PRACTICAL SOLUTIONS FOR CHALLENGING PIPELINES

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ABSTRACT

As the overall infrastructure in the oil and gas industry is aging there is an increasing demand to assess the integrity of all existing assets. As a result pipeline inspection using In-Line Inspection (ILI) tools has become the standard for pipelines that can be considered piggable. Many of the world's pipelines were however never designed to be pigged, the so-called unpiggable pipelines.

To operators these unpiggable pipelines are equally important to the overall integrity of the pipeline system and suitable inspection solutions are therefore required. Although alternatives like direct assessment and spot checks using in-field, non-destructive testing exist, the most valuable information can only be obtained from the inside of the pipeline using in-line inspection devices.

Typical challenges involve access (no pig traps installed), operating conditions as well as the pipeline geometry. Due to the individual challenges arising from pipelines deemed to be unpiggable a wide variety of tailored solutions has been developed in recent years.

One of ROSEN's recent developments is the extremely short Bi-Di Inline-Inspection tools. Their bi-directional design, passage capabilities and wide range of operating conditions provide great flexibility to operators, thus minimizing the operational impact and required pipeline modifications. Applications include ILI of tanker loading/unloading pipelines, gathering pipelines, branch connections, risers and flare lines.

This paper will discuss the continued development of ILI solutions specifically designed to close the gap between piggable and unpiggable pipelines by discussing their challenges, practical application, case studies, and the future of additional research and development.

1 INTRODUCTION

Pipelines are proven to be the safest way to transport and distribute gaseous and liquid hydrocarbons. Regular inspection is required to maintain that reputation. Today, a large part of the pipeline systems can be inspected with "standard" In-Line Inspection (ILI) tools. Since first use in the early 1960's, the ILI tools have been significantly developed and improved. Challenges of the early days of pipeline inspection, such as high speed in gas lines, tight 1.5D bends, dual-diameter, heavy wall thickness, high pressure and -temperature, multi-diameter, long distances, etc., have been resolved and modern ILI tools are able to cope with these challenges (cp. Figure 1).

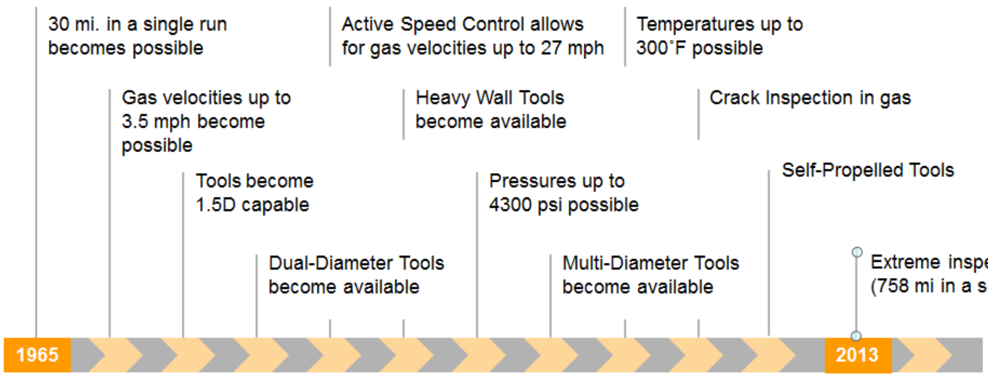

Figure 1: Unpiggable Timeline

Still many pipelines cannot yet be inspected with existing tools and procedures and as mentioned above, reasons why pipelines are classified as unpiggable are numerous. Typical reasons for pipelines classified as non-piggable include:

- No access, meaning launcher and receiver are missing
- Geometry (eg. such as plug valves, 90° miter bends, dead ends, off-takes, etc. (cp. Figure 2)
- Operating conditions (eg. low flow, low pressure, no flow)

