

Installed Inspection Sensors & Cloud-based Software for Continuous Corrosion Monitoring and Advanced Analytics

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Abstract

Corrosion and erosion cost industries billions of dollars every year in, “lost production, unplanned downtime, equipment failure, high maintenance repair costs, imposed fines or compensation costs.” The president of NACE International, the U.S. professional technical society dedicated to reducing corrosion, said, “The cost of corrosion is a waste of resources and investments.” He then went on to state that the direct cost of corrosion is more than 3% of the U.S. Gross Domestic Product (GDP). That is more than \$300 billion annually in the United States alone. That global cost of corrosion is \$2.5 trillion dollars, and represents ~6% of global GDP.

However, both NACE.org and NASA studies estimate that companies can save between 15% to 35% of annual corrosion-related costs through optimum corrosion management practices. That means working together to address this problem through a variety of means could result in \$330-\$550 billion-dollar savings globally.

The most frequent scenario of plant failure is wall thinning due to erosion and corrosion. Conventional inspection “NDT” methods are deployed in order to measure, map, and monitor the thinning rate. These inspections create significant cost, can result in downtime, and present safety risks, especially those that required in difficult-to-access locations. In addition, each technology has limitations, and often human factors affect the accuracy and accountability of data for long-term analyses or corrosion trending.

This paper aims to present the value of deploying continuous wireless corrosion monitoring of interior piping wall thickness to mitigate or control the effects of corrosion and increase confidence on corrosion data. In addition, it will explain the differentiations between conventional inspection “NDT”, intrusive methods, and continuous corrosion monitoring. Lastly, the paper will demonstrate how implementing installed inspection sensors can decrease inspection costs, improve asset performance, and optimize process/operations

Keywords: Corrosion Monitoring, Digital Inspection, Asset integrity, Corrosion Management

1. Introduction

In order to comply with industry regulations, protect employees, assets, and the environment, and avoid equipment failures and unplanned shutdown, industries are spending billions of dollars. The goal of this type of investment is to enable a better understanding about the corrosion challenges and overall integrity picture at a site. Corrosion control remains a particularly challenging phenomenon that need will continue to evolve. Continuous monitoring plays a vital part of that evolution

Why Corrosion Management?

Aging:

- Most assets are aged, “some of which now have been in operation for double the original design life”
- 60% of worlds pipelines are ~40 years old, with an elevated risk of failure

Cost

- Inspections for corrosion are expensive, require specialized skill sets, and are often required in difficult-to-access locations
- Corrosion can result in unplanned downtime, maintenance, and costly repairs
- Unanticipated piping wall loss or acceleration in corrosion rate can result in downtime driving the loss of production, and lost revenue

Safety

- Dangerous site access “hard-to reach, high & low temperature, confined space entry”
- Hazardous environments: radiation, extreme temperatures, highly combustible gas, toxic or acidic vapor

Reputation / Image

- Multi-million-dollar fines
- Image damage to company when accidents happen

2. Corrosion Management: Conventional Methods

2.1 Traditional ultrasonic inspection



Regularly scheduled inspections will validate corrosion rates and allow engineers and operators to better plan for maintenance situations. The number and location of Thickness Monitoring

(TMLs) that needs to be a tested will depend on the required confidence we are looking for. More locations should be used to monitor higher risk locations, driving cost & inspection time up.

Additional challenges:

- Measurements are point-in-time, and often infrequent, rather than continuous: not suitable for short-term corrosion rates, need for more and quicker data with higher quality
- Trained and certified inspector is required
- Gaining access to the site, including scaffoldings, rope access, and insulation removal are time-consuming and expensive
- Hazardous environments, and access during difficult conditions
- Location repeatability ... ensuring that the exact same spot on the piping is going to be measured over a period of time
- Performance and accuracy factors: equipment used, variation on the equipment calibration, surface roughness, coupling technique, curvature of the test piece, velocity variations, temperature
- Human factor, i.e. expertise of the operator, actual performance of the testing in the field
- Equipment & hardware costs

