"Deployment of Smart Ultrasonic Sensors for Internal Corrosion Monitoring using Internet of Things"

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ABSTRACT

Equipment inspection and monitoring for any signs of internal corrosion are vital activities for safe operation in the Oil and Gas industry. The aim is to determine corrosion rate, location and likely causes to ensure Fit for Service (FFS) or if early intervention is needed. A well-managed plan is set to avoid an uncontrollable release of flammable products with the potential to cause a fire, explosion, environmental disaster, and loss of personnel. These incidents can have a huge effect on company reputation, budget and its ability to stay in business.
Since the dawn of the industry there has been a need for procedures / devices able to ensure that internal corrosion was not an issue. At the time, procedures to create a "mechanical fuse" were developed. Tell-Tale holes were common, aiming to fail before a major release occurred.
Later, new intrusive devices were invented: Corrosion Coupons, Corrosion Probes. Their main objective was measuring a Corrosion Rate (CR) from inside the equipment and to some extent (by coupons) types of corrosion (i.e. pitting or uniform). These were combined with non-intrusive apparatus like Ultrasonic Thickness Measurement (UTM) Meters able to measure equipment's remaining thickness. Therefore, FFS calculation could have been performed.
New Deployment of Smart Ultrasonic Sensors are now available taking advantages of what is called Internet of Things (IoT). This basically improves a proven method (UTM), by removing the operator (major source of data errors) and adding data logging, allowing analysis and trending of data, online on a cloud environment from anywhere in the world using a Laptop, Tablet or Smartphone. Reports can be customise including flagging alarms of integrity status without dispatching technicians to dangerous, remote or inaccessible sites improving asset integrity and productivity while increasing safety.

1 INTRODUCTION

Since the foundation of the Oil and Gas Industry, inspection and monitoring for any sign of internal corrosion have been considered vital activities to ensure equipment integrity. The aim has been to confirm if internal corrosion is occurring, and if it is, to calculate the rate of corrosion, locations where it is expected to arise, and likely root cause (s). This led to the importance of inspections and collection of quality monitoring data. Using this data, Fitness for Service (FFS) calculation for vessels, pipelines or other plant equipment are made. It is therefore possible to determine if it is safe to operate and when maintenance/replacement is necessary.

In the early days, engineers confronted with internal corrosion recognized the need for procedures / devices capable of indicating the "health" of pressure containment equipment to effectively manage process safety and business risks. Our peers at the time came out with the idea of a "mechanical fuse" in the form of a Tell-Tale Hole (TTH) drilling. This is a pre-drilled hole of certain depth into the pressure envelope of vessels from the outside diameter surface. Once internal wastage reaches this depth due to heavy corrosion, erosion or mechanical abrasion, a small leak will occur. The ultimate goal of a Tell-Tale hole was to avoid an uncontrollable release of flammable products which potentially could cause a fire, explosion, environmental disaster and loss of personnel. A leakage from any of these purposed “pilot” or “weeper” hole provides a “controlled release warning” that the pressure containment has been compromised to the predetermined allowable minimum wall thickness. This process is still used to this day in some refineries [1].

During the forties and fifties, a lot of research occurred with the focus of developing reliable methods for monitoring internal corrosion. Intrusive systems like Corrosion Coupons (CCs) started to become popular after 1950, when the 2" access fitting was introduced together with the first high-pressure retriever tool making on line extraction of them possible [2]. The main objective of a coupon is to estimate corrosion rate of the system. A coupon is a piece of material of known shape and weight (with composition similar to the equipment being monitored), expose to equipment operating conditions for a period of time. After the set time elapsed, the coupon is retrieved and re-weighted with any loss of mass associated to internal corrosion. Over the years, standards procedures were developed to normalize approach of this industrially accepted method, for manufacturing, installing, and examining results. This included the calculation of corrosion rates from corrosion coupons [3, 4].

Another intrusive method developed at a later stage (taking advantages of the 2” access fitting and retrieval tool mentioned) was the Electrical Resistance Corrosion Probes, normally referred to as “ER probes”. They are based on the principle that a wire will increase its resistance to current flow upon reduction of its cross section. As with corrosion coupons, the probe is equipped with a sensing element which is a material having similar characteristics to that of the equipment being monitored. A baseline resistance reading of the sensing element is taken upon installation as a reference reading. Any increase of sensing element resistance going forward is associated to metal loss and a corrosion rate can be estimated.

Over the last 50 years different Non-Destructive Testing (NDT) methods for internal corrosion monitoring have been applied like Ultrasonic Thickness Measurement (UTM), Radiographic Testing (RT) or In Line Inspection (ILI) Tool for piping (Pigging). Also, process stream sampling for chemical analysis to measure key parameters like Iron counts , pH, chlorine, conductivity, Total Dissolved Solids (TDS), O_2 content, bacteria enumeration and other elements have been applied as monitoring tool to gather data about process corrosiveness. Today, any process plant will have a combination of the above (intrusive and non-intrusive) techniques for its assets monitoring and inspections to ensure internal corrosion is not a threat for pressure containment.