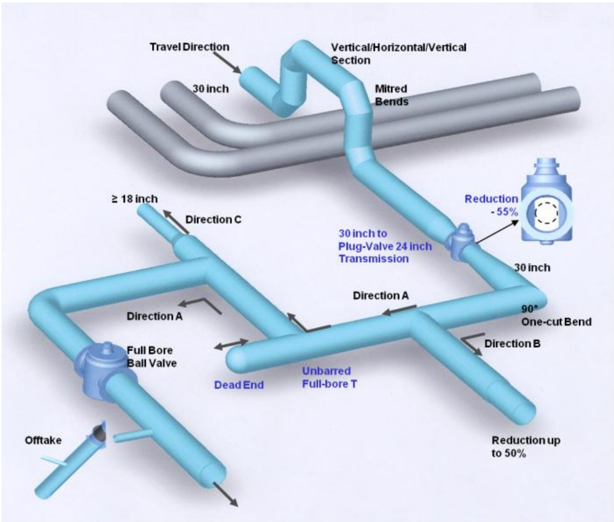

Figure 2: Non-piggable installations

2 CLOSING THE GAP – ULTRA COMPACT BI-DIRECTIONAL INSPECTION TOOL

Due to the variety of challenges the optimal solution for unpiggable pipelines is not a single tool, but rather a project by project driven tailored solution.

For those pipelines that have only access from one end, special bi-directional ILI tools have been developed. These tools require in general no tether and are therefore not restricted in inspection length and can pass an unlimited number of bends. Due to the often challenging conditions the preferred inspection technology is Magnetic Flux Leakage (MFL). This robust and reliable technology only requires moderate cleaning and can be deployed both in gas and liquid lines. Due to the compact tool design also pipelines with launchers too short for conventional inspection tools now become piggable.

3 PRACTICAL SOLUTIONS

3.1 Propulsion

For pipelines requiring a bidirectional inspection approach, specific procedures have to be developed to bring the in-line inspection tool to the turn-around point and back to the entry point. The below described propulsion methods are required to be carefully reviewed on a project by project driven basis. If a propulsion method has been selected for the application of a bi-directional tool, procedures have to be developed to ensure the in-line inspection tool traverses the entire section of pipe to be inspected to achieve the inspection objectives.

- Reversed flow

For a free-swimming bi-directional tool the easiest way of navigating through a pipeline is by pumping the tool to the turn-around point, stop it and then reverse the flow in the pipeline system to propel the tool back to the launching facilities. This can e.g. be done if a parallel line is available by simply connecting these via flexible hoses or by installing a temporary pump spread on the other side to push the product back in the opposite direction.

- Push against product pressure

Short sections of gas pipelines can be inspected by pushing the tool against the product pressure into the pipeline up to the turn-around point. The remaining gas volume behind the tool is then used to send the tool back to the entry point by controlled pressure release at the launching facilities.

- Gravity based

For the inspection of vertical sections a gravity based approach can be used. The tool is pushed down the pipeline using the hydrostatic pressure of a storage tank and pumped back by permanently available or temporarily installed pumps.

- Pump in – pull out

Another approach of deploying a bi-directional tool is to pump the tool into the pipeline by using product (e.g. nitrogen or air) and then recovering it by pulling it out using a winch and a tether.

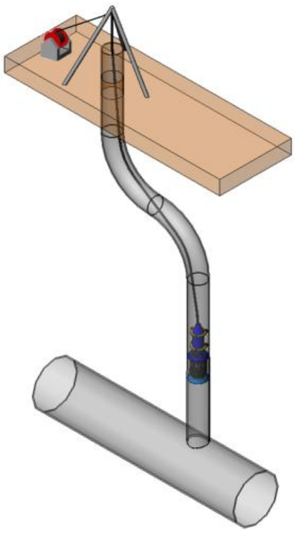

Figure 3: Schematic illustration of gravity based/pump in – pull out approach

Both equipment and procedures require tailored engineering and preparation for the selected propulsion method and inspection conditions.

3.2 Cleaning

As with every inspection, a clean pipeline is a requisite for a successful inspection of a challenging pipeline. Being classified as ‘challenging’ often means that also no maintenance pigging has been carried out and the cleanliness of the pipeline is unknown. The requirement to carry out an extensive cleaning regime ahead of an ILI inspection is therefore inevitable.

