# Achieving successful in-line inspection

Recommended Practice

POF 300

October 2018
Amended November 2021

## Foreword

This recommended practice on achieving successful In-Line Inspection (ILI) is an update of the document "Guidance on achieving ILI First Run Success" of December 2012. It can be used by operators and contractors and is written to facilitate ILI run success.

The objective of In-line Inspection (ILI) is to obtain data on the pipeline condition as part of the baseline and/or revalidation process. It is highlighted that this recommended practice is written to improve first run success rate of ILI works and is not designed to provide an introduction or fundamentals for completing in-line inspections or appropriate tool selection.

For details of the ILI questionnaire, recommended check lists and best practices referred to in this document, please visit the "Documents" page on the POF website (www.pipelineoperators.org).

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.

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 purpose of this revision is to comply with the new POF document numbering system. Changes consist of updated references to other POF documents. In addition, editorial corrections may have been made.

## Acknowledgement

Photographs used in this recommended practice have been provided by and are used with permission from a number of sources including ILI suppliers.

# Table of Contents

# 1. Introduction

The objective of in-line inspection (ILI) is to obtain data on pipeline condition as part of the integrity management process. Getting ILI right is important to minimise inspection cost and verify pipeline integrity. A failed run usually results in a re-run which generates extra cost such as increased production loss, additional mobilisation or tool adjustment. Health, safety and environment aspects can also be affected as well as reputation. For offshore operations where support vessels are involved, the cost induced by a re-run can be considerable.

Achieving ILI run success requires close collaboration between the operator and contractor teams, where adequate planning and preparation are important factors. Pipeline data and definition of expected anomalies must be up to date. Operating conditions passed on to the contractor must apply for the inspection run, as the selection and set-up of the ILI tool is based on this information.

POF 100 [1] recommends criteria and conditions for a successful ILI run as well as actions in case of failed ILI run. This document uses the same criteria to define ILI run success.

**Definition ILI run success**

| |
|---|
| Criteria for successful ILI run<br>*Ref: Chapter 7.1 of POF 100 – version 2021* |
| • Accumulated loss of data from all primary sensors simultaneously less or equal to 0.5 % of pipeline length.<br>• Accumulated loss of data from individual primary sensors less or equal to 3% of pipeline surface area.<br>• Accumulated loss of data from adjacent primary sensors, covering more than 25 mm circumference less or equal to 10% of pipeline length. |
| Conditions |
| The criteria apply to each section of the pipeline i.e. each diameter, wall thickness and pipe manufacturing process. The tool speed shall be within the limit for specified feature detection capability. Example of data loss is when report of internal and external features is expected but only one of the two feature locations can be reported. |

When data loss exceeds one of the criteria above, operator and contractor should discuss possible causes of failure. It can be several reasons or combination of reasons, e.g. rough pipeline surface, scale or wax on pipe wall, defective sensors or tool exceeding speed limit. The client can accept an ILI run that fails to comply to the criteria if e.g. contractual agreement states otherwise or the ILI run provided satisfactory data for the pipeline sections of interest. When a failed run cannot be accepted, a re-run should be performed as specified in the contract.

Checklists to support achievement of ILI run success are provided in POF 302 [2].

# 2. Definitions and abbreviations

## 2.1 Definitions

For the purposes of this document, the definitions in POF 100 apply.

## 2.2 Abbreviations

For the purposes of this document, the following abbreviations apply:

| | |
|---|---|
| AGM | Above Ground Marker |
| ART | Acoustic Resonance Technology |
| ATEX | Atmosphères Explosibles |
| CFD | Computational Fluid Dynamics |
| ERF | Estimated Repair Factor |
| HSSE | Health, Safety, Security and Environment |
| ILI | In-Line Inspection |
| MEG | Mono-Ethylene Glycol |
| MFL | Magnetic Flux Leakage |
| NORM | Naturally Occurring Radioactive Material |
| ROV | Remotely Operated Vehicle |
| UT | Ultrasonic Testing |

# 3. ILI Preparation

## 3.1 General

ILI projects require a significant level of preparation including:

- Definition of objectives
- ILI tool selection
- Tool qualification, if required, e.g. for emerging inspection technologies
- Pipeline information gathering
- Site visit & stakeholder engagement
- Risk assessment.

Through the preparation process the operator, working with the contractor, should confirm that the selected ILI tool will be able to meet the initial objectives and requirements. Final confirmation of ILI tool selection should take place after the information gathering, site visit & stakeholder engagement and risk assessment have been completed.

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

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

## 3.2 Causes of failed ILI runs

Experience from operators and ILI companies shows that historically around 50% of failed ILI runs are caused by failures of the ILI tool itself and 50% by operational issues outside the contractor's control.

### 3.2.1 ILI Tool Failures

Figure 1 illustrates a breakdown of the main causes of ILI tool failures.

Failed runs from trap to trap are a small percentage of overall failed runs. A majority of ILI run failure cases involve failure of some hardware components, resulting in an incomplete inspection coverage of the pipeline wall and might be intermittent through the pipeline length.

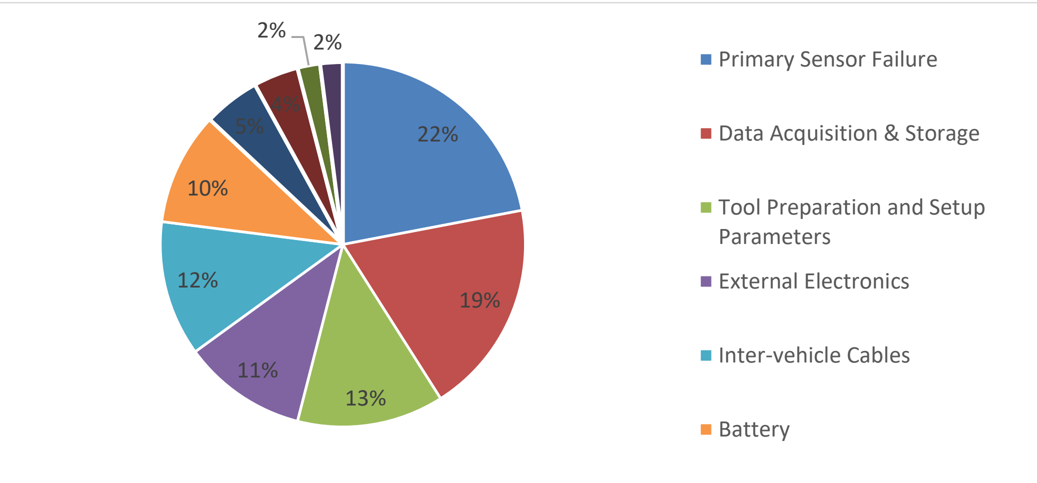



*Figure 1 - Causes of ILI tool failure*

### 3.2.2 Operational Issues

Figure 2 illustrates a breakdown of the main causes of operator-related ILI run failures.