2.2 Intrusive methods

Intrusive methods like corrosion coupons attempt to manage a target corrosion rates set by the producer

- May be based upon corrosion allowance and asset lifetime
- May use NACE defined corrosion rates

RP0775-2005

Table 2: Qualitative Categorization of Carbon Steel Corrosion Rates for Oil Production Systems

	Average Corrosion Rate		Maximum Pitting Rate (See Paragraph 2.5)	
	mm/y ^(A)	mpy ^(B)	mm/y	mpy
Low	<0.025	<1.0	<0.13	<5.0
Moderate	0.025-0.12	1.0-4.9	0.13-0.20	5.0-7.9
High	0.13-0.25	5.0-10	0.21-0.38	8.0-15
Severe	>0.25	>10	>0.38	>15

^(A) mm/y = millimeters per year

^(B) mpy = mils per year

Intrusive methods most- commonly used include:

- Weight loss coupons
- LPR (Linear Polarization Resistance)
- ER (Electrical Resistance)
- Metal ion analysis (iron counts)

Each method has its own advantages and disadvantages, including those highlighted as-follows:



- Indirect measurement: these tools provide data on the corrosion rate of the fluid, but do not provide accurate data on the wall thickness. Measurement is carried out on a shining piece of metal, meaning that different materials experience different levels of corrosion.
- Flow changes: these tools could create some change (could be small) on the internal flow that which could generate relatively different corrosivity conditions to the rest of the process, and data could be highly variable
- Installation, maintenance, download data and retrieval would require access, driving higher risks, lost time, and cost.
- Solid deposit could generate misleading results and short-circuit mechanism of reading.
- Allow for global evaluation of the corrosion process but doesn't indicate where corrosion occurs
- Would measure corrosivity for the position it is in (not area)
- Could be placed at locations where they are easy to install / collect data, not necessarily where corrosion is likely to occur

“In order to avoid undesirable effects, a chemical injection program is almost always coupled with a monitoring and inspection program ...”

3. Implementation of New Technologies

3.1 Implementation of Digital Technologies & Wireless Connectivity

Digital technologies and wireless connectivity are revolutionizing all industries, and applied across a wide range of applications. They are creating new innovations, and shifting business models to create new demands.

Cloud technology has enabled data availability, integration, storage without limits, and computation capacity. Inspection data is no longer a representation of a single point in time, but rather becomes an informative and transformational business tool. Cloud technologies enable easier access, real-time updates, and more effective data storing, integrating and sharing across the business network. Today, less than 10% of the data in oil and gas companies is effectively used. The cloud unlocks data so that more-informed decisions can be made across the enterprise.

With the acceptance of change come significant improvements to the world of inspection: centralized, cloud-based technology, sensor and monitoring technologies, drone and robotics technologies, and remote collaboration. The results of these innovative technologies are increased safety, increased productivity, improved data quality, and overall improved asset integrity, with reduced downtime, cost, and risk.