Figure 4: MFL/Geo tool after run in insufficiently cleaned pipeline

Without a doubt the most critical technology is Ultrasonic Testing (UT). Known as a much more robust technology the versatile MFL is therefore often considered as a good alternative to UT. However, the physical requirements of yokes, magnets and brushes actually make these tools fairly efficient "cleaning pigs" (ref Figure 4). In worst case this efficiency can lead to such a large accumulation of debris in front of the tool that an impact on the operation cannot be excluded.

Since every pipeline will have its own challenges with regards to cleanliness, tailored solutions are required. To enable the ROSEN engineers to develop suitable cleaning programs, they can chose from an almost endless variety of solutions and configurations, such as spider noses, pressure bypass valves, multi-diameter configurations, high temperature PU etc.

For pipelines with only one entry point bi-directional asymmetric cleaning might be required to prevent the debris from being pushed in critical locations such as a Pipeline End Manifold (PLEM). Bi-directional asymmetric cleaning enables debris recovery in a single access pipeline. The cleaning efficiency is reduced on the way to the turn-around point and increases on the way back to the launching facilities. Besides the advantage of easy debris handling this approach allows a thorough analysis of the cleaning process and enables the engineers to improve the efficiency of the cleaning program on-site.

3.3 Monitoring of cleaning progress

The cleaning progress is monitored with ROSEN's Pipeline Data Logger (PDL). By providing a time based recording of temperature, absolute and differential pressure profile and tri-axial acceleration (inclination and tool rotation) temperature profiles can be recorded, restrictions and deposits can be detected and located, tool behavior can be monitored and the cleaning progress and effectiveness can be assessed and monitored. The PDL can be attached to any standard cleaning tool and employs fast response, low current sensors which can record for more than 30 days and up to 500 km (310 miles) of inspection. Data are presented in an easy to understand graphical format using supplied software.
Figure 5 shows the time based recording of the differential pressure (DP) over the cleaning tool for two consecutive runs. The repeat run (bottom) shows a reduction of deposits due to the progress of cleaning.

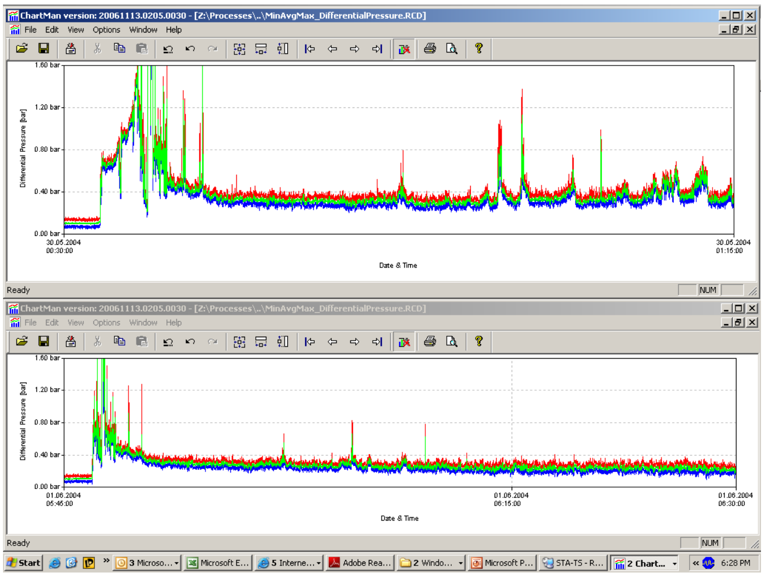

Figure 5: Time based DP recording for consecutive runs

4 APPLICATIONS & EXAMPLES

4.1 Loading lines

A typical application for bid-directional MFL tools is the inspection of loading/offloading lines. Loading lines normally go from the onshore facility, such as a tank farm, to a Pipe Line End Manifold (PLEM). The PLEM is connected with flexible hoses to a loading buoy that serves as a single-point mooring (SPM) for tankers loading/ offloading. These pipelines are usually inspected from the onshore location. The tool is pumped towards the PLEM. Subsequent to arrival at the PLEM flow is reversed and the tool is pumped back to the onshore facilities.

