UKOPA

United Kingdom Onshore Pipeline Operators' Association

Good Practice Guide

In-line Inspection (ILI)

UKOPA/GPG/021 Edition 2

February 2026

GUIDANCE ISSUED BY UKOPA:

The guidance in this document represents what is considered by UKOPA to represent current UK pipeline industry good practice within the defined scope of the document. All requirements should be considered guidance and should not be considered obligatory against the judgement of the Pipeline Owner/Operator. Where new and better techniques are developed and proved, they should be adopted without waiting for modifications to the guidance in this document.

Comments, questions, and enquiries about this publication should be directed to:

UK Onshore Pipeline Operators' Association
Ripley Road
Ambergate
Derbyshire
DE56 2FZ

E-mail: secretary@ukopa.co.uk

Website: www.ukopa.co.uk

Disclaimer

Revision and change control history

Planned revision: 2031

Edition	Date	No. of pages	Summary of changes
1	20/03/2020	38	First issue for use
2	01/02/2026	34	Editorial updates, inclusion of new ILI technologies

CONTENTS

1 Introduction 1
1.1 Background 1
1.2 Scope 1
1.3 Application 1
2 Legislation 3
3 Pipeline Operators Forum & NACE Documents 4
3.1 POF documents 4
3.2 AMPP documents 5
4 ILI Tools 6
4.1 Preparatory and cleaning tools 6
4.2 Intelligent or smart inspection tools 7
4.2.1 Geometry detection tools 7
4.2.2 Metal loss detection tools 7
4.2.3 Crack detection tools 9
4.2.4 Mapping tools 9
4.3 Supplementary services 9
5 ILI Strategy 11
5.1 ILI throughout the pipeline life 11
5.2 Tool Run Sequence 11
6 Selection of ILI Tools, Specification & Performance 12
6.1 Selection of ILI tools 12
6.2 ILI tool specification and requirements 17
6.3 ILI tool performance 18
7 First Run Success 19
8 Planning & Preparation 20
9 ILI Field Operations 22
9.1 Pre-launch 22
9.2 Launch, ILI run and receive 22
9.3 Safety and environmental aspects 23
9.4 ATEX and explosive atmospheres 23
10 Reporting 25
11 Assessment of Results & Integrity Management 26
12 Locating Features, Pipeline Excavation & Pipe Inspection 28
13 Tool Failures & Lessons Learnt 29
14 ILI System Qualification 30
15 ILI Frequency & Pipeline Design Codes 31
15.1 IGEM/TD/1 31

15.2 PD 8010 ... 31
15.3 ASME B31.4 ... 32
15.4 ASME B31.8 & ASME B31.8S ... 32
16 Difficult to Inspect Pipelines & Emerging Technology ... 33
17 References ... 34

1 INTRODUCTION

1.1 Background

In-line inspection (ILI) is the inspection of a pipeline from the inside using an ILI tool as it travels through the pipeline. ILI is used extensively in the pipeline industry, although not all pipelines are in-line inspectable i.e. currently able to be inspected using a conventional ILI tool. ILI operations include, but are not limited to, cleaning and inspecting the pipeline. ILI tools provide information on the condition of the pipeline as well as the extent and location of any specific features. Where feasible, ILI is part of the condition monitoring activities for the pipeline and is an important part of a pipeline integrity management programme to ensure integrity and safety.

ILI is used to establish the "baseline" or "fingerprint" condition of newly built and the current condition in operational pipelines.

Pipelines can be exposed to many different threats and each individual pipeline can therefore be subject to a number of different types of defects. ILI tools have developed to identify and size defects (with tolerance) from different types of threats, enabling the pipeline operator to be provided with information on the location and severity of the defects. The pipeline operator should identify and understand the threats credible to their pipeline before selecting which ILI tool or tools to run as part of an ILI programme.

ILI technology has developed and improved over the years to help pipeline operators identify defects which have the potential to cause pipeline failure in the future. This document is a general review of the types of ILI tools currently available and outlines good practices for the ILI of pipelines. As tools are continually developing, this document should be periodically reviewed and updated. It is recommended that future reviews of ILI technology are carried out at 4-5 year intervals.

1.2 Scope

The guidance in this document is applicable to all buried pipelines operated by the UKOPA member companies, which are able to be inspected using ILI tools. These pipelines can be categorised as:

- Natural gas transmission and distribution pipelines.
- Petrochemical liquids and gas pipelines.
- Oil and refined liquid pipelines.

For gas pipelines the guidance is generally applicable to pipelines with maximum operating pressures above 7 bar. The principles of the document can be equally applied to gas pipelines operating at lower pressures, however there can be technical challenges relating to ILI tool velocity control in low pressure gas pipelines.

Readiness of ILI tools for pipelines transporting hydrogen or hydrogen blends is an active area or research in the industry. A white paper has been published by the Pipeline Operators Forum (see section 3.1).

1.3 Application

This document presents a current 'state of the art' review of ILI inspection techniques to assist pipeline operators in specifying and using ILI.

This document provides advice on the range of ILI tools, their capability and selection following a review of integrity threats. The document references some key supporting documents developed by the Pipeline Operators Forum (POF) covering tool specifications, first run success, planning and preparation, operations, the reporting of results and field inspection. Some guidance on the assessment of results is provided in this document.

Definitions used in the document are as follows:

- 'In-Line inspection' (ILI) is the inspection of a pipeline from the inside using an ILI tool as it travels through the pipeline. The ILI tool collects various forms of data about the condition of the pipeline using sensors and electronics. In-line inspection may be referred to as 'pigging'.

- 'ILI tool' refers to a device or vehicle that uses a non-destructive testing technique to inspect the pipeline from the inside. An ILI tool may be referred to as an 'intelligent pig'.

- A 'trap' is the means to insert vehicles and tools into the pipeline and remove from the pipeline under safe working conditions without interrupting product supplies. Trap facilities may be a permanent or portable facility. Traps may be classified as pressure vessels when used with a relevant fluid. They typically have an oversized section of pipe, which reduces to the normal pipeline diameter. This gives an all-round clearance and allows the tool to be inserted and removed through the closure on the end of the trap. The trap is pressurised to launch the tool into the pipeline. The tool is then pressure-driven by the flow of the product in the pipeline to propel it along the pipeline until it reaches the trap at the receiving site.

Within this document:

Shall: indicates a mandatory requirement.

Should: indicates good practice and is the preferred option.

2 LEGISLATION

The principal legislation governing the safety of pipelines operated by UKOPA members is the Pipelines Safety Regulations (PSR) 1996 [1], which is goal setting requiring that pipelines are designed, constructed and operated so that the risks are as low as reasonably practicable (ALARP). In judging compliance, the Health and Safety Executive (HSE) expects duty-holders to apply relevant good practice as a minimum.

PSR Regulation 7 *Access for examination and maintenance* highlights that the pipeline design should take account of the need to facilitate examination, referring to '*in-service inspections, such as pigging*'.

PSR Regulation 13 *Maintenance* addresses the maintenance and inspection requirements of a pipeline i.e. *'The operator shall ensure that a pipeline is maintained in an efficient state, in efficient working order and in good repair'*. It also states; *'The operator needs to consider both how and when the pipeline should be surveyed and examined to validate and maintain it is in a safe condition'*. Hence once in operation, a pipeline should be periodically inspected to ensure its continued fitness for purpose.

ILI provides a means to periodically inspect a pipeline and obtain reliable quantifiable data on the condition of the pipeline.

Pipeline operators should make appropriate use of technical advances to ensure that the risk of pipeline failure continues to be ALARP. The HSE considers ILI to be 'industry good practice' for periodically establishing the condition of onshore pipelines.

