Detecting defects in *marine terminal pipes*

Dr. Rainer Schmidt and Basil Hostage, 3P Services, Germany, describe inline inspection technologies used in unpiggable pipelines.

Since the late 1980s, pipelines transporting crude oil, natural gas and refined products have benefitted from the development of high resolution inline inspection (ILI) technologies. Deployment and application of this technology has become quite standard in pipeline networks around the world.

The high resolution ILI tools' accuracy and detection capabilities are well proven and trusted. Inspection data from these tools is widely accepted as the necessary basis for an assessment of the integrity of the pipeline asset. Life extension, up-rating and change of service are

Figure 1. Launching a 42 in. bi-directional MFL tool into a marine terminal sea line.

some of the events in a pipeline's life that can be achieved without recourse to further mid life hydrotesting.

Maintenance and repair programmes of increasing sophistication and economy now depend upon these powerful diagnostic technologies. There are a number of these: ultrasonic wall thickness measurement, ultrasonic crack detection, electromagnetic acoustic (EMAT) and magnetic flux leakage (MFL) are merely a few. All of the technologies have specific capabilities; they are able to detect specific types of defect because of their different measuring techniques. No inspection tool is able to detect all defect types. Probably the most versatile and broadly capable technology is MFL.

Marine terminal pipelines

A key example of 'unpiggable' pipelines is the various types of marine terminal pipelines. Marine terminal operators have had to rely on techniques that offer only partial inspection and qualitative condition assessment. Often, the lines have never been pigged, much less inspected. Techniques and tools developed by 3P Services more than 15 years ago offer practical solutions to these applications.

A typical marine terminal pipeline connects a shore-based installation, such as a refinery or tank farm, to a subsea pipeline end manifold (PLEM). The PLEM usually lies in water about 25 - 40 m deep and is connected to a single point mooring (SPM) buoy by a flexible hose or hoses. Floating flexible hoses complete the connections to a tanker.

While PLEM/SPM installations do have similar characteristics, it is also fair to say that each system and installation contains unique configurations. The PLEM can connect to the shore with a single pipeline or several. Of course, diameters can vary – dual diameter pipelines are occasionally encountered. When several lines connect the PLEM to shore, they typically have different diameters and may be used for different products.

Unpiggable or hard to pig

The pipeline networks that are suitable for inspection pigging are relatively well known. Piggable pipelines are designed to allow standard inspection tools to negotiate them. As a minimum, this means that the bore will be rather constant, bends will have a sufficiently long radius, and there will be launching and receiving traps that allow the pigs to be inserted into and recovered from the pipeline.

Within the pipeline industry where large volumes of oil and gas are transported over long distances, the pipeline networks consist mainly of piggable pipelines and may be subject to regular ILI. However, usually these networks have a certain percentage of unpiggable kilometres, which – from a perspective of asset integrity – need an inspection solution.

There remains a significant portion of the total installed pipeline infrastructure that is either outright unpiggable or is quite difficult to pig. Estimates of the extent or volume of these unpiggable lines vary between approximately 10% and 50% of the world's pipeline population. Having said that, it is clear that such lines will benefit from – and probably actually need – the sort of millimetre by millimetre inspection that high resolution tools can bring to bear.

So, what are some pipeline characteristics that render them unpiggable or difficult to pig? Age, for example. Many pipelines still in operation today were constructed before the development of intelligent inspection pigging. That means that they often lack installations such as launching and receiving traps, which enable pigging activities to take place.

Such pipelines may contain a variety of features that are typically unpiggable:

- Multiple diameters in the same pipeline.
- Non-nominal diameter.
- Mitred or very sharp bends (1.5 D or maybe less).
- Back to back bends.
- Unbarred tees.
- Reduced bore valves.

Figure 2. The pipeline departs to the left. The trap valve is in the centre.