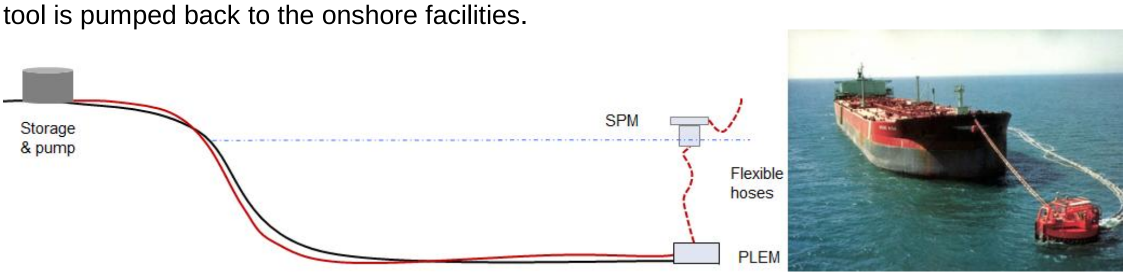

Figure 6: Schematic layout of a typical loading line (left) / Tanker connected to a monobuoy (right)

4.2 Gathering lines & branch connections

Gathering pipelines are part of a group of smaller interconnected pipelines forming complex networks with the purpose of bringing crude oil or natural gas from several nearby wells to a treatment plant or processing facility. Pipelines are usually short -a couple of hundred meters- and are often not designed to be pigged.

Branch connections are very similar to gathering lines. They are typically unpiggable elements of a larger – piggable – pipeline system. A typical example are tank farms were storage tanks are connected to the main piggable feeder line via unpiggable branch pipelines.

Figure 7: Branch connections inside a tank farm (left) / gathering lines (right)

4.3 Risers

Risers connect the topside of an offshore platform with the pipeline on the seabed. Due to the nature of a riser, these are subject to more integrity concerns then the line pipe on the seabed. Especially the splash zone is often subject to external corrosion in case the neoprene sleeve, protecting the riser from water exposure, is damaged. When conventional pigging is not feasible (e.g. no receiver or the sub-sea line pipe is not of the same diameter), these systems can be inspected from one end only.

Figure 8: Typical riser configuration incl. splash zone

4.4 Flow lines with pig launch valves

Tree way ball valves capable of launching cleaning tools offer a cost effective solution for flow lines that require frequent pipeline cleaning.

The cleaning tool is inserted into the valve while the valve is closed and the door can be opened. After the door is closed, the valve is opened and the tool is launched with the flow. The next downstream ball valve has the same functionality and is used as a receiver. At one end of the ball valve, a steel mesh is installed to stop the tool.

If only one valve is installed, the cleaning can be done with a BiDi cleaning tool. The tool is launched as described above. Once the end of the pipeline has been reached the flow is reversed and the tool is pumped back to the ball valve.

Figure 9: Pig Launch Valve

In the past, these ball valves have been used for cleaning only. With the new small ultra-compact MFL tools these lines can now also be inspected.

4.5 The low flow low pressure pipelines

Another application for the ultra-compact tool is the inspection of low flow / low pressure (LPLF) pipelines.

Getting the tools from the launcher to the receiver is not the main challenge in LFLP pipelines. The speed excursions which normally occur during the inspection runs in LFLP lines are usually caused by obstacles, such as excessive girth welds, bends, dents, diameter changes, etc. The tool stops at this obstacle, as the pressure (force) is not high enough to move the tool over it. After a certain time, the pressure behind the tool builds up and forces the tool over the obstacle. In some cases, tool speeds of over 67 mph (30 m/s) are reached, whereas most MFL ILI tools have a maximum speed specification of 11 mph (5 m/s). Furthermore, after the tool starts to move again, the head pressure in front of the tool is typically low, therefore, the high speed phase is elongated.

