THE IMPORTANCE OF NON-DESTRUCTIVE TESTING AND INSPECTION OF PIPELINES.

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1. Introduction

While initial capital outlay is important, the ongoing operating costs and maintenance of a pipeline can outweigh the savings made by selecting a pipeline with a lower installation cost but a high risk of failure and a limited working life.

As a result, for the purposes of cost optimization, the need for Non-Destructive Testing (NDT) and inspection during the manufacturing, construction and the operation stage is both inevitable and invaluable. Based on a study conducted by Röentgen Technische Dienst, the NDT industry suffers from a perception that NDT is viewed, in a best case scenario, as a necessary evil. This perception does hurt the industry as it impedes technological advancement as well as it being overlooked by investors as a valued added to a capital investment.

In order to maximize on investments as well as reducing operating costs and maintenance, adequate NDT and inspection by suitably qualified personnel is essential during all stages of pipe manufacture, construction and operation.

The use of the latest inspection methods and equipment will assist in obtaining the maximum life expectancy from a pipeline reducing the overall operating costs.
As a result, the use of fluoroscopy, computed radiography, digital radiography and automated ultrasonic testing, would, in general, improve the probability of detection (POD) of discontinuities. In addition the possibility of operator error and the cost of inspection by saving time and reducing the quantity of consumables used are reduced. That said, the use of these methods is predicated on budgetary constraints and the availability of suitably of qualified personnel.

The objective of this paper is to introduce technologically advanced NDT methods for the inspection of pipelines during manufacture, construction and operation. Some of these methods are digital radiography, automated ultrasonic testing, time of flight diffraction (TOFD), phased array, alternating current field measurement, long range ultrasonic testing, intelligent pigging and three dimensional laser beam measurement of corrosion.

In summary, the oil and gas industry exhibits a proclivity of reducing costs by minimizing the need for NDT. This in turn creates market conditions that erode the prices for NDT services and in turn generates an environment that is more predisposed to maintaining a status quo then an environment that fosters technological advancement and long term thinking. This could, however change, if and when NDT is no longer perceived as a requirement, but as a solution that produces tangible savings by an increase of quality, safety and time.

2. Non-Destructive Testing

Over time various NDT methods were developed, each one having advantages and limitations making it more or less appropriate for a given application. According to recent market studies, modern NDT methods have become more quantitative and less obtrusive, which in many scenarios, translates into savings over time. As a result, these advanced NDT methods have the potential that could lead to significantly lower repair rates while maintaining existing safety standards as long as adequate criteria and procedures are adapted.

As indicated, the industry is weary of replacing well-established and conventional procedures with advanced technology without a time consuming validation effort. However, several international projects have tackled these issues over time, some of which produced some tangible changes. For example, digital radiography is now accepted by ASME and has been used to produce acceptable images on material up to 100 mm thick using Ir-192. Furthermore, under the direction of the International Pipe Line and Offshore Contractors Association (IPLOCA), criteria have been developed for the use of a combination of automated ultrasonic testing and time of flight diffraction on the testing of weld discontinuities on pipeline welds.

With the variety of NDT methods available, it is important to select the method that will provide reliable results. A combination of different NDT tests may be applied to provide assurance that the material or component is fit for use.

2.1. Radiographic Inspection

The equipment required to perform radiographic inspection can be either an X-ray machine, which requires some electrical input, or a radioactive isotope that produces gamma radiation. The isotope offers increased portability as no electrical power supply is required.

Radiation detectors used are image intensifiers in fluoroscopic and real time imaging systems. Electronic imaging panels and phosphorescent imaging screens are used to produce digital images for computed and digital radiography.

Real time imaging can be used online close to the welding station and can detect defects at an early stage thus reducing the amount of faulty welds produced.

The use of phosphorescent imaging plates in digital radiography replaces X-ray film and processing chemicals. They are reusable and the X-ray images are stored electronically on optical disc. These images can be electronically enhanced to increase or reduce density enabling discontinuities which may have previously been undetectable, to be seen.

Electronic imaging panels produce real time images but the panels are flat and rigid and are electronically connected to the image processor thus limiting their portability for in field use. The phosphorescent imaging screens are flexible and are used remotely as is conventional x-ray film. The phosphorescent screens store a latent image which is scanned with an infrared laser scanner. The images are then viewed on a monitor. Functions such as magnification and measuring tools are available for further evaluation of images.