This paper will focus on the application of non-intrusive Ultrasonic Thickness Measurement, for internal corrosion monitoring, emphasizing the advantages of the Deployment of Smart Ultrasonic Sensors using the Internet of Things (IoT) to manage the data collected. This new monitoring approach, basically, improves a proven method (UTM) that has played a key role in the Oil and Gas industry since its first patent was granted back in 1940 [5]. This new system removes the NDT technician (major source of data errors). variability of equipment used and thickness monitoring location (another known source of errors) whilst also adding data logging. This innovation allows for analysis and trending of data, online in a cloud environment from anywhere in the world by connecting to the internet. Reports can be customised to include flagging alarms of integrity status without dispatching technicians to dangerous, remote or inaccessible sites improving asset integrity and productivity whilst increasing safety.

2 NON-INTRUSIVE INTERNAL CORROSION MONITORING ULTRASONIC SMART SENSORS USING INTERNET OF THINGS (IoT)

The use of ultrasonic thickness measurement for internal corrosion monitoring is a well-known and industry accepted approach with over 70 years of use. It is a solid pillar to the foundation of any plant monitoring system. It is simple and provides a direct non-intrusive measurement of thickness remainder, therefore, UTM is key for corrosion rates calculation as well as Fitness for Service assessment.

The new system described in this paper pertain to the application of "conventional" ultrasound for thickness gauging coupled with the use of Internet of Things (IoT) in a Cloud environment.

Before describing the system, a definition of IoT is necessary. Recommendation ITU-T Y.2060 [6] from ITU[1] defined IoT as:

> 'A global infrastructure for the information society, enabling advanced services by interconnecting (physical and virtual) things based on existing and evolving interoperable information and communication technologies'.

The Internet of Things is rapidly becoming popular, as, through the installation of low-cost sensors and actuators into equipment (for data collection, monitoring, decision making, including process optimization) and bringing them into the Internet, businesses are able to gain a competitive edge [7]. However, it is not a recent discovery. Gathering equipment data relating to their operation and condition using sensors has been on the market for more than 20 years [8]. Internet of Things is in the spotlight today due to the massive growth in mobile devices and applications, in parallel with widespread wireless connectivity. These facts are responsible of a massive expansion of worldwide coverage, bringing prices down rapidly, and changing the way to communicate over Internet Protocol (IP) networks.

Another significant factor triggering this popularity has been the advent of the Cloud as a lane to easily store, share and process large volumes of data. The Cloud provides an avenue to use internet-based analytics technologies, allowing businesses to customize how they manage and extract relevant information from huge volume of data rapidly, with minimal or no local software or processing power needed, thus making the entire process very cost-effective [7, 8].

Internet of Things and the Cloud are considered "Disruptive Technologies"[2] with an estimate forecast impact to the world economy in 2025 of US $ 2.3 to 6.2 trillion and 1.7 to 6.2 trillion respectively, with a combine effect of US$ 4 to 12.4 trillion (Figure 1) [7]. A business survey conducted in September 2014 on early adopters of these platforms asked about potential areas being considered for the deployment of Internet-of-Things-based solutions during the next 18 months [8]. The five top areas on the list were as follow:

- Remote Asset Management and/or Asset tracking,
- Security,
- Energy Data Management,
- Condition-Based Monitoring and
- Fleet Management.

Figure 2 demonstrates the results. It can be seen that 36% of total surveyed are looking at Internet of Things initiatives for Remote Asset Management and/or Asset tracking, and 21% are doing the same for Condition-Based Monitoring proposals [8]. This reinforces the relevance and timing of the "Deployment of Smart Ultrasonic Sensors for Internal Corrosion Monitoring using Internet of Things" presented in this paper.

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[1] International Telecommunication Union

[2] Technologies that have "the potential to disrupt the status quo, alter the way people live and work, rearrange value pools, and lead to entirely new products and services"[7]