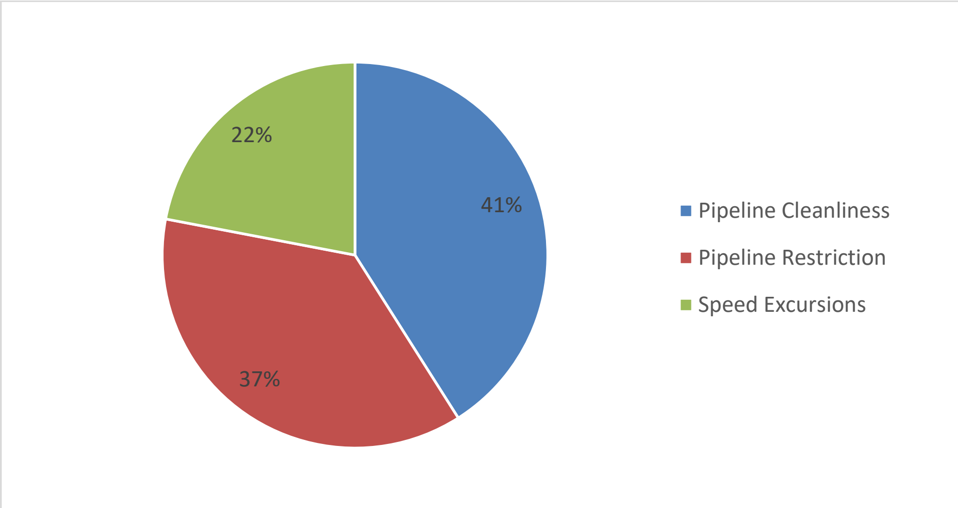



*Figure 2 - Operational causes of failed ILI runs*

As with ILI tool issues, the objective of accurate and complete data collection is not achieved, and may not be trap to trap, but intermittent or localized to certain lengths of the pipeline segment.

## 3.3 Inspection objectives & tool selection

The inspection process adds value when the inspection objectives are clearly set and aligned with the threat assessment with a clear understanding of the critical features that may potentially be present in the pipeline.

The operator should clearly define the 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 operator and contractor. Factors that may influence tool performance, such as level of cleanliness and pipeline operating conditions should be considered as well.

Some of the variables to consider include:

- Pipeline operating history
- Pipeline threats and objective of the inspection run (i.e. what are the pipeline deterioration mechanisms to be potentially observed and defect types resulting from these processes?)
- Critical feature detection, sizing and the level of assurance is needed
- Pipeline operating conditions: product composition, flow conditions, pressure, temperature.
- Ability to clean the pipeline to the required level for good inspection performance.
- Physical properties of the pipeline: wall thickness, range of internal diameters, bend restrictions, length of pig traps, diameter etc.
- Presence of internal flow coating
- Experiences from previous pigging and in-line inspections
- Contractor performance: HSSE performance; inspection solutions offered; tool availability and performance; reporting times; run success rates.

Inspection tools can often be optimised to the inspection requirements by using special modification kits. In advance of an inspection campaign, it is often worthwhile asking different ILI companies for the best suited solution, which might save costs while performing the inspection or when following up on the inspection results at a later stage.

Much of the preparatory information is collated in the ILI pipeline questionnaire available in POF 301 [3].

## 3.4 Pipeline information gathering

ILI preparation requires a multitude of information gathering activities. Operators should adopt a cross-discipline attitude to defining fully the inspection “environment”. Input from key discipline functions will be necessary so that an accurate picture of the risks to operations/production is built prior to engagement with ILI contractor. Based on the pipeline questionnaire, an early technical review starts the process of matching the inspection objectives and requirements with the tool attributes and inspection capabilities for a range of technologies that could be deployed.

The discussion should address the physical limitations of the ILI tool types and their inspection performance for the anticipated operating conditions. Understanding the technical limitations for inspection and the key parameters that drive both probability and accuracy of detection are important aspects that should be considered at an early stage.

It may be possible that the operating conditions in the pipeline can be optimised to maximise tool performance through adjustments to the flow rates or frequency of sampling. For heavy wall pipelines, when using MFL principles, understanding the relationship between achieved magnetization and the tool velocity is critical. Checks should be made to ensure that the tool selected can inspect the targeted wall thickness for a given tool velocity. For other technologies, similar restrictions may exist depending on what accuracy is required. UT tools may require a cleaning run and ART tools require a minimum operating pressure.

Information required for successful project execution will include at a minimum: pipeline design data, pipeline operating parameters and product composition. Physical line constraints to be considered include both bore restrictions and pig trap lengths which are more critical where either combination tools or higher-level accuracy tools are required. A detailed feature list or bore map should be created for the pipeline and provided to the contractor. Appendix A contains an example feature list.

For pipelines that have not been subject to ILI before or for known challenging pipelines, a detailed piggability review is recommended to identify problem areas and actions to be taken to minimise risks related to damaged, stalled or stuck ILI tools.

Key information gathering subjects include:

Information required by operator

- ILI tool specifications
- Defect detection capabilities
- Sizing accuracy
- Tool class history
- Bore & bend passing capabilities
- Tool length and weight
- Speed thresholds
- Maximum wall thickness
- Technology availability
- ILI tool schedule availability.

Information required by contractor

- Objective of inspection (e.g. defect types, etc.)
- Technology requirements
- Pipeline design conditions

- Operating conditions
- Product composition
- Pipeline condition (Cleanliness)
- Trap dimensions
- Facilities and procedures to load and recover the tool
- Proposed ILI schedule
- Logistic issues associated with controlled items e.g. isotopes, inertial navigation systems.

Other requirements

- Above Ground Marker (AGM) information established
- Alignment sheets / As-built drawings
- Past ILI reports as applicable
- Other historical data
- Roles & responsibilities (key personnel)
- Site restrictions (hazardous areas etc.)
- ATEX requirements
- Hazardous substances (e.g. Naturally Occurring Radioactive Material (NORM), Mercury, Polychlorinated Biphenyls (PCBs) etc.) and arrangements for cleaning.

Other criteria may also be considered, but for the purpose of this document the above referenced items are key components of communication between operator and contractor.

Some inspections may require specialist tool modifications or changes to operating practices and procedures. Early discussion with the contractor and information transfer is recommended to ensure that these can be accommodated within the inspection programme.

## 3.5 Site visits and stakeholder engagement

Project site visits and early stakeholder engagement are critical components of pipeline information gathering and provide an opportunity to identify operating limitations, potential risks to consider during the planning phase, or if minor modifications are required to accommodate the selected ILI technology. Stakeholders are defined as all parties involved in the ILI project including those providing third party services (e.g. tracking, cleaning or subsequent field measurement) and those impacted by the inspection activities (e.g. downstream facilities).

The site visit and stakeholder engagement promote buy-in from all personnel involved in planning and conducting the ILI project. Identifying all prospective stakeholders allows for a more thorough assessment of risk management actions required due to schedule, resource, or commercial concerns.

Properly documenting the site visit and stakeholder engagement can assist with identification of risks and the planning of a more comprehensive project scope. The site visit and stakeholder engagement checklists (see POF 302) are a resource that can be utilised for this purpose. A simple stakeholder mapping exercise can help identify the key stakeholders and will assist teams in establishing the appropriate interfaces, see Figure 3 for an example.