When exceeding the tool target speed the magnetic field is affected in a way which makes it difficult to correctly size or even identify corrosion features. Furthermore the resolution is impaired.

To achieve stable run conditions in LPLF pipelines low and constant friction are required. In addition a zero bypass drive system is required.

One key for low-friction is the optimization of the magnetizer. While the brushes serve a valuable purpose they also increase the friction between the pipe wall and the inspection tool. To reduce this drag effect in low-pressure pipelines, a special friction reducing magnetizer was developed.

In addition to that an optimized cup design is equally important to further reducing the friction. Three different cup designs are presented in Figure 10. Besides the standard design which is intended to carry high loads, a low friction design and a wheel design are shown. The low friction design is incorporated into the sealing components of the tool, while the wheel design carries the additional measurement and electronic units, if present.

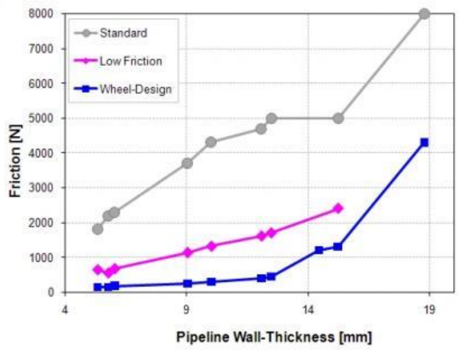

Figure 10: Dynamic friction force demonstrated for different cup designs

The ultra-compact design further reduces the number of cups required to support the tool weight and in such further reduces the overall friction. The final tool set-up is shown in Figure 11. The low tool weight supports the tool to return to normal speed after an acceleration.

Figure 11: Ultra compact 10" RoCorr MFL / LFLP

Figure 12 shows the current possibilities for the inspection of low pressure pipelines. As can be seen a conventional tool of 10" works best at a pressure level of 510 psi (35 bar). With relatively minor modifications to a conventional ILI tool (low pressure kit) it is nowadays possible to inspect a 10" pipeline at a pressure of 220 psi (15 bar). With a dedicated low pressure tool inspection is nowadays possible at pressures as low as 115 psi (8 bar).

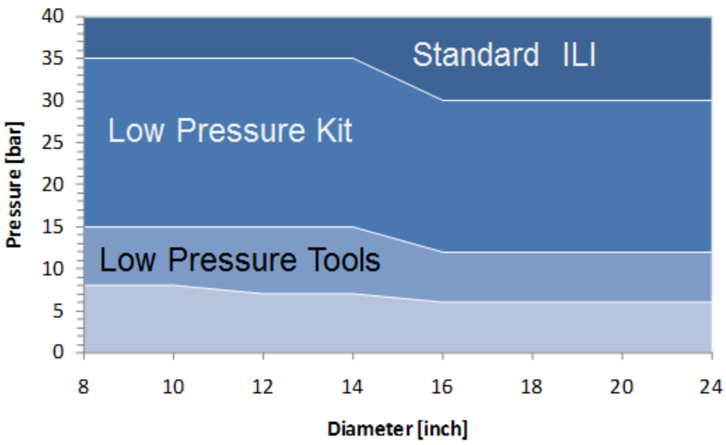

Figure 12: Tool selection guideline for low pressure gas pipelines

4.6 Storage systems

Short sections of pipe that can easily be taken out of service can also be inspected by simply pulling a tool though the line. The high friction forces of conventional MFL tools limit the bend passage capabilities and introduce the risk of a broken cable or a tool getting stuck. Also here the low friction design of the wheeled MFL provides greater flexibility and lower risk.

In bi-directional configuration the tools can be pumped in with for example air and pulled back via a cable. The principle set-up for this operation is shown below in Figure 13 on the right side.

