Pipeline Inspection Techniques

A vast network of pipelines transports large volumes of energy products over long distances from production wells to processing and consumption sites. Historically, pipelines have proven to be a relatively safe transportation mode. As with any infrastructure, the integrity can be affected by time dependent degradation and abrupt damage from outside forces. The pipeline industry relies on nondestructive testing (NDT) methods to detect and characterize the degradation and damage. To quickly and economically survey the large portions of the infrastructure, autonomous in-line inspection tools, commonly referred to as pigs, examine the pipe from the inside as they are propelled by the product flow.

Inspection tool developers are challenged to implement sensitive measurement technology on a platform that must survive the pipeline environment. Inspection tools must meet measurement specifications for long distances at high speeds, while negotiating tight bends that induce substantial forces, obstructions that protrude into the pipe, debris that forces the sensors from the pipe and other inspection dilemmas.

Furthermore, the reliability of the inspection system must be high since the pipeline anomalies are typically localized events, not general degradation. One inspection technology, magnetic flux leakage, can be implemented to overcome the physical barriers while adequately detecting and characterizing corrosion anomalies. Other technologies address other classes of anomalies such stress corrosion cracking, mechanical damage, seam weld anomalies and more precise corrosion assessment. Some pipelines, referred to as unpigable, have excessive physical or operational barriers that prevent the use of available pigs. Crawler technologies are being implemented that overcome these barriers, sometimes with alternative inspection methods. After internal inspection, the details of the anomalies are commonly quantified after excavation using more classical NDT methods.

In-the-ditch sizing methods for corrosion and cracking are used to quantify pigging results.

Application of Inspection Methods to Pipelines

In-line inspection equipment is commonly used to examine a large portion of the long distance transmission pipeline system that transports energy products from well gathering points to local distribution companies. A piece of equipment that is inserted into a pipeline and driven by product flow is called a ‘pig’. Using this term as a base, a set of terms have evolved. Pigs that are equipped with sensors and data recording devises are called ‘intelligent pigs’. Pipelines that cannot be inspected using intelligent pigs are deemed ‘unpigable’. But many factors affect the passage of a pig through a pipeline, or the ‘pigability’. The concept of pigability pipeline extends well beyond the basic need for a long round hole with a means to enter and exit. An accurate assessment of pigability includes consideration of pipeline length, attributes, pressure, flow rate, deformation, cleanliness, and other factors as well as the availability of inspection technology. All factors must be considered when assessing the appropriateness of inline inspection (ILI) to assess specific pipeline threats.

In terms of implementing an integrity management plan (IMP), the first step is the evaluation of potential threats that exist in the pipeline or segment being considered and their credibility. Once the credible threats are established, the appropriate integrity assessment method(s) are then selected. Where instrumented non-destructive ILI tools are deemed appropriate, several preliminary aspects must then be considered. Otherwise, alternative integrity assessment methods that may include pressure testing and direct assessment will be required.

Each inspection technology implementation must be examined to determine suitability of both assess-
ment of threats and passage of pipeline attributes.

Some pipelines may constitute a single source of supply to a locale that cannot be easily interrupted even for scheduled ILI or other maintenance operations. If an interruption does occur, alternative (and often very expensive) supply sources such as truck is required to maintain service. Even where suitable permanent launchers/ receivers (or some temporary configurations) are available, pipeline operating characteristics may need to be modified to conduct a successful ILI integrity assessment. Such operating parameter modifications can impact gas delivery and may not be acceptable. Also, more detailed piggability assessment should be performed to ensure free passage of ILI tools.

The length of the pipeline or segment to be assessed is also an important initial consideration. It is rarely practical to run product driven ILI tools in short segments of pipeline that might include a short high consequence area (HCA), crossovers between pipelines, and short length laterals. Equipping such pipelines or segments for periodic ILI tool operation would be expensive unless the equipment was also used for other pipeline operational purposes such as liquid removal. Furthermore, the required flow conditions for proper ILI operation may be difficult to achieve in short segments. Costs for gas driven ILI tools are typically compared on an approximate cost/mile basis that includes the ILI vendor's fixed mobilization charge. A typical cost/ mile analysis shows that gas driven ILI run lengths should exceed about 50 kilometers (30 miles) to approach the least unit cost.

