ON THE ISSUES OF INSPECTING CHALLENGING PIPELINES

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Abstract

Nearly half of the world`s oil or gas pipelines have until recently been considered “un-piggable”.

This term is used when a pipeline cannot be inspected with a free-swimming in-line inspection tool without a need to modify the tool or the line to be inspected. Typical examples are for instance missing launching and receiving facilities, diameter variations, tight bends, low pressure and flow conditions or high pressure and high temperature environments, onshore or offshore.

In this paper the typical issues regarding the inspection of challenging pipelines will be discussed. A new concept will be introduced, the so-called “toolbox approach”. The driving idea behind the concept is based on having a large variety of services with all the required technologies, including magnetic flux leakage (MFL), eddy current or ultrasound, enabling tailor made solutions to be packaged utilizing exactly the right technical resources for a specific inspection and integrity challenge.

But it is not limited to a technology perspective. It also uses market information to identify mid- and long term market needs as well as special operational procedures.

In addition it must be stated that this type of work relies heavily on the expertise and experience of the crew involved, because of the often extremely complex boundary conditions and operational parameters encountered during the job performance.

Several case studies will be presented to illustrate this approach and address the major issues of successfully inspecting pipelines previously considered “unpiggable”, with a special focus on accessibility, negotiability and propulsion.

1 INTRODUCTION

Pipelines constitute a valuable asset that needs to be protected. In order to achieve this a modern pipeline integrity management program will include regular inspections followed by integrity assessment and if required repair and rehabilitation measures.

A well proven method for the inspection of pipelines, especially high pressure transmission pipelines is the use of automated inspection tools which can survey the line from within providing full circumferential and axial coverage. These tools, generally referred to as free swimming in-line inspection tools (ILI) or intelligent pigs utilize non-destructive testing techniques such as magnetic flux leakage (MFL), ultrasound technology (UT) or eddy current (EC) or a combination thereof to detect, size and locate possible anomalies or flaws present.

Unfortunately not all types of pipelines can be investigated with this type of tool in a straight forward manner, and therefore some pipelines have been assumed “un-piggable”.

There are today approximately four million kilometers of high pressure transmission pipelines, and various numbers are quoted for the kilometers or mileage of non-piggable pipelines around the world. Depending on the source figures quoted range from around half of the globally installed pipelines to very much larger numbers. The issue is really that the term “un-piggable” is not precisely defined and this also applies to actually defining the asset classes involved.

2 PIGGABLE VERSUS UNPIGGABLE

The term “piggable” is associated with the use of ILI tools. The successful use of such a tool means that the inspection device can be inserted into the line at a suitable location and subsequently retrieved again. This implies that a pipeline needs launchers and receivers. ILI and also cleaning tools can negotiate certain pipeline geometries. If a line to be surveyed has some “un-usual” geometric features, e.g. different diameters, complicated bends or other geometric obstacles, then this could class the line “un-piggable”. ILI tools are usually applied whilst the pipeline remains in operations, in turn this implies that the operational conditions during a survey must be in-line with its capabilities. Fig. 1 shows a possible definition.