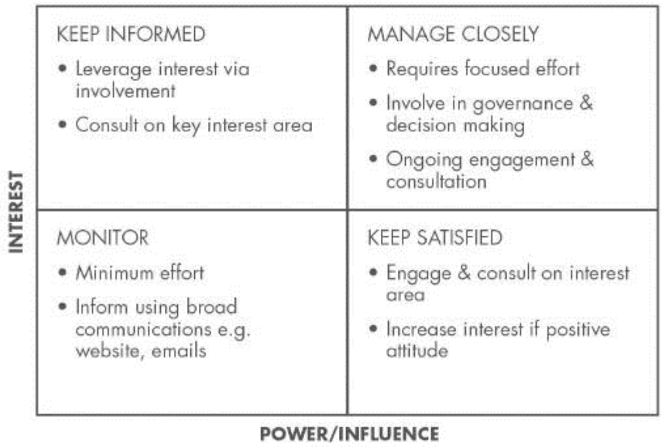



*Figure 3: Example stakeholder map*

The following items should be addressed during site visits and stakeholder engagement:

- Confirmation of information to assess the effort to perform the inspection.
- Collection of information to establish the detailed inspection procedures and action plans.
- Collection of information to assess required (3rd party) support; e.g. lifting, pumping facilities, rigging, etc.
- Confirmation that site facilities are suitable for execution of the works using the selected ILI tool. This includes a readiness check of pig traps, integrity of its isolation valves and associated facilities such as cranes.
- Identification of key personnel and establishment of communications.
- HSSE audits and contingency / mitigation plans.
- Identification of local communication lines, logistics and crew accommodation.
- Specific final inspection reporting requirements.

## 3.6 Risk assessment

Successful ILI requires effective management of risks. These should be clearly identified at an early stage in the ILI process.

By conducting risk assessments, the key factors can be evaluated for their impact and probability of occurrence (or likelihood). The risk factors are generally assessed against the impact to safety, the environment and the operations including lost production.

Risk assessments associated with personal safety are well established. Further risk assessments on wider process safety issues require increased attention addressing the impact the ILI tool run can have on operation of the pipeline, including: process upset conditions due to the transfer of pipeline debris; changes in flow conditions and pressure changes due to ILI operations (with the potential of increasing line pressures) and the implications of a stalled or stuck ILI tool.

Environmental considerations generally consider the effects of cleaning operations, disposal of materials and decontamination of tools and equipment.

Business considerations include the impact on production of a stalled or stuck tool. Failure to recover a complete ILI tool with all of the parts may also have implications in pipelines which are regularly pigged to control liquid inventories.

The information gathering and site visit phases of the ILI preparation facilitate the identification of risk factors which should be considered during project planning, including risks based on pipeline construction, operating conditions and location (e.g. a pipeline located onshore may incorporate less risk than that of a pipeline offshore). The information obtained during the information gathering steps must be measured against the project scope to effectively anticipate potential risks that could threaten the success of the project.

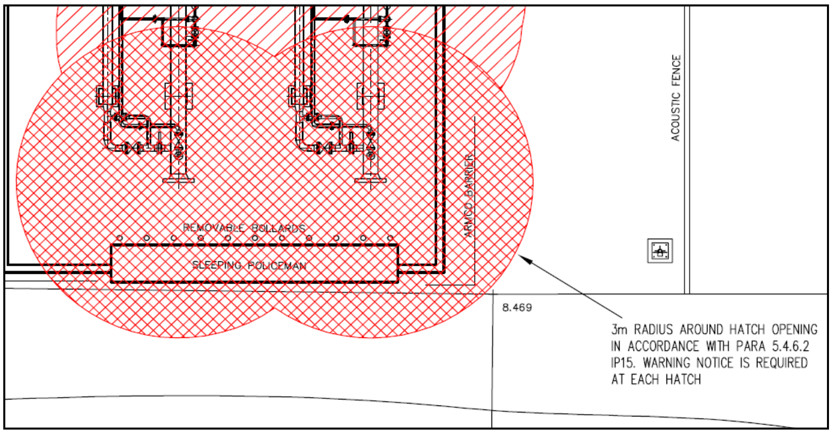



*Figure 4: Typical hazardous area drawing*

A risk assessment checklist (see POF 302) is a good way to document and evaluate the findings. When assessing potential risks associated with ILI projects, the operator should incorporate the following contributing factors into their business risk assessment strategy:

- Potential risk criteria for consideration: Available historical data (data related to the pipeline design & construction process, information received from any previous cleaning runs and historic pipeline inspections, history of known pipeline defects etc.)
- Existing pipeline conditions indicated by gauge plate information including pipeline valves and fittings
- Valve operability and leakage rates
- Pipeline geographic location
- Pipeline access at launch / receipt and along pipeline length for marking and tracking
- Pipeline operating conditions and product composition, including effect of launching medium on downstream systems
- Subsea operations e.g. diver/ROV access
- Recovery options in case of a stalled or stuck pig
- Weather (wind, wave & current) conditions for subsea and offshore operations
- Seasonal complications (human factors, access and environmental issues).

The risk assessment should take into consideration the following common causes of failed ILI runs:

- Speed and pressure related issues (too high and too low)
- Pipeline related damage
- Bend configurations (bend radius and back to back bends)
- Wall thickness changes
- Line debris/paraffin/pyrophoric dust
- Pipeline bore restrictions or openings (i.e. valves)
- Availability of product (e.g. tank volume to maintain flow)
- Tool component failure
- Separation of multi-module ILI tools

- Wrong inspection technology selection
- Operational failures
- Pipeline valve operations & isolation difficulties
- Launch cassette sealing difficulties
- Loose components in the pipeline (e.g. previous ILI tool parts, bolts, welding rods, tee bars)
- Incorrect pigging procedures or not following procedures.

Pigging on paper exercises with key stakeholders and go/no go pre-requisites have proven useful for more complex ILI activities.

# 4. Pipeline cleaning and verification

## 4.1 Introduction

The quality of inspection results is not only dependent on the quality of the inspection methodology used, but also on the operational conditions of the pipeline during the inspection. A critical parameter to the success of an inspection is the cleanliness of the internal surface of the pipeline to be investigated. Ineffective cleaning can also have consequences for the normal operation of the pipeline, including reduced flowrates and reduced efficiency of corrosion inhibitors with accelerated degradation of the pipeline condition. Presence of debris or liquid slugs in gas lines can cause tool damage or poor data quality.

The consequences of ineffective cleaning are even higher, when the cleaning regime is not specially geared in preparation of inspecting the pipeline using ILI tools, see an example of a damaged tool in Figure 5. In such cases it can lead to:

- Incomplete and/or degraded inspection data
- Damage to the inspection tool
- Worst case, a lodged inspection tool.

*Figure 5: Damaged tool due to excessive debris*

The ability to clean the pipeline adequately should be taken account of as part of ILI technology selection. For difficult to clean applications, technology that requires less cleaning should be considered.