The use of phosphorescent screens requires shorter exposure times which can amount to considerable savings. Lower kV levels are required to produce the images thereby extending the life expectancy of X-ray tubes and allowing isotope sources to be used for a longer period of time. As the exposure times are also much shorter there will be a general reduction in radiation levels.

2.2. Ultrasonic testing

The primary benefit of UT is that it is considered to be a truly volumetric test. That is, it is capable of determining not only the approximate dimensions and location of a defect, but it will also provide the testing technician with information as to the type of defect. Another major advantage of UT is that it only requires access to one side of the material being tested and it will best detect those more critical planar discontinuities such as crack's and incomplete fusion which may not be possible with radiographic testing. Because a variety of beam angles can be used, UT can detect defect which may not be detectable by radiography.

Portable UT equipment is lightweight and often battery-powered. UT requires highly skilled technicians because interpretation of indications can be difficult. Reference standards are required for calibration and setting up of the equipment. Test scans can be recorded by most equipment providing automated scanning.

This test method is generally limited to the inspection of butt welds in materials that are thicker than 6 mm.

Automated UT is often found in pipe mills where the welds are inspected soon after welding, by a multiple array of probes, scanning the entire weld thus detecting any discontinuities at an early stage. AUT is an accepted in-field test method. An array of probes mounted in a scanner is placed on the pipe and the weld area is scanned as the scanner is moved along the weld. An encoder will record the probe position in relation to the distance traveled, which enables the weld to be tested in a shorter period of time, giving a complete volumetric test of the weld and reducing operator error.

Time of flight diffraction is another automated scanning and sizing technique which produces a permanent record of the test. Multiple channels can be recorded and displayed simultaneously for evaluation. The probes are set up to scan different zone areas of the weld in one pass and record the results for evaluation at a later stage. As a result, the inspection is completed in a reduced time and most importantly, it reduces operator error.

Phased Array UT inspection of welds is a relatively new inspection method developed from medical applications. The transducer unit contains multiple elements which can be focused by the timing of the ultrasonic pulses of the different elements. This allows the probe to scan through different angles, scanning the weld in a single pass. The probe distance from the weld can be maintained at a fixed distance and the probe moved along the weld, which results in the scanning of the complete weld in one scan. The results are recorded for later evaluation and this minimizes operator error and reduces inspection time. Once the sound wave is in the material it behaves exactly the same as pulse echo. The difference is the probe where the angle of the sound wave can be “steered” through a range of angles. The electronics of the display is a different and can display a three dimensional image which aids in the interpretation of indications.

2.3. Alternating Current Field measurement (ACFM)

ACFM is an electromagnetic technique that uses induced uniform currents and magnetic flux density sensors to detect and size surface breaking discontinuities. The main advantage of this method is the ability to test through coatings several millimeters thick, the ability to obtain depth information on cracks up to 25 mm (1 in.) deep, and easier testing at material boundaries such as welds. The intensity of a uniform field performance does not drop off very rapidly with probe liftoff, so alternating current field measurement can be used to test through thick nonconductive coatings.

The second advantage is that the larger inducing coil forces currents to flow farther down the face of a deep crack. The same feature occurs with an alternating current field measurement probe but, because the depth of penetration down the crack face is related to the size of the magnetic field inducing coil, the probe can measure more deeply, typically 15 to 30 mm, depending on the probe type. The ACFM method allows for the detection and sizing of fatigue cracks, stress corrosion cracking, hydrogen induced cracking, and corrosion pitting.

2.4. Pipe coating inspection

The surface preparation prior to coating is of prime importance before the application of any coating to any surface. If the pre-requisite conditions have not been met, the durability and life expectancy of the coating may be considerably shortened. The correct application of the coating to the required thickness is also important. As a final test, a pinhole detection check is carried out for air entrapped in the coating which could lead to premature failure of the coating.

The proper and effective preparation of a surface prior to coating is essential. Making sure that the correct surface roughness – or profile – has been generated is essential. If the profile is too low, the adhesion of the coating to the surface will be reduced. It is important that a coating is applied to the correct thickness. Applying too much wet coating will not only waste time and money, but there is also a possibility of the coating cracking during the curing process. Too little coating and there is a chance that the substrate will not be sufficiently covered. To control process variables, it is often desirable to measure the film while it is still wet. Wet film measurements are also useful for systems where the dry film thickness can only be measured destructively.

