CASE STUDY WITH A CORROSION MONITORING SYSTEM USING ULTRASSONIC SENSORS OF HIGH RESOLUTION AND NON-INTRUSIVE IN PIPELINES
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IBP1150_13 CASE STUDY WITH A CORROSION MONITORING SYSTEM USING ULTRASSONIC SENSORS OF HIGH RESOLUTION AND NON-INTRUSIVE IN PIPELINES

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Abstract

This paper aims to present a case study with a corrosion monitoring systems using ultrasonic sensors of high resolution in the monitoring of internal corrosion of pipelines and their applications in mining that can be used in petrochemical industries, Gas, Oil, Sanitation, etc ... This system has probes which are mounted on the surface of the pipeline and has characteristic of being of the non-intrusive means of intelligent probes. This system provide a high resolution of 0,00254 mm (0.0001 inch) to measure the thickness of the pipelines storing this information over time is used in the calculation of internal corrosion with high precision instead of another ultrasonic systems. Provides a reliable data for corrosion management and the basis to satisfy external audit as those made by regulatory agencies. Finally we conclude that it is ideal to meet the ICDA (Internal Corrosion Direct Assessment) standard, and allows easy and a correct monitoring of corrosion in places of difficult access to high cost benefit compared to other methods of monitoring intrusive for example.

1. Introduction

Keeping pipelines safe from internal corrosion or erosion can be a challenging and expensive business. Industry estimates run to several billion dollars annually in the world. A USA company, who operates approximately 29000 km (18,000 mile) of interstate pipelines, performed over 300 anomaly investigations. They budgeted US$50,000 per investigation in rural areas, but if it is in an urban area, US$50,000 may not even cover permitting. Also a single dig for inspection of one location could cost over US$250,000. In the worst cases, we have to add civil penalties and fines between US$25,000 and US$ 1,000,000 for violations or accidents due to internal corrosion or erosion.

Corrosion/Erosion can typically reduce a pipeline wall thickness at a rate of two to three mils/year, but it can happen much more quickly if process and fluid conditions changes unexpected. Usually corrosion occurs at low spots, under roads or rivers, on spot or location without access. To mitigate the potential for incidents related to internal corrosion, the pipeline industry works assiduously to reduce risk. In order to comply, pipeline operators rely on a range of survey methods supplied by third parties. Generally, internal corrosion monitoring & detection is broken down into three techniques, 1) Intrusive, 2) In-Line Inspection (ILI) and 3) Non-intrusive.

Non Intrusive offer the best alternative for continues corrosion monitoring because external sensors help avoid expensive interventions such as shut down. The most common non-intrusive device is the ultrasonic monitor. However, to conduct a survey, the pipeline is dug up then a portable device is held against the metal. The devices are quick, easy to use and inexpensive, but they still have to expend thousands of dollars digging up the pipeline each time they run a test. Also, traditional ultrasonic monitors have a sensitivity range in the order of 0,127 mm to 0,254 mm (5 mil to 10 mil) accuracy, so if the corrosion is only 0,0762 mm per year (3 mpy), it takes 3 years to start to see it in a statistically significant manner.

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Therefore, new ultrasonic equipment with simultaneous RTD temperature compensation and high degree of positional and stability because these are a permanent mounted transducer was developed. The net effect of these two innovations is to increase resolution capability to 0,00254mm (0.1 mils). These new ultrasonic technology is helping to

reduce OPEX cost to the pipelines operators. After initial installation, access to the monitoring point is no longer required. This equipment is capable of monitoring low rates of corrosion such as 0,0508 mm per year (2 mpy) or less.

2. Methodology

2.1 Ultrasonic technique. Theory of Operation

Ultrasonic is the most common non-intrusive device for internal corrosion monitoring and detection. The use of high frequency sound waves for the measurement of ferrous and non-ferrous materials has been employed since the Second World War. Technological advancements through the years have improved the resolution of the measurements, and the speed of operation, in addition to the reduction in the size and weight of the instrumentation.