For those pipelines referred to as Major Accident Hazard Pipelines (MAHPs), as defined in PSR, the maintenance plan should form part of the pipeline's safety management system.

The other key legislation applying to some onshore pipelines is the Pressure Systems Safety Regulations (PSSR) 2000 [2], which covers the safe design and use of pressure systems. The aim of PSSR is to prevent serious injury from the hazard of stored energy (pressure) as a result of the failure of a pressure system or one of its component parts.

PSSR applies to those onshore pipelines which constitute a 'pressure system' where the operating pressure is greater than 3 bar absolute (2 bar gauge) and conveying a 'relevant fluid', as defined in PSSR.

PSSR Regulation 8 *Written scheme of examination* and Regulation 9 *Examination in accordance with the written scheme* requires the User to have a Written Scheme of Examination (WSoE) for any pipeline that falls within the scope of the regulations, and to examine the pipeline in accordance with the scheme. The WSoE should identify all components, within a specific pressure system, that require examination and state the nature and frequency of the examination. The examination is conducted to assess the condition of those parts of the system in which failure of a defect would result in the sudden release of stored energy and give rise to danger.

Not all pipelines will be subject to the specific requirements of PSSR but all will be subject to PSR. It is industry good practice for pipelines subject to ILI for the pipeline operator to specify the nature and frequency of the ILI inspection.

Pipeline operators must identify, assess and properly control significant potential threats to their pipelines. The nature of the examination should be the result of a review to identify a pipeline's susceptibility to specific integrity threats. Thus, the selection of appropriate ILI tools should be to mitigate the identified integrity threats. Further details are provided in Section 6 of this document on the selection of ILI tools and their specification and performance.

3 PIPELINE OPERATORS FORUM & NACE DOCUMENTS

The Pipeline Operators Forum (POF) and the Association for Materials Protection and Performance (AMPP, formerly known as NACE International) have both published useful information on ILI.

POF is a non-profit forum enabling pipeline inspection and integrity engineers to share and build good practices, with the ultimate purpose of improving the quality of pipeline integrity management at every level, hence protecting people, the environment and operational integrity of pipelines globally. POF members include numerous pipeline operators from around the world, who have contributed to the development of the POF documents and shared their experiences and best practices.

AMPP is a global community for corrosion and coatings expertise. As part of its activities, the organisation publishes industry standards and technical reports covering ILI.

3.1 POF documents

POF has issued a number of documents, which provide useful guidance on the use of ILI, such as:

- POF 100, Specifications and requirements for in-line inspection of pipelines [3].
- POF 300, Achieving successful in-line inspection [4].
- POF 301, In-line inspection pipeline questionnaire [5].
- POF 302, In-line inspection check lists [6].
- POF 303, In-line inspection data feedback form [7].
- POF 310, Field verification for in-line inspection [8].
- POF 520, In-line inspection tool readiness for hydrogen pipelines [9].

The Pipeline Operators Forum documentation is accessible at www.pipelineoperators.org

The POF document ‘Specifications and requirements for in-line inspection of pipelines’ (POF 100) is a key document and is widely used in the pipeline industry. This document specifies the advised operational and reporting requirements for tools to be used for geometric measurement, pipeline mapping, metal loss, crack or other anomaly type detection.

It provides guidance on the following:

- Standard definitions for commonly used terms associated with ILI.
- Health and safety requirements as ILI of pipelines typically involves working with pressurised components and potentially explosive and/or flammable environments. Adequate procedures should be in place to prevent any harm to personnel, environment or equipment.
- Tool specification requirements to present a consistent approach for presenting tool specifications. Tool specifications typically consist of the combination of tool data sheets and tool performance specification.
- Personnel qualification and certification requirements for personnel operating the ILI systems and the personnel handling, analysing and reporting the inspection results.

- Reporting requirements, which provides detailed guidance for the field report, tool operational data, tool calibration, pipe tally, list of anomalies, list of clusters, summary and statistical report etc.

POF 300 describes good practices for achieving first run success and can be used by both pipeline operators and ILI contractors. ILI first run success rates are one of many critical Key Performance Indicators (KPIs) that are used by pipeline operators and ILI suppliers to manage performance. The POF document provides detailed guidance from project initiation through field operations to lessons learnt.

3.2 AMPP documents

There are two key documents published by AMPP[1] on ILI:

- NACE SP0102. Standard Practice In-Line Inspection of Pipelines [10].
- NACE 35100. In-line inspection of pipelines [11].

AMPP/NACE industry standards are available from www.ampp.org

NACE SP0102 is a standard practice document and outlines a process of related activities that a pipeline operator can use to plan, organise, and execute an ILI project. Guidelines pertaining to ILI data management and data analysis are included.

NACE 35100 is described as a key companion guide to NACE SP0102. It is a report that analyses available and emerging technologies in the field of ILI tools and reviews their status with respect to characteristics, performance, range of application, and limitations. It is intended as a practical reference for both new and experienced users of ILI technology. It is aimed at assisting in the provision of an understanding of the practical aspects of using the tools, highlighting the implications, and helping assess the benefits. It has an extensive bibliography and list of references.

[1] The latest editions of these documents pre-date the name change from NACE to AMPP and still carry NACE document numbers.

4 ILI TOOLS

Running an ILI tool through a pipeline involves risks as there is a possibility for a tool to get damaged or become lodged in the pipeline. A stuck tool can result in a pipeline shutdown and cut out to remove the tool. To minimise this risk, it is important that a feasibility assessment to define the tool acceptability and the appropriate sequence of preparatory tool runs is carried out prior to the insertion of the ILI tools. The sequence of preparatory tools generally covers cleaning of the pipeline and gauging its internal dimensions to ensure the ILI tool can safety pass through any obstacles in the pipeline.

The sequence of preparatory tools is intended to give increasing confidence in the ability to pass the ILI tool through the pipeline undamaged. The types of preparatory tools and their sequence is specific for each pipeline. It is important that a critical analysis is carried out after each run before continuing with the next run. This is to give confidence that product flow will not be disrupted in subsequent tool runs.

4.1 Preparatory and cleaning tools

There are a range of preparatory and cleaning tools, which include:

- Foam tool: this is mainly used to dewater a pipeline after hydrotesting, or to prove the pipeline bore if severe restrictions are anticipated, for example as a result of solid debris build-up or external damage to the pipeline.

- Swabbing tool: this is to remove bulk liquids or condensate.

- Proving tool: this is a slender body device with conical flexible cups and is capable of passing severe bore restrictions, typically passing a 25 to 30% reduction of the pipeline bore. This is used to prove that the gauging tool will pass through the pipeline.

- Gauge tool or combined gauge and profile tool: this gives confidence that the pipeline can be internally inspected end to end and provides feedback on the presence of debris. It is mounted with a flexible metal plate or plates to gauge the internal diameter of the pipeline. Pipe bore restrictions less than the plate diameter or short radius bends will permanently deflect the plate material. It can also give an indication of the flow control required for the subsequent inspection runs. A simple gauge tool can be used to prove the pipeline bore for re-inspections where there have been no changes or modifications to the pipeline. Any problem will be indicated by damage to the gauge plate. The configuration of the profile tool confirms the configuration of the pipeline is suitable for running the inspection tools.

- Cleaning tool: this uses cups, discs, scrapers, or brushes to remove dirt, rust, mill scale, corrosion products, and other debris from the pipeline. Cleaning tools are utilised to increase the operating efficiency of a pipeline or to facilitate inspection of the pipeline.