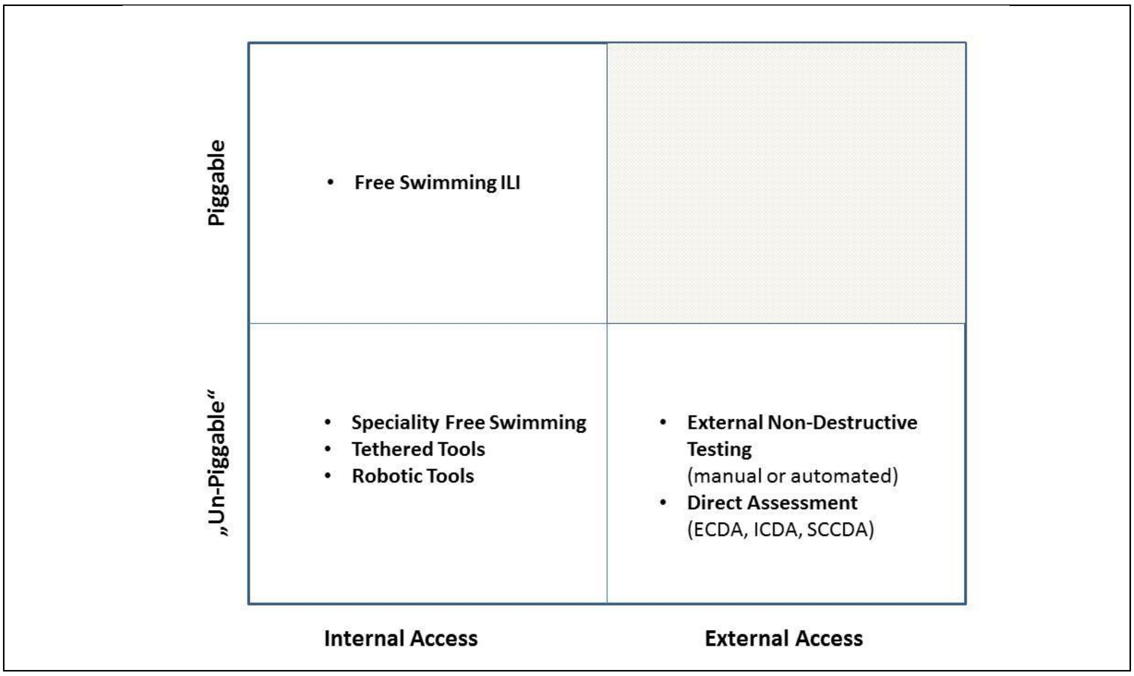

Figure 1: “Piggable” and “un-piggable”

As figure 1 addresses, the question is whether a given line can be inspected from the inside or only from the outside. Considering that the majority of pipelines is not freely accessible, i.e. either covered in the ground or running offshore, it is preferable to inspect them internally. In this way full coverage of the pipe wall can be achieved. Following this logic means that pipelines which provide internal access and are piggable will usually be surveyed utilizing in-line inspection tools.

If this is not a straight forward exercise, implying that either the equipment used or line to be inspected have to be modified significantly with all the associated cost, then specialized equipment for the internal inspection or suitable external inspection methodologies would be applied.

Three categories of internally applied tools are available today. Firstly “specialized free swimming” tools. This term relates to providing a specialized or modified free swimming ILI tool which can negotiate pipelines with certain geometric restriction, obstruction or challenges. Examples may be multi-diameter lines, small bend radii, certain pipe installations such as wye- or T-pieces, or single access pipes that require bi-directional tools in order to be launched and received at the same location.

There may also be a benefit to use a cable operated or tethered tool, whereby the cable can be used for energy supply and/or data transfer or simple as an option to pull the tool back or retrieve it. Tethered tools still do not have their own drive and need to be pumped at least in one direction.

If pumping or provision of a differential pressure is not feasible, then an inspection device would need its own drive or propulsion unit. This is the realm of “Robotic” tools.

If access from the inside is generally not possible at all, then a suitable external inspection methodology would have to be applied utilizing external non-destructive testing techniques or the various direct assessment disciplines such as External Corrosion Direct Assessment (ECDA), Internal Corrosion Direct Assessment (ICDA) or Stress Corrosion Cracking Direct Assessment (SCCDA), providing assessment procedures for metal loss or stress corrosion features.

As stated already the term “un-piggable” is not clearly defined and two mistakes are sometimes made: that the term implies that a given pipeline cannot be inspected from the inside or worse that the pipeline cannot be inspected at all.

It is therefore recommended to use the word “challenging” rather than “un-piggable” in future.

3 THE TOOLBOX APPROACH

In order to address challenging pipelines the issues of accessibility, geometry and operational parameters have to be considered. Partially these issues can be solved through suitable hardware, i.e. making tools very flexible, designing them with dual- or multi-diameter capabilities, making them bi-directional or capable of running in low flow/low pressure environments and/or high pressure/high temperature conditions.