Wavelength is dependent on the speed of sound propagation through the material under test but remains constant in a given material. Since different materials propagate sound waves at different speeds, the wavelength in the different materials will vary. It is important to choose a transducer frequency that is best suited for the material under test. Wavelength (as depicted in Figure 1), can be determined by the formula:

$$\lambda = \frac{v}{f} \quad (1)$$

Where
λ = wavelength
v = ultrasonic velocity in inches per microsecond
f = the center frequency of the transducer in megahertz

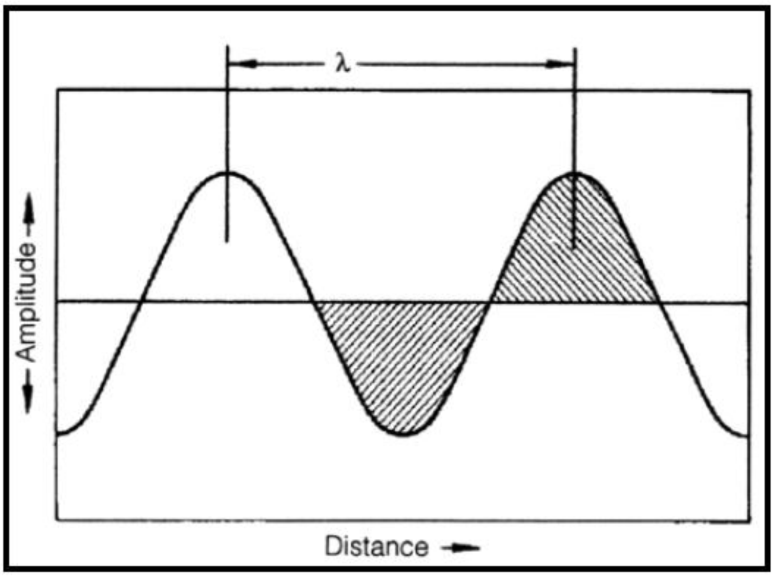

Figure 1 - Wavelength Definition

The relative flaw detection threshold (Ft) can then be determined by:

$$F_t = \frac{\lambda}{10} \quad (2)$$

It can be seen from equation (2) that, in general, the higher the frequency the greater the sensitivity (or the smaller the detectable flaw) and conversely, the lower the frequency the lower the sensitivity.

To conduct a survey, the pipeline is dug up and then a portable device is held against the metal. Inside the device, voltage is applied across a piezoelectric crystal to generate an ultrasonic sound wave that propagates through the metal. The time it takes to travel through the metal and back to the transducer is directly proportional to its thickness. The devices are quick, easy to use and inexpensive, and operators do not have to shut off flow or risk breeching the pipeline in order to take a reading. On the other hand, they still have to expend thousands of dollars digging up the pipeline each time they run a test. Also, traditional ultrasonic monitors have a sensitivity range in the order of 0,127 mm to 0,254 mm (5 mils to 10 mils) accuracy, so if the corrosion is only 0,0762 mm per year (3 mpy), it takes 3 years to start to see it in a statistically-significant manner.

In order to deal with this situation, a new technology was developed. Permanently mounted transducers provide high resolution thickness measurement which, when combined with surface temperature compensation, permits corrosion rates to be determined non-invasively. The transducer (probe) is a small, with following dimensions, 25,4 mm diameter by 25,4 mm higher (1 inch diameter by 1 inch high) sensor which is permanently mounted to the monitoring point. This is accomplished using a special adhesive which also acts as an ultrasonic couplant. The transducer has a magnetic base to aid in holding it in position while the adhesive cures. The temperature sensor on the transducer using a RTD allows for automatic correction of acoustic velocity as a result of the metal temperature. This provides a significantly more accurate reading of thickness. The resolution of this newest transducer is 0,00254 mm (0.1 mil or 0.0001 inches) which provides a true corrosion monitoring. These newest generation transducers also have the capability of storing and transmitting location and configuration information to the handheld instrument, for ease of operation and to eliminate operator errors.

The instrument can be used to log multiple transducers from a common connection point, to provide periodic time and date stamped measurements of wall thickness, or for more critical applications. It can automatically collect and store continuous measurements from a single transducer. Unlike normal ultrasonic devices, this new technology is capable of monitoring low rates of corrosion at a resolution of one tenth of a mil and once installed, and provides years of continuous service without the need for replacement.

This newest transducer is ideally suited to form the backbone of an ICDA (Internal Corrosion Direct Assessment) asset integrity system for pipeline operators. Sensors are permanently attached to the exposed surface in areas such as low lying spots, drips on other locations where corrosion should be monitored. After backfilling, the sensors are read from the surface by way of attached cables. The high resolution of this transducer enables pipeline operators to detect changes in corrosion rates and readjust accordingly scheduled reassessment intervals to suit. Repeat excavations are unnecessary, and the guesswork about re-inspection intervals is removed.

Typical measurement time per transducer is a few seconds. The user can program the instrument to collect data from as many as 50 transducers, or alternatively, it can be programmed to collect up to 1,024 data points from one transducer at programmed intervals. Operation is made very simple by a series of user prompts shown on the LCD display.

