PIPELINE INTEGRITY: STUDY, ANALYSIS, AND PROPOSAL TO SOLVE A REAL CASE

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Abstract

A 6” LPG Pipeline laid in 1980 provided with a bituminous coating, was not originally protected against corrosion by a CP System. A Cathodic Protection System by using sacrificial anodes was installed in 2008. In 2010 some corrosion were discovered on the pipeline. Some of these corrosions were through the wall so that temporary repair systems were installed (bolted half shells) and an impressed current CP System was installed and regularly monitored. Specialized electrical surveys have been performed along some sections of this pipeline demonstrating that a very high level of CP current was required due to interferences from other Structures. Solving the interference problems, the current requirement was noticeably reduced. The pipeline is not piggable, at the moment. The following questions should be answered:

- How can it be classified from the integrity point of view ?
- Which methods and devices are to be used to assess its conditions ?
- How to refurbish such a pipeline in order to make it safe from the operating point of view ?

A team of specialists in Pipeline Integrity and intelligent Pigging operation are jointly going to study this specific pipeline in order to propose a plan to reach the final goals: a careful, complete assessment of the integrity of the pipeline and the necessary actions to reinstate the pipeline to safe conditions from the operating point of view.

Foreword

The LPG pipeline whose length is about 3 km, has been laid in 1980 and has been buried without cathodic protection for a long period.(2008-1980 = 28 years). No insulating joints were installed since its laying. Some corrosion sites have been discovered since then. In 2008, Cathodic Protection was installed with sacrificial anodes without Insulating Flanges which drained current at both ends.
In Nov. 2010 some other leaks were found; 85 m of pipeline was substituted and road crossing sleeves installed; their position is not exactly known.
On Jan. 2011 n. 2 Flanged Joints were installed at both ends of the pipeline.
A careful C.P: survey was made only in 2012.

1.0 – Electrical Surveys

An electrical survey has been made on the pipeline, Potential and Current measurements, and some length of the pipeline has been inspected with the Transverse Gradients Technique.

The entire pipeline is cathodically protected by a CP Station placed into the Starting Point.
The CP Station is able to supply up to 30 A. The current presently delivered is 12,5 A and the CP System is properly working.

The pipeline, along the first part which has been tested with the Transverse Gradient Technique (around 600 m), shows some important coating defects.
Some of the corrosions examined nearby a part of the pipeline which is presently exposed showed that a corrosion is present in the repair coating between the 2 welded spools. The corrosion appears to be quite uniform and, considering the long period during which the pipeline has been without any Cathodic Protection, is to be considered “a normal corrosive process with a superficial, uniform corrosion”.

An important observation made in the ditch is that the corrosive process appears now stopped; the corrosion appears in fact no more active at the moment of the excavation.
This means that if some corrosion phenomena have been active during the lifetime of the pipeline, these are probably now stopped due to the action of the existing CP System.
In some areas corrosions (probably due to static interference) have been found and repaired during time. The exact position of these corrosions is not known.

2.0 – Guided Waves Technique

If a pipeline is NOT PIGGABLE, discovering the presence of corrosions along a pipeline is particularly complex because of the unpredictability with which faults and corrosive phenomena occur. In particular, external agents can often interfere by changing locally the corrosion rate, thus making it difficult to assess how the real state of structural integrity might evolve and therefore to decide whether to repair or replace a structure.
The methodology of Ultrasonic Guided Waves was developed specifically to complement traditional methods based on the measurements of corrosion rate and corrosion potential, electrical attenuation and gradients.

These diagnostic tests are placed in the context of a complex procedure and flexible structural algorithm that combines the mechanical with the corrosion aspects through an innovative Mechanical/Corrosion Diagram.

2.1 – Application of Ultrasonic Guided Waves in pipelines

The Guided Waves technique used for testing pipelines are ultrasonic waves at low frequencies (generally below 100 kHz). When using the conventional ultrasonic technique, only the region of the structure immediately close to the transducers can be tested (see Figure 1(a)). Ultrasonic Guided Waves enable the screening of a relatively long section of the structure from a single remote position. These waves propagate along the structure instead of going through the thickness as shown in Figure 1(b).

These waves are obtained by using special transducers array. The contact between the pipe and the transducers is of dry, mechanical type, or a pneumatic applied force is used to ensure a good coupling of the transducers array to the pipe. After the transducers ring has been placed around the pipe, the operator starts the test which automatically sweeps several frequencies collecting data from either side of the ring at once (the system works in pulse-echo mode). The propagation of the ultrasonic signals depends on the conditions of the pipe under test.