The pipeline operator should decide on cleaning responsibilities; it can be performed by the operator, the ILI contractor or a specialist third party cleaning contractor. The selected ILI contractor can be consulted for advice in this matter. In some cases, extensive cleaning is required and in other cases only limited, final cleaning/gauging is sufficient:

- The best case: the pipeline operator has a well-established cleaning strategy in place and cleaning runs have been performed regularly. In this case only final cleaning/gauging runs by the contractor is necessary prior to ILI.
- The worst case: there is no cleaning strategy or it is not efficient and an intensive cleaning phase is necessary prior to ILI. A dedicated, jointly agreed cleaning program needs to be established where some parts can be executed by the operator and other part by the contractor, depending on experience of the operator and practicalities of the execution.

Planning of cleaning should include handling of waste products such as sand, scale and wax, with specific attention to the handling of hazardous waste (e.g. NORM, mercury, benzenes and pyrophoric dust) and the effect that debris can have on downstream facilities and operations.

It is recommended that early proving of the pipeline bore is carried out during the pipe cleaning phase. Ideally the tool should contain multiple gauge plates and mimic the profile of the proposed ILI tools. This will allow an early assessment to be made of the suitability of the ILI tool to pass through the pipeline. It will also allow time to mobilise a calliper tool if a more detailed assessment is required. Completing this early in the process will help to minimise cost, should either ILI tool or pipeline modification be required.

It should be noted that the use of gauge plates will not detect overbore sections of pipe. These have caused ILI tools to get stuck or damaged. Use of a dedicated calliper tool is recommended for lines where there is uncertainty of the pipe bore or the gauge/profile tool indicates a bore restriction.

## 4.2 Preparation of cleaning campaign before inspection

Time should be taken to conduct a kick-off meeting or site visit together with the inspection contractor. The meeting should be scheduled shortly after the contract has been awarded and well in advance of the inspection campaign. If the pipeline operator does not have a well-established cleaning strategy, the preparations for cleaning should start well in advance of the planned inspection date. In this way there will be sufficient time to:

- gather all historical cleaning and operational information
- define a progressive cleaning program if required
- execute the program
- monitor the effectiveness of the cleaning and adjust if necessary
- analyse the cleanliness of the pipeline.

Between the initial cleaning programme and inspection runs the pipeline should be maintained with regular pigging.

The effort for cleaning may depend on:

- the type of product transported within the pipeline
- the frequency and type of cleaning runs previously completed
- the inspection technology to be used and the proposed setup of the ILI tool.

Different types and amount of debris is usually observed in pipelines depending on their service. The following table gives a rough indication for the pipelines commonly used in the oil & gas industry.

*Table 1: Typical pipeline debris*

| Service | Type of debris | Typical amount of debris |
|---|---|---|
| Refined products | Corrosion product. | Little. |
| Crude oil | Hard and soft paraffin (wax), asphaltenes, sand, hard scale, corrosion product. | Potentially large depending on product composition, temperature and crude velocity. |
| Multiphase | Hard scale, sand, wax, corrosion product. | Potentially large depending on product composition. |
| Injection water | Hard scale, sand, corrosion product. | Potentially large depending on product composition. |
| Dry gas | Corrosion product, compressor oil, black powder. | Usually little if pipeline is regularly cleaned and not affected by black powder. |

In pipelines that have never been pigged before, construction related debris such as bricks, poles, tools and welding rods may also be expected.

Routine pigging, as part of the pipeline operations and management, can generate useful information on the condition of the pipeline and its contents that can be used when planning an ILI programme. Information about the frequency, type of cleaning tools and analysis of material in pig traps should be used as input when setting up the cleaning program (also refer to section 4.3).

To reduce the risk of a failed run, the cleaning programme objective should be to remove all debris from the pipe wall, independent from the inspection technology to be used. However, due to operational reasons the pipeline may contain some inspection tool residual deposits which can limit the number of suitable inspection techniques. This is particularly the case with waxy crude pipelines where due to the wax appearance temperatures, the line will normally have deposits. In these cases, a combination of chemicals and mechanical cleaning may be required.

Debris mapping tools (instrumented pigs) have become available to actually map the amount (and thickness) of debris on the internal surface of the pipe. These tools can help optimise cleaning results and ensure adequate cleaning prior to running an inline inspection tool.

## 4.3 Cleaning procedures

The cleaning procedure determines the sequence and type of cleaning tools to be run. A relatively simple brush tool is depicted in Figure 6.

Usually "progressive cleaning techniques" are used for pipeline cleaning, which implies that the aggressiveness of the cleaning tools gradually increases as the cleaning activities are progressing. For certain applications, it is useful to start with chemicals, e.g. introducing a wax dissolver in a gel pill followed by flushing has proven to be useful in waxy pipelines. Thereafter, the safest way to continue a progressive cleaning program is by running gel or foam pigs.

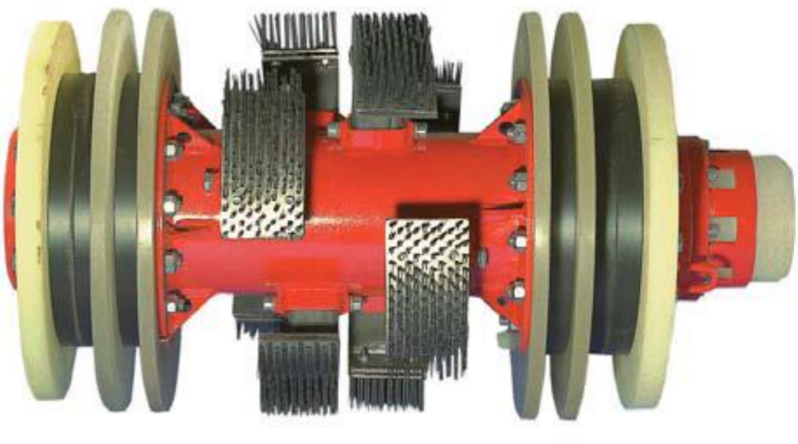


*Figure 6 – Typical bi-directional brush cleaning tool*

The success of a cleaning program is heavily dependent on the experience and knowledge of the pipeline operating conditions.

Each cleaning program is uniquely defined for its objective, the pipeline and the given operating conditions. Therefore a great variety of cleaning procedures and cleaning tools exist. Combining mechanical cleaning with the use of chemicals can significantly reduce the time and number of runs required.

## 4.4 Assessment of cleaning results

During a cleaning program the cleanliness of the pipeline should be assessed continuously to identify the moment in which the objective has been achieved.

Various assessment types can be distinguished:

- Visual assessment of all cleaning pigs and retrieved deposits immediately after the run. If possible, the debris should be recovered shortly after the cleaning tool reaches the receiving trap and flushing of the trap should be minimized.
- Monitoring of relevant pipeline operating conditions such as pressure, flow, etc.
- A pipeline data logging unit can be used in order to identify trends, such as the movement of any soft wax deposits in the pipeline. These can be identified by measuring the differential pressure of the tool, while it is travelling through the pipeline. A logger can be installed on standard cleaning pigs and does not require any additional runs just for monitoring.
- Debris mapping tools which are basically a more advanced version of a cleaning pig with data logger. These tools are typically offered by companies that specialise in helping pipeline operators clean pipelines in preparation for an ILI run. They have sensors to measure debris thickness and may even include some inspection capability to confirm the ability to capture data.
- Non-intrusive methods such as acoustic pulsing, radio-isotope diagnostics, or even digital radiography (CT scans) for subsea pipelines can be used to assess/measure level of debris in a pipeline.