The last readings from the handheld instrument may be displayed on its LCD. Readings stored on the portable data logging unit can be uploaded to a PC, where proprietary software is used to organize, store, and graphically display data. Simple plots of thickness, versus time, are augmented with a cursor driven corrosion rate calculator permitting detailed event analysis. The Corrosion Management Software controls the transfer of data from the handheld instrument into a personal computer. It can also convert the data to a CSV (comma separated value) format for export into any spreadsheet program. The software is a powerful application that can perform the above functions and much more.

This system helps solve the problem of monitoring in locations where sensor access is difficult, and will particularly suit buried pipeline operators faced with the problem of ICDA activities. After the initial dig to expose and ultrasonically examine HRHC (high risk, high consequence) locations, these transducers or sensors can be installed on the line, and the excavation backfilled. They can subsequently be accessed for measurement via a test post, located at ground level, above the line. Readings can then be taken every 3 to 6 months to verify the corrosion behavior thereby minimizing or eliminating the need for costly future excavations.

Figure 2 below shows the system diagram and it features:

A) Transducer

B) Signal Cabling
C) Reading Point
D) Handheld Instrument
E) PC Running Corrosion Management Software

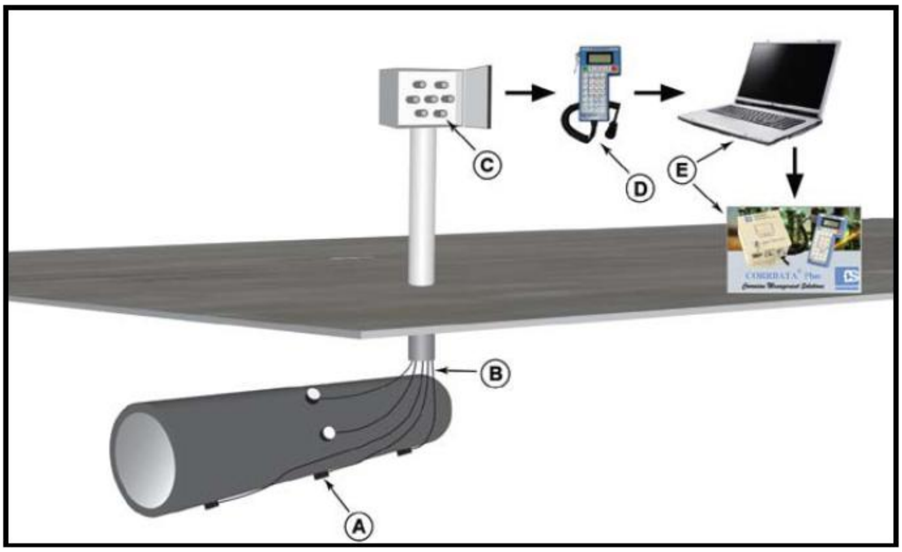

Figure 2 - System Overview

2.2 Field Experience or Successful Histories

Anglo America, explores, mines, process and market copper cathodes, anodes, blister and concentrates, molybdenum concentrate and sulphuric acid, and employ more than 10,000 people throughout Chile. Total production in 2009 was 5% up on 2008 and amounted to 669,814 tons of fine copper, which accounted for 12.4% of Chile's total copper export volume. We also produced 3,886 tons of molybdenum and 457,621 tons of sulphuric acid in 2009. In 2010 an expansion project began. The expansion of the Los Bronces copper mine is the largest mining job in Chile today, and one of the largest ever for Bechtel's Mining & Metals business. Located in the Andes northeast of Santiago, the project includes expansion of a copper concentrator, construction of a new concentrator, crushing and conveying equipment, grinding and flotation circuits, and other equipment. The projects will more than double throughput at the facility.

The project's high altitude—some 3,200 m above sea level—has presented significant challenges. Due to a shortage of oxygen, people's reactions are slower, so they can't move at the same pace as under normal conditions. Everyone coming to the job site must pass medical exams, and some employees have had to go on special diets to lose weight or to reduce their blood pressure so they can handle the altitude.

Bechtel performed an EPC and construction management for customer Anglo American SUR S.A. Since work began in December 2007, Bechtel's project scope has increased by about 40% and now includes managing engineering and construction of two 52 km slurry and water pipelines connecting the grinding and flotation plants.