But the inspection of a challenging pipeline requires more than that. It also entails developing and using tailor made processes for a given inspection task, in other words it requires an optimized solution engineering approach. This would also include the correct required cleaning and pipeline preparation procedures. Sometimes cleaning is not possible and then specialized procedures need to be developed to take this into account. With other words it is a matter of using an optimized inspection tool, specialized auxiliary equipment for logging pipeline data or tracking combined with the correct and effective processes, see also *Lindner and Graaf* (2013). The definition of optimized procedures is directly linked to the skills and experience of the service provider. It also requires best possible know-how of the operational condition of the line being inspected, taking information from the Scada system or obtained through intelligent pipeline data logger systems, see *Lindner, Bartsch and Voss* (2014).

Having an optimized tool available implies all aspects of mechanical design, suitable non-destructive testing technology, electronics, storage devices and propulsion means, as described by *Steinvoorte and Vages* (2013).

The toolbox approach covers all these aspects by including technologies covering different tool types, for example bi-directional systems that can be pumped, tethered tools or tools with their own robotic drive unit. It also includes different propulsion designs in order to provide maximum traction for a given pipeline environment. In addition the toolbox approach also refers to using the correct procedure and process for successfully performing the inspection.

The toolbox approach really implies that a comprehensive range of tangible and also intangible resources is necessarry to effectively inspect challenging pipelines.

Toolbox Factors	
Tool Type	Free swimming, tethered or robotic
Propulsion	Pumped, tether/cable, self-propelled
Direction of Travel	Uni- or bi-directional
Passgae Capabilities	Constant bore, dual-diameter, multi-diameter
Bend Capabilities	≥1 D (D = diameter)
Non destructive testing technologies	Magnetic Flux Leakage (axial, circumferential) Ultrasonic Technology (piezo-electric, electro-magnetic acoustic emission) Eddy Current (standard, far-field, pulsed)
Operational Parameters	Low/high flow; low/high pressure, low/high temperature
Supportive/auxiliary	Cleaning, specialised markering (onshore/offshore), pipeline data loggers
Procedures	Specific, tailor made procedures

Table 1: Factors influencing the choice of tool box elements

All non-destructive testing technologies used for ILI today should be accessible and available in order to be able to choose the most suitable one for a given inspection task.

The next layer would then involve modifications of free swimming tools to overcome any low friction and/or low pressure requirements, or high pressure and/or high temperature as often found in an offshore environment. A third level would then be the need for a self propelled unit. Table 1 provides an overview of some of the factors affecting the choice of elements.

4 CASE STUDIES

In the following three short case studies will be used to show examples of using tool box elements to provide tailor made inspection solutions for the inspection of challenging pipelines.

4.1 BiDi Metal Loss Inspection of Jet Fuel Feeder line

The challenges which prevented the line from being inspected with a traditional free swimming ILI approach were:

- No launching or receiving traps installed
- Access only possible from one end
- Tight miter bends in the line

Additional requirements regarding the inspection of this 6” fuel line, length approximately 1300 m and wallthicknesses ranging from 4.5 to 5.6. mm, were that no interference with normal airport operations during the inspection were tolerable. Any risks had to be minimized. Procedures had to ensure that the product was not contaminated, that there was no digging related to accessing the pipe nor any presence of project related personnel near any run- or taxiways of the aircraft during the time of any flight activities.

The available operational pressure was low compared to normal ILI operations.

The solution chosen utilized various elements of the tool box. A 6” bidirectional ultrasonic metal loss survey tool was utilizied, currently the shortest UT tool on the market. The mechanical design of the tool allows to negotiate the mitre bends present in the line, both 1.5 D. Tool design also enables passage of 1D bends. A temporary tool trap was installed without the need for any digging. Fixed installation were used for pig tracking purposes. A hydrant system was used for propulsion purposes. Special procedures were developed including arranging a loop at the tank farm which allowed the tool to be pushed back using the same pumps. Flow control was ensured through a reduced diameter ball valve and a flow meter. The project was completed within a 12 week period from award to completion.