Other types of instrumented ILI tools (i.e., wireline ILI tools) are more appropriate for shorter lengths of pipe. Another initial consideration is the particular instrumented ILI technology that is capable of assessing the established threats and the suitability of that technology in pipelines.

Each of the available ILI technologies has its strengths and limitations for anomaly detection. Inspection technologies for each of these conditions are at various stages of development. Many of the inspection technologies are product specific and may not applicable in gas or liquid pipelines in all cases.

Pipeline operating pressure and flow conditions can dictate if it is feasible to satisfactorily operate an ILI tool. For gas natural pipelines, low pressure (25-40 bar, 400-600 psi) and flow conditions may not be sufficient to efficiently drive a pig. A minimum gas pressure is needed to assure stable ILI operation since higher pressures create a higher density fluid column behind and in front of the pig thus minimizing speed variations and surges. The effects of low pressures can be more extreme in hilly terrain since the gas column would not effectively restrain the tool thus permitting velocity variations. Instrumented ILI tools should be operated within their recommended velocity ranges to achieve optimum inspection results. For example, magnetic flux leakage (MFL) tools speeds are typically 13 m/s and inspection results can degrade when an ILI tool when operated out of the recommended range, especially where excessive velocities occur.

Typical pipeline operating parameters may require modification to control flow rates and product pressures thereby optimizing ILI inspection results. In some pipelines, the pressure increases needed to assure satisfactory ILI operations may be precluded by pressure limiting restrictions. This may include pressure regulator adjustments, compressor station operation modifications, and flow throttling with valves. ILI tools equipped with gas bypass technology are now being applied to provide improved inspection velocities in a wider range of flow conditions.

Solutions & Solution Providers

3P Services

3P Services offers in-line inspection (ILI) services for both onshore and offshore pipelines. Various inspection techniques are applied on-board “intelligent pigs”, which measure different integrity parameters while being pumped through the pipeline together with the product. Pipelines are inspected for metal loss (such as internal and external corrosion), mechanical deformation and other features without interrupting the transportation process.

In-line pipeline inspection tools

3P Services has a well-proven range of in-line pipeline tools covering the following categories:

- Magnetic flux leakage (MFL) high-resolution tools from 3in in diameter and larger; this is the classical tool to locate both internal and external metal loss such as corrosion
- Direct magnetic response (DMR) tools to inspect for internal local metal loss in pipelines of 2in in diameter and larger, regardless of the wall thickness
- GEO (high-resolution and multi-channel geometric) tools to identify discontinuities of the internal geometry (including dents and ovalities) of pipelines of 2in in diameter and larger
• XYZ mapping available on any of the tool types
• Buckle detectors for real-time geometric inspection during offshore pipe lay
• Bi-directional offshore riser inspection
• HandyScan: external MFL scanner equipment, sales and support; test heads from 2in and larger; tank floor scanners for bottom, wall and roof

**Inspection technology for difficult pipelines**

3P concentrates on applying its inspection technologies in pipelines that are considered to be difficult or impossible to pig. Our unique modular design philosophy means that we tailor-make the inspection tools that we will use in nearly every inspection project. Some examples of these special applications include the following:

- Bi-directional tools for pump-in/pump-out operation in single-access pipeline situations
- GEO tools that negotiate, determine and measure mitred bends
- MFL tools that can negotiate short radius elbows, for example 4in pipeline and 1.5D-90° bends
- DMR tools to inspect small-diameter pipelines with heavy walls
- WAX tools to measure thickness of paraffin or other sedimentation
- Multi-diameter lines
- Lines with difficult and mitred bends
- Difficult flow conditions

**Specialised inspection equipment**

All specialised inspection equipment is of genuine 3P Services’ origin. The development of all components, including hard and software, is carried out under one roof at 3P Services in Germany.

**Marine-terminal loading and unloading pipelines**

“Unpiggable” pipelines include various types of marine terminal pipelines, which are often referred to as tanker-loading lines, tanker-unloading lines, jetty lines and submarine pipelines. As marine terminal operators rely on techniques that offer only partial inspection and qualitative condition assessment, often pipelines have never been pigged and much less inspected.

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 around 25m to 40m deep and is connected to a buoy by a flexible hose or hoses. Floating flexible hoses complete the connection to the tanker.