- Magnetic cleaning tool: this has steel brushes and permanent magnets to remove any heavy metal deposits or debris in the pipeline.

Ineffective cleaning can lead to incomplete and/or degraded inspection data or to damage to the inspection tool. If necessary, cleaning runs should be repeated until the cleanliness of the pipeline is sufficient to ensure the quality of the inspection results.

4.2 Intelligent or smart inspection tools

Different ILI tools have been developed over the years to help manage specific integrity threats. Commercially available ILI technology can generally be classified as:

- Geometry detection tools.
- Metal loss detection tools.
- Crack detection tools.
- Mapping tools
- Other specialist tools.

4.2.1 Geometry detection tools

A geometry tool utilises either mechanical arms or electromagnetic methods to measure the bore of the pipe, to identify dents, other ovality changes and deformations.

Geometry tools are sometimes further classified as:

- Calliper tools, which are generally low-resolution geometry tools. These are often used for new construction inspections to detect dents and ovality caused during construction.
- High resolution geometry/deformation tools, which are used to identify and more accurately size deformations, such as dents, bends, wrinkles, buckles, ovality and evidence of strain, or sometimes internal metal losses.

4.2.2 Metal loss detection tools

There are two commonly used techniques for detecting and measuring metal loss, which may be caused by corrosion, or mechanical damage, or may be related to pipeline construction or pipe fabrication. These are Magnetic Flux Leakage (MFL) and Ultrasonic compression wave (UT).

MFL is an ILI technology in which a magnetic field is induced in the pipe wall between two poles of a magnet. A pipeline steel wall without defects creates an undisturbed and homogeneous distribution of magnetic flux. Anomalies, such as metal loss, affect the distribution of the magnetic flux in the wall, which, in a magnetically saturated pipe wall, leaks out of the pipe wall. The MFL pattern is used to detect and characterise anomalies in the pipeline wall. Sensors on-board the tool detect and measure the amount and distribution of the flux leakage. The flux leakage signals are processed, and resulting data is stored on-board the MFL tool for later analysis and reporting.

MFL provides an indirect measurement of metal loss, and with additional sensors discriminates between internal and external defects.

MFL tools are commonly classified into standard resolution and high-resolution tools, depending on the number, size, and orientation of MFL sensors, magnetic circuit design and magnetisation levels, and the type of analysis that is applied to recorded data supplied by each type of tool. High resolution tools can provide an improved characterisation of anomalies in the pipeline.

All types of MFL tools use magnets to induce a magnetic field into the pipe wall, and either inductive search coils or solid-state (Hall effect) sensors to detect flux leakage. Standard-resolution tools have fewer MFL sensors for a given pipe size than high resolution tools. Each of these sensors covers a larger part of the circumference of the pipe and gives an average of the flux leakage distribution in the area that it covers. The much smaller and more advanced Hall sensors (used on high resolution tools) can examine a smaller area of the pipe wall and reveal more detailed information.

Based on the direction of magnetisation, at least three types of MFL tools are available:

- Axial field MFL is the standard MFL tool that magnetises the pipe wall in the axial direction to detect circumferentially oriented metal loss defects, with limited sensitivity to narrow, axially aligned defects.
- Transverse field MFL tools magnetise the pipe wall in the circumferential direction so as to be able to detect longitudinally aligned metal loss. This makes transverse field MFL tools particularly useful for detecting longitudinally oriented corrosion associated with longitudinal seam welds.
- Spiral MFL tools magnetise the pipe wall in a helical direction, enabling the detection of both axially and circumferentially oriented metal loss, although with potentially reduced accuracy compared to an axial field or transverse field tool.

Factors affecting MFL performance include:

- Cleaning.
- Sensor damage.
- Magnetic properties of the line pipe.
- Remnant magnetisation, which may be an issue when running in bidirectional pipelines.
- Wear to mechanical components, such as drive cups and suspension arms, due to length of run or aggressive in-pipe conditions.
- Speed excursions and/or sensor lift-off.
- Wall thickness, as a result of the magnetic saturation requirement.

UT is an ILI technology to measure pipe wall thickness and detect metal loss from the inner and outer walls of the pipeline. UT tools can only be used with a liquid coupling medium, so are generally used only on liquid pipelines. These tools are equipped with transducers that emit ultrasonic signals perpendicular to the surface of the pipe. An echo is received from both the internal and external surfaces of the pipe and, by timing these return signals and comparing them to the speed of ultrasound in pipe steel, the wall thickness can be determined.

UT tools provide a direct measurement of metal loss and can discriminate between internal, mid-wall and external defects. UT tools generally require a higher degree of cleanliness than MFL tools.

Acoustic resonance technology (ART) is a recently introduced new technology for ILI that provides the ability to perform high resolution, direct measurement in a natural gas environment. ART is an acoustic inspection technology which uses the phenomenon of half-wave resonance. A broadband acoustic signal is transmitted to the pipeline wall, which then resonates at certain frequencies which are characteristic of the wall thickness. The half-wave resonant frequencies are then used with the speed of sound in the pipe material to calculate the local wall thickness. During post-processing, multiple measurements can be combined to estimate the size and depth of flaws, such as wall loss. ART differs from traditional ultrasonic inspection in that it uses lower frequencies and a wider bandwidth. This enables its use in the inspection of gas pipelines without a liquid couplant.

4.2.3 Crack detection tools

There are two commonly used techniques for detecting crack-like features, these are UT shear wave and EMAT (Electro-Magnetic Acoustic Transducer).

Conventional UT crack detection tools are based on liquid coupled, shear wave transducers and are used to detect longitudinal cracks, longitudinal weld defects and crack-like defects (such as stress corrosion cracking) in pipelines. Because most crack-like defects are perpendicular to the main stress component (i.e., the hoop stress), ultrasonic pulses are injected in a circumferential direction to obtain maximum acoustic response. UT tools are also available for the detection of circumferential cracks.

EMAT technology is suitable for gas pipelines as it uses electromagnetic effects to induce an ultrasonic signal directly in the pipe wall without a liquid couplant. This technology can be used for detection of cracks and also external coating disbondment.

4.2.4 Mapping tools

Mapping tools record the 3D pipeline route and are based on the inertial navigation system of the ILI tool, using built-in gyroscopes and accelerometers. Mapping tools record the exact 3-dimensional geographical pipeline co-ordinates (x, y, z), as they pass along the pipeline, to give a precise depiction of its route and profile. This requires known reference points along the pipeline to achieve the desired accuracy. Pipeline markers are used along the length of the pipeline, with a typical interval of 1 km. The accuracy of the established absolute coordinates depends on the accuracy of the known reference points and the coordinate spacing. The integration of the reference point geographical data into the ILI data results in accurate feature location for the dig sites in the field. Sequential inertial mapping data can be used to measure changes in bending strain and curvature that can result from geotechnical movement etc. Specific post-survey interpretation may also allow detecting and sizing of free spans, landslides etc.

Pipeline mapping tools are often attached to an MFL or other inspection tool, whereby the inspection unit has a double functionality.

4.3 Supplementary services

Speed control of the ILI tool allows the ILI tool to travel at a lower speed than the product being transported. It is primarily used for gas pipelines operating at high flow rates. This allows inspection without the pipeline operator needing to greatly reduce throughput to accommodate the ILI tool speed requirements to achieve optimal data acquisition. This is achieved by a by-pass system which allows varying volumes of gas to pass through the tool to achieve the programmable target speed.