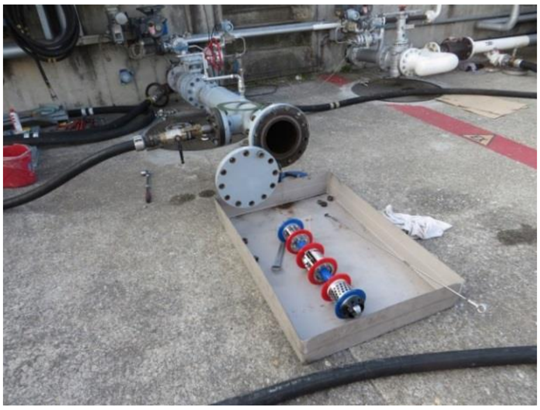

Figure 2: Launching (left) and receiving (right) the tool

The major benefits achieved related to economic, safety and quality issues. Cost savings were achieved through avoiding any digging. The installation of the temporary trap only required minor pipe modifications. The chosen tool is extremely light weight and could be hand carried avoiding any cost relating to lifting equipment. Ultrasonic technology allows the inspection to be carried in the medium transported, in this case jet fuel.

Any risk of blockage was avoided by utilizing a bi-directional highly flexible devise – it was possible to reverse the tool at any time during the inspection.

The tool used provided full inspection coverage and the high resolution data obtained from UT tools is ideally suited for integrity assessment purposes.

4.2 Metal Loss Inspection of Multi-Phase Oil Line with Difficult Access

The mission of this project was the inspection of a number of 10" flow-lines transporting a multi-phase medium consisting of oil, water and natural gas. The lines transport the multi-phase medium to a gathering line. They are hard to clean, carry a medium of elevated temperature, high water cut and are prone to microbiological corrosion.

There were no launchers and receivers and the lines are operated in a low pressure and/or low flow regime. These prevailing operational parameters made the line "un-piggable" and therefore required a customized, highly specialized solution in order to be inspected from within and ensuring full coverage of the pipe wall.

It was furthermore not feasible to install special launchers and receivers, neither permanent nor temporarily. The only access to the line available were specialized three-port valves which had originally been installed to launch cleaning scrapers, see fig. 3.

Figure 3: Three-port valve as used for launching cleaning tools

For this project the full scope of the toolbox philosophy had to be applied. One component was the choice of a suitable inspection technology to detect and size any metal loss present. The next was a suitable tool configuration to negotiate the line and ensure that the passage through the line would and could not lead to a stoppage of production. A pre-requisite to the inspection was that the line should stay operational during the inspection. As a consequence of these technical needs, this project also required highly specialized processes and procedures.

The non-destructive testing technology chosen was magnetic flux leakage technology. Ultrasound was not suitable in this case because of the multi-phase environment. Eddy Current would have had the limitation of only addressing near field, or rather internal features.

The next step to consider was the actual tool configuration. Normal in-line inspection (ILI) tools are free-swimming and usually designed for uni-directional use, i.e. they are launched at an upstream location and retrieved from the line downstream at a suitable receiver. The toolbox provides various solutions for tool propagation: free swimming, tethered or self-propelled, depending on the requirements. In this case pumping, in the sense of providing the required differential pressure for movement, was possible, however only within low flow and low pressure operational parameters. The flow within the line comes from a well and then travels towards the gathering line into which the flow lines feed. In order to limit any risks it was decided to use a bi-directional tool, so that if necessary the tool could be moved back to its launch site.

The flow lines were equipped with special three-port valves which were originally chosen for their ability to allow the launching and receiving of cleaning pigs. The special requirement in this case was therefore to modify an ILI-metal loss survey tool in order to fit into the very confined space of the three-port valve, see figure 4. In addition a launching and receiving procedure had to be developed to ensure that the ILI tool would safely enter the line and could also be safely retrieved. In order to ease the actual introduction of the tool into the valve a special metal cage was designed into which the tool could be pre-loaded. For receiving a similar device was used at the downstream valve into which the tool travelled, was then stopped and could then be retrieved.