Premature corrosion of a substrate is usually due to the failure of the coating. A major cause of failure is the presence of flaws in the finished coating. Early inspection for coating flaws will prevent the expense and inconvenience of a coating failure.

2.5. Adhesion testing

Adhesion testing after the coating process will quantify the strength of the bond between substrate and coating, or between different coating layers or the cohesive strength of some substrates. Routine testing is used as part of inspection and maintenance procedures to help detect potential coating failures. The coating may be continuous and look good, but how well is it connected to the substrate?

Tests can be made on flat or curved (concave and convex) surfaces. A reusable dolly is adhered to the coating’s surface and the force required to push the dolly from the surface is applied. The value of the force applied is displayed either on a digital display or on a dial.

3. In-service inspection

3.1. Detection of in-service corrosion

Pipelines world-wide are subject to corrosion and the early detection and measurement of this corrosion plays a significant part in their safe operation.
The methods used today to detect corrosion damage and material loss in pipelines are long-range ultrasonic testing and intelligent pigging which includes magnetic flux leakage.

3.2. Long Range Guided Wave Ultrasonic Testing

Long range guided wave ultrasonic testing is a non-invasive method used for the detection of both internal and external corrosion and erosion in thermally insulated, coated and buried pipelines, corrosion under pipe supports and hidden welded joints.

Use is made of low frequency guided waves to detect corrosion, erosion and material loss in the pipelines being tested. A unit comprising three rings of piezoelectric transducers is clamped around the pipe and ultrasound is sent first in one direction along the pipe and then in the other direction. The signal obtained is similar to a conventional ultrasonic A-scan, where the horizontal axis represents distance along the pipe and the vertical axis represents signal amplitude, which is indicative of the severity of the corrosion.

Although propagation distances vary according to pipe geometry, contents, coating, insulation and general condition, in ideal conditions, it is not unusual that a range of up to 30m in either direction from the transducer belt can be inspected. However care must be taken as this distance is substantially reduced for buried pipelines and pipelines with heavily attenuating coatings. The technique is equally sensitive to internal and external corrosion.

The principal advantage of this technique is that it provides 100% initial screening coverage, and only requires local access to the pipe surface (i.e. removal of a small amount of insulation) at those positions where the transducer unit is to be attached. It is suitable for use on pipe diameters above 50mm (2.0") and on wall thicknesses up to 40mm.

3.3 Intelligent Pigging

Pipeline pigs are intrusive devices that are inserted into and travel throughout the length of a pipeline driven by product flow. They were originally developed to remove deposits which could obstruct or retard the flow through a pipeline. Nowadays pigs are used during all phases in the life of a pipeline for cleaning purposes and for internal inspection.

The pigs used as in-line inspection tools provide information on the condition of the line as well as the extent and location of any problems. Intelligent pigging uses ultrasonic thickness measurement and magnetic flux leakage methods to determine areas of corrosion, pitting, erosion and cracks.

As a result, the magnetic flux leakage technique leads to a substantial time and financial savings, which has been used for the testing of hundreds of kilometers of piping in the desert. The evaluation of the data has shown that a testing rate of 1 km per day was easily achieved - a rate far greater than that achievable through conventional wall thickness measurements.

3.4. Three dimensional laser profile measurement

Three dimensional (3D) laser profile measurement of the corroded surface has proven to be a rapid and accurate method of measuring corrosion depth and the related software programs enable on site reporting, corrosion mapping and finite element analysis.

Once the area of corrosion has been located by long range ultrasonic testing or intelligent pigging, the pipeline may be excavated in the case of a buried pipeline, or the insulation removed in the case of a pipeline above ground. The protective coating or wrapping must be removed to expose the area of corrosion. The surface must be cleaned removing all protective coatings, scale, rust and any contamination, which could interfere with the accuracy of the laser-beam measurements to be made.

Scanning of the corroded surface is rapid and accurate with the scanned area being viewed on the computer monitor to ensure full coverage of the area being scanned. The scanning arm has several encoders which are able to give the co-ordinates of any measured position and thus build up corrosion maps of the surface. The laser beam scanner takes 69,000 measurements per second.