There is increasing use of the combination of inspection technologies into a single ILI tool. These are sometimes referred to as ‘combo-tools’. Combining inspection technologies on a single ILI tool allows a fuller range of features to be detected during a single inspection run and can improve the overall characterisation and accuracy of the features detected. These could typically include combining geometry, metal loss and mapping into a single tool or combining technologies (i.e. axial field and transverse field MFL) to give an enhanced metal loss inspection. Combination tools are typically longer than single technology tools which should be considered as part of the tool selection process and feasibility assessment.

Multi-diameter ILI tools can pass through pipelines with varying diameter. Whilst the majority of modern pipelines are constructed from pipes with a single diameter, some older pipelines (and some subsea pipelines) are constructed from pipes with two or more diameters. Special ILI tools are able to inspect two consecutive nominal pipe sizes, e.g. 18 and 24 inches, by using collapsible mechanisms for the drive discs and mounting of the sensor arms.

5 ILI STRATEGY

5.1 ILI throughout the pipeline life

The typical approach to the ILI of pipelines throughout the pipeline life is:

1. Baseline (fingerprint) inspection carried out soon after commissioning in order to record the as-built feature signature of the pipeline. This is of particular importance in identifying the features present in the pipeline at the start of operation which have been subject to the pipeline hydrotest, including mill/manufacturing features and construction damage. The results of this inspection facilitate the identification of changes detected in subsequent inspections during the pipeline operating life.

2. First operating inspection carried out after a number of years defined by the pipeline operator. This inspection is of particular importance in establishing any time dependent failure mechanisms e.g. corrosion growth and enables the operator to establish the future inspection frequency, using either a deterministic (fixed interval) or risk-based approach.

3. Subsequent operating inspections carried out at frequencies defined using a deterministic or risk-based approach. The frequency of subsequent inspections should be informed by a comparison of sequential inspection results to determine the extent of active degradation (e.g. corrosion growth).

4. Inspection carried out to establish condition at a change in operating conditions (e.g. uprating or change of use), life extension or when bringing a decommissioned pipeline back into service.

5. Ad-hoc inspection in response to a specific integrity-related event, e.g. suspected but unconfirmed third party impact.

5.2 Tool Run Sequence

Depending on the requirements of the pipeline, a typical pigging sequence for initially proving the pipeline would include:

- Proving tool.
- Gauge or profile tool.
- Magnetic/brush cleaning.
- Geometry inspection.
- Intelligent tool inspection.

For repeat inspections, some steps may be omitted, so a typical sequence could be:

- Gauge or profile tool.
- Magnetic/brush cleaning.
- Geometry inspection.
- Intelligent tool inspection.

Combination tools may be used to reduce the total number of runs.

6 SELECTION OF ILI TOOLS, SPECIFICATION & PERFORMANCE

6.1 Selection of ILI tools

The selection of the appropriate ILI tools should be a result of a review to identify a pipeline's susceptibility to specific integrity threats. ILI is part of the overall integrity management process required to manage threats and demonstrate fitness for purpose for continued safe operation. The results of the inspection allow the operator to assess the integrity of the pipeline and as a result, where required, schedule remedial actions, such as pipeline repairs.

ILI tool and service provider selection should take account of the integrity threats, the specifics of the pipeline section, and the expected performance of the ILI tool and service provider. Pipeline parameters such as wall thicknesses, pressures, flow rates, bend radius, and other geometrical features should be considered alongside the pipeline integrity management objectives in order to minimise the operational and integrity risks.

ISO 19345-1 [12] states that the operator should assess and demonstrate the reliability of the chosen ILI method by examining the following:

- Ability to detect the presence of multiple cause anomalies.
- Confidence level of the ILI method and service provider specification (e.g. probability of detecting, classifying, and sizing the anomalies).
- Performance history of the ILI method/tool and service provider.
- Success rate/failed surveys and service provider track record.
- Ability of detection and classification, sizing accuracy and location accuracy of the tool.
- Validation of specifications by either pull through testing or correlation excavations or other equivalent methods.
- Impact to quality of data collected considering the nature of transported product (e.g. gas bubbles, wax content), quality of pipeline cleaning and targeted wall thicknesses.

There is a wide range of ILI tools available from the ILI service providers, although the availability of some tools may be limited. Information on their tools is available on the ILI service provider websites and in published literature and pipeline journals. However more current and specific information should be sought from ILI vendors for pipelines to be inspected.

Table 2 in ISO 19345-1 presents a detailed overview of the types of anomalies and the most commonly used ILI tool categories, indicating their appropriateness for the objective of the inspection. This table is reproduced below as Table 1.

Note that this table is an updated version of Table 1 in NACE SP0102-2017.

UKOPA gained permission to use the table from BS EN during the development of Ed 1 of this GPG and that remains in place, for this addition.

Anomaly	Imperfection / defect / feature	Metals loss detection tools				Crack detection tools		Deformation detection tools
		Magnetic flux leakage (MFL)			Ultrasonic compression [m]	Ultrasonic shear wave [m]	EMAT	
		Standard resolution (SR)	High resolution (HR)	Transverse MFL				
Metal loss	External corrosion Internal corrosion Scratches	Detection [a] Sizing [b] No ID/OD discrimination	Detection [a] Sizing [b]	Detection [a] Sizing [b]	Detection [a] Sizing [b]	Detection [a] Sizing [b]	Limited detection	No detection
Crack like anomaly	Narrow axial external corrosion	Detection [a]	Detection [a]	Detection [a] Sizing [b]	Detection [a] Sizing [b]	Detection [a] Sizing [b]	Limited detection	No detection
	Stress corrosion cracking	No detection	No detection	Limited detection [a, c] Sizing [b]	No detection	Detection [a] Sizing [b]	Detection [a] Sizing [b]	No detection
	Fatigue cracks	No detection	No detection	Limited detection [a, c] Sizing [b]	No detection	Detection [a] Sizing [b]	Detection [a] Sizing [b]	No detection
	Long seam features (toe cracks, hook cracks, incomplete fusion, preferential seam corrosion)	No detection	No detection	Limited detection [a, c] Sizing [b]	No detection	Detection [a] Sizing [b]	Detection [a] Sizing [b]	No detection
	Circumferential cracks	No detection	Detection [c] Sizing [b]	No detection	No detection	Detection [a] Sizing [b,d]	Detection [a] Sizing [b,d]	No detection
	Hydrogen-induced cracks (HIC)	No detection	No detection	No detection	Detection [a]	Limited detection	Detection [a] Sizing [b]	No detection

Anomaly	Imperfection / defect / feature	Metals loss detection tools				Crack detection tools		Deformation detection tools
		Magnetic flux leakage (MFL)			Ultrasonic compression [m]	Ultrasonic shear wave [m]	EMAT	
		Standard resolution (SR)	High resolution (HR)	Transverse MFL				
Deformation	Sharp dents	Detection [e, g]	Detection [e, l]	Detection [e, g]	Detection [e, g]	Detection [e, g]	No detection	Detection [f] Sizing
	Smooth dents	Detection [e, g]	Detection [e, l]	Detection [e, g]	Detection [e, g]	Detection [e, g]	No detection	Detection [f] Sizing
	Buckles	Detection [e, g]	Detection [e, l]	Detection [e, g]	Detection [e, g]	Detection [e, g]	No detection	Detection [f] Sizing
	Wrinkles, ripples	Detection [e, g]	Detection [e, l]	Detection [e, g]	Detection [e, g]	Detection [e, g]	No detection	Detection [f] Sizing
	Ovalities	No detection	No detection	No detection	No detection	No detection	No detection	Detection Sizing [b]
Misc. components	In-line valves and fittings	Detection	Detection	Detection	Detection	Detection	Detection	Detection
	Casings (concentric)	Detection	Detection	Detection	No detection	No detection	No detection	No detection
	Casings (eccentric)	Detection	Detection	Detection	No detection	No detection	No detection	No detection
	Bends	Detection	Detection	Detection	Limited detection	Limited detection	Limited detection	Detection [h] Sizing [h]
	Branch appurtenances / hot taps	Detection	Detection	Detection	Detection	Detection	Detection	No detection
	Close metal objects	Detection	Detection	Detection	No detection	No detection	No detection	No detection
	Thermite welds	No detection	No detection	No detection	No detection	No detection	No detection	No detection
	Pipeline coordinates	No detection	Detection [k]	Detection [k]	Detection [k]	Detection [k]	No detection	Detection [k]
Previous repairs	Type A repair sleeve	Detection	Detection	Detection	No detection	No detection	No detection	No detection