All above assessment results should be assessed jointly by the operator and contractor during the cleaning process.

Regardless of contract requirements, the final decision on whether the pipeline is ready for the ILI inspection run should be made jointly by the operator and contractor.

*Figure 7: Debris build up within trap as a result of cleaning*

# 5. ILI Tool Preparation

## 5.1 Introduction

A number of failures have been caused by inappropriate tool preparation and set up and can be avoided through the use of simple check lists as discussed in Section 3. These usually manifest themselves through loss of data through loose connections although more significant failures have occurred where component parts have been substituted.

## 5.2 Use of new tools and components

The introduction of new tools will remain a feature of the ILI sector. Driven by competition between contractors and requests from operators to inspect ever more challenging pipelines, their introduction poses a dilemma as this introduces a level of uncertainty, particularly as contractors report a higher level of incidence associated with new tools or components.

Contractors who extensively test tools before their introduction generally have lower failure rates. How rigorous the testing programme may be, there will inevitably be times where new components are introduced and used. This should never be done without consultation between the contractor and operator and the risks should be discussed and included in the risk assessment.

## 5.3 Pipeline environment

Even when tools have been tested and their design proven over a period of time, new applications will be found to challenge and test the tool. It is important therefore that each contractor maintains records of the lines inspected. Failures may occur either due to an environment at the limit of operational experience, such as operations in dry environments and higher pressures or they may be the result of fatigue. Each failure should be recorded and used to build the envelope of suitable operating conditions.

As with new tools or components, wherever the use of the tool is proposed in an environment that is at the edge or beyond of current proven operating conditions, this should be recognised and discussed between the contractor and operator and the risks included in the risk assessment. The operator needs to consider the normal operating conditions and also any abnormal transient conditions that could be generated.

## 5.4 Tool set up

Tool design can play a part, particularly where tool designs change between models. Whenever new tools are introduced, their design should consider field operatives and consistency of operation with earlier models. Failures have occurred simply due to the change of orientation of an on/off switch.

Training and knowledge of field technicians is crucial if these failures are to be avoided. This should not only include the use of check lists but also a good understanding of tool operation. Failures reported in this category include lack of knowledge of battery histories.

# 6. Field operations

## 6.1 Introduction

The operational objectives are to ensure that the ILI tool is configured and run within defined limits to acquire usable data without incident. To achieve this, effective coordination and communication is needed between operator and contractor. The knowledge of operations about the flow, off-takes, debris, wall thickness, bends, etc. is essential information for the contractor.

## 6.2 Onsite Preparation

The onsite preparation phase generally covers the period from ILI tool mobilisation to site, final and preparatory checks prior to launch. During this phase general issues and documentation should be reviewed to confirm that all procedures are in place; the pipeline is ready and that the tool has been appropriately prepared and is set up to meet the inspection requirements.

Typical documents reviewed during this phase include:

- Pre-mobilisation documentation (Pipeline questionnaire, feature list, site visit and stakeholder meetings and risk assessments)
- Method statement with pigging program, operating procedures, risk assessment, drawings, principal pipeline characteristics, roles and responsibilities, contingencies.
- Communication procedures: clearly identifying who is responsible and who should be aware or notified
- Site safety meetings: specific to each location where work will be carried out including compliance with ATEX requirements.

To ensure that the pipeline has been prepared and the ILI tool has been set up appropriately, the contractor will use and will make reference to a number of check lists. Significant failures have occurred where recognised steps have not been followed. Although the check lists may differ slightly with each contractor and for each ILI tool, the basic contents are similar:

- Pre-job meetings to confirm objectives, scope of work, operating procedures, safety, risk assessments
- Setup and calibration checklist to confirm that the tool is properly configured
- Mobilization checklist to make sure that all required support equipment is onsite
- Pipeline operations checklist to ensure medium pressure and flow are adequate to ensure stable run conditions and ability to launch and receive the tool
- Site safety meeting onsite with operator and contractors to reconfirm the work, operating procedures, safety, risk assessments and communications
- Location of Above Ground Markers to support the accuracy of geographic surveys
- Operational training if applicable.
- Provision for pre-mobilisation quality check/tool inspection onsite in case of critical runs

Location accuracy of features is essential for the field verification success, for instance for features location in dense urban areas. It is directly linked to Above Ground Markers (AGM) implantation.

AGM implantation should be anticipated and is generally established with contractor as part of the preparation of ILI operation. AGM spacing depends on:

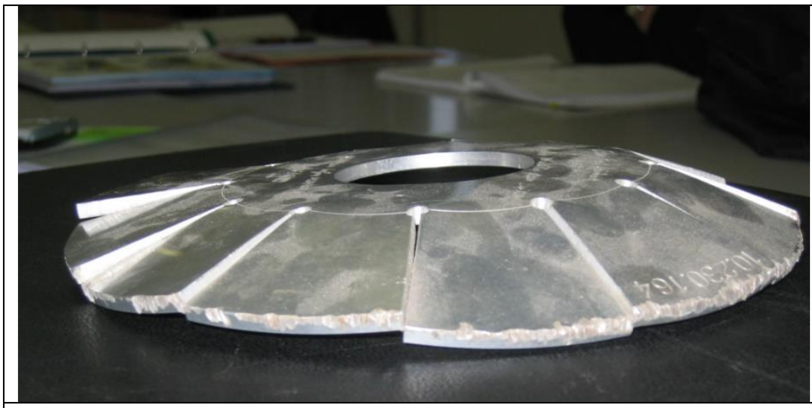
- Technology used: simple AGM or mapping require different AGM spacing to reach the claimed location accuracy of features
- Pipeline profile: for instance, AGM spacing is shorter in areas where the pipeline profile is disturbed

- Pipeline environment: in order to locate accurately features for field verification in critical area, it is a good practise to increase the number of AGM

## 6.3 Final cleaning, profile or gauge plate run

Whilst early proving of the pipeline bore is recommended as an early activity in the process, the final step should be verification that the line is clean and ready for this ILI tool. This should normally be completed in the presence of the contractor.

A key step in all inspection runs is the final profile or gauge plate run. This should be completed no more than one week prior to running the ILI tool. The gauge or profile tool is used to verify that the line does not have any obstructions that could cause the ILI tool to get stuck. (e.g. a changed valve position or corrosion monitoring point). As such the profile or gauge tool should be sized to mimic the ILI tool. Examples of features identified by running gauge plate tools are depicted in Figure 8. Figure 9 is a photo of a damaged UT sensor carrier.



Deformed gauge plate

Gauge plate damage caused by weld penetrations

Gauge plate damaged by gate valve

*Figure 8: Damaged gauge plates*

All operational changes between running the profile and gauging tool should be discussed by operator and contractor and any risks should be recognised and acted on accordingly.