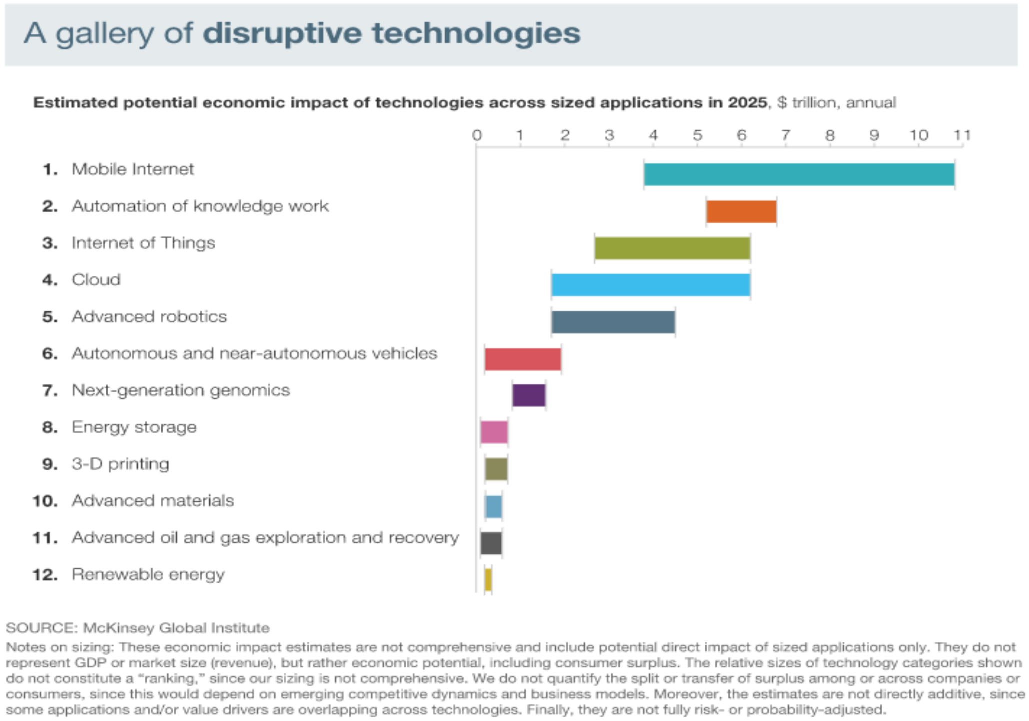

Figure 1.- Disruptive Technologies Estimated Potential Impact to World Economic in 2025. Reprinted from *Disruptive Technologies: Advances that will Transform Life, Business and The Global Economy*. *Slideshow* (exhibit 1) by McKinsey Global Institute Report, May 2013, McKinsey Global Institute. Copyright 2013.

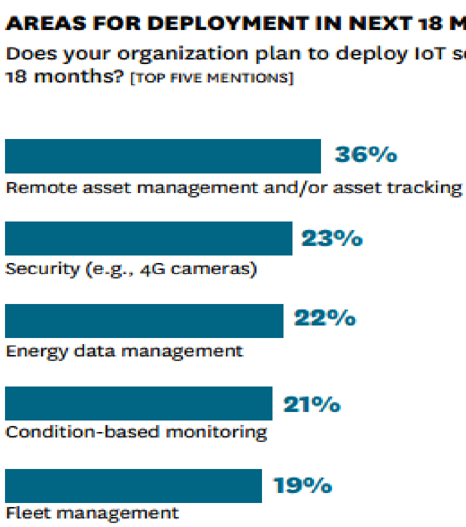

Figure 2.- Top Five Business areas for IoT based initiatives Deployment from a September 2014 Survey on early IoT adopters Companies. Reprinted from *Internet of Things: Science Fiction or Business Fact* (p.4) by hbr.org/hbr-analytic-services, September 2014, Harvard Business Review. Copyright 2014.

2.1 ULTRASONIC THICKNESS MEASUREMENT (UTM) USING SMART ULTRASONIC SENSORS

As stated, UTM using smart ultrasonic sensors is based on the same theory that has been used over the years for ultrasonic thickness gauging and corrosion rate monitoring. It will propagate ultrasonic pulse-waves through the material been tested by the use of a sensor or transducer attached to the surface either permanently or temporarily. Figure 3 below shows the ultrasonic principle on which the system is based. A transducer -made of a crystal with the capacity to convert electrical energy to high-frequency acoustic or ultrasonic energy and vice- versa- is used in intimate contact to the surface of the object being tested. The transducer is excited by an electrical pulse to generate a stress wave through the object. This wave will travel until it reaches the back wall of the object or a defect, returning echoes back which are converted to voltage. This reading is measured and recorded by the ultrasonic instrumentation that is attached to the transducer. The transit time between the initial pulse and return echoes (or between successive echoes) is used to calculate wall thickness, when the velocity of sound on the object being tested is known. Physical indications such as the actual object wall thickness, or the remainder thickness on a defect or corroded area (e.g. pit, crack, blister) can be very accurately measured with this technique.

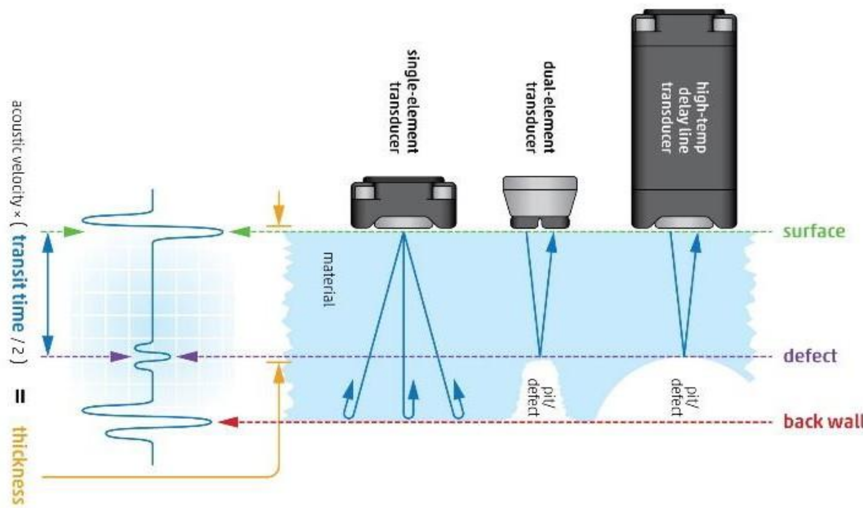

Figure 3.- UTM principle measures transit time between the initial pulse and return echoes is used to calculate wall thickness. Physical indications such as actual wall thickness, or remainder wall thickness on a corroded area (e.g. pit, crack, blister) can be very accurately measured [9].