Anomaly	Imperfection / defect / feature	Metals loss detection tools				Crack detection tools		Deformation detection tools
		Magnetic flux leakage (MFL)			Ultrasonic compression [m]	Ultrasonic shear wave [m]	EMAT	
		Standard resolution (SR)	High resolution (HR)	Transverse MFL				
	Composite sleeve	Detection [i]	Detection [i]	Detection [i]	No detection	No detection	No detection	No detection
	Type B repair sleeve	Detection	Detection	Detection	Detection	Detection	Detection	No detection
	Patches/half soles	Detection	Detection	Detection	Detection	Detection	Detection	No detection
	Puddle welds	Limited detection	Limited detection	Limited detection	No detection	No detection	No detection	No detection
Misc. damage	Laminations	Limited detection	Limited detection	Limited detection	Detection Sizing [b]	Limited detection	No detection	No detection
	Inclusions (lack of fusion)	Limited detection	Limited detection	Limited detection	Detection Sizing [b]	Limited detection	No detection	No detection
	Cold work	No detection	No detection	No detection	No detection	No detection	No detection	No detection
	Hard spots	No detection	Detection [j]	No detection	No detection	No detection	No detection	No detection
	Grind marks	Limited detection [a]	Limited detection [a]	Limited detection [a, b]	Detection [a, b]	Detection [a, b]	No detection	No detection
	Strain	No detection	No detection	No detection	No detection	No detection	No detection	Detection [j]
	Girth weld anomaly (voids, etc.)	Limited detection	Detection	No detection	Detection	Detection [d]	Detection [d]	No detection
	Scabs / slivers / blisters	Limited detection [a]	Limited detection	Limited detection [a]	Detection [a, b]	Detection [a, b]	Detection [a, b]	Limited detection

Table 1 Types of ILI tools and inspection purposes

Notes to Table 1

a. Limited by the detectable depth, length, and width of the indication.

b. Defined by the sizing accuracy of the tool.

c. Reduced probability of detection (POD) for tight cracks.

d. Transducers to be rotated 90°.

e. Reduced probability of detection (POD) depending upon size and shape.

f. Also, circumferential position, if tool is equipped.

g. Sizing not reliable.

h. If tool is equipped for bend measurement.

i. Composite sleeve without markers is not detectable.

j. If tool is equipped, dependent on parameters.

k. If tool is equipped with mapping capabilities.

l. Sizing is tool dependent.

m. ILI technologies that can be used only in liquid environments, e.g. liquids pipelines or in gas pipelines with a liquid couplant.

Table 1 is copied from BS EN ISO 19345-1.

6.2 ILI tool specification and requirements

The POF document 'Specifications and requirements for in-line inspection of pipelines' (POF 100) gives an outline of advised specifications for the ILI of pipelines. This document is widely used in the pipeline industry and is generally accepted by pipeline operators and ILI service providers as a basis for describing the requirements for ILI.

Tool specifications enable the pipeline operator to clearly understand the capabilities and limitations of an ILI tool before selection and use. 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. Typically, separate tool data sheets exist for each diameter and inspection technology combination. These present tool identification, tool specifications, safety, operating conditions/parameters, pipeline restrictions and tool launch and receive requirements.

- Performance specifications describe the inspection capabilities and limitations of the inspection technology applied. The tool performance specifications define the ability of the ILI system to detect, locate, identify, and size pipeline features, components and anomalies. The tool accuracy is related to the inspection technology used, and therefore varies for the detection of different features.

POF 100 presents a classification of metal loss anomalies, which are generally used to describe the performance of a MFL tool. The metal loss anomaly terms are:

- General metal loss.
- Pitting.
- Axial grooving.
- Circumferential grooving.
- Pinhole.
- Axial slotting.
- Circumferential slotting.

These terms are defined in Table 2.1 of POF 100 and illustrated in Figure 2.2 of the same document, which is often referred to as the 'POF diagram'. These terms can be used to describe the system performance in terms of detection and sizing capability.

The performance specification covers:

- The Probability of Detection, POD (a), which is the probability that a feature with size 'a' will be detected by the ILI tool. POF 100 recommends specifying the POD90/95 value, where a 90/95 is the feature size at which the lower 95% confidence limit of the POD is 90%.

- The Probability of Identification, POI, which is the probability that a feature is correctly identified by the ILI tool. This identifies the types of anomalies, components, and characteristics that are to be detected, identified, and sized by the ILI system. Identification is the result of data analysis and is a combination of algorithmic identification and human interpretation of the data. Algorithms are vendor-specific, whilst human interpretation is driven by experience and is therefore analyst-specific.

- The measurement specifications for the detection and sizing of the various anomalies and pipeline location.

Table A4-2 of POF 100 presents a typical way of describing the overall performance of a MFL tool for the detection and sizing accuracy for the different types of metal loss anomalies (general metal loss, pitting etc) by stating the following:

- Depth at POD of 90%.
- Depth sizing accuracy at 90% certainty.
- Width sizing accuracy at 90% certainty.
- Length sizing accuracy at 90% certainty.

Note that a different sizing accuracy will usually be stated for the MFL performance for metal loss anomalies in the parent pipe body compared to anomalies in the girth or seam weld or their heat affected zone. Similarly, the performance will also be different in a seamless pipe body compared to the parent pipe body of seam welded pipe.

A typical performance specification for a high resolution MFL tool for general metal loss, due to corrosion, at a POD of 90% is to have a minimum detection depth of 10% of the wall thickness and a depth sizing accuracy, at 80% certainty, of +/- 10% of the wall thickness and a length sizing accuracy, at 80% certainty, of +/- 15mm.

6.3 ILI tool performance

The performance of the ILI tool and ILI service provider should ideally be verified by either pull through testing or comparisons between predicted and actual in-ditch measurements.

More guidance on field verification can be found in POF 310, API 1163 [13] and UKOPA/GP/026 [14].

7 FIRST RUN SUCCESS

A key performance indicator that can be used to measure performance is the ILI first run success rate. Achieving this requires close coordination between the pipeline operator teams and the ILI service provider. The ILI tool has to be set up and run with the right operating conditions, with a complete data set to be downloaded and analysed. The run is only complete when the report has been received, features verified, and data quality confirmed. It is a key driver of the performance of both the pipeline operator and ILI service provider and how they effectively work together.

Achieving a high ILI first run success rate is one of the activities a pipeline operator can undertake to reduce process safety risk across pipeline operations.

The POF document ‘Achieving successful in-line inspection’ (POF 300) has been developed to provide guidance on best practice for achieving first run success.

POF 300 is a detailed document providing guidance on:

- ILI preparation.
- Pipeline cleaning and verification.
- ILI tool preparation.
- Field operations.
- Field verification.
- Lessons learnt.