As typical marine terminal pipelines have not being made for pigging, there is no access to the subsea end of the line to either insert or retrieve a pig. There is very often limited opportunity to get access even to the shore end of the pipeline as space can be very tight. While PLEM/SPM installations do have similar characteristics, each system and installation contains unique configurations. The PLEM can connect to the shore with a single pipeline – or several. Diameters can vary and dual-diameter pipelines are occasionally encountered.

**ROSEN**

ROSEN offers a complete range of services for high-resolution and quality defect identification utilizing Geometry, MFL, UT, EMAT, EC and AE technology.

The Optical Inspection tool (RoVisual) is a unique ROSEN innovation that integrates a high quality camera with its own lighting support into a robust pipeline cleaning tool. RoVisual provides dramatic visualization of the inside of pipeline, capturing and recording the information on-board for review later.

With RoVisual the pipeline operator can investigate the pipeline for many key properties, including:

- Pipeline damage (e.g. dents)
- Cleanliness (e.g. degree of dust contamination)
- Condition of pipeline fittings (e.g. open valves, valve seals, guiding bars)
- Quality of pipeline repairs
- Presence of water

RoVisual is optimized for pipelines with transparent products and can be mounted on ROSEN cleaning tools ranging from size 16” to 56”.

**Leak Detection Tool (RoLeak)**

ROSEN’s ultrasonic leak detection technology is the ideal inspection solution for liquid pipelines.

RoLeak is designed for robust and easy use, supported by intelligent software to automatically evaluate measurement results with the least possible effort for the pipeline operator.

The Key Benefits:

- Simple detection and location of small leaks in liquid pipelines
- Easy launching and receiving
- Tool accommodates various pipeline conditions
• Automated data analysis of repeated inspection runs

Combined ILI Technology

Combined ILI technology provides accurate and efficient inspection results, making an invaluable contribution to pipeline integrity management.

ROSEN’s in-house development, design and manufacturing ensure robust, reliable inspection equipment that is modular and compatible through the entire inspection range. Specific integrity threats can be identified through the wide range of options available. Technologies can be combined on a single tool to tailor the inspection capabilities to specific inspection goals.

The tool’s main unit is used for corrosion detection. It uses odometers, acceleration and orientation sensors, ancillary systems as well as the data processing and storage electronics. The main body can be combined with various technologies and/or add-ons to create a tool with capabilities specific to the extended multi-inspection challenge.

Shaw Pipeline Services

A division of ShawCor, Shaw Pipeline Services provides reliable pipeline weld inspection services to the oil and gas industry. Shaw Pipeline Services’ pipeline inspection techniques and procedures provide high-resolution weld evaluation using state of the art automated ultrasonic testing equipment.

Shaw Pipeline Services’ ultrasonic testing equipment provides weld evaluation and defect sizing assessment for automatic, semi-automatic and manual welding processes.

Their pipeline inspection capability benefits from decades of experience in the pipeline industry. Their procedures meet standard inspection specifications for Workmanship Acceptance Criteria or Alternative Acceptance Criteria based on the Engineering Critical Assessment (ECA) method. They ensure that welding repairs are kept to a minimum by providing welders with quick and accurate process control feedback derived from ultrasonic inspection data.

Shaw Pipeline Services’ “total weld inspection” philosophy incorporates the use of focused probe technology, augmented by Time Of Flight Diffraction (TOFD) techniques, to accurately locate and size flaws within a weld. In dynamic offshore environments, Shaw Pipeline Services continues to meet the ever-changing demands of its customers by successfully adapting its inspection techniques to increasingly challenging technical applications through hardware and software enhancements.

AUT Pipeline Inspection Technology and Applications

Shaw Pipeline Services inspects onshore and offshore pipeline facilities where welding processes such as GMAW, SAW and Manual Stick are utilized. Shaw Pipeline Services also specializes in the inspection of risers, Steel Catenary Risers (SCR), flowlines, specialty fabrications and clad material systems. We have developed the largest, most experienced technician pool in the industry with over 130 AUT personnel, including 30 SCR qualified operators.