The contractor should have a clear set of procedures for setting up the gauge/ profile tool consistent with the ILI tool being run. The procedures should include clear guidance on interpreting damage to the plates. If any doubts arise during the cleaning and proving process, a calliper tool should be run to establish if more than a single incidence has caused damage to the gauging plate, speed effects or pipeline geometry. If a profile / gauge tool is damaged, a calliper tool will be required to locate the restriction.

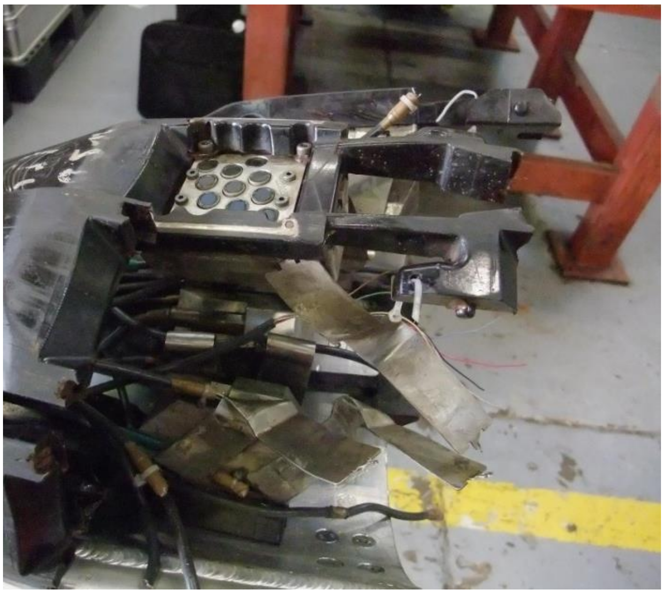


*Figure 9: Damaged UT tool sensor carrier due to bore restriction*

If pipeline gauging is not carried out, the reasons to justify this (including risk assessment) should be clearly documented. If pipeline gauging is carried out, the details of the gauging tool, analysis of the tool on receipt and confirmation that the inspection run can proceed, should be documented. This documentation should be approved by both operator and contractor.

## 6.4 Launch, ILI run and receipt

After the pre-job meeting, responsibilities and duties for all personnel involved should be clear. At this point, the main responsibility for the interactive process of operating the pipeline belongs to the operator. The contractor's ILI crews are available to assist as appropriate and as requested.

In general responsibilities are shared as follows, notwithstanding any contractual or project specific agreements made in between operator and contractor:

- The contractor is responsible for ensuring tool is fit for purpose prior to launch; handling of the ILI tool into and out of the pig traps.
- The operator is responsible for safety on the site and all operating conditions in the pipeline; pressurising the pig traps and running the ILI tool; de-pressurising pig traps on receipt and providing assistance with cleaning the ILI tools. Where the tool is contaminated due to the pipeline contents (e.g. NORMs) the operator is responsible for providing specialist cleaning services. A pre-NORM measurement is advised before loading the tool in the launcher.

*Figure 10: Preparing for ILI launch*

ILI tool tracking and monitoring can be with both parties and needs to be mutually agreed. Failure of tracking devices can lead to failed inspection runs. Nevertheless the contractor should provide the required training prior to start of the tracking.

The condition of the ILI tool should be recorded on receipt and following cleaning to verify that the tool is undamaged and that all components of the ILI tool have been received. If there is any doubt at the receiver site on the part of either the operator or the contractor that communication is initiated with supervisors or other stakeholders as appropriate.

After the ILI tool is received, safely extracted from the receiver and cleaned, the contractor is responsible for downloading the data and getting that data where it needs to be to begin the analysis process. This may take minutes or hours according to the length and diameter of the pipeline and the complexity or density of the data. Specific checks include whether the ILI tool speed has remained within inspection limits and the completeness of data recovery. Some data loss may be acceptable if this is not in a critical section of the pipeline where any data loss would defeat the inspection objectives.

Although the contractor’s ILI supervisor may be capable of deeming the run successful, some ILI companies require that the data be reviewed by a senior analyst. This may seem an extra step but remember that the entire purpose of the pig run is to provide suitable data for suitable answers. The time involved in this step can be minimized with good planning. For instance, data upload may prove to be slow if carried out from an offshore platform or support vessel.

Documents that help to ensure that this part of the project is successful include:

- Field data check
- ILI run acceptance form
- Short field run report

It is generally advisable that the data is reviewed and approved according to the agreed criteria. If data irregularities are discovered, clear communication between operator and contractor is required to determine next steps prior to releasing the ILI crew. A little extra time can pay dividends here: after the tool and crew have been released, the complexity and cost of a rerun increase dramatically.

## 6.5 ILI tool tracking

Following the ILI tool during the run is crucial for run success. Current information about speed, passage, position can be used to adjust the process settings during the run if necessary. Tracking is also required to confirm that the ILI tool has left the launch site and arrived at the receipt site before valves are operated to isolate the pig launcher/receiver.

Tracking can be performed using a variety of methods, including:

- Geophone
- AGM´s
- Handheld pig detectors
- Intelligent pig tracking system
- Pressure measurement

## 6.6 Subsea launch/receipt

For subsea pig launch and receipt operations the same principles apply as for onshore operations, but the added complexity of ROV and /or diver intervention creates interfaces which are required to be managed proactively to reduce the risk of operational delays. Vessel day rates introduce costs which are significantly higher than onshore pipeline intervention costs and because of this and delays to the inspection schedule often becomes a key cost driver. The subsea interface also introduces other risks and additional Stakeholders which may have an impact on successful execution of the inspection.

The risk of hydrates and potential for environmental incidents through lack of control during pig launch/receipt is increased subsea and requires special focus. As such, the focus for subsea ILI is more on subsea equipment handling, pig trap connection and flushing and valve operations than the pig launch/receipt or running the tool itself. Subsea receipt usually uses the same medium to get the ILI tool into the receiver as used for propelling the ILI tool through the pipeline. Subsea launching may require to be set up with a different medium compared to the medium in the pipeline, e.g. pushing the ILI tool into the pipeline using MEG or other medium. This requires flushing of the downline, to avoid hydrates in the launcher and valve from water ingress during installation. The ILI tool should be launched using a well-thought-out valve operation sequence which aims to allow for reversing the procedure at any time to get back to a safe state.

It is therefore highly recommended that for subsea pigging operations, project controls such as used for major project developments are used, with regular project risk management reviews, involvement of specialists where appropriate and monthly reporting to management. Planning for subsea-to-subsea pigging operations should ideally start around 2 years prior to the offshore operation with issue of a project execution strategy document and a high-level execution plan endorsed by all stakeholders.

The main responsibility for the interactive process of operating the pipeline and controlling flows during pig launch and receipt lies with the operator. Detailed step-by-step procedures will have been developed in close cooperation with the offshore intervention and pumping contractors as well as equipment suppliers. It may be worth conducting an onshore pumping test to verify that pig launch is feasible using the approved procedures, especially for a first inspection of a pipeline. This will enable pumping equipment to be fully tested before use offshore, temporary hardware (spools etc.) to be verified to be compatible with proposed pig design and the pressure profile/envelope to be established prior to introducing mechanical tools into the pipeline for the first time. Focus during subsea pig launch and receipt needs to be on rigorous compliance with agreed procedures and controlled management of change processes where procedures need to be changed.