2.1.1 System Description

The concept was to develop a flexible and cost-effective system capable of handling deployment of hundreds to thousands of ultrasonic transducers (sensors) for standard ultrasonic thickness measurement data collection. This data is used to assess internal corrosion by continuous monitoring. The equipment that is being monitored will be fitted with one or more transducers (sensors). These sensors will connect to each other and to systems that can understand or present information from the sensor's data feeds. Connection will be by means of IoT solutions, in both wired and wireless versions, using industry-standard communication protocols. This allows for integration with existing plant equipment and Data Control Systems (DCS) or a backhaul to an Internet Provider network, like a Cloud-based database using cellular or wireless connectivity. A schematic view including wired and mobile (cellular) wireless transmitters, transducer (Sensor) types and tablet PC for either manual or fully-automated data collection is shown in Figure 4. The explanation of each system component shown in this figure is presented on points 2.1.1.1 to 2.1.1.7.

2.1.1.1 System controller

A tablet PC, industrial computer, or remote terminal unit (RTU) depending on whether the data collection will be manual, automated or integrated with a plant control system can be acting as the system controller. The system controller communicates with the network of Digital Sensor Interfaces or "DSIs" via Modbus over a RS-485 cable, which is a well-known industrial instrumentation practice. The system controller then transmits the data to an IP server where it can be viewed, analyzed and/or stored for trending. For wireless systems, the system controller is not needed, as data is sent to the IP server by a cellular (mobile) transmitter.

Figure 4.- Schematic view including wired and cellular (mobile) wireless transmitters, transducer types and tablet PC for either manual or fully-automated data collection [9].

2.1.1.2 Digital Sensor Interface (DSI)

It is a dedicated instrument box for ultrasonic data collection equipped with a CPU[3] that can handle up to 16 transducers. The box is programmed for pulsing and receiving data from the transducers, digitizing the collected data and converting the digital ultrasonic data into thickness values then transmitting it to the system controller. The DSIs can be set up in a multi-drop network of up to 32 DSIs daisy-chained, giving room for a maximum of 512 individual transducers. When a cellular (mobile) is selected, as mentioned, there is no need for a system controller as the DSI will have room for a SIM[4] Card and data will be uploaded to the Internet Provider network by wireless connection through the protocol of the mobile service provider.

2.1.1.3 Sensors (Transducers)

The ultrasonic sensors (transducers) are just piezo-electric[5] ceramic materials that upon an excitation pulse will transmit and receive ultrasound. They can be manufactured in several models and types, such as according to equipment operational conditions, mechanical properties and likely corrosion mechanisms expected. For example, dual-element sensors are the optimal selection for thin measurements (< 2.5 mm or 0.100”) and highly-pitted back-wall surfaces. Sensors can be set randomly, or in square or linear array, allowing the corrosion engineer to install them based on known trouble locations or expected damaged mechanisms (e.g. elbow extrados, bottom of lines / vessels, injection nozzles, among others). They can be magnetically attached or clamped to the monitored piping or equipment. Table 1 below presents the different smart sensors models available including their technical specifications and recommended application.

[3] Computer Processing Unit
[4] System Identity Module
[5] A material that can convert electric pulse into mechanical waves of sound and vise-versa

Table 1: Technical Specifications of Different Smart Sensors Available

	single-element contact	dual-element contact	delay-line contact	matPIMS
model	XD-101	XD-301	XD-201	XD-401
application	general purpose	severe pitting	ultra-high temp	general wall loss
frequency	5 MHz	5 MHz	7 MHz	7.5 MHz
active area (dia.)	0.25"/6.35mm	0.375"/10mm	0.375"/10mm	0.25"/6.35mm
overall (dia. x h)	1.0 × 1.0" 25.4 × 25.4 mm	0.75 × 0.75" 19 × 19 mm	0.8 × 2.25" 20.3 × 57.2 mm	1.0 × 9.12" 25.4 × 231.6 mm
# of transducers	1-16	1-8	1-16	16 (1 reference, 15 active)
resolution	0.001"/0.025mm	0.001"/0.025mm	0.001"/0.025mm	0.001"/0.025mm
thickness range†	0.200-6.0" 5.1-150.0mm	0.040-6.0" 1.0-150.0mm	0.125-1.0" 3.0-25.0mm	0.125-6.0" 3.0-150.0mm
temp range	-5 to +150 °F -20 to +80 °C	-5 to +300 °F -20 to +150 °C	-5 to +932 °F -20 to +500 °C	-5 to +150 °F -20 to +80 °C
attachment	magnet/adhesive	magnet/adhesive	mechanical clamp	adhesive

†*minimum resolutions stated as typical values, but will vary with pipe condition*

2.1.1.4 Couplants
It is known that for an ultrasonic thickness measurement system to work, the sensor must have an intimate contact with the surface of the material being tested without any air gap. As the sensors are intended to stay in place for long periods of time (regardless of if they are considered permanent or temporary installed), a liquid couplant normally applied during manual UTM cannot be used. The smart sensor system will stop taking any reading as soon as the liquid dried out. To overcome this issue, different solid couplants have been assessed. Three options have been chosen to cope with the range of temperatures that the sensors can handle, as follow: dry coupled to the pipe using a proprietary elastomeric material (for standard temperatures i.e. -20 to 65 °C), adhesively bonded (for temperature up to 150 °C), or clamped with gold metal foil (for temperatures up to 500 °C).