2.3 Situation

In regarding to internal corrosion/erosion monitor, the project considered to use the most common philosophy used in this industry at that moment in Chile, which is build a buried enclosure with a surface access in order to take measurements with portable ultrasonic equipments. Along over the pipeline were considered 54 locations with buried enclosures with 6 corrosion monitoring points per pipeline. These enclosures were estimated in US$ 3,700,000.00. Additionally to the highest cost, these buried enclosures represented a risk for the person or worker such as flood of the enclosures, tumbles, poisoned animals inside, waste of time trying to open old cover or lock or it is blocked, along with others natural risk. With these buried enclosures, an operator must to go inside and down to carry out the measurements. Figure 3, below, are showing current buried enclosure for an existent pipeline in the same site.

Figure 3 - buried enclosure for an existent pipeline

A summary of pro and cons and risk of the traditional method (buried enclosure and digging) is shown in the table 1.

Table 1 – Summary of pro and cons and risk of the traditional methods

	Buried Enclosure	Digging
Level of difficult to carry out measurements	Rubbish, contact with poisoned insector reptiles, water accumulation	Rocks, cross road, pipeline exact location
Measurement	No accurate because never will be exactly the same point or position. +/- 0.0004 inch	
Damage to the pipeline	Remove coating, material fatigue, damage during the digging up, and constant corrosion potential	
Tools and materials needed	Minors tools and cleaner tools, illumination, escalators	Heavy Trucks, build wall supports, minors tools and cleaner tools
Time to take measurement	Minimum 2 hours	Minimum 6 hours
Trained Personnel	2	5

2.4 Solution

A new ultrasonic technology with permanent sensor and temperature compensation were installed instead to use traditional ultrasonic equipment and buried enclosure or digging up pipelines. Since the corrosive phase or erosion action in the system is in the bottom quadrant of the line, a sensors was installed at 6 o'clock position with two additional sensors offset by 15° and 30° either side; these two sensors should be located such that they are just below the position adjacent to the average liquid / gas interface, tailings concentration, since this is often the region of most intense corrosion or erosion. (Figure 4). These three transducers (probe) of 2,54 mm (1 inch) diameter by 2,54 mm (1 inch) high were permanently mounted to the monitoring point on each location.

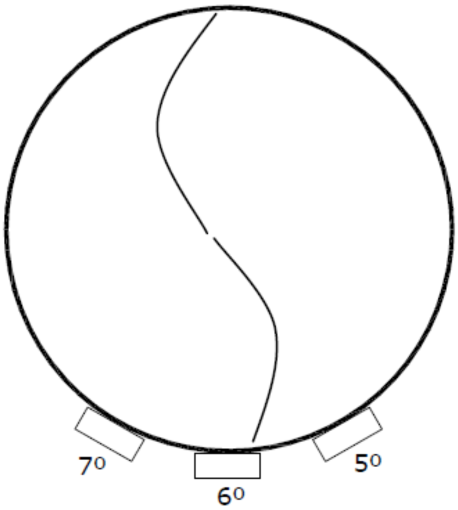

Figure 4 – Position for install 03 sensors

Transducers are to be installed on the bare pipe (Figure 5). So, paint and coating must to be removed in order to install the sensor. This is accomplished using a special adhesive or epoxy which also acts as an ultrasonic couplant. The transducer has a magnetic base to aid in holding it in position while the adhesive cures.

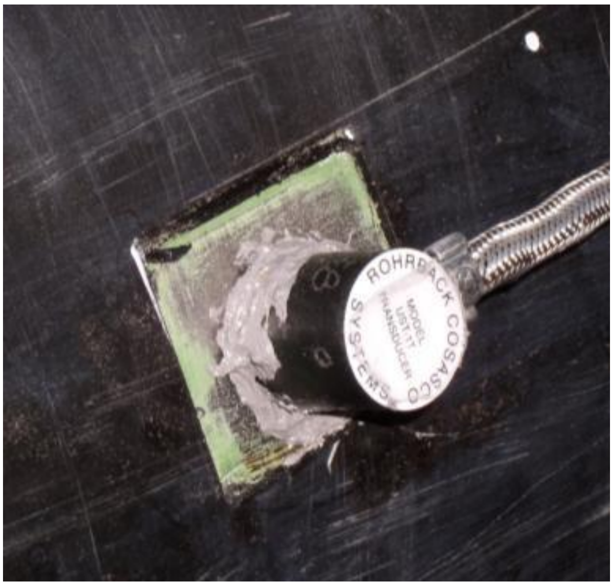

Figure 5 – Sensor installed

After an visual inspection of the site to make sure all the sensors were mounted securely to the pipe wall and no damage was found, the pipe was coated using a two-part epoxy paint for protection.