In general responsibilities are shared as follows, notwithstanding any contractual or project specific agreements made in between operator and contractor:

- Invariably, subsea intervention on systems requiring cleaning/inspection will drive regulatory permits & approvals. These should be submitted by the pipeline operator in a timely manner. Experience in this area has proved that the usual formal approval process can be longer than anticipated. The authority applications should provide clarity on the main areas of risk through a step by step review of planned activities, their associated risks and proposed mitigations to reduce these risks to acceptable levels.

- The contractor is responsible to ensure that the ILI tool is fit for purpose prior to mobilisation and that it has been properly mounted in the subsea launcher prior to vessel mobilisation. The reliability of MFL inspection tools can be reduced in the presence of sea water and this can increase the probability of run failure when using for inspection in a subsea environment. The operator should make clear all operational constraints when defining the scope of work to be performed by the contractor to enable a full appraisal of tool requirements and recommendations for a fit for purpose inspection vehicle.

- The ILI tool bypass rate should be stated by the contractor based on the operational conditions to be used. Launching/receiving conditions and pipeline conditions should be considered separately. In this respect it is important to recognise that it must be possible to deliver the launch medium at a faster rate than the bypass rate across the pig. This often implies having to use a liquid for pig launch.

- The operator is responsible for safety on the site and all operating conditions in the pipeline; flushing and pressurising the pig traps to acceptable levels using glycol, nitrogen or the flow medium, running the ILI tool by controlling pressures and flow rates, controlling subsea release of gas where necessary and de-pressurising pig traps after receipt. Where the ILI tool is contaminated due to the pipeline contents (e.g. NORM) the operator is responsible for providing specialist cleaning services on the vessel and onshore site prior to transportation to the contractor's workshop.

Pig tracking and monitoring can be done using non-intrusive pig locators on the pig trap and by external electromagnetic or radioactive trackers on subsea piping. Failure of tracking devices can lead to failed inspection runs and very high costs related to locating the pig to verify that it has been launched and not stuck in a main line valve. The use of pig tracking should be part of the overall risk evaluation.

Subsea pig receipt is a complex operation. When release of gas is necessary, it should be modelled using plume and dispersion modelling CFD tools such that the support vessel is always up-wind and up-current of the location where a gas plume is expected to surface. It is highly recommended to partially open the subsea choke valve on the pig receiver around 1 minute before the ILI tool arrives at the bypass line, so that the pig does not stop at the tee and continues to move at a controlled and pre-determined speed into the receiver. A stalled pig in a tee or the main receiver isolation valve can create problems. It is therefore useful to use two pig trackers around 100m upstream of the pig trap, thus allowing time for the subsea choke to be opened prior to ILI tool arrival at the bypass line tee.

The condition of the ILI tool should be recorded on receipt and following cleaning to verify that the tool is undamaged and that all components of the ILI tool have been received. If there is any doubt at the receiver site on the part of either the operator, the offshore intervention contactor or the ILI contractor that the pig has completely entered the receiver, this should be communicated to the operator onshore support team.

Guidance for design and operation of subsea pig trap systems should be obtained from a reputable pipeline/subsea facilities contractor who has experience with design and/or operation of subsea pigging systems. Additionally, the Pipeline Research Council International (PRCI) has published guidelines for subsea pig trap design and operations based on input from PRCI membership companies. These guidelines can be purchased via PRCI's website, www.prci.org.

# 7. Field verification

## 7.1 Introduction

Pipeline operators often perform additional measurements of several indications identified by an ILI tool. The process which is followed in the field to achieve this is important as inappropriate inspection techniques in the field can invalidate an otherwise valid report.

Field verification of reported features has two important aspects as this helps confirm:

- The reported features confirming the condition of the line to operator and generating data for a more detailed defect assessment in order to support any actions that may be taken.
- The specified tool performance for acceptance/rejection of ILI run or for use on other lines where dig verification is not possible.

Detailed guidance is provided in POF 310 [4]. Hence, this section is not meant to give exhaustive details on field verification but to give some highlights of the main parameters making field verification successful.

The main steps for field verifications are:

- Features selection
- Procedures preparation
- Operation:
  - Features location and excavation
  - Features sizing
- Data analysis: ILI measurements vs. field verification measurements.

## 7.2 Features selection

Features selection is also an important parameter. The first reflex would be to focus only on the most critical features. This is necessary but it is not sufficient to achieve field verification objectives.
A good practice for features selection should be, as minimum but not limited to:

- The most critical features in depth, length, width and/or ERF
- Features close to the minimum detection threshold of the ILI tool
- Features located in the most representative areas of the pipeline. For example, if there is an evidence of corrosion mechanism on the pipeline in a specific area, even not critical, some features on this area should be verified.

## 7.3 Procedures preparation

As for all inspection operations, the preparation phase is key factor.

It is important to have a consistent and reliable data set in which to work. In order to achieve consistency, it is necessary to set standards and protocols that must be followed, and to train and certify field personnel to gather the data with the required accuracy and competency so that the results can be relied upon. The techniques and equipment used should be tested and certified in calibration. The calibration and device tolerances should be taken into account when evaluating the results.

Procedures, technical or organisational, should be developed in the early project stage.

Contractors should be contacted prior to dig verifications either to have the possibilities to attend or to recheck the proposed location and give additional advice e.g. other corrosion that could exist in the same joint.

## 7.4 Operation

Field personnel assigned to dig verification should be certified competent with the equipment being used to measure the required defects reported.

Significant problems have occurred where reported feature sizes are incorrectly measured in the field. This has an impact not only on the verification of the reported features but also on determining the tool performance.

Contractors will usually support field verification work as this helps support verification of tool performance. It is important to check that qualifications of field technicians comply with acceptable and recognised standards.

Results should be recorded on agreed “official table” formats for consistency. Example of an “official table” is shown in POF 310**Error! Hyperlink reference not valid.**.

## 7.5 Data analysis

A unity plot can clearly and graphically display the performance of any inspection results against actual field measurements, and should be produced for every pipeline inspection, which has a field verification program.

# 8. Lessons learnt

Performing an ILI run on a pipeline can be a straightforward exercise when the operating conditions and pipeline design are just right for the tool that is being used. That is in the ideal world. For this reason it is imperative to have the most detailed information about the line design, including bends, barred tees, valves and wall thickness, as well as the operating conditions of the pipeline, including the cleanliness of the line, composition of the propelling liquid and the conditions under which the tool is being run (e.g. temperature, pressure, pressure differential). It may also be useful to review the speed from previous runs to identify any locations where tools persistently tend to stop.

Unfortunately, not all of this information is always available from the operator. In many cases data has either not been recorded or has been lost. It is therefore recommended that the run experience report supplied by the contractor is registered in the pipeline integrity management system for each pipeline such that it can be easily retrieved when the next inspection is being planned.

