

Wireless UT Sensors For Structural Health Monitoring & Remote Operations In A Post COVID19 World

Steve Strachan
Sensor Networks, Inc.
366 Walker Dr, Suite 200
State College, PA 16801-7085
United States of America

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ABSTRACT

Nothing like a crisis to force people think and act differently. The concept for deployment of installed ultrasonic sensors to either replace or augment manual inspections to improve operational efficiencies and outcomes is by no means a newfangled idea. As with all technology, components get smaller and sensors become more deployable and affordable. The same with wireless UT sensors. Over the last decade the O&G industry has been marked by falling oil prices, reductions in new builds/expansions, declines in CAPEX budgets, and corporate reorganization in efforts to cut costs. Then COVID19 arrived, and the world changed in a matter of weeks. Instead of trying to cut costs, many refining and chemical plants shifted their thinking to working smart versus hard. This presentation will detail how wireless UT sensors combined with new ways of thinking has transformed the industry to save millions of dollars in asset integrity and operating efficiencies.

Key words: Corrosion, Ultrasound, UT Sensors, PIMS (Permanently Installed Monitoring Systems), Downstream, Refining, Chemical, Wired UT (Ultrasonic Thickness), Wireless UT (Ultrasonic Thickness), Monitoring, Asset Integrity

INTRODUCTION

For decades, many asset owner/operators across the O&G value chain (and other critical industry segments) of upstream, midstream, & downstream have struggled to identify the root cause of fluctuating corrosion/erosion rates due to unreliable or infrequent data during various operating intervals on their most valuable of assets. This key missing data point has forced mechanical integrity teams, corrosion engineers, inspectors, and operations to, in many cases, make the best guess or hypothesize how to operate with a limited data set of information. In almost all cases, a time-based inspection or maintenance interval is used to gauge the useful lifetime of assets based on this limited data simply because these assets couldn't give their owners a real-time health diagnostic of how they were doing ... until now. This paper will detail how COVID-19 offered a much needed reset button of opportunity for asset owners across many segments to rethink their decision making process by using technology to their favor. Many of these asset owners have now been able to take the next leap into strategic asset integrity planning by utilizing sensors and real-time data to not only safely and more efficiently operate assets but in some cases, achieve the financial holy grail of life-extension services for their most critical assets and components.

UT Thickness – Comparing Manually Taken Readings to Automated Sensor Readings

Similar to manual ultrasonic thickness gauging, installed ultrasonic sensors utilize the same ultrasonic principals. Ultrasonic waves are sent through the material, given the time it takes to travel through the material and the material velocity, the distance (thickness) can be determined (#1). See figure 1 below:

$$\text{Equation: } T = (V) \times (t/2)$$

T = Thickness

V = Material Velocity

t = Time

However, the technique is fundamentally different in that the transducers and instrumentation are deployed permanently or temporarily with automatic data backhaul. This addresses several of the shortcomings of existing manually deployed solutions. Some of the major advantages are as follows:

- Instrumentation and probes are deployed on the asset in a permanent or semi-permanent fashion and can be accessed remotely, thus the cost of access is reduced over time and operators are not deployed to the point of the inspection. Once the sensor is deployed, data can be remotely accessed.
- Due to the fixed transducer position and instrumentation, operator-to-operator, probe-to-probe, and instrument-to-instrument variability is eliminated. This removes significant sources of error and allows for improved measurement resolution, precision, and accuracy which is particularly important for corrosion-rate trending and asset management down to .001" (1 mil) of accuracy.
- Data can be collected on a more frequent basis (>1X per day) as the sensors are battery powered. This allows for more accurate corrosion-rate trending through statistical data analysis i.e. monitoring versus general inspection. Battery life is >15 years on one reading per day.
- The system is deployed with an integrated temperature measurement device so that changes in material acoustic velocity due to temperature variation can be automatically removed from the measurement, thus eliminating another significant source of error.
- Installations are dependent largely on material thickness, diameter, and temperature. Typically a dual element or high temperature single element (5MHz – 7MHz) frequency sensor is appropriate to cover from .040"/1mm up to 4"/101mm in thickness. These sensors are recommended to have surface prep to bare metal to be installed using a magnetic base (typically for >36"/914mm assets like vessels & tanks), and a clamp for piping. The sensors can be coupled permanently using epoxy or metal foil or temporarily using temporary couplant or metal foil. Once installed, they can be insulated or coated as necessary.