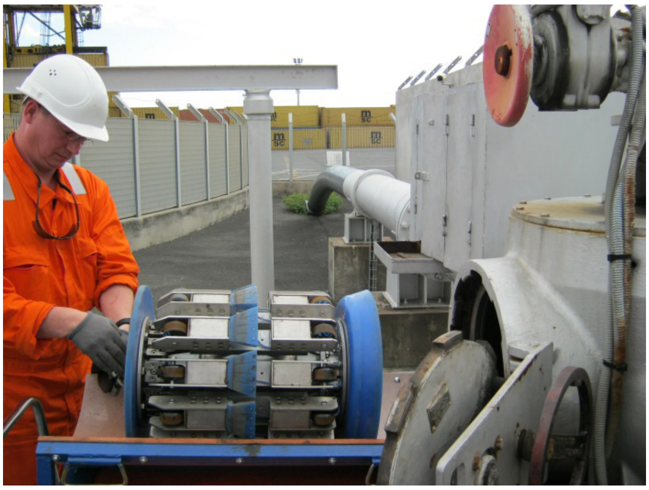

Figure 3. Loading the MFL tool into the trap valve in readiness for launch.

- Heavy wall thickness.
- Limited or no access to the pipeline ends.
- Small and odd diameters.
- Multiphase flow or low pressure gas.
- Internal liner or repair layer.

Installation of new, permanent pig traps can be, and often is, an expensive and disruptive operation. There is usually significant impact to the direct working environment, especially the existing installations and pipe work, and to the pipeline operations. The ability to work with an inspection tool that does not require traps at each end of the line and that can operate in normal and reverse flow, brings significant cost reduction.

Take another example of offshore pipelines, where access to a submerged location on a pipeline is virtually impossible. A number of scenarios exist, for example risers. Pigs can be launched from a top-side trap but there is no pigging loop available, and attaching a trap at an underwater location will be astronomically expensive. The ability to launch the inspection pig from the platform, navigate to a pre-determined stopping point and return to the launch position offers an attractive solution for many of these installations.

Existing techniques for inspecting non-piggable pipelines include pressure testing, direct assessment, tethered ultrasonic tools and tethered camera tools.

While much work has been done to reduce the uncertainties associated with such techniques, performance capabilities of general assessment technologies are simply not powerful enough to economically deliver the data necessary for safe life extension calculations and detailed repair programming planning.

Experience and evolution

There are numerous ways to achieve the benefits of ILI in these unpiggable pipelines. Firstly, there is the option to modify the pipeline in a way that it becomes piggable. In most cases though, this option is actually not so easy. Modifications usually require interrupting operations and/or the replacement of the unpiggable elements. Therefore, it can be expensive or, in the case of some offshore installations, actually impossible. Secondly, the inspection equipment can be modified and tailored to the existing conditions in order to overcome the situation or obstacle(s) that are considered to be unpiggable for standard inspection tools. And finally, combining the above, it may be practical or necessary to modify both the pipeline and the ILI tool.

Whether a cost-effective solution can be finally developed depends largely on the flexibility and versatility of the ILI technology available. The better an inspection tool can be tailored to the individual obstacles of the pipeline, the smaller the need to modify the pipeline. In the ideal case, a special tool will be engineered to the requirements of the pipeline and the pipeline will stay as it is.

In one case, a refined product storage facility was connected to the import jetty with a 16 in. pipeline of 3800 m in length. Several berths were connected to the pipeline via a manifold, which allowed the pipeline to transport product that was off-loaded from tankers, berthed at different locations on the jetty.

The pipeline had been in operation for more than 20 years. But, new regulations for safe pipeline operation required the operator to achieve an ILI in order to be permitted to continue operating the line. This pipeline was not built with any thought for intelligent pigging. At the jetty end, there was no launch trap suitable for an ILI tool.

Instead, a three way trap valve was present, which is used to launch batching pigs to separate different products being pumped. The trap valve is actually a full bore main line valve that is equipped with a side opening door. When the ball is oriented at 90° to the pipeline (when it is closed), the side door can be opened to allow the batching pig to be inserted.