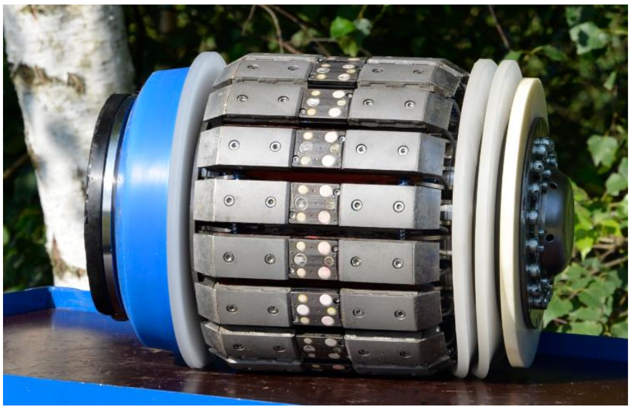

Figure 4: Inspection tool being retrieved from three-port valve (left), picture of bi-di MFL tool (right)

A very important and indeed critical aspect was the tool tracking during the inspection and especially as the tool approached the receiver. It was of great importance to be able to detect the tool approach and measure with high precision, to ensure that the tools final approach could be controlled and stopped exactly at the location of the valve. In the worst case an uncontrolled approach could lead to permanent damage resulting in costly downtime and repairs. Table 2 provides a general overview with some typical technical specifications for the tool and auxiliary equipment used for this project:

Specifications:	
Diameter:	10”
Length	Single Body – not exceeding length of cleaning pigs previously used – 385 mm
Direction of Travel	Bi-directional capabilities for enhanced operational safety
Real-Time wireless tracking system	Allows very tight motion control along the line with minimum manpower required during inspection.
Data Handling	Additional data-channels available for remote telemetry (e.g. pressure, temperature)
Velocity Range	0.2 – 1 m/s*
Wall Thickness Range	5.96 – 13.8 mm*
Defect Specs	ILI High Resolution Benchmark; threshold 0.1 t, accuracy 0.1 t (t = wall thickness)

Table 2: Selected Technical Specifications for the tool and additional equipment used for this project (*higher velocities and higher wall thickness capabilities available upon request)

Normal markering equipment and procedures as used for free-swimming ILI was not sufficient. Again the toolbox approach was helpful by providing technology and tailor made procedures to ensure the appropriate tracking accuracy required. For this project a specialized telematics system was developed and applied which allowed tool tracking with a sub-meter accuracy. The additional benefit of the system used was the tracking of the tool in real time, without any need for excessive manpower deployed along the line. The final approach of the tool was even monitored by a cable connected pig-locator chain incorporating more than 30 reference points and ensuring a tracking accuracy within a centimeter resolution. Hereby the ILI tool could be maneuvered precisely and safely into the receiving valve. See a simplified schematic in figure 5.

The major benefit was that a flow line initially considered “un-piggable” and therefore not accessible from within could be inspected utilizing an in-line inspection device. This provided the means to inspect the entire circumference and length of the line.

A tailor made tool and procedures allowed the inspection of the pipe during normal operations and therefore no loss of production. The bi-directional tool design paired with an advanced telematics markering process minimized inspection risks.