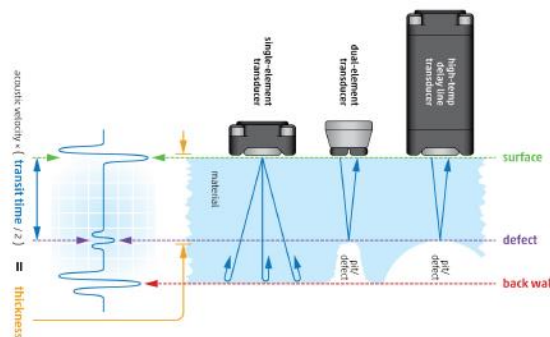


Figure 1: Principles of Ultrasound

Installed UT Sensor History

The concept for deployment of permanently or temporarily installed ultrasonic sensors to either replace or augment manual inspections is by no means a newfangled idea. The first versions of installed sensors were

hard wired and introduced over 20 years ago and extremely niche as they were expensive and quite limited in capability. As with all technology, components get smaller, have more computing power, can be more easily deployed/integrated, and ultimately become more affordable. The same can be said about installed UT sensors. Over the last ten years especially, the installed sensor concept has seen vast technological advancements. Today, sensor systems come in a multitude of packaging of all shapes and sizes which can be offered as a solution to just about any application:

- Single point, multi-point, and even area coverages
- Wired (integrated to SCADA/PLC/DCS) or wireless (2.4GHz, 900MHz/LoRa, Cellular, Satellite, etc.)
- Extremely high (1100F/593C) or low temperatures (-40F/C)
- Buried or above ground
- Permanently or temporarily installed in under 15 minutes

Given the vast improvements in this arena, it is easy to see why so many asset owners and end users have embraced the concept and found places to leverage the technology. Today, asset owners, manufacturers, and operators across nearly every industrial segment (Oil & Gas, Power Generation, Pulp & Paper, Mining, etc.) are looking for ways to cut costs, improve efficiency, and maximize safety. In the current environment (perhaps now more than ever before) where time is money and even the slightest edge could mean the difference between profit, break even, and loss, it is of paramount importance to analyze where and how human resources and technology are being utilized and deployed. When relating to installed UT sensors to replace or augment manual inspection, the industry isn't heading that way, it's already here. The asset owners who are leveraging installed UT sensor technology are learning more than ever before with regard to plant efficiencies, feed stocks, chemicals, inhibitors, and moving from a time-based maintenance interval to a predictive based interval, leaving those who are not, in the dark ages of asset integrity prioritization and management.

Inspection VS. Monitoring

Perhaps the most important differentiation being recognized (and put into practice) across nearly every major industrial segment is that of inspection versus monitoring. In the coming section, we will define each practice, explain how it is currently utilized, give examples of why each practice is diametrically different, and finally outline how both can be used in tandem to bolster a wholistic (and strategic) asset integrity management plan.

Inspection

As defined by the Cambridge Dictionary (#2) is "The act of looking at something carefully, or an official visit to a building or organization to check that everything is correct and legal." In practical terms, inspections are typically required by some governing body or procedure and performed at varied and infrequent intervals. Inspections are also often performed by humans which is by nature subject to flawed or imperfect data and in many cases is prone to higher safety risks each time a 'manual inspection' is performed.

As an everyday example, taking your car in for an annual inspection. This is done infrequently (annually), code driven by the Department of Transportation (DOT), and is performed by a human (take your car to a dealer or auto mechanic, performs work, completes report, and submits to owner).

As an industrial example, UT thickness readings which are done infrequently (annually, bi-annually, or even longer based on a multitude of inputs), code driven (ASTM, API, insurance requirements, etc.) and is performed by a human (inspector manually uses handheld gauge and records reading, completes report, submits it to owner). In the UT thickness example, let's go a level deeper to objective and the environment of this inspector. Their goal is to take an extremely precise reading (or series of readings) in a small area typically about the size of a 3"/76mm circle, where each millimeter of surface area could be a different thickness. Add in the environment, for which this inspector is working:

- The asset could potentially be at an elevated surface which he/she has to climb ladders or scaffold (or use ropes?).
- The asset could be operating at high temperatures (up to 500+ F or C).
- Many refineries and petrochemical facilities are located in harsh ambient environments, for example the Gulf Coast of the US where it is not uncommon for 100F/55C temperatures or Northern Canadian Provinces where temperatures can reach extremes at the other side of the temperature spectrum (40F/C).