A range of 100 meters in either directions from the transducers ring position can be efficiently scanned on a bare pipe, in overall good conditions, having a low number of features (such as change of directions, drains, vents, valves, welds etc..). This useful range is reduced to less than 20 meters if the pipe is bare and/or heavily corroded over its length. The system has been designed to detect defects having metal loss of about 5% of the pipe wall cross section area, although defects much smaller than 5% (e.g. 1-2%) can be identified in pipes which are in generally good conditions.

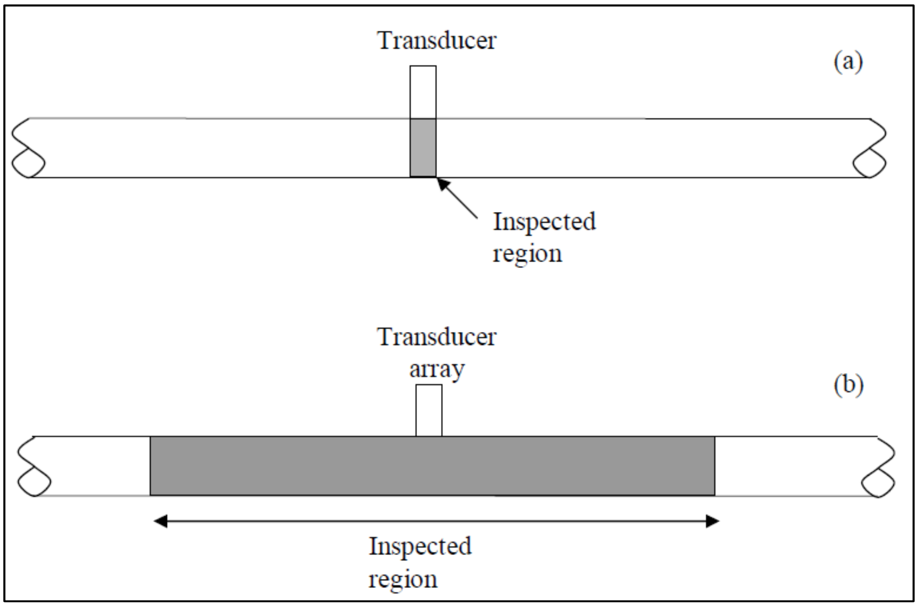

Figure 1 – Difference between the traditional Ultrasonic techniques (a) and Ultrasonic Guided Waves techniques (b).

2.2 – Structural Assessment

The evaluation of the structural safety level of pipelines is fundamental in order to establish their residual life and to decide the type of repair or if a replacement of the spool is necessary.

Mechanical/Corrosion Diagrams have been developed with complex and flexible algorithms that calculate, for every spot under examination, the safety margin for the pipeline.
Considering all the data measured and gathered (geometrical characteristics, materials, corrosion behaviour etc.) and the relevant applicable Standards, the diagram in Fig 2 shows the limits of the remaining safety margin for the structure under examination

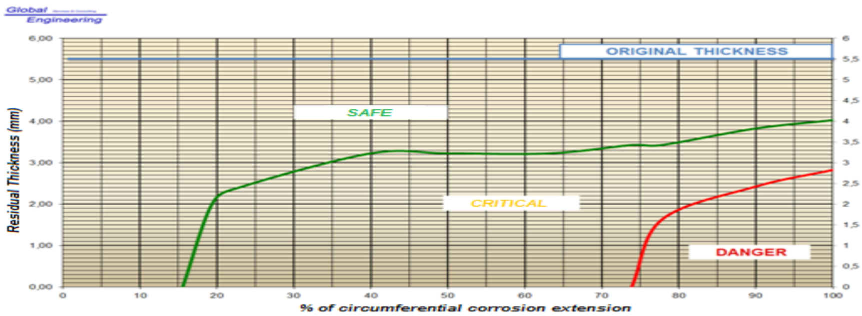

Figure 2 - Limits of the remaining safety margin for the structure under examination

Once the excavations have shown the damage features, their classification will be made by applying the ASME B31G – 2009 Manual for Determining the Remaining Strength of Corroded Pipelines.

According to the results and the various type of damages:

- Corrosion;
- Gauge;
- Smooth dent;
- Dent and Gauge;

The category of damage will be assessed as:

- Superficial damage
- Moderate damage
- Severe damage

According to these categories of damage, the various repair systems will be applied. This procedure will allow to re-instate the operating safe conditions of the pipeline.