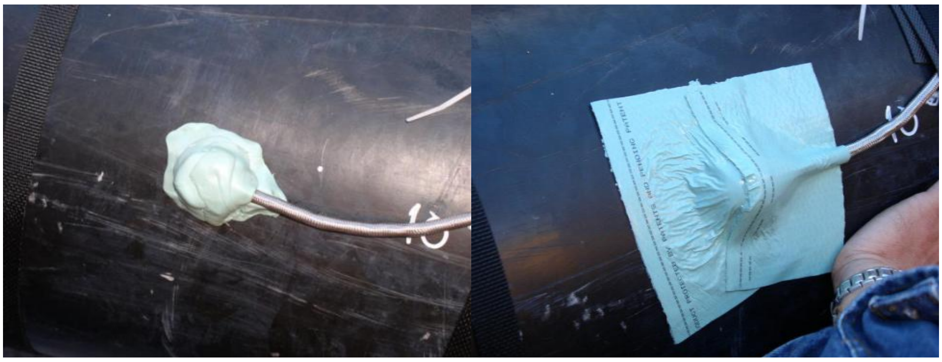

Figure 6 – With repairing kit

The pipe line was now ready for repair. Pipeline repair kit was used on pipe which is well suited for the ultrasonic transducers. This kit is a proven way of repairing pipe and preventing corrosion after the ultrasonic transducer installation. This repair kit is considered a visco-elastic fluid, which means it feels like a solid or rubber, but still has the characteristics of a fluid. These fluid properties allow the material to adhere to the pipe remarkably while providing resistance against cathodic disbonding and giving excellent corrosion protection.

Figure 7 – Finishing the installation

The sensor are by nature non-consumable and, once installed, will last the life of the pipeline, with no need for costly excavations for replacement or repair. Therefore they meet the unique requirements for monitoring buried pipelines. Cables between sensor, and the best test post, may be run for distances up to 60 m and will therefore serve for use even on deeply buried lines..

2.5. Results and discussion

After install all sensors along the 54 km pipeline, first readings was carried out. These are listed in the table below. The results of data were satisfactory. These readings were compared with the current thickness wall of the pipeline which was accepted by the end user as an official values, obviously considering the tolerance of each instruments.

A summary of cost effective between uses the traditional method (buried enclosure and digging) versus new technology is shown in the table 2. This table includes CAPEX for initial construction of the buried enclosure or Ultrasonic equipments:

Table 2 – A summary of cost effective between uses the traditional method (buried enclosure and digging) versus new technology

	New Ultrasonic Technology	Buried Enclosure	Digging
Level of difficult to carry out measurements	Just the difficult of the access road	Rubbish, contact with poisoned insect or reptiles, water accumulation	Rocks, cross road, pipeline exact location
Measurement	+/- 0.0001 inch in just one fixed CM point	No accurate because never will be exactly the same point or position. +/- 0.004 inch	

Damage to the pipeline	None	Remove coating, material fatigue, damage during the digging up, and constant corrosion potential	
Tools and materials needed	Handheld	Minors tools and cleaner tools, illumination, escalators	Heavy Trucks, build wall supports, minors tools and cleaner tools
Time to take measurement	5 minutes	Minimum 2 hours	Minimum 6 hours
Trained Personnel	1	2	5

In view of this, a new alternative and technology in ultrasonic instrument could install for less than 10% of the acquisition of Buried Enclosure or digging pipeline. This new technology represent a simply system and provide better data.

7. Conclusions

The main benefits on this new technology, obviously it costs less than 10% of any other conventional method or technique with better resolution accomplished by the temperature compensation and because it is a permanently installed offering high degree of stability. This allows to this technology follow low corrosion rate faster than conventionally technique.

A summary of the benefits that this new technology is able to offer are the following:

a) Projects CAPEX can be dramatically reduced more than 90%. From to build buried enclosures (each one has a high cost), compared with the final investment made additionally for better and accurate.
b) Practically eliminate OPEX cost such as digging each time measurement is need. Additionally, reduce risk either for the operator, assets and environment during operation or during taking measurement
c) Practically reduce risk involved during taking measurement process. The only risk involve is the natural risk of the road or path to access the place where is the test post.
d) Other benefits is to follow up corrosion rate as low as 0,0254 mm per year (1 mpy) in a reasonable period of time
e) Make process change in cased it is needed.
f) A reliability and continue data base of corrosion rate, very important variable to calculate a long term corrosion rate for the RBI program or Risk Assessment Program.he acknowledgement section, when there is one, must be placed before the list of references.

8. References

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