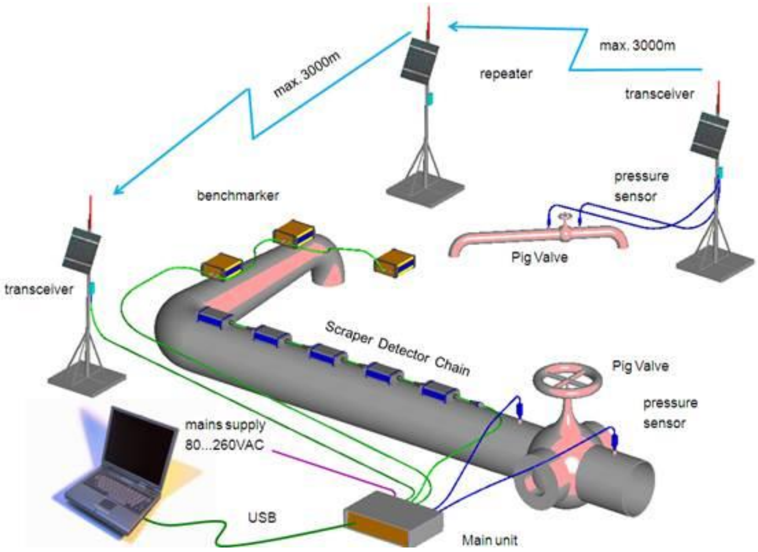

Figure 5: Schematic of a telematic markering system to control the tool approach

The inspections were performed with a short turnaround time and the data quality obtained was of the accuracy needed for a comprehensive integrity assessment of the line.

4.3 Inspection of a Loading line

The project related to two 20” loading lines transporting refined products from a vessel to the onshore terminal. A schematic of such a loading line is shown in figure 6. The challenge consisted of having a pipeline with only one entry point. A temporary trap for launching and receiving needed to be installed, and any modifications and the subsequent inspection run had to be performed within an extremely tight schedule.

Again the solution consisted of a technical, tool based component as well as the associated tailored procedures for successfully executing the job.

The solution included implementation of a series of modifications to the pipeline to allow for the installation of the temporary trap within the complexity and space constraint at the terminal. A bi-directional gauging operation and use of a bi-directional high resolution MFL metal loss tool were completed within the time frame specified by the customer. The procedure consisted of launching the tools at the launcher, pumping from the terminal site until they reached the subsea Pipeline End Manifold (PLEM). The end of inspection was controlled by monitoring the discharge pressures at the terminal pumps. A circuit was created by interconnecting both loading lines with a top side interconnection implemented at a mono buoy. In order to allow for the tools to return to the terminal, pumping was done in the reverse direction until both gauging and MFL units reached the trap, now acting as a receiver.

The clear benefit to the customer was the collection of high quality metal loss data under complex operational conditions and within the required short time frame. The tailor made procedures also included a risk minimization process, especially important as the refined product is supplying a large metropolitan area.

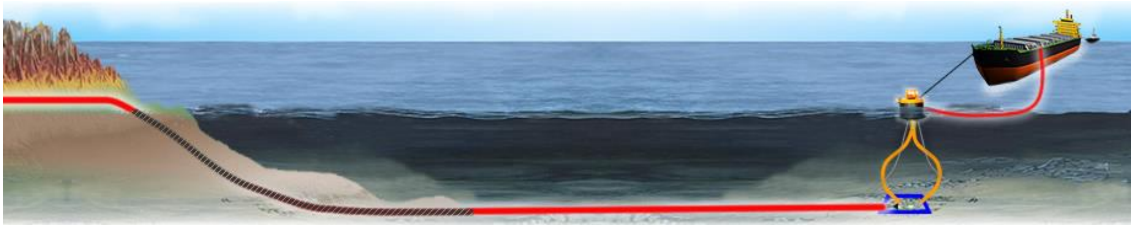

Figure 6: Schematic of loading line running from vessel to onshore terminal.

5 CONCLUSIONS

The toolbox concept has proven to be a reliable approach to inspecting pipelines previously considered “un-piggable”. It addresses the main issues of accessibility, pipeline-geometry and propulsion which differentiate the “un-piggable” from the piggable lines. The importance is that the concept includes a variety of technical aspects covering drive, optimized inspection techniques, maneuverability inside the pipe and also procedural aspects, built largely on experience and skills sets of the personnel involved. It can therefore be truly stated that a vast proportion of the pipelines present globally which were deemed “un-piggable” until now can be inspected from the inside with full coverage and with all the associated benefits. It is therefore recommended to refer to these lines as “challenging”, a term already used by some authors and leave the term “un-piggable” to the proportion of lines which cannot be inspected from the inside at all and therefore need to be accessed from the outside.

6 REFERENCE

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