3.0 – SmartBall® Autonomous In-Line Leak Detection System

SmartBall® was introduced in 2005 and, following two years of development and field trials, the system was commercialized in June 2007. Since then, SmartBall®, an autonomous, in-line, leak detection system, has been used to survey thousands of kilometers of oil, water and wastewater pipelines of different materials for many different agencies in North America, Australia, Asia, Europe, Middle East, and India. SmartBall® has identified many leaks several of which have been verified and repaired.

3.1 – SmartBall® Description

SmartBall® is an acoustic-based inline inspection technology that detects anomalous acoustic activity associated with leaks in pressurized pipeline. The SmartBall® technology consists of an instrumented aluminum alloy core (containing a power supply, electronic components and instrumentation including an acoustic sensor, tri-axial accelerometer, tri-axial magnetometer, GPS synchronized ultrasonic transmitter, and temperature/pressure sensor) that is enclosed in a polyurethane shell.

There are two modes of deployment for the SmartBall®. The aluminum core can be encapsulated inside a protective outer foam shell, which allows the device to be propelled through the pipeline by creating a larger surface area for the product flow to make contact with. This method is typically used for pipelines of 16” diameter and larger. In the second design, the aluminum core is encapsulated in a polyurethane coating and is suitable for deployment into pipelines ranging from 4” to 14” in diameter. Both the outer foam shell and polyurethane coating also help to reduce low frequency ambient noise that is typically present in the pipeline.

It is important to note that the SmartBall® tool is not a pig and does not seal against the inside wall of the pipe, nor rely on differential pressure for propulsion. The SmartBall® tool is designed to be of a smaller diameter than the ID of a pipe, and physically rolls through the pipeline, propelled by the flow of that product in the pipeline. Acoustic activity in the pipeline is recorded as the SmartBall® traverses the pipe. Therefore, the acoustic sensor inside the tool traverses no more than one pipe diameter from the location of a leak.

3.2 – Launching SmartBall®

The SmartBall® is typically launched and received from a pipeline at existing pig traps. Since this particular pipeline for inspection is “non-piggable”, then a minor modification to either install an insertion spool (Fig. 3) or alternatively provide a 4” hot tap (Fig. 4) will be required as per photos below.

Fig. 3 – Short insertion spool

Fig. 4 – Hot-tapped insertion

3.3 – Tracking SmartBall®

During the run, the SmartBall® can be tracked using standard pig tracking boxes. The location data from these boxes is used during data analysis process to calculate the location of the leaks. Tracking the position of the SmartBall® in the pipeline is critical for locating important acoustic anomalies such as leaks. The on-board accelerometer records the rotation of the SmartBall® which is used to determine the angular velocity of the SmartBall®, which is then used to determine a velocity profile of the device as it travels the entire length of the pipeline. This data is aligned with the acoustic recordings to give a precise location of any recorded anomaly. To correlate the accelerometer data to an absolute position and time a reference point is required. Tracking the position of the SmartBall® via SmartBall® Receivers (SBRs) and above ground markers (AGMs) provides a time and position to be stamped on the velocity profile resulting in a position versus time relationship for the entire run of the device that is used to report the location of acoustic anomalies.

3.4 – Receiving SmartBall®

The SmartBall® is then captured at a point downstream and extracted from the pipeline typically at the receiver trap. Since the pipeline is “non-piggable” minor modification to install an extraction tee spool “catch facility” is required as per Fig. 5 below.

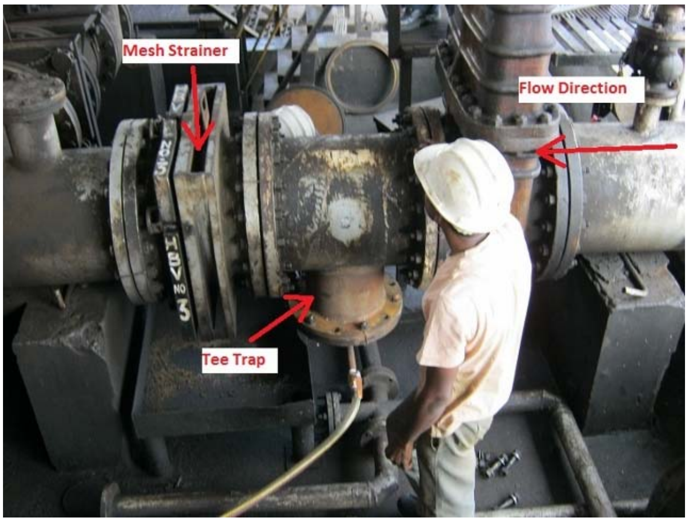

Fig. 5 – Extraction tee spool “catch facility”

The data is then reviewed to determine the presence and location of any leaks in the pipeline. This technique provides excellent acoustic data on a pipeline which is used to identify leaks in pressurized pipes.