2.1.1.5 Temperature measurement device
To achieve the most accurate and precise readings using ultrasound, it is necessary to correct the ultrasonic velocity for changes that occur due to fluctuations in asset temperature (Refer to Table 2). Changes in temperature have an effect in the velocity of sound, which therefore varies the value from the true thickness. The system incorporates a Resistance Temperature Detector (RTD) that can be placed on the asset adjacent to the ultrasonic transducers to correct the readings.

2.1.1.6 Data reporting
The system includes a cloud-based software for data management allowing access to thickness and corrosion-rate data from any connected device with an internet browser. Each sensor can be configured with up to six hierarchy levels of tagging. As a result, accurate and near real-time data reporting from the sensor locations is achievable. Furthermore, the system is able to issue alerts via email or text message, identifying the precise sensor (s) where the thickness or corrosion rate is triggering the alarm level. Hosting may be carried out by any internet cloud provider or on a company's intranet.

Data collection can be done manually using a portable tablet PC solution, allowing data and report files to be emailed from the device or sent to the cloud-based software. This can be completed when back at the office. In the case of Sensors Cellular (Mobile) Wireless System, data is sent to the cloud-based software by “hands-shaking” between the Digital Sensor Interface unit and the cellular (mobile) tower at the frequency set (e.g. 2X day, 1X day, 1X Week). The regularity of data transmission is based on a compromise between minimum frequency needed and battery life usage.

2.1.1.7 Data Accuracy, and Precision

Ultrasound thickness gauging equipment uses different methods to do the measurement calculation. This is normally programmed as a routine into the circuitry of the gauge.

For the deployment of smart sensors a tablet loaded with a software called DataPIMS is used for commissioning and data logging of Modbus Wired System (refer to figure 5). For Cellular (Mobile) wireless system, the DataPIMS loaded tablet is only needed for commissioning, as data will be going straight to the internet provider network (refer to figure 6).

It is known that Ultrasonic Thickness Measurement can provide very accurate and precise thickness values of equipment tested when all factors that impact on quality of these parameters are controlled to reduce variability. These devices typically have a display resolution of 0.025mm (0.001”) with precision gauges usually showing a resolution as low as 0.0025mm (0.0001”) [9]. However, the UTM field accuracy and precision is another story, as it has been shown to be orders-of-magnitude worse, primarily due to operator and equipment variability [9]. In Table 2 a list of the most relevant factors affecting precision and accuracy of UTM field measurements are presented. It is noted that majority of factors affecting accuracy and precision can be eliminated by the installation of Smart Ultrasonic sensors. Other factors (like echo quality and surface roughness) can be controlled, as a case by case, through optimization of the application and selection of sensors based on corrosion type [9].

Table 2.- Factors Affecting Gauge Accuracy and Precision in the Field* [9]

Accuracy	Precision
Operator variability	Operator variability
Sound velocity and acoustic zero calibration	Velocity and acoustic zero cal (msmt to msmt)
Echo quality	Echo quality
Sound velocity uniformity	Electronic or ultrasonic noise
Surface roughness	Transducer placement variability
Transducer coupling variability	Transducer coupling variability
Temperature variation	Temperature Variation

* Parameters in green are eliminated or reduced with smart Ultrasonic sensors

Figure 5 shows a schematic view of the typical arrangement used in the Deployment of a Smart Sensors Modbus wired Manual System. As illustrated, the smart sensors system allows for data collection outside of hazardous or difficult to reach areas, which would be unavoidable for normal manual ultrasonic thickness measurements. Data collection from sensors can be done by running a wired from the Digital Sensor Interface (DSI) to a Nema box installed in a “friendly zone”, providing easy and safe access to the data.