Check lists summarising the recommendations are available separately in POF 302 ‘In-line inspection check lists’. Check lists are provided for the following aspects of the inspection following vendor selection:

- Project Initiation: Project approval.
- Stakeholder engagement.
- Project initiation: Risk assessment.
- Project initiation: Site visit.
- Operations: Preparation and cleaning.
- Operations: Mobilisation of ILI tool
- Operations: ILI tool run – Prelaunch.
- Operations: ILI tool run and receipt.
- Data Analysis and reporting.
- Performance feedback.

The POF check lists are provided only as examples and these should be reviewed and customised for individual operators and users for their own specific circumstances.

8 PLANNING & PREPARATION

ILI operations can be complex projects, which involve coordination of many different aspects: planning, preliminary work, safety and operational procedures.

An initial desktop study of the pipeline records should establish the accurate position of the pipeline and installations and the design features of the pipeline and launch and receive traps. This should identify if there are any features that could affect the data recording during the inspection and whether there have been any modifications since the last ILI.

The study should review:

- Previous results, if available.
- Pipeline operational records for any previous experience that could impact on the inspection operation.
- Critical pipeline details, such as wall thickness, changes in wall thickness, bend configurations.
- Short radius bends: The majority of inspection tools are capable of negotiating a 3D bend radius or greater. Any bends that are tighter should be addressed on a case-by-case basis, depending on the tool to be used and the wall thickness of the bend. An increasing number of tools are capable of passing a 1.5D bend radius.
- Back-to-back bends: Bends installed in a back-to-back configuration, e.g., without an intervening section of straight pipe between the bends, can present an impediment or sticking hazard for ILI tools or for over-torquing coupling joints, leading to snapping of the joint.
- Valves: Reduced port valves can restrict the passage of a tool and result in tool damage, and in extreme cases, they can result in the tool becoming lodged in the line. Close attention should be given to the ability of tools to negotiate through check valves and so-called 'full bore' valves. Before ILI runs, check valve clappers should be locked in the open position whenever possible. Consider valve status and position.
- All branch connection spacings, ensuring that they are not spaced to allow product to bypass the vehicle cups.
- Branching greater than 50% of the main line bore, ensuring pig bars are fitted to prevent the vehicle becoming lodged in the tee.
- Whether the branch supplies can be isolated for the duration of the vehicle run.

As part of the early planning, the following on site should be checked:

- Clearance behind the trap closures at launch and receive sites for insertion and removal of the tool.
- Dimensions for the trap pipework and working area.
- Access, car parking and working areas to ensure no restrictions.

It is essential to record all of the information along with any previous inspection difficulties, and to share this information with the ILI service provider.

Examples of inspection questionnaires are provided in POF 301 and NACE SP0102, although the ILI service provider, working with the pipeline operator, will usually have a customised version for their use.

The pre-planning should liaise with the control room to identify the operational window and to put contingency measures in place.

The consultation will include consideration of the minimum pressures and flows and ensure that the inspection operation does not conflict with any other operational work.

It is often necessary to plan ILI operations in a way that minimises interruption or restriction on product flows, or otherwise affects normal pipeline operation. This requirement may be in conflict with the optimum tool operational parameters, and therefore the tool run dates should be carefully considered alongside pipeline operational parameters such as the pressure and flow velocity. In liquid or multiproduct lines it may also be necessary to consider batch or parcel sizes, product hazards, and segregation of products at the receipt site.

Traps, and trap closures come with many designs, and have a wide range of operational and maintenance requirements. Trap maintenance, and the correct tool launching and receiving operational procedures, are critical to safe and successful in-line inspection operations.

All of the planning and preparation activities, the use of ILI check lists, together with the appropriate sequence of preparatory tools, are intended to minimise the possibility of a tool becoming lodged in the pipeline. The implications of a stuck tool and the recovery of a stuck tool should be considered in the contingency plan, including insurance aspects.

9 ILI FIELD OPERATIONS

9.1 Pre-launch

The period on site before the launch of an ILI tool is the last opportunity to ensure that the pipeline has been prepared, operating procedures and communication arrangements are in place and the ILI tool has been set-up correctly.

The ILI service provider should use check lists to ensure that the ILI tool has been correctly set up before launch. The pipeline operator should satisfy themselves that these checks are adequate and are sufficiently detailed for the ILI tools being used. If considered necessary, the pipeline operator should have these checks independently audited.

One of the key checks before running the ILI tool is verification that the pipeline is clean and that the final gauge plate/profile run is accepted by the ILI tool service provider.

The main reasons for ILI tools becoming stuck are:

- Failure to correctly size and interpret damage to the gauge/profile tool.
- Valve position changes.
- Changes to operating conditions.
- Tool failure.
- The presence of tight bends or non-standard bends (e.g. mitred bends).

9.2 Launch, ILI run and receive

There should be clear responsibilities identified for the ILI service provider and the pipeline operator for the site operations.

The ILI service provider is generally responsible for ensuring the ILI tool is fit for purpose prior to launch, and for handling of the ILI tool into and out of the traps.

The pipeline operator is generally responsible for safety on the site and all operating conditions in the pipeline, pressurising the traps and running the ILI tool, de-pressurising traps on receipt and cleaning of the ILI tool.

Requirements and responsibilities for vehicle tracking and monitoring activities during the ILI run should be agreed.

The condition of the tool should be before operations, at receipt, and after cleaning.

The ILI service provider will download data from the ILI tool and undertake a preliminary review of the data. This may identify any speed excursions and whether sufficient data has been collected, although this may require a more detailed analysis of the data later.

9.3 Safety and environmental aspects

ILI typically involves working with pressurised components and potentially explosive and/or flammable or polluting environments. Adequate procedures should be in place to prevent any harm to personnel, environment or equipment.

Special care and attention should be given to:

- Measures to prevent unsafe situations during ILI activities where potentially explosive atmospheres may be present i.e. when ILI tools are inserted into and retrieved from the pipeline. This should be through safe operating procedures, which may include nitrogen purging of traps to ensure safe atmospheres and the use of ATEX certified equipment. The pipeline operator should specify if ATEX certification is required. Further information on ATEX is provided below.
- Use of certified lifting equipment and the equipment required for inserting and retrieving ILI tools into and out of traps.
- The potential effect of the very high magnetic fields associated with ILI tools on nearby personnel and other equipment.
- Ensuring that either side of the ILI tool is fully depressurised before opening of trap doors.
- Detailed written operating procedures giving valve operating sequences for launching and receiving ILI tools.
- Facilities for spillage of liquid products, vehicle cleaning, standards and levels of cleanliness required and disposal of waste, including arrangements for any NORM (Naturally Occurring Radioactive Material) or pyrophoric dust.
- Consignment of hazardous waste for transport from the tool receive facility on public roads.

9.4 ATEX and explosive atmospheres

ATEX is the name commonly given to the two European Directives for controlling explosive atmospheres:

1. Directive 99/92/EC (also known as 'ATEX 137' or the 'ATEX Workplace Directive') on minimum requirements for improving the health and safety protection of workers potentially at risk from explosive atmospheres. In Great Britain, the requirements of Directive 99/92/EC were put into effect through regulations 7 and 11 of the Dangerous Substances and Explosive Atmospheres Regulations 2002 (DSEAR).

2. Directive 94/9/EC (also known as 'ATEX 95' or 'the ATEX Equipment Directive') on the approximation of the laws of Members States concerning equipment and protective systems intended for use in potentially explosive atmospheres. In Great Britain, the requirements of Directive 94/9/EC were put into effect through BIS Equipment and Protective Systems Intended for Use in Potentially Explosive Atmospheres Regulations 1996 (SI 1996/192). The Regulations apply to all equipment intended for use in explosive atmospheres, whether electrical or mechanical, and also to protective systems.