In order to maximize the run success rate and ease of execution of the inspection run it is important to be able to capture pertinent information and develop a methodology of record keeping of the data on the line. The steps followed to execute the project and any lessons learned can make subsequent projects run smoother. Information on a particular line may also be of value for other pipelines operating with similar conditions. Records should, where possible, include photographs.

Typical pipeline and operating data that should be retained follows the steps required for run success:

Project preparation

- Pipeline operating history
- Pipeline questionnaire and any updates
- Previous inspection data including calliper runs.

Pipeline cleaning and preparation

- Records of the cleaning programme; quantities and debris analysis
- Cleaning tool details (disc type, cup type etc.) and specifications
- Subsequent cleaning and pigging runs
- Results of gauge plate inspections
- AGM placement.

Pipeline inspection

- Procedures and special operating requirements
- Operating records including pressure traces
- Line conditions and valve arrangements
- Comments on the effectiveness of the cleaning programme.

Dig Verifications

- ILI inspection reports
- Feature verifications
- Actions taken.

Most of the information should be held by the operator but data will also be held by the contractor. Where inspection was not successful, records should be retained of the failure investigation and any steps taken to rectify the problems.

A feedback form that can be used for an ILI contract is available in POF 303 [5].

Each failed ILI run should be thoroughly investigated as the root cause initially reported from the field may not be the critical factor. Investigations should look at common causes across a number of runs as component fatigue may be a factor to consider.

Mechanical failures associated with tool hardware are generally more significant as they can lead to a tool becoming stuck or severely damaged. Equally important for disclosure and discussion between the operator and the contractor are the changes that may be made to data processing algorithms particularly where improvements have occurred since a previous inspection if a comparison of results will occur.

In all cases it is important that the results of contractor failure investigations are clearly understood and communicated to the operator.

# 9. Summary

Understanding the impact and causes of failed ILI runs are key steps in the process of improving run success rates. In some cases, particularly where there are high operating costs associated with the inspection runs, as may be found with subsea operations. A discussion on the anticipated run success rates may result in changes to the inspection programme support requirements and the need for a standby inspection tool.

This recommended practice has drawn together some of the key points developed from best practices used across the industry. Run success however, can only really be declared when field data verifies the inspection report. It is one of several performance metrics that can be used to help improve the performance of ILI operations.

Successful ILI requires good communication between all parties from the initiation of an ILI project and selection of the tool to field execution, analysis and field verification.

Whilst check lists, competency and experience clearly play a significant part, the common factor in most failed runs is a break down in the communication process between operator and contractor.

Building on the operational data gathered from earlier inspection runs and the pipeline questionnaire use of the best practices in this document should help improve run success rates. It cannot be used however, as a substitute for open discussion in the preparation for each inspection project.

Improvements in ILI run success will be driven through improved feedback and investigation of failed runs. This requires changes to reporting processes which will improve over time. Without feedback and a willingness to improve processes, it is not possible to fully realise the potential value anticipated with improved run success rates.

Continued dialogue and use of best practices will continue to help improve the ILI run success rate and will help reduce operational risks for operators. Regular review of the metrics and root causes is recommended.

# 10. References

1. Pipeline Operators Forum, POF 100, *Specifications and requirements for in-line inspection of pipelines*, November 2021
2. Pipeline Operators Forum, POF 302, *ILI check lists*, November 2021
3. Pipeline Operators Forum, POF 301, *ILI pipeline questionnaire*, November 2021
4. Pipeline Operators Forum, POF 310, *Field verification procedures for in-line inspection*, November 2021
5. Pipeline Operators Forum, POF 303, *ILI data feedback form*, November 2021

# Appendix A - Pipeline Feature List

| ROUTEMAP NR. N-569-12-KR- | Length Routemap (m) | Accumulated Length Routemaps (m) | AGM | TYPE OF FEATURE or REFERENCE | Stationing Feat./ Ref. (From start routemap) (m) | Accumulated Stationing Start Pipeline (m) | Clock Pos. hrs:min | Distance between Tee's (m) | REMARKS/SPECIALS Detail drawings of crossings and constructions |
|---|---|---|---|---|---|---|---|---|---|
| | 13.0 | | | **MOBILE LAUNCHER** | | | | | S-114 Hoogvliet |
| | | | | **Temporary installation** | | | | | A-690-S-114 |
| | | | | Flange | | | | | A-517-LM-079-1 |
| | | | | API 18" WT = 11,13 | | | | | |
| | | | | Weldolet DN50 | | | 09:00 | | |
| | | | | Pig Switch | | | 00:00 | | |
| | | | | 10D Bend 30° | | | | | |
| | | | | Tee 18"x6"x 18" | | | | | |
| | | | | Weldolet 2" | | | | | |
| | | | | Pig Switch | | | 00:00 | | |
| | | | | 3D Bend 15° | | | | | |
| | | | | 3D Bend 15° | | | | | |
| | | | | WTC 7,72 x 6,43 | | | | | |
| | | 13.0 | | | | | | | |
| 001 | 310.6 | | | API 18" WT = 11,13 | | | | | A-537-XW-001-1 (VE) |
| | | | | Steel Casing (Begin 11,9m) | 3,5 | 16.5 | | | A-537-XW-001-2 |
| | | | | Steel Casing (end) | 15,9 | 28.9 | | | |
| | | | | 10D Bend 80° | 18,5 | 31.5 | | | |
| | | | | 40D Bend 9,5° | | | | | |
| | | | | 40D Bend 9,5° | | | | | |
| | | | | Steel Casing (Begin 25,24m) | 39,5 | 52.5 | | | |
| | | | | Steel Casing (end) | 64,7 | 77.7 | | | |
| | | | | 10D Bend 15° | 66,9 | 79.9 | | | |
| | | | | 10D Bend 15° | 72,3 | 85.3 | | | |
| | | | | 10D Bend 11° | | | | | |
| | | 323.6 | | | | | | | |
| 002 | 282.3 | | | API 18" WT = 11,13 | | | | | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | WTC 14,,27 x 11,13 | | | | | |
| | | | | API 18" WT = 14,27 | 258,3 | 581.9 | | | |
| | | 605.9 | | | | | | | |
| 003 | 285.2 | | | API 18" WT = 14,27 | | | | | |
| | | | | WTC 19,05 x 14,27 | | | | | A-537-LP-003-1 |
| | | | | API 18" WT = 19,05 | 61.0 | 666.9 | | | A-537-XD-003-1 (VE) |
| | | | | 15D Bend 45° | 74.8 | 680.7 | | | |
| | | | | 15D Bend 45° | 95.1 | 701.0 | | | |
| | | | | Sheet Pilling | 98.2 | 704.1 | | | |
| | | | | Sheet Pilling | 99.2 | 705.1 | | | |
| | | | | WTC 19,05 x 14,27 | | | | | |
| | | | | API 18" WT = 14,27 | 109,7 | 715.6 | | | |
| | | | | 40D Bend 5° | 143.0 | 748.9 | | | |
| | | | | 40D Bend 5° | 176.3 | 782.2 | | | |
| | | | | WTC 14,27 x 11,13 | 285.2 | 891.1 | | | |
| | | 891.1 | | | | | | | |