Rather than requiring a substantial modification to install a 'normal' launch trap for an ILI tool, 3P Services was able to construct a series of special cleaning and ILI tools that were capable of being launched through the existing installation. This avoided substantial costs associated with such modification as well as time.

An inspection solution

Despite the difficulties and challenges, over several years 3P Services has developed a unique technology – BiDi MFL inspection – which can achieve the inspection of these pipelines. These tools are typically multi dimensional with a short bend radius capability and are also free swimming; they do not require a tether. They are launched and received at the same point, and are free to negotiate a series of 1.5 D bends. The tools also have a range of hundreds of kilometres – more than enough for the longest stretch from a beach to a PLEM.

The company's BiDi MFL delivers the same performance specification as uni-directional tools, and offers the prospect of a real and quantitative condition assessment. While based on the established principles, sensor type and other features found in 3P's classic uni-directional tool, the company's bi-directional MFL tools are designed from the outset to be fully bi-directional. The design of the sealing and guiding polyurethane discs are customised for each tool, to allow the correct flow conditions so that the tool is actually pulled through the line, whatever the direction of travel.

The inspection covers the entire circumference of the pipe, with internal/external discrimination. Sensor spacing and type achieves a density sufficient to deliver the highest possible performance in terms of defect detection, classification and sizing.

3P's concept of stand-off sensors greatly reduces the friction of the MFL tools when travelling through the pipeline. This is equally true for its bi-directional tools. Depending on the diameter, the magnetiser yokes may be supported by what the company calls 'roller skates'. This is an advantage for pipelines that operate at lower pressures and assists in the selection of a pumping spread for any given inspection project.

The robust MFL technology is known to be less demanding of cleanliness than other inspection tools. Nearly all available fluids are compatible, such as:

- Most types of crude.
- Fresh or sea water.
- Diesel and other hydrocarbon products.

Scheduling inspection operations in these lines is always sensitive, due to the demands of ship movements and refinery or export operations. MFL tools can be pumped at a relatively high speed, typically at 0.5 - 1.0 m/sec. This means that the elapsed time of inspection pigging operations is kept to a minimum, reducing the impact on normal operations.

Clearly, defining the pumping spread(s) and procedures is also one of the challenges. In the instance where there is a single pipeline connecting the shore location with the PLEM/SPM, means of temporarily storing a line fill of liquid and locating a pumping spread at the PLEM/SPM end of the line is needed. The storage and onboard pumping capabilities of most tankers are quite sufficient for this purpose.

Scenario: tanker loading/unloading system/PLEM-SPM, single pipeline

- General layout.
  - Pipeline connects onshore terminal with PLEM.
  - Only one pipeline in place.
- Special challenge.
  - No possibility to circulate propellant (crude, water etc.).
  - Therefore, barge or tanker required to store line fill and pump back.
  - Temporary launcher required at onshore terminal (if no permanent trap present).

Figure 4. Temporary trap.

Figure 5. Temporary trap – a pipe joint.

