - Composite sleeve begin/-end - Weld deposit begin/-end - Coating begin/-end - Crack arrestor begin/end Weld: - Bend begin/-end - Buckle arrestor begin/end - Change in diameter - Change in wall thickness - Adjacent tapering - Longitudinal seam - Spiral seam - Not identifiable seam - Seamless	 ANOD CASB/CASE CPCO ESUP FLG ANCH OFFT PFIX TEE VALV AGM MGNT WSLB/WSLE CSLB/CSLE WDPB/WDPE COTB/COTE CRAB/CRAE BENB/BENE BUAB/BUAE CHDI CHWT ADTA LOSE SPSE NISE SMLS	No abbreviation for all welds different from welds below
Anomaly class		- Axial grooving - Axial slotting - Circumferential grooving - Circumferential slotting - General - Pinhole - Pitting	AXGR AXSL CIGR CISL GENE PINH PITT	See Figure 2.2
Clock position	h:min			See Figure 2.1
Nominal t	mm			Nominal wall thickness of every joint
Reference t	mm			The actual not diminished wall thickness surrounding an anomaly
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				

Column title	Unit	Prescribed terminology	Abbreviation	Explanatory note
Bend angle	°			
Bend radius	xD	Either a value or range		
Comments	-	-		-

Appendix 3: Detailed tool data sheet requirements

Provide following data where appropriate.

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 and outer 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 crystal
- Frequency of UT signal
- Stand-off distance of UT transducers
- Diameter of UT beam at the inner 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
- Focal zone of UT beam. The focal zone of the sound beam is defined by sound field depth where the sound pressure is within 6 dB of its maximum
- Maximum tolerable attenuation in liquid and metal to receive sufficient response.

UT crack detection (in addition to UT specific):

- Targeted angle of UT signal in steel

- Direction of targeted 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 and ART UT:

- Type, mode and frequency of ultrasonic signal generated.

Safety:

ATEX and/or IECEx certification
Type of batteries
Magnetization hazard warning label or information
Pressurized containers hazard warning label or information

Operating Parameters:

Maximum Operating Pressure
Minimum Operating Pressure
Temperature range
Speed range for full performance specification
Acceptable (proven) pipeline media (e.g. H_2S, saline water, chemicals)
Excluded pipeline media

Pipeline Parameters:

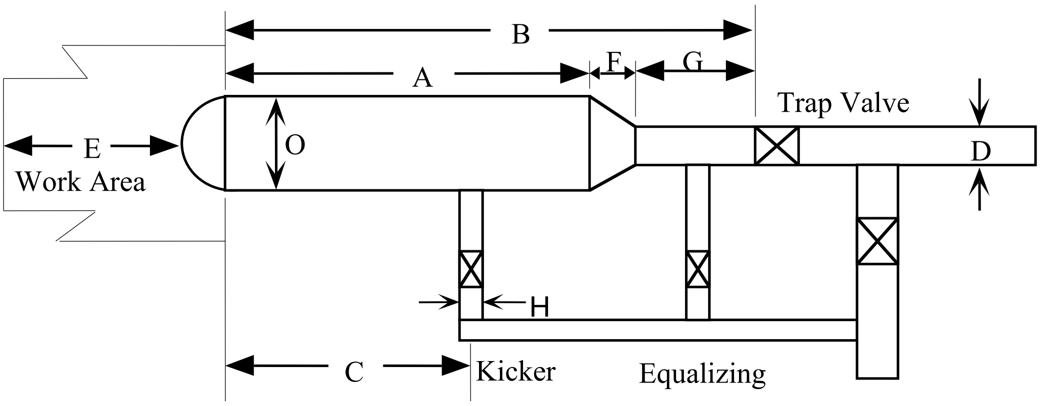
Maximum nominal bore
Minimal nominal bore
Minimum pipeline bend radius
Minimal internal diameter in bend
Maximum diameter barred tees
Maximum diameter unbarred tees
Minimum full bore adjacent tees
Minimum full bore adjacent tees - Centreline separation
Gauge plate diameter
Back-to-back bend capability

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)
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 4: Tool technology performance specifications

Tool technology performance specifications shall define the ability of the ILI system to detect, locate, identify, and size pipeline features. 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 minimum magnetic field strength H in kA/m at the inner and outer 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.
- Focal zone of UT beam. The focal zone of the sound beam is defined by sound field depth where the sound pressure is within 6dB of its maximum
- 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 A4 - 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			
- close metal object			
Anomaly:			
- arc strike			
- artificial defect			
- blister			
- buckle global			
- buckle local			
- buckle propagation			
- bulge			
- coating disbondment			
- corrosion			
- corrosion cluster			
- corrosion related to CRA			
- crack			
- crack cluster			
- crack-like			
- dent complex			
- dent cycled			
- dent kinked			
- dent plain			
- dent re-rounded			
- gouge			
- gouge cluster			
- grinding			
- girth weld crack			
- girth weld anomaly			
- hard spot			