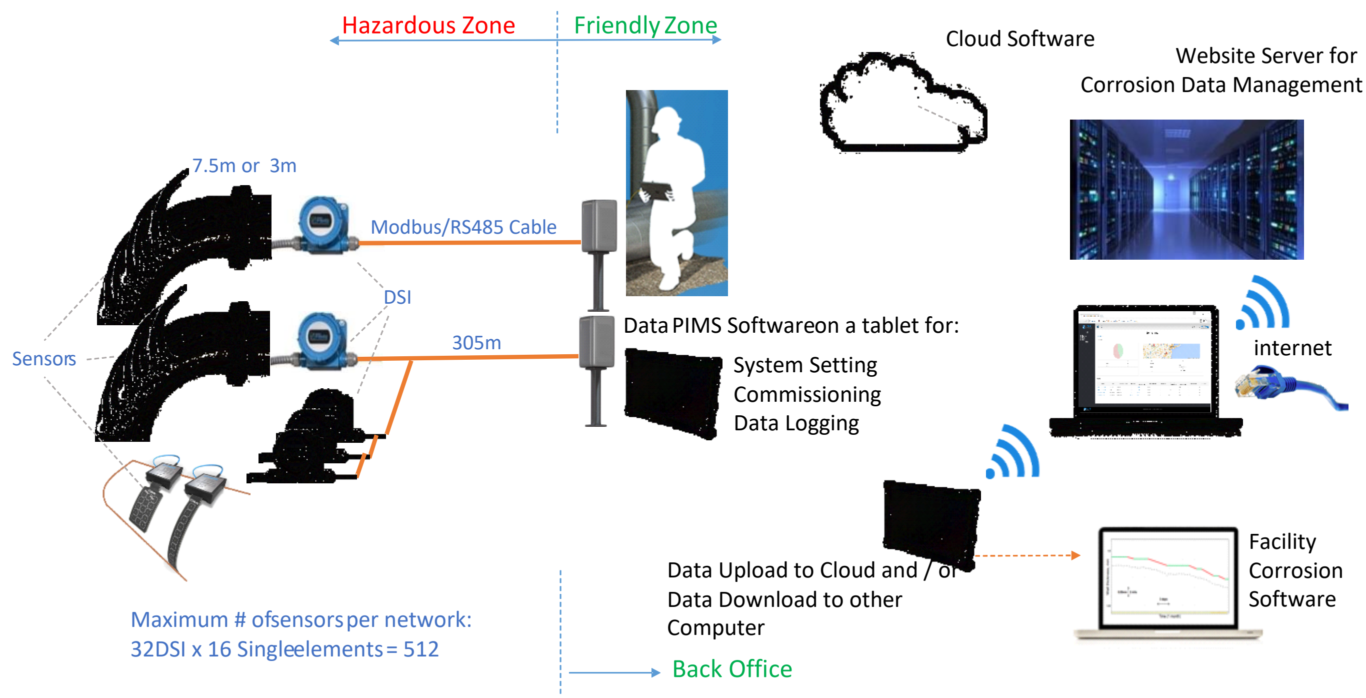

Figure 5.- Schematic view showing typical components integration for deployment of a Smart Sensors Wired Modbus System.

While Figure 6, shows a schematic of typical arrangement for Deployment of a Smart Sensors Cellular (Mobile) wireless Automatic System. It is noticed, that on-site installation is faster than the Modbus wired system as there is no need to run cables and install a Nema box for data collection. Data starts to flow to the internet provider network, customer data server, or intranet, immediately at the frequency deemed necessary by the asset owner.

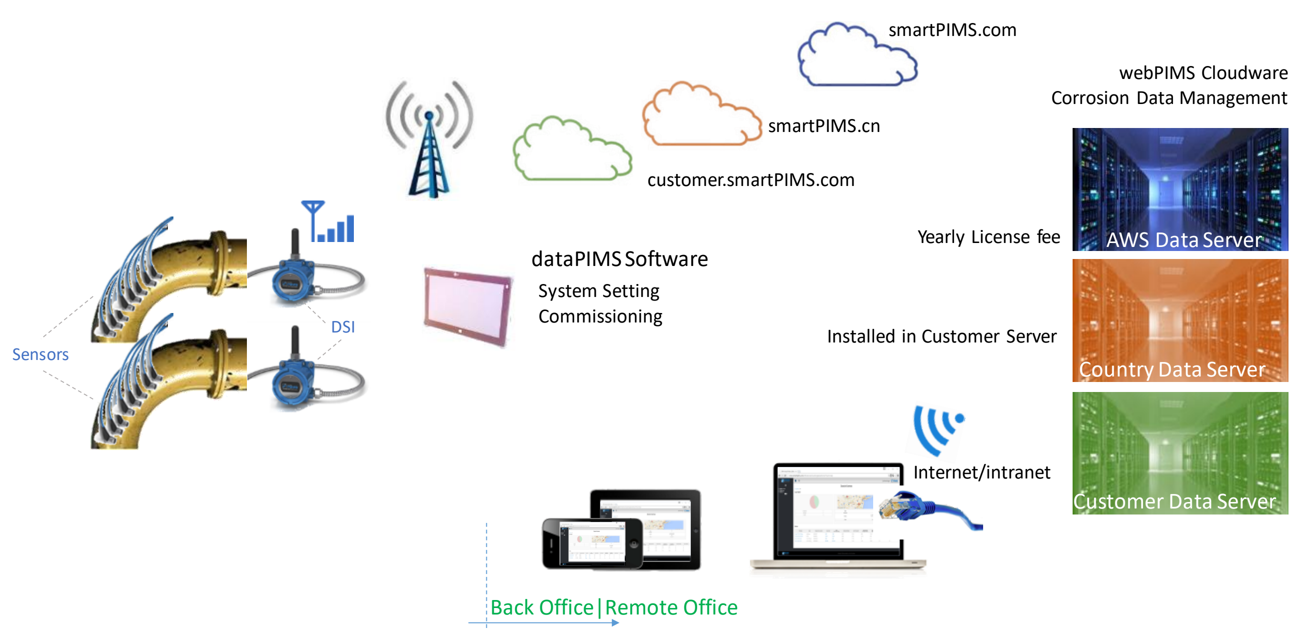

Figure 6.- Schematic view showing typical components integration for deployment of a Smart Sensors Cellular (Mobile) Wireless System.