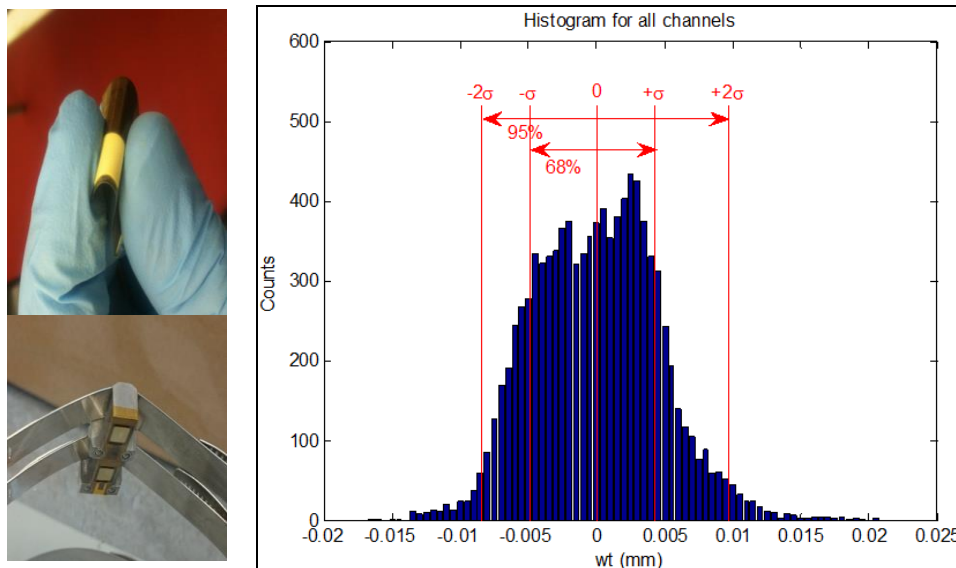
Over the past several years, sensors have become notably more powerful and cost effective, enabling a broader scale and depth of information to be continuously available. Installed on-site and connecting directly to the cloud, sensors can provide real-time visibility across assets through a simplified, central view of inspection data, including thermal and thickness measurements. Instead of periodic, point-in-time inspections that leave windows in which a failure can occur, and provide a limited view of corrosion risk, organizations can continuously “inspect”, detect actual problems, and predict potential areas of concern. This enables more proactive asset management, keeping operations both productive and safe.

3.2 Implementation of Dry-Coupled Ultrasonic Sensors

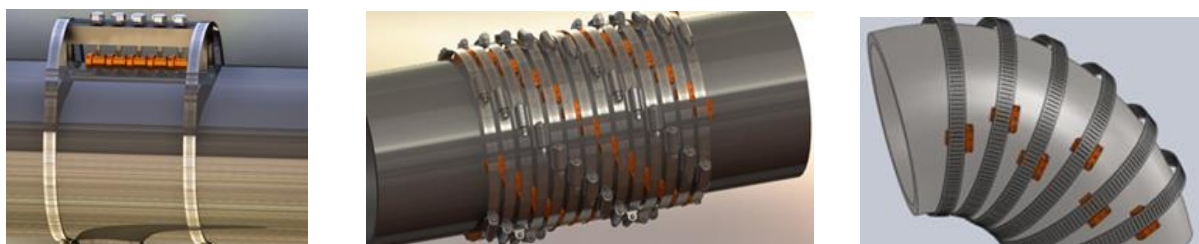
Ultrasonic sensor, applied directly on the pipe provide 0° pulse-echo ultrasound measurements of the wall thickness.

Advantages to this type of sensor include:

- Footprint of only 1x1", meaning a higher density of sensors can be achieved
- Low profile of only 16mm, meaning the sensors can easily be placed under insulation
- Accuracy measurements of the wall thickness, with a resolution of 0.1 mm or better.
- Testing has shown that precise measurements can be obtained with a repeatability margin of 0.02 mm.
- Sensors are ATEX certified
- SolGel Ceramic Technology: Dry coupled, IP67, meaning sensors can be installed without the need for a couplant
- Sensors have minimum of 10 years lifespan with an estimated 15-20 years lifespan without SNR loss, even with temperature cycles
- Thermocouples are installed with sensors, meaning each A-scan is paired with a temperature measurement. This data is saved in a database and undergoes post processing to calculate the wall thickness.
- The sensors are clamped on as a non-intrusive method, no welding is required to install, hence there is no shut down required.



A histogram showing the distribution of 40k measurements with 95% of measurements fall within a margin of 0.02 mm.