The benefits of laser beam scanning far outweigh the mechanical methods of measuring due to accessibility, accuracy and speed. Where older mechanical means of measuring are not possible or difficult be used on some curved surfaces such as bends, nozzles and compensating rings this problem is eliminated by laser beam scanning.

Reports are generated on site. Out of roundness measurements can be taken of the pipe circumference creating references on the scan data for the determination of the best fit cylinder enabling finite element analysis calculations to be reported.

Color plots of critical areas are obtained and X and Y cross sectional views can be obtained from the display of the corroded area indicating the worst case scenario. Corrosion measurement and analysis can be done on any accessible surface with an accuracy of <0.07 mm and on site reports generated.

Internal corrosion can be differentiated by ultrasonic thickness measurement of the internal surface by a thickness measurement probe attached to the mechanical scanning arm. Automatic importation of ultrasonic thickness measurements with X, Y and Z probe positioning coordinates on scan data enable the condition of internal surfaces to be included in the report.

The analysis of the report will allow the best repair method to be determined. When comparing previous measurements of the same area an accurate rate of corrosion can be determined by the 3 dimensional data recorded. Determination of corrosion may be interpreted and analyzed with software and data processing in accordance with different codes and specifications. Computer generated reports will indicate the surface corrosion using a color depth scale and also a graphical worst case profile.

3D corrosion measurement used during risk based inspections is a rapid cost effective method of determining the integrity of the pipeline or plant enabling finite element analysis to be completed in a short space of time allowing qualified engineering decisions

4. Conclusion

Making use of the latest technology, such as digital radiography can result in considerable savings for the user in time as well as consumable costs and also enhance the probability of detection of defects.

Automated ultrasonic testing that utilizes TOFD and phased array produces recordable results and a permanent record, which can be evaluated by third party inspectors at a later stage. Mostly importantly, this tangible benefit translates into a reduction of operator error and substantial time saving, which is derived from the high testing speed.

Long range ultrasonic testing is a good screening tool for surface or insulated pipelines and will reveal suspect areas for further evaluation by other methods. An ideal example for what a great money saver this method is the testing of pipe crossings underneath roads and other short pipe lengths on pipe sleepers which are unable to be pigged or the use of pigs would be consider an overkill due to the associated costs.

Intelligent pigging is extensively used for the evaluation of corrosion in pipelines and can be used on all pipelines fitted with pig launching facilities.

Three dimensional laser beam profile measurement of corrosion is an extremely accurate tool for the measurement of the corrosion depth and location, finite element analysis and on site report generation allowing qualified engineering decisions to be made.

Use of the above methods assisted in the development of risk assessment strategies and pipeline integrity management programs.

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Non-destructive Testing of Pipelines. January 2001. AuthorsÂ This paper shall present different, contemporarily available non-destructive testing (NDT) methods of pipelines and compare them to each other from the technical and economical point of view. An evaluation of their suitability for CERN activities, based on the opinions and experience of various specialists at CERN (LHC, ST, TIS), is also introduced. Non-destructive test (abbreviated, NDT) used to evaluate the physical and mechanical properties of a welded connection without damaging the equipment. The most common non-destructive tests are visual inspection, penetrating fluids, magnetic particles, radiographic (RX) and ultrasonic examination (UT). Types of non-destructive testing.Â Even if a weld is to be examined by more-accurate methods of inspection, it should be subjected to the basic visuals, because of their low cost. Also, if imperfections are detected visually, an additional examination can be intensified around this area of concern. Liquid Penetrants (LP). Non-Destructive Testing (NDT) is the application of measurement techniques in order to identify damage and irregularities in materials. NDT often provides the only method of obtaining information about the current 'health' of process plant. If done well, NDT can provide useful information to assist in the management of plant safety. Non Destructive testing (NDT) and inspection services are important if you donâ€™t want the usefulness of your equipment, materials, or components changed or destroyed in any way. NDT is a comprehensive way to find, size, and locate surface and subsurface flaws and defects that could have an adverse impact on safety, reliability, and the environment. NDT plays a crucial role in everyday life for companies using pipelines, bridges, refineries, oil platforms, power stations, and more. Itâ€™s a quality assurance management tool to help companies make sure theyâ€™re following standards and regulations a