3.5 – Acoustic Leak Detection

A leak inside a pressurized pipeline produces an acoustic signal. This acoustic signal is created as the pressurized product inside the pipeline escapes into the lower pressure atmosphere outside the pipe. While the SmartBall® traverses the pipeline it continuously records this acoustic data, which is analyzed after tool extraction to identify acoustic activity associated with leaks along the pipeline. As the SmartBall® is rolling along the bottom of the pipeline, it will always pass within one pipe diameter of the leak, allowing for extremely high detection sensitivity. SmartBall® locates leaks as small as 0.03 gpm (0.1 lpm).

As the SmartBall® approaches a leak the acoustic signal detected by the SmartBall® will increase. The acoustic signal will peak at the point at which the SmartBall® passes the origin point of the leak and will then diminish as the SmartBall® continues away from the leak. This is demonstrated in Fig. 6 below showing a typical acoustic signature resulting from a leak.

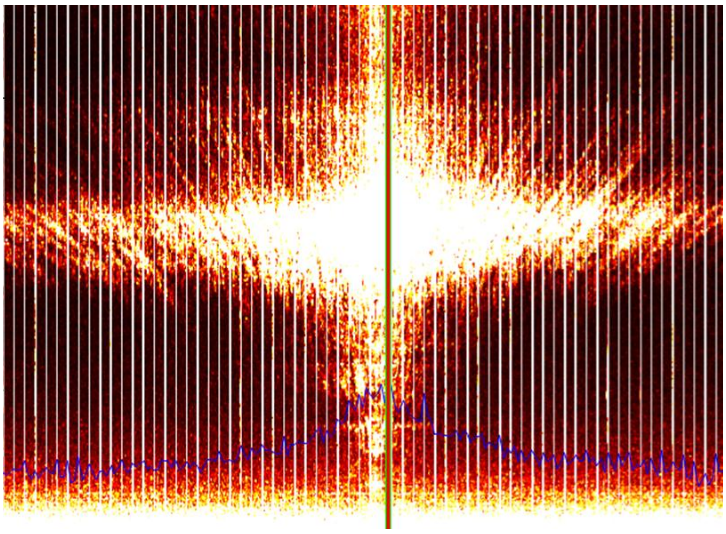

Fig. 6 – Typical leak signature

3.6 – Technical Requirements for using the SmartBall®

Laterals, tie-ins and other connections exceeding the diameter of the ball must be valved off or barred while the SmartBall® is in the line. If it is not possible to shut off all valves, it is acceptable to have some inflows into the section of main being surveyed. Outflows are not acceptable. Ideally, all the connections will be valved off. All in-line valves between the launcher and receiver must be completely open. We must ensure that the line is clear for the passage of the SmartBall®. This may require a cleaning pig run ahead of SmartBall®. Minimum flow velocity in the pipeline must exceed 0.5 m/s throughout the inspection. Line pressure should be maintained in the range of 3.5 bars to 137 bars.

4.0 – Conclusions

The pipeline has been subject to corrosion phenomena during its lifetime without Cathodic Protection, and has quite certainly some corrosion spots along its length, also because it has been subject to static electrical interferences due to the presence of other pipelines and/or the connection to buried structures as Copper Grounding Systems etc.

The pipeline is NOT PIGGABLE.

A complete Electrical Survey can help assessing the presence of spots where possible corrosion sites could be found.

An inspection by using the SmartBall® Leak Detection System can be performed by simple modifications to the existing pipeline structure. This inspection will give full information on possible existing leaks, even pinhole leaks as small as 0.03 gpm (0.1 lpm) with location accuracy of +/- 1 meter.

A further Inspection by using the Ultrasonic Guided Waves Technique will be performed to determine the position and the gravity of possible corrosion sites. This Survey can be performed by opening some small trenches along the pipeline (1 m x 1 m), in order to place the Transducers Array over it (e.g. every 100 m or more frequently, e.g. every 50 m).

A deep analysis of the various techniques will allow to localize the spots, excavate corroded sites, and allow a careful classification of the damages into the various classes, according to ASME B31G – 2009. This will allow to make a precise evaluation of integrity, applying the various repair methods.

At this stage, may be some spools should be replaced, and this can be done in a unique phase.

The scope of our work has been satisfied, by reinstating the pipeline to its original Integrity and Operability.

The only alternative solution is the complete replacement of the pipeline.
After a careful survey and economical evaluation for the deployment of the above said integrated techniques, it will be a choice of the Operating Company to decide whether replace the complete pipeline or rely on the combined results of the above proposed survey techniques.