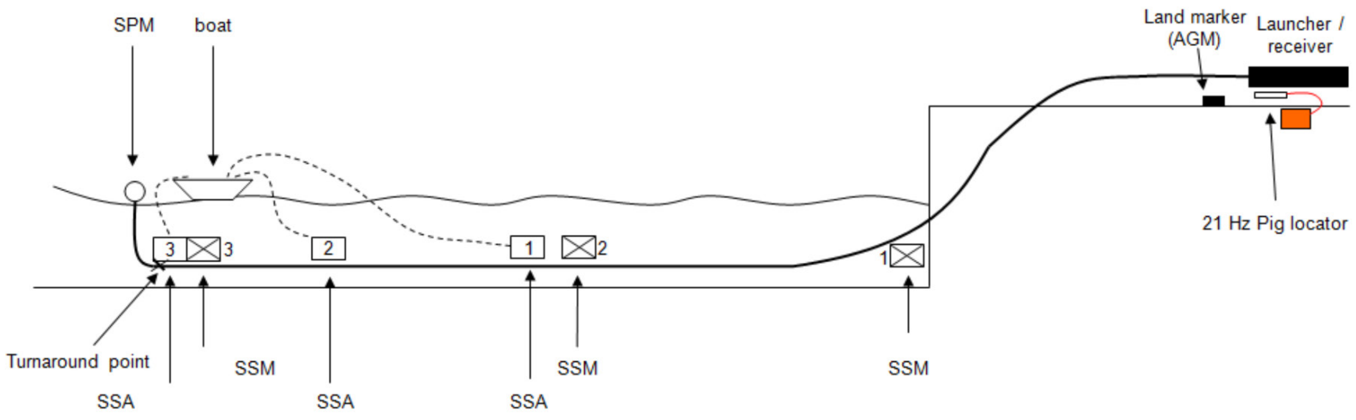

Figure 6. Typical positioning of subsea antennae and markers.

Where there is more than one pipeline connecting to the PLEM/SPM, the operator has the option of temporarily isolating the lines from the shore installations and creating a closed circuit. This configuration permits using a single shore based pumping spread to propel the tools in both directions.

Scenario: tanker loading/unloading system/PLEM-SPM, two pipelines

- General layout.
  - Pipelines connect onshore terminal with PLEM.
  - Two or more pipelines in place.
- Special challenge.
  - Propellant (crude, water etc.) can be circulated, pumping exclusively onshore.
  - Therefore, no barge or tanker required.
  - Temporary launcher required at onshore terminal (if no permanent trap present).
  - If circulation cannot be done via jump over the inside of the PLEM, circulation may take place on the SPM.

When pipelines are not constructed for pigging, it is usual that no pig traps are present. 3P has faced this situation on many of its projects, and has developed simple and low cost concepts for temporary launching/receiving chambers that require a minimum of intervention, if any, on the existing installations.

In this application, it is critical to monitor the progress of all pigs during all phases of their journey. One of the most important tasks is to control the approach of the pigs to the PLEM and to stop accurately at a pre-determined position. Specially developed subsea antennae are used to detect the arrival of the pigs. These navigation antennae are sensitive to different impacts (magnetic, electromagnetic etc.) and have redundant sensors for maximum reliability. Antennas are used together with other markers, both onshore and subsea, whose purpose is to provide location references in the inspection data.

It is further important to monitor and control several pumping parameters, pressure and flowrate, as well as to have clear communications between the PLEM, pumping spread and pigging control.

3P's method of pig and inspection tool configuration and assembly, guarantees the tools are built specifically for each pipeline. When a pipeline contains unusual and difficult configurations, such as mitred bends and multiple diameters, the tools are additionally tested in a purpose built test loop.

The tools record data for their full distance of travel: on the return journey as well as on the outward journey. A second complete data set can be obtained from a single run.

Defect assessment can be done according to a variety of specifications, typically ASME B 31.G, Rstreng, DNV RP-F101 and others. The quality of the data, in terms of completeness and accuracy, is sufficient for a full fitness for purpose study (FFS) to be undertaken. Performance specification and reporting standards are according to the POF standard.

Conclusion

The oil and gas pipeline transportation infrastructure worldwide is ageing – with many lines coming to the end of their design life. The cost of replacement of such assets often significantly exceeds the cost of life extension. Asset integrity managers, maintenance managers and operations managers must compete for their maintenance and CAPEX budgets with other investments.

Life extension, though, requires a precise and complete assessment of the existing condition of a given asset. Operators now have a cost-effective means of performing a full diagnostic inspection of marine loading lines. 3P's bi-directional high resolution MFL delivers inspection data of detail and accuracy sufficient to plan repair and life extension of these lines. 3P has achieved a substantial track record of projects for this new approach with a number of international companies.