Figure 13: Tool loading (left) / launcher set-up (right)

Benefits
As can be seen in the above mentioned examples the ultra-compact tool provides unique possibilities for the inspection of pipelines previously classified unpiggable.
The operators benefits:

- Minimized risk exposure - The tools can be pumped back, not depending on tether thus not restricted in distance and bends
- Quality - reversed cleaning approach enables onshore debris handling and MFL only requires moderate cleaning
- High resolution - Same performance as uni-directional MFL tools
- Provides redundancy - 100% coverage in one pass, the tool records in both ways
- Convenient - The inspection can be carried out in gas, multiphase or liquid and does not require complete line fill
- Cost effective - Eliminates the need for expensive subsea trap, emptying, purging, …winching
- Light weight and easy to handle - tools up to 14” require no cranes, less manpower and therefore reduce the door open to door close times
- Quick turnaround time - The tools can travel at high flow rates

5 THE MOST NEEDED INSPECTION TOOL

Still many pipelines remain classified as unpiggable, even with these enhanced technologies. If the inspection of these pipelines with a free swimming or tethered inspection tool even after modification of piping or tools is still not feasible, then tailored solutions are required. Such a solution shall provide information about the condition of the entire pipe wall, without taking the pipeline out of service, while it has to tackle:

- restrictions due to medium & operating conditions
- narrow or miter bends
- reduced bore valves
- wrinkles
- dents in bends
- un-barred full-bore tees
- off-takes
- (unknown) reductions and diameter changes
- dead ends
- all kind of debris in the line (inspection without cleaning!)

The most needed inspection tool would be a multi-purpose tool that can do all. Such a tool will however likely not become available in the next decade.
More realistic are tailored solutions based on the toolbox concept.

6 TAILORED SOLUTIONS BASED ON THE “TOOL BOX CONCEPT

The ‘Smart Toolbox’ contains each other complementing elements to allow the ROSEN Application Engineering the widest spread of solutions for challenging inspections. One example of the tool box approach is the RSS, a modular Robotic Survey System (RSS) which can be adapted and equipped with the required inspection technology. The system is targeted for pipeline sizes ranging from 8" to 20".

Figure 14: RRS - self-propelled metal loss inspection device

The RSS is being specially designed for inspecting challenging pipelines. It can carry different measurement systems and is capable of driving vertical and passing 1.5D back to back bends. Most significantly it is able to operate within a pipeline without medium to drive it.

Key technology advantages

- High reduction passing
- Tight bend passing capacity
- Multi-diameter capacity
- Extremely high driving force enables vertical climb
- Self-adapting tractor drive unit in one body
- Intelligent and redundant on-board mission control
- Single entry to the pipeline
- Capable of safely negotiating 1.5D bends
- Bi-directional operation
- Autonomic (only batteries) or tethered (external cable with communication) operation possible
- Reliable in various media (water, gas, crude oil and dual-phase products)

Sensor carriers (Shallow Internal Corrosion, UT, EMAT, etc.)

7 CONCLUSION

With the development of the ultra-compact bi-directional MFL inspection tools another gap between piggable and unpiggable, or challenging pipelines has been closed.

For a bi-directional inspection various propulsion methods can be used to bring the tool back to its entry point and a wide selection of effective cleaning tools ensure suitable inspection conditions. The reversed bi-directional cleaning prevents the debris ending up in unwanted locations such as PLEM’s and dead ends and enables assessment of the cleaning result. The PDL provides a simple and effective means of monitoring and further optimizing the cleaning process and helps assessing and locating the possible geometrical obstructions.

With the ultra-compact MFL tool in a flow friction configuration gas pipelines with pressures as low as 6 bar can now be inspected. The low friction tool furthermore provides greater flexibility in inspecting pipelines by pulling the tool with a cable.

Typical applications include Loading lines, Flow lines, Branch connections, Storage systems, Risers and Low flow low pressure pipelines.

Due to the variety of challenges every pipeline will however require a specific tailored solution. Only where essential pre-requisites such as experience, a suitable and effective cleaning approach and reliable and safe inspection tools and procedures are brought together a challenging inspection project can be successfully completed.

Those pipelines that remain classified unpiggable, even with the recent developments, require and will be handled with tailored solutions based on the tool box approach.

8 REFERENCES

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