3 ADVANTAGES OF SMART ULTRASONIC SENSORS SYSTEMS USING INTERNET OF THINGS

Smart ultrasonic sensors are emerging as a new technology to compete with manual Ultrasonic Thickness Measurement inspections and existing or traditional corrosion-rate intrusive monitoring solutions like corrosion coupons and ER probes. The main benefits are the use of the proven UTM technique for quality high frequency data collection, whilst combining a non-invasive installation with the ability to operate remotely without operator interaction, subsequently cutting personnel access costs over time by using Internet of Things.

3.1.1 High-Frequency & High-Quality Data

A major advantage of smart ultrasonic sensors is the ability to collect a larger quantity of high-quality thickness data. This is possible as the equipment used and location targeted after the sensors are installed is set. This is backed up by the 3000-value storage capacity built into the Digital Sensor Interface units. Having 1X per day or even 2X per day reading is not an issue for these smart ultrasonic sensor systems. This would be impractical or too costly from manually-collected measurements.

It is known that corrosion metal losses are rarely constant and can vary between periods of virtually zero corrosion to episodic events causing high corrosion rates [9]. The smart sensor systems (either when permanently or temporarily installed), can produce large amount of data that allows visibility to the dynamics of the wall thickness reduction process. Smart sensors allow for setting targets for minimum wall thickness or acceptable corrosion rate. After a target is hit, an alarm is triggered, and an e-mail is sent to asset owners for action almost in real-time. More quality data also means that numerical tools such as data filtering and linear regression are easily deployed in the cloud-solution software to do corrosion rate calculations.

3.1.2 Internet of Things

Cloud data allows for alarm settings, e-mail warnings, flagging potential issues for maintenance planning practically in real-time. Data can be accessed from anywhere in the world, using any device that can connect to an internet provider network. Alternately, data can be integrated with company corrosion software as it is readily available either on the network for wireless cellular (mobile) systems, or from a table for wired manually systems (refer to Figure 5 & 6). Integrity status can be known without dispatching technicians to dangerous, remote or inaccessible sites.

3.1.3 Installation

Instrumentation and sensors can be deployed on the equipment in a permanent or temporarily mode and access to locations inside hazardous or difficult to reach areas is only needed during initial installation (including wired Modbus systems), as the collection point can be move to a friendly zone away from these challenging areas (refer to Figure 5). The system can also be rapidly installed without welding, ensuring sensors can be easily moved for short term installation.

3.1.4 Save in Opex budget

The system allows for asset managers to use resources only when needed, eliminating the repetitive cost of access – scaffolding, lagging /delagging, offshore access (e.g. Flights, accommodation, training), personnel costs (crew daily rates).

3.1.5 Improve Ultrasonic Thickness Measurement Accuracy and Precision

Removes significant sources of error due to the fixed sensor position and instrumentation. The variability on results caused by operator-to-operator, probe-to-probe, and instrument-to-instrument is eliminated (Refer to Table 2).

4 FIELD APPLICATION SHOWING BENEFITS OF DEPLOYMENT OF ULTRASONIC SMART SENSORS USING INTERNET OF THINGS

4.1 Atmospheric Gas-oil Line

4.1.1 Overview

During a shutdown this line was found to have an area with low wall thickness. It was not part of the scope of the turn-around. Asset owner wanted to extend life to next turn-around and make sure that line is no longer corroding.

4.1.2 Details

Atmospheric gas-oil, operation temp. 270 °C, 80 mm Schedule 40 (5.5 mm Nominal Wall Thickness), subject to severe but uniform corrosion, most piping is < ½ nominal thickness (2.7mm).

4.1.3 Product Used

- A Digital Sensor Interface Cellular (Mobile) wireless system with 4 High Temperature Sensors (SmartPIMS) probes temporarily attached, managed by on-site service provider.
- Monitoring interval set: 4 hours.
- Data is monitored & trended daily using cloud based software (webPIMS) available through Internet Provider network.
- Installation time: 6 hours.

4.1.4 Outcome

By installing the smart sensors system the refinery achieved the following benefits:

- Personnel can safely monitor process piping internal condition that otherwise would have required to perform inspection at high temperature.
- Replacement of line can be planned, avoiding the need to extend turn-around schedule and losses due to production deferrals.
- More data available to monitor trend and plan repairs that would have been risky, impractical or too costly by manual inspection.



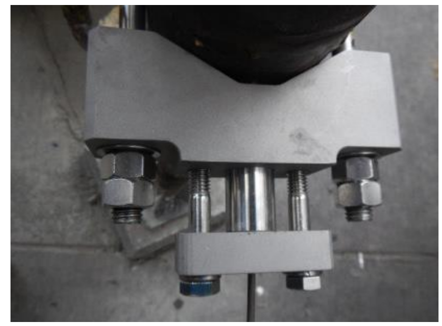

Figure 7.- Gas-Oil Line Smart sensors Installation. Left: general view of location of sensors installed. Top right: details of Digital Sensor Interface cellular (mobile) installation. Bottom right: clamp used to install one of the High Temperature sensors.