Depending on the vendor, the inspection tool may or may not be intrinsically safe when activated. ILI tool suppliers should ensure their tools are never the source of ignition while operated in potentially explosive atmospheres. One method of achieving this is to avoid any possible contact between the explosive atmosphere and potential sources of ignition within the ILI tool.

10 REPORTING

POF 100 specifies that at least two reports should be provided by the ILI service provider: an Operations Report and a Final Report. Other reports may be provided as agreed between the ILI service provider and pipeline operator.

If during the preparation of the reports, the ILI service provider identifies any feature that could be an immediate threat to the integrity of the pipeline, this should be reported immediately to the pipeline operator.

The Operations Report summarises the important operational information (i.e. run preparation, running of the tool etc) and provides information on the success of the inspection and quality of data collected. This should detail speed excursions, equipment malfunctions, such as sensor loss, odometer slippage, whether sufficient data has been collected and whether data has been collected for any previously identified critical locations. If the data quality is not acceptable, a re-run (if possible) should be considered.

The Final Report provides the full inspection data. POF 100 specifies a detailed format for this report, which includes:

- Pipe tally.
- List of anomalies, clusters, data loss and other lists.
- List of components.
- Summary and statistical data (covering metal loss, crack like features, geometric features, other features).
- Performance.
- Dig sheet.
- Data viewing software.
- Anomaly ranking method.
- Detection of markers.
- Personnel qualification.

Other reports requested by the pipeline operator may be raw data, run comparison reports or pipeline integrity reports. It is noted that data not requested when agreeing the scope with the ILI vendor may incur further costs if requested at a later stage.

11 ASSESSMENT OF RESULTS & INTEGRITY MANAGEMENT

Depending on the ILI tool type and capabilities, the ILI Final Report will present the inspection results for a wide range of feature types, which may include:

- Metal loss features due to external corrosion.
- Corrosion under sleeves.
- Metal loss features due to internal corrosion.
- Milling and construction features.
- Metal loss features classified as a gouge or possible gouge.
- Dents.
- Girth and seam weld anomalies.
- Cracks and crack-like features
- Close or touching (ferrous) metal objects.
- Touching or eccentric sleeves.
- Pipeline repairs.
- Attachments such as CP connection points.
- Pipeline features such as valves, tees, and offtakes.
- Geographical information, potentially including strain or pipeline movement.
- Other pipeline features and anomalies.

A preliminary assessment of the ILI results is usually undertaken by the pipeline operator to ensure that the run was successful, to consider whether there are any features requiring immediate attention, and to give a qualitative overview of the general condition of the pipeline i.e. many or few features.

Following the preliminary assessment, a more detailed assessment of the reported features should be undertaken. This should include a defect assessment of the reported features to determine the maximum allowable time before on-site investigation should take place. The defect assessment will provide detail on the predicted failure, and a risk assessment of the deterioration rate and consequences of failure should consider the following:

- Current condition of reported feature.
- Expected future condition based on likely degradation.
- Interaction.
- Pipeline location.

- Pipeline criticality.

In all situations, the primary objective should be to maintain safety. Secondary considerations, e.g. pipeline criticality, should then be used to determine the maximum allowable time before on-site investigation shall take place.

The more detailed assessment may include fitness for purpose assessments of reported features, using industry recognised damage assessment techniques. The assessment can provide recommendations for risk mitigations, such as pressure reduction, future repairs and next inspection dates.

12 LOCATING FEATURES, PIPELINE EXCAVATION & PIPE INSPECTION

The operator should consider the requirement for reported features to be verified in the field, particularly if the size of detected features exceed the operator specified fitness for service limits. Field verification confirms the condition of the pipeline and helps support any remedial actions that are to be taken. Feedback of the field inspection results to the ILI service provider also helps the ILI service provider to continuously improve the validity and accuracy of the data analysis.

Reported features need to be correctly measured in the field to support the verification and also to determine the tool performance. This requires competent trained field personnel, using calibrated techniques and equipment, to gather the data with the required accuracy so that the results can be relied upon.

POF 310 gives detailed recommendations on the following:

- Planning
- Locating anomalies in the field.
- Pipeline excavation and pipe inspection.
- Layout of anomalies.
- Anomaly inspection.
- Pipeline recoating and reinstatement.
- Reporting

13 TOOL FAILURES & LESSONS LEARNT

POF 300 highlights that a significant proportion of failed runs are attributable to tool failures and identifies a number of common factors:

- Use of new tools or components.
- Pipeline environment.
- Tool preparation and set up.
- Electronics and software.

A key element of successful ILI inspections is good communication and co-operation between the ILI service provider and the pipeline operator during all stages of an ILI project.

Understanding the causes of failed ILI runs is key to improving first run success rates, and to understanding the responsibility for run failure and requirements for cost recovery.

14 ILI SYSTEM QUALIFICATION

API 1163 (In-Line Inspection Systems Qualification) provides performance-based requirements for ILI systems and enables service providers and pipeline operators to provide rigorous processes that will consistently qualify the equipment, people, processes and software used in ILI.

The standard covers:

- Systems Qualification Process. Overall process description with referenced qualification requirements for ILI personnel and equipment.

- ILI System Selection. Requirements for selecting an ILI system for a specific pipeline application.

- Qualification of Performance Specifications. Requirements for establishing, documenting, and statistically validating performance specifications of ILI systems. The performance specification defines the capabilities of the ILI system to detect, locate, identify, and size anomalies.

- System Operational Validation. Requirements that must be met before, during, and after running an ILI system to assure that the system functioned properly.

- System Results Verification. Requirements for verifying that the results of an inspection are consistent with the performance specification.

- Reporting Requirements. The standard describes the process that shall be used to verify that the reported inspection results have been met and are consistent with the performance specification for the pipeline being inspected.

- Quality Management System. Requirements for documentation, quality control, continuous improvement, and system review.

Use of API 1163 is required by regulation in the United States and is considered good practice worldwide.

15 ILI FREQUENCY & PIPELINE DESIGN CODES

Once in operation, a pipeline should be periodically inspected to ensure its continued fitness for purpose. The frequency of inspection should ideally be determined using a risk-based approach, which takes account of the results of previous inspections and other factors such as the damage mechanisms, the failure modes and the probability and consequences of failure.

PSSR states that all relevant factors should be taken into account when deciding on the appropriate interval between examinations, including:

- The safety record and previous history of the system.
- Any generic information available about the particular type of system.
- Its current condition, e.g. due to corrosion/erosion etc (internal and external).
- The expected operating conditions (especially any particularly arduous conditions).
- The quality of fluids used in the system.
- The standard of technical supervision, operation, maintenance and inspection in the user's/owner's organisation.
- The applicability of any on-stream monitoring.

There are a range of approaches to setting suitable re-inspection intervals. The appropriate method is dependent on the pipeline history, current condition, degradation causes and on-going growth rates. Comparison of ILI signals can be used to provide more accurate feature growth rate estimates. This can be done either on a feature-by-feature basis (to give a local growth rate) or over a pipeline segment basis (to give an average growth rate over the segment). While signal matching growth estimates can be useful, care is required to ensure ILI tool measurement errors, and differences between ILI tools (and ILI service providers) are properly accounted for in the assessment.

If a risk-based approach is not practical, then the inspection frequency should be in accordance with the relevant pipeline design code.