Feature	Yes POI>90%	No POI<50%	May be 50%≤POI≤90%
- lamination			
- lamination surface breaking			
- longitudinal weld crack			
- longitudinal weld anomaly			
- mill anomaly			
- mill anomaly cluster			
- ovality			
- ripple/wrinkle			
- roof topping			
- SCC			
- spalling			
- spiral weld crack			
- spiral weld anomaly			
Component:			
- anode			
- casing			
- eccentric pipeline casing			
- CP connection			
- external support			
- flange			
- ground anchor			
- material identification			
- off take			
- pipeline fixture			
- tee			
- valve			
Marker:			
- above ground marker			
- reference magnet			
Repair:			
- welded sleeve begin/end			
- composite sleeve begin/end			
- weld deposit begin/end			

Feature	Yes POI>90%	No POI<50%	May be 50%≤POI≤90%
- coating begin/end			
- crack arrestor begin/end			
Weld:			
- bend			
- buckle arrestor			
- change in diameter			
- change in wall thickness (pipe/pipe connection)			
- adjacent tapering			
- longitudinal weld			
- spiral weld			
- not identifiable seam			
- seamless			

Table A4 - 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 A4 - 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 A4 - 4: 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 Table A4 - 2 and Table A4 - 3.

Wall Thickness … - -… 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 performance							

Table A4 - 5: 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-like opening (mm)				
Depth sizing accuracy at 90% certainty				
Length sizing accuracy at 90% certainty				
Orientation limits (in degrees) for detectability				

Table A4 - 6: 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 A4 - 7: Detection and sizing accuracy in 90˚ bends

Minimal bend radius for detection of metal loss anomalies as given in Table A4 - 2, Table A4 - 3, Table A4 - 4	OD*
Minimal bend radius for sizing accuracy for metal loss anomalies as given in Table A4 - 2, Table A4 - 3, Table A4 - 4	OD*
Minimal bend radius for detection of crack or crack-like anomalies as given in Table A4 - 5	OD*
Minimal bend radius for sizing accuracy of crack or crack-like anomalies as given in Table A4 - 5	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 Table A4 - 1, Table A4 - 3, Table A4 - 4. Table A4 - 5.

Table A4 - 8: 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 A4 - 9: 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 Contractor'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 km spacing, but for very or extremely high accuracy work 1 km or even 500 m spacing can be used.

Table A4 - 10: Bend sizing

Accuracy of bend angle at 90% certainty	
Accuracy of bend radius at 90% certainty	

Appendix 5: Pipe tally example*

Log distance [m]	GPS coordinates			Feature type and ID			Reference joint						Feature location on joint			Anomaly size						Comments
	latitude	longitude	altitude [m]	Feature type	Feature identification	Cluster ID	Girth weld Nr	Joint manufacturing type	Joint / component length [m]	Internal diameter [mm]	Nominal thickness [mm]	Measured/reference thickness [mm]	Abs. Dist. to upstream weld [m]	Clock position seam / anomaly	Surface location	Mean depth [%t, %OD or mm]	Max. depth [%t, %OD or mm]	Length [mm]	Width [mm]	Metal loss anomaly dimension classification	ERF (metal losses)	
-1.136				Weld			10	SMLS	2.272	508	14	14.2										
0				Component	Valve								1.136									Starting point: City
1.136				Weld	Change in wall thickness		20	SPSE	8.001	508	12	12.3										
9.137				Weld			30	SPSE	12.001	508	12	12.1		8:04								
21.138				Weld	Change in wall thickness		40	LOSE	12.001	508	8	8.4										
23.139				Anomaly	Corrosion							8.4	2.001	10:32	EXT	18%	25%	126	42	GENE	Not calculated	Abnormal signal
30.143				Marker	Above Ground Marker								9.005									AGM
33.141				Weld			50	LOSE	11.003	508	8	8.3		7:26								
35.001				Anomaly	Dent kinked							8.3	12.860	0:22	EXT	12%	21%	31	67		Not calculated	
35.801				Anomaly	Gouge cluster	GOCL-01						8.3	2.800	0:10	EXT	8%	15%	38	20	AXGR	Not calculated	
44.144				Weld	Bend begin		60	LOSE	2.004	508	12	12.2		1:38								
44.999				Anomaly	Corrosion cluster	COCL-01						12.1	0.855	8:36	EXT	16%	32%	42	25	PITT	Not calculated	
46.148				Weld	Bend end		70	LOSE	11.145	508	8	8.4		11:10								
47.151				Anomaly	Mill anomaly cluster	MACL-01						8.4	1.003	8:53	INT	17%	36%	159	120	GENE	Not calculated	
57.293				Weld			80	LOSE	10.999	508	8	8.5		7:12								