Their automated ultrasonic weld inspection equipment is readily adaptable for all fabrication scenarios including single, double and quad joint facilities, offshore S-Lay and J-Lay configurations. Shaw Pipeline Services maintains sophisticated training facilities based in Houston and Great Yarmouth. These facilities are utilised for SPS personnel, client and contractor training.

Automated Ultrasonic Girth Weld Inspection (AUT)

Shaw Pipeline Services was established in 1990 to deliver AUT services for the pipeline industry and is now regarded as the leading company in its field.

Led by a carefully planned growth strategy, Shaw Pipeline Services has successfully expanded its equipment fleet to serve the global market.

Shaw Pipeline Services completed its first AUT weld inspection project in 1991, servicing a 270km, 48in pipeline for TransCanada Pipeline. In 1994 it introduced AUT technology in the Gulf of Mexico on the offshore Mars project.

In 1997 the division implemented its global expansion strategy with the acquisition of the UK-based
QED. This enabled the division to strengthen its presence in the Eastern Hemisphere. The same year, Shaw Pipeline Services introduced AUT into Saudi Arabia on the Shaybah project. In 1998 its AUT technology was introduced to Latin America on the Gasbol project, to the North Sea on the Ketch Corvette projects, and to the Far East on the West Natuna project. In 1999 its AUT technology was introduced to the US land sector on the Alliance project.

As the new millennium rolled in, Shaw Pipeline Services further expanded its service capabilities through the acquisition of the leading US pipeline inspection company, Edwards Pipeline Services. Growth continues to be a central strategy as we focus on the dynamic needs of our customers in a technically challenging environment.

**TDW**

TDW delivers customized inline inspection services specifically engineered to optimize system performance with a minimum of downtime. TDW inline inspection technologies are fully engineered to ensure pipeline integrity in even the harshest environments and provide the most accurate data available, usually in just one run.

Active Speed Control Technology - When a tool moves too quickly though a pipeline, data quality can suffer. Active Speed Control Technology is specifically designed to pair with MFL inspection technology for use in high velocity gas lines.

Deformation Technology - Engineered with sensors designed to ride directly on the internal pipe surface rather than behind a cup for increased sensitivity. High resolution data from these tools can be analyzed for induced dent strain and can precisely measure expanded pipe locations.

GMFL Technology - Provides accurate detection and sizing of internal and external metal loss and other ferrous anomalies. Engineered to negotiate reductions and reduce tool drag for more consistent velocities.

Inline Inspection Support Services - With inline inspection support services from TDW you can survey and optimize pipeline performance, troubleshoot potential problems and make downtime a thing of the past.

KALIPER® 360 Technology - Specifically engineered for use in newly constructed pipelines and for pipelines currently in the active service of moving liquid, gas, chemical or other line-transportable products.

MFL Technology - Provides accurate detection and sizing of internal and external metal loss and other ferrous anomalies.


SpirALL® Magnetic Flux Leakage Technology - Provides the most accurate long seam assessment possible without adding significant tool length.

XYZ Mapping - Allows operators to determine the precise centerline trajectory of a pipeline in latitude, longitude and elevation.

Interactive Reporting Software - Designed with inline inspection services customers in mind, easy-to-use Interactive Report software from TDW enables users to view potential problem areas and identify critical anomalies.

**Weatherford**

Weatherford P&SS provides pipeline inspection services using SAAM, the Original Smart Utility Pig. The SAAM (Smart Acquisition Analysis Module) technology is a revolutionary inspection system, and provides a versatile, cost-effective solution to pipeline operators.

The SAAM unit is installed completely within a utility pig, and measures and records the pig’s behavior through a pipeline. Post-survey interpretation of the data logged provides useful information, enabling operators to make informed decisions about the integrity of their pipeline. Applications of the SAAM tool include:

- 3D out-of-straightness measurement
- Locate internal debris (e.g. paraffin wax)
- Locate internal bore restrictions (e.g. dents)
- Locate internal corrosion
- Log process data (pressure, temperature)
- Diagnose and optimize pigging

The SAAM tool can be used in a regular direct assessment and maintenance role, as well as in one-off troubleshooting applications.

* SAAM is a registered trademark in the United Kingdom.

**References**

- 3P Services
- PetroMin Pipeliner
- ROSEN
- Shaw Pipeline Services
- TDW
- Weatherford