4.2 Crude Overhead Line

4.2.1 Overview

Customer installed new overhead lines connecting units. Lines ware in un-accessible area. Many of these lines have no platform access. Customer wanted data on corrosion rates and inspection needs.

4.2.2 Details

Crude Overhead Line 100°C-38°C

- 300 mm Sch. 40 … all nominal wall thickness 10.1 mm +/- 12%

4.2.3 Product Used

- Customer installed permanently sensors (SmartPims) to monitor pipe intrados, extrados, top and bottom locations.
- A Digital Sensor Interface Cellular (Mobile) wireless system with 8 dual element sensors (probes) permanently attached.
- Monitoring interval: 1 reading every 2 days, transmission every 6 days. Estimated battery life ~4 yrs.
- Digital Sensor Interface unit bolted to hand rail and Unistrut, cables run to thickness monitoring locations

4.2.4 Outcome

- Cut Inspection costs – lift, scaffolding, or rope access required to reach locations at 12 m off the ground.
- Process control – access to higher volume of more accurate and quality data to trend corrosion rates, including impact of process excursion within days of occurring.

Figure 8. - -Overhead Lines Smart Sensors Installation. Top: general view of line including installation of Digital Sensor Interface (the blue box). Bottom Left: Showing sensors installed on an elbow extrados with one sensor at 6 o'clock. Bottom Right: showing sensors installed on an elbow intrados with one sensor at 12 o'clock.

4.3 Gas Pipeline

4.3.1 Overview:

An In Line Inspection (ILI) report showed a number of low spots at three separate locations along a 30 m stretch of gas pipeline. When the previous ILI was performed 7 years ago, these low spots did not exist. The operator not only wanted data to tell if the corrosion was episodic in nature or active but also did not want to fix/repair the pipeline and did not want to perform another ILI on a shorter interval. After mapping the internal corrosion on the pipeline, installed sensors were deployed to monitor the low spots along the excavated line.

4.3.2 Details:

Monitoring pits low spots instead of fix/repair

- 750 mm natural gas transmission line nominal wall thickness ~ 7.6 mm
- Low spots ranging from 3.1 to 6.1 mm– buried

4.3.3 Product Used:

Sensors **(**SmartPIMS) Modbus wired configuration with/ 8 dual element sensors (probes) (7.6 m length cable) permanently attached and buried to monitor "low spots" as identified by manually ultrasonic thickness measurement screening.

- Sensors were attached via epoxy & viscoelastic putty used to seal sensors before wrapped and buried
- A Nema enclosure used to house Digital Sensor Interface unit & act as collection point for techs
- Operator will vary frequency of manual readings.

4.3.4 Outcome:

- Condition monitoring of "low spots" without the need of dig out the area to access the points or run an in-line inspection tool
- Process control – access to higher volume of more accurate and quality data to trend corrosion rates and confirm if corrosion was episodic or is still active.

Figure 9. – Gas Pipeline Smart sensors Installation. Top Left: Showing sensors installed on the line. Top Right: Showing one sensor now totally covered by the putty in preparation for wrapping the area. Centre: General view after sensors have been installed before the final wrap is applied. Bottom Left: showing the section finally wrapped in preparation to buried the line back. Bottom Right: Nema Box for Digital Sensor Interface unit installation and data downloading going forward.

5 CONCLUSIONS

Equipment inspection and monitoring for any signs of internal corrosion are vital activities for safe operation in the Oil and Gas industry. New Deployment of Smart Ultrasonic Sensors are now available taking advantages of what is called Internet of Things (IoT). This basically, improves a proven method (UTM), by removing the operator (major source of data errors) and adding data logging, allowing analysis and trending of data, on line on a cloud-based software environment from anywhere in the world using a laptop, tablet or smartphone. Reports can be customise including flagging alarms of integrity status without dispatching technicians to dangerous, remote or inaccessible sites improving asset integrity and productivity while increasing safety.

Deployment of Smart Ultrasonic Sensors can offer:

- Higher-fidelity and higher-frequency data collected.
- Internet of Things: Data on Cloud available, alarm settings, e-mail warnings, potential issues flagging for maintenance planning.
- Integrity status without dispatching technicians to dangerous, remote or inaccessible sites.
- Lower cost-per-point for thickness monitoring location (TML) with a wide temperature range of applications
- Upon installation system offer data that can be monitored locally or remotely.
- Can be temporarily installed without welding - sensors can be easily moved.
- Short Term Installation/Data: Re-useable smartPIMS Sensors
    - Quick Deploy, Experimental research, Evaluation, among others applications.
- More reliable and safer for personnel than manual Ultrasonic Thickness Measurement inspection.
- Save in Opex budget by using resources only when needed
- Integrate with current corrosion intrusive monitoring devices like coupons and ER probes, as well as, customer corrosion monitoring and / or Risk Based Inspection software, enhancing Plant integrity.

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