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

Appendix 6: List of anomalies example*

	GPS coordinates			Feature type and ID			Reference joint						Feature location on joint			Anomaly size						
Log distance [m]	latitude	longitude	altitude [m]	Feature type	Feature identification	Cluster ID	Girth weld Nr	Joint manufacturing type	Joint / component length [m]	Internal diameter [mm]	Nominal thickness [mm]	Measured/reference thickness [mm]	Abs. Dist. to upstream weld [m]	Clock position seam / anomaly	Surface location	Mean depth [%t, %OD or mm]	Max. depth [%t, %OD or mm]	Length [mm]	Width [mm]	Metal loss anomaly dimension classification	ERF (metal losses)	Comments
23,139				Anomaly	Corrosion							8.4	2,001	10:32	EXT	18%	25%	126	42	GENE	Not calculated	Abnormal signal
35,001				Anomaly	Dent kinked							8.3	12,860	0:22	EXT	12%	21%	31	67		Not calculated	
35,801				Anomaly	Gouge cluster	GOCL-01						8.3	2,800	0:10	EXT	8%	15%	38	20	AXGR	Not calculated	
44,999				Anomaly	Corrosion cluster	COCL-01						12.1	0.855	8:36	EXT	16%	32%	42	25	PITT	Not calculated	
47,151				Anomaly	Mill anomaly cluster	MACL-01						8.4	1,003	8:53	INT	17%	36%	159	120	GENE	Not calculated	

* On request of the Client, columns can be added or deleted, for specific inspection columns like e.g. roof topping, ovalities, material identification etc., depending on the ILI tool technology/technologies applied.

Appendix 7: List of clusters example*

Log distance [m]	GPS coordinates			Feature type and ID			Reference joint						Feature location on joint			Anomaly size						Comments
	latitude	longitude	altitude [m]	Feature type	Feature identification	Cluster ID	Girth weld Nr	Joint manufacturing type	Joint / component length [m]	Internal diameter [mm]	Nominal thickness [mm]	Measured/reference thickness [mm]	Abs. Dist. to upstream weld [m]	Clock position seam / anomaly	Surface location	Mean depth [%t, %OD or mm]	Max. depth [%t, %OD or mm]	Length [mm]	Width [mm]	Metal loss anomaly dimension classification	ERF (metal losses)	
35,801				Anomaly	Gouge cluster	GOCL-01						8.3	2,800	0:10	EXT	8%	15%	38	20	AXGR	Not calculated	
35,801				Anomaly	Gouge	GOCL-01.01						8.3	2,800	0:10	EXT	8%	12%	30	11	AXGR	Not calculated	24° angle
35,811				Anomaly	Gouge	GOCL-01.02						8.3	2,811	0:14	EXT	5%	15%	28	12	AXGR	Not calculated	35° angle
44,999				Anomaly	Corrosion cluster	COCL-01						12.1	0.855	8:36	EXT	16%	32%	42	25	PITT	Not calculated	
44,999				Anomaly	Corrosion	COCL-01.01						12.2	0,855	8:36	EXT	10%	24%	13	13	PITT	Not calculated	
45,015				Anomaly	Corrosion	COCL-01.02						12.3	0,871	8:43	EXT	20%	32%	26	20	PITT	Not calculated	
47,151				Anomaly	Mill anomaly cluster	MACL-01						8.4	1,003	8:53	INT	17%	36%	159	120	GENE	Not calculated	
47,151				Anomaly	Grinding	MACL-01.01						8.4	1,003	9:16	INT	14%	36%	64	70	GENE	Not calculated	
47,221				Anomaly	Mill anomaly	MACL-01.02						8.4	1,073	9:42	INT	12%	12%	10	12	PITT	Not calculated	
47,232				Anomaly	Lamination	MACL-01.03						8.4	1,084	8:53	MID	11%	24%	78	55	GENE	Not calculated	

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

Appendix 8: Run comparison example*

DATA RUN 1 (yyyy-mm-dd)															DATA RUN 2 (yyyy-mm-dd)															Difference			
Log distance [m]	Latitude	Longitude	Altitude	Girth weld number	Joint Length [m]	Wall thickness [mm]	Feature to upstream weld [m]	Feature type	Feature identification	Clock position	Length [mm]	Width [mm]	Depth %	Suface Location	Log distance [m]	Latitude	Longitude	Altitude	Girth weld number	Joint Length [m]	Wall thickness [mm]	Feature to upstream weld [m]	Feature type	Feature identification	Clock position	Length [mm]	Width [mm]	Depth %	Surface Location	Δ Length [mm]	Δ Width [mm]	Δ Depth %	Comment
10250.25				7500	14.65	10.0		Weld							10250.00				7500	14.81	10.5		Weld										Weld matched
10256.63						10.0		Anomaly	Corrosion	06:00	35	40	12	INT	10257.00								Anomaly	Corrosion	05:42	120	80	18	INT	85	40	6	Corrosion matched
															10262.65								Anomaly	Corrosion	04:12	15	10	5	INT				New corrosion
10263.30						10.0		Anomaly	Mill anomaly	11:04	120	80	8	EXT	10263.50								Anomaly	Corrosion	11:00	140	90	12	EXT	20	10	4	Identification correction mill anomaly to corrosion
10264.90				7510	15.10	10.0		Weld							10264.81				7510	15.08	10.5		Weld										Weld matched
10280.00				7520	15.00	10.0		Weld							10279.89				7520	3.11	10.5		Weld										Weld matched
															10283.00				7522	7.00	12.5		Weld										New weld
															10290.00				7524	4.90	10.5		Weld										New weld
10294.80				7530	14.80	10.0		Weld							10294.90				7530	14.80	10.5		Weld										Weld matched

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