15.1 IGEM/TD/1

For high pressure natural gas pipelines designed in accordance with IGEM/TD/1 [15], the frequency of ILI should be set by a risk-based approach. The risk-based approach should take into consideration the age and standard of construction, previous inspection results, results from CP monitoring, any evidence of ground movement, ground conditions, density of population surrounding the pipeline etc. If a risk-based approach is not practical, the maximum interval between ILI should not exceed 10 years.

15.2 PD 8010

PD 8010-1 [16] highlights some of the factors to be taken into account when defining the requirements for condition monitoring for onshore steel pipelines. These include the results of earlier inspections, the predicted deterioration in the condition of the pipeline and the inspection time intervals. Possible deteriorations in pipeline condition include general and pitting corrosion, changes in the pipe wall, geometry (such as ovality, wrinkles, dents, gouges), cracking (such as stress corrosion and fatigue cracking), changes in the pipeline position, support or cover, and loss of weight coating.

PD 8010-4 [17] states that pipeline systems should be designed to use ILI tools, and that, in many cases, this is the most effective way of confirming that the integrity management strategy has been effective.

Annex C.4 of PD8010-4 gives general guidance on inspection, surveillance and monitoring intervals. This highlights the use of engineering judgement to decide the longest period that could possibly be acceptable (i.e. associated with the lowest possible risk), and then to determine inspection intervals on a linear scale of risk. It recommends inspections between one and 10 years depending upon the risk.

15.3 ASME B31.4

For pipelines transporting liquid hydrocarbons, ASME B31.4 [18] section 451.6.1 highlights the need for periodic integrity assessments, which may consist of ILI, followed by remediation of anomalies indicated by the inspection to be possibly injurious. It does not specify a frequency of inspection.

15.4 ASME B31.8 & ASME B31.8S

For gas transmission and distribution pipelines, ASME B31.8 [19] does not prescribe a detailed set of operating and maintenance procedures.

ASME B31.8S [20], as a supplement to ASME B31.8, presents guidance on managing the system integrity of gas pipelines by developing and implementing an effective integrity management programme.

Section 5.6.1 and Table 5.6.1-1 presents maximum ILI intervals of 5, 10, 15 and 20 years, depending on the operating pressure and predicted failure pressure, for pipelines with a prescriptive integrity management programme.

Section 5.6.2 allows risk analysis as a basis for establishing inspection intervals for pipelines with a performance-based integrity management programme.

Section 6.2 discusses the use of ILI tools for managing different threats and lists some of the considerations when selecting the appropriate ILI tool:

- Detection sensitivity.
- Classification of types of anomalies.
- Sizing accuracy.
- Location accuracy.
- Requirements for defect assessment.

Section 7.2 presents guidance on prioritising responses to ILI by considering the results of a risk assessment and the severity of ILI indications. It recommends responses be divided into:

- Immediate: indication shows that defect is at failure point.
- Scheduled: indication shows defect is significant but not at failure point.
- Monitored: indication shows defect will not fail before next inspection.

16 DIFFICULT TO INSPECT PIPELINES & EMERGING TECHNOLOGY

Some pipelines are not currently inspected with ILI tools and are often referred to as 'unpiggable' or 'difficult to inspect' pipelines. The definition of a so-called difficult to inspect pipeline could be:

- The pipeline cannot pass a standard ILI tool from one end to the other end.
- The pipeline is defined in the operator's asset list as 'un-inspectable', due to geometry, process, operational factors or cost.
- A decision process has concluded that ILI is not reasonably practical, i.e. the cost of making the pipeline inspectable is greater than the replacement cost.

The current approach for pipelines not subject to ILI is to use above ground survey techniques, typically Close Interval Potential Survey (CIPS), Direct Current Voltage Gradient (DCVG) and Magnetic Tomography Method (MTM). However, these techniques have limitations, especially for some difficult to access areas. ILI for these pipelines would enable a more searching and comprehensive inspection to be carried out, giving more confidence in the future integrity and safety of the pipeline.

Some existing pipelines are not currently able to be inspected with a standard ILI tool because of:

- Geometry or passage restrictions i.e. small diameter, multi-diameters, valve configurations.
- Bends and connections, i.e. small radius (sharp) bends, mitred bends, back-to-back bends, unbarred tees etc.
- Low flow rates, low pressures, excessive dirt or debris.
- Absence of vehicle launcher and receiver facilities.

All newly constructed pipelines should be designed to accommodate ILI tools.

A review of the reasons that a pipeline is not currently subject to ILI may find:

- Some pipelines are now easier to carry out ILI using conventional flow driven ILI tools due to new ILI tool developments e.g. developments have extended the range for conventional flow driven ILI tools to small diameter pipelines, low pressure/low flow pipelines using special low friction tools, multi-diameter pipeline tools.
- Some pipelines can be made to accept conventional flow driven ILI tools fairly easily e.g. minor modifications and provision of launch and receive facilities.
- Some pipelines will still be very difficult to be made to accept conventional flow driven ILI tools and these pipelines provide a formidable technical and financial challenge for the pipeline industry.

There are now many new developments in robotics and sensor technology, with emerging inspection technologies targeting currently difficult to inspect pipelines. New ILI technologies include tethered tools and robotic tools that are self-propelled and capable of travelling with or against product flows and navigate through previously prohibitive bends and other restrictive pipeline features.

17 REFERENCES

1. The Pipelines Safety Regulations 1996, UK Statutory Instruments 1996 No. 825
2. The Pressure Systems Safety Regulations 2000, UK Statutory Instruments 2000 No. 128
3. POF 100, Specifications and requirements for in-line inspection of pipelines, Pipeline Operators Forum, November 2021
4. POF 300, Achieving successful in-line inspection, Pipeline Operators Forum, November 2021
5. POF 301, ILI pipeline questionnaire, Pipeline Operators Forum, November 2021
6. POF 302, ILI checklists, Pipeline Operators Forum, November 2021
7. POF 303, ILI data feedback form, Pipeline Operators Forum, November 2021
8. POF 310, Field verification for in-line inspection, Pipeline Operators Forum, December 2023
9. POF 520, In-line inspection tool readiness for hydrogen pipelines, Pipeline Operators Forum, May 2024
10. NACE SP0102-2017, In-Line Inspection of Pipelines, AMPP, 2017
11. NACE 35100-2017, In-line Inspection of Pipelines, AMPP, 2017
12. ISO 19345-1, Petroleum and natural gas industry - Pipeline transportation systems - Pipeline integrity management specification - Part 1: Full-life cycle integrity management for onshore pipeline, International Organization for Standardization, May 2019
13. API 1163, In-line Inspection Systems Qualification, American Petroleum Institute, September 2021
14. UKOPA/GPG/026 Edition 2, Verification of Features Identified by In-line Inspection, United Kingdom Onshore Pipeline Operators Association, September 2024
15. IGEM TD/1, Steel pipelines for high pressure gas transmission, Edition 6, Institution of Gas Engineers & Managers, 2021
16. PD 8010-1:2015+A1:2016, Pipeline systems - Part 1: Steel pipelines on land - Code of practice, British Standards Institution, 2016
17. PD 8010-4:2012, Pipeline systems - Part 4: Steel pipelines on land and subsea pipelines - Code of practice for integrity management, British Standards Institution, 2012
18. ASME B31.4, Pipeline Transportation Systems for Liquids and Slurries, American Society of Mechanical Engineers, 2022
19. ASME B31.8, Gas Transmission and Distribution Piping Systems, American Society of Mechanical Engineers, 2025
20. ASME B31.8S, Managing System Integrity of Gas Pipelines, American Society of Mechanical Engineers, 2025