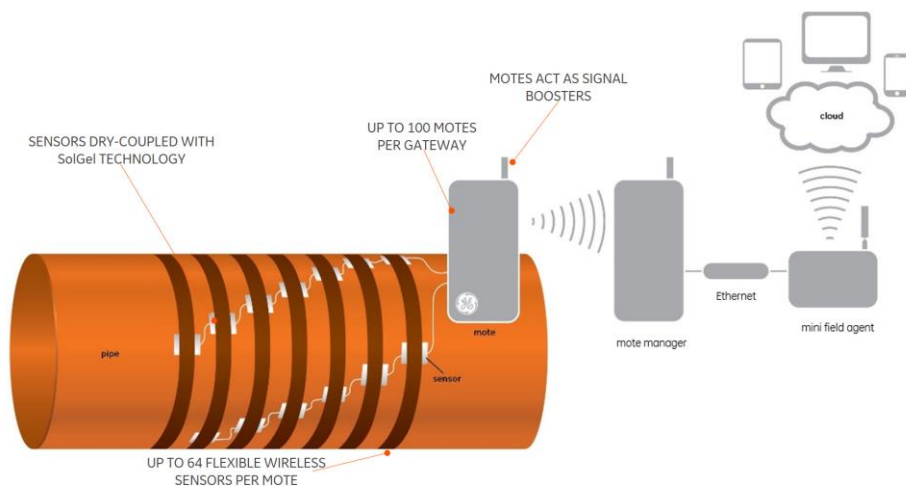


Sensors can be attached using a variety of methods and configurations on straight pipes, elbows, headers on different orientation, corrosion mechanism in combination with the most critical area of a certain asset will drive the probe locations

4. Wireless Communication and Data Acquisition

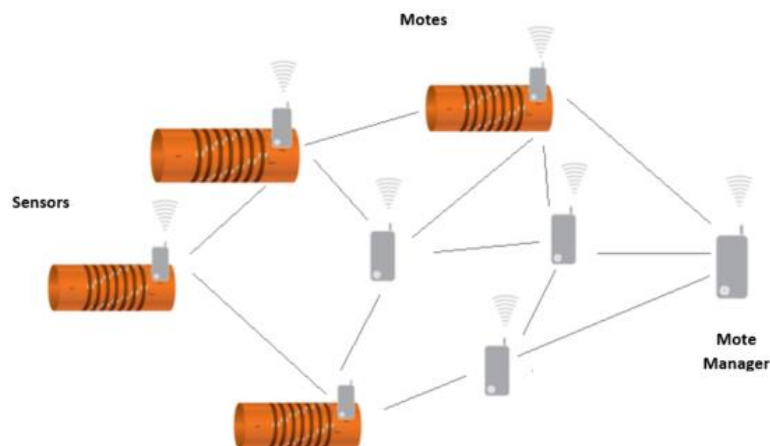
The goal of monitoring is to provide insights enabling experts to get smarter about their assets. This allows them to better-predict how they will perform, make informed decision about when to repair or replace, so they can maximize the value of investments while simultaneously reducing the risk of catastrophic failures.

This marriage of the latest digital technologies, wireless connectivity, and dry-coupled ultrasonic sensors can offer real-time thickness measurement, and the ability to perform advanced data analytics. This shift enables improved asset integrity management, and simultaneously opens the door for innovative ways to utilize this data to optimize plant and process performance.



Each probe is controlled by a battery-powered controller box called the ‘mote’. The mote capable of serving up to 64 probes. Each individual probe is connected to the mote by a single coax cable and powered by battery with a minimum of 5 years battery life, guaranteed for 64 sensors. The battery life has a potential life well-beyond 5 years, dependent upon the volume of sensors and frequency of readings.

The Mote manager gathers and transfers measurements from multiple motes to the mini field agent. Up to 100 motes can communicate to the mote manager, making a mesh network. Within a mesh network, every device can communicate to the mote manager either directly or via one or more other devices in the network.



Additional motes can be added to cover the mesh network

The mote managers are powered via Power Over Ethernet, and hard wired with an Ethernet cable to the Mini Field Agent.

The mini field agent orders the motes through the mote manager to wake up and take measurements. The mini field agent also encrypts the data received and sends the data to the Predix Cloud essentially acting as a gateway between the hardware and the software.

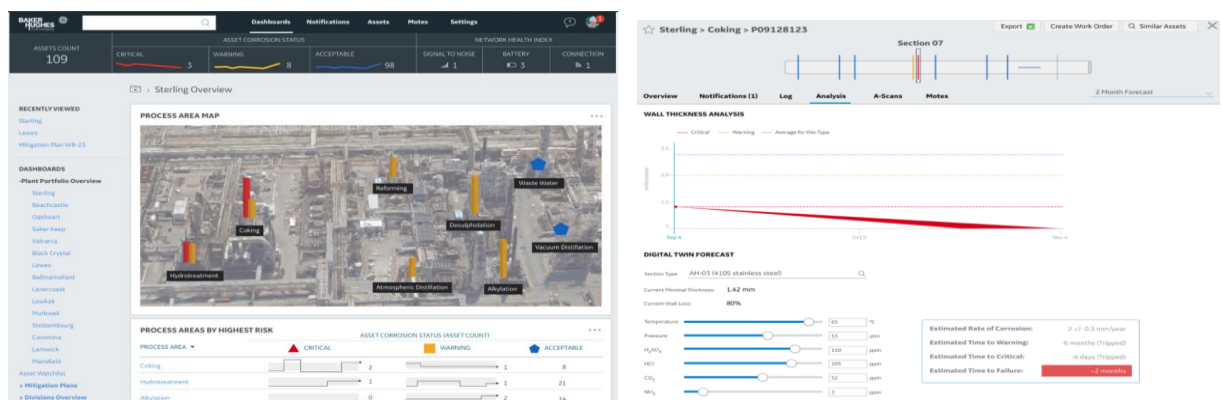
The system operates a private, segregated wireless mesh network for sensor data collection. This network is managed by the mote manager, which uploads processed sensor data to the GE Predix cloud via ethernet. It is therefore not required to be integrated into existing wireless deployments, and does not interfere with site standards adoptions.

5. Data Analysis Software

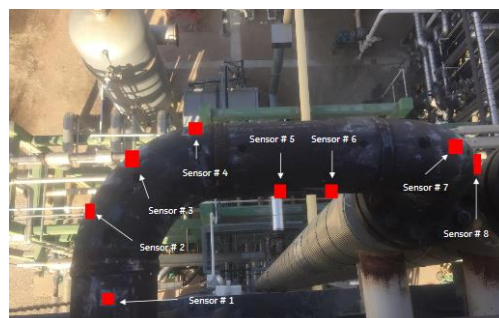
The sensors are continuously collecting interior piping wall thickness and temperature readings, and feeding them into the cloud-based software. Users can benefit from more reliable inspection data, and then start to trend and predict failures due to corrosion and erosion.

Software benefits include:

- Geo-spatial view allows you to see your assets in real-time
- Plant summary highlights the areas of concern by level of criticality, with a summary trend
- Stores the full A-scan ultrasonic testing data, as well as the calculated thicknesses
- Data analysis, reporting and exporting
- Remote control, automatic scheduling
- Diagnostic review of remote sensors, the motes, and other components so that it's doing its job of monitoring your production assets.
- Temperature adjusted thickness readings



This information will improve the reliability of inspection data, and enables users to trend and predict piping failures due to corrosion. The result is enables asset owners to extend the life of piping assets across a facility.



6. Conclusions

Continuous corrosion management solutions move operations beyond manual inspection to continuously connect assets, data, and people. The technology provides the actionable intelligence needed to access data from virtually anywhere. It allows users to forecast remaining asset life, predict future corrosion-related risks, manage related risk, and proactively maintain systems.

Results from continuous monitoring:

Decrease inspection costs:

25% savings potential or \$250K/year for average refinery inspection budget = \$1M/year

- Offset points with high cost-of-collection
- Optimize with better decisions from continuous data
- Identify critical points that are unmonitored today

Improve asset performance:

15% asset life extension potential, through better maintenance and the identification of equipment that may need modification to its operating profile or chemical treatments.

Optimize process/operations:

15% improvement in process efficiency

- Extend run-times
- Optimize corrosion inhibition
- Make better decisions through predictive analytics

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