Painting this picture makes it easy to see why inspections can not only be difficult, but are also in many cases fraught with data fidelity and safety concerns, and of course, costly. However, inspections are necessary in achieving what they are intended – code/compliance driven and go/no-go data to drive safety and operation of a particular asset.

By requirement this data now exists for all to use (great!), and has even given the asset owners/operators some valuable hints as to where potential probes could arise, this is the critical trap that so many find themselves falling subject to – using inspection data to drive maintenance activities. Yes, in some cases for lower value, less critical assets, inspection data can prove to be useful. However, for risk-ranked assets/equipment where downtime is not an option and the potential for asset extension (of even a couple months to a few years) can be a financial game-changer is the sweet spot for monitoring techniques.

Monitoring

As defined by the Cambridge Dictionary (#2) is “A machine that regularly checks something.” In practical terms, monitoring is the exact opposite of inspection. Monitoring is not typically required by a government body or procedure and is a self (or enterprise) driven decision whereby an individual or team of individuals hypothesize that they can enhance the operational efficiency of a process or piece of equipment to get a better outcome; improve performance, gain efficiencies, operate more safely, make/save money.

Staying with the automobile example of everyday monitoring might be an individual who installs a device on their car (which many insurance companies are now giving to their drivers for free) to track location, speed, acceleration, and other driving habits. Not only to does this provide valuable safety information on drivers to insurance companies, but it promotes safe driving, economical fuel mileage, and ultimately less wear and tear on automobiles to allow owners to get the most life out of their vehicle as possible.

Similarly, sticking with the industrial example of UT thickness monitoring in lieu of (or in conjunction to manual inspection). Imagine this same location has been flagged as a ‘bad actor’ or ‘problematic’ location during an inspection. In this case, in order for the corrosion, operations, or asset integrity team to be able to make recommendations on operational or maintenance details, they would significantly benefit from more and better data. Enter monitoring. In this case, a sensor(s) is installed in the problematic area and takes a reading at the same location daily (or hourly, depending on the severity of the issue) to be able to glean an ultra-precise corrosion rate (.001” in resolution) to understand how, when, and why the asset is being affected. From this data the team is then able to track, trend, and overlay other key operational parameters; crude slate, pressure, temperature, inhibitor type & dosage, etc. From here the team can discern if the corrosion is linear (rarely) or if it fluctuates based on a myriad of different operating intervals. At this point the team can now pinpoint and map the corrosion equation to find the zero, low, moderate, and high levels of corrosion in this particular location. Finally, they can now make more informed decision about the disposition of the asset; remove from service at a particular date, make remediation recommendations to combat the issue, or learn how they might be able to extend the life of the asset based on this newly available, timely, and accurate data.

Ideally, the sensor can be installed at the same time (or shortly after) of the inspection, reducing additional safety issues, and now having access to all that valuable data (and the sensors won’t complain about the asset’s heat or weather outside). Thus now creating a cradle-to-grave asset integrity strategy incorporating the best of both worlds – inspection and monitoring.

In summary, both inspection and monitoring data is extremely important. The difference is knowing WHEN and WHERE to use (or not use) both types of data. Inspection data is critical to drive compliance reviews, identify 'bad actor' locations (which are perfect candidates for monitoring) and can give precious go/no-go safety operations. Inspection data is not beneficial in understanding the day-to-day health or operational efficiencies of equipment and processes. This is where the sweet spot for monitoring, and potentially the largest opportunities for financial gain (life extension) or loss (unexpected outages & downtime).

The Battered O&G Industry ... Is it Time to Make Changes in Thinking?

According to Reuters (#3), in the last 20 years the average price of oil has steadily declined on the average over 44%. With this decline, so have the profits from literally every large, medium, and small National Oil Company (NOC) and Independent Oil Company (IOC) on the planet ... that is, if they were able to avoid bankruptcy during this tumultuous period. To quote Rex Tillerson, former CEO of a Multinational Oil Conglomerate, in an interview with Reuters in 2012, "The days of \$100 oil are long gone, and likely won't be back anytime soon. Which is why we are focusing on technology and efficiency as our path to get back to the profitability of the past."

Each multi-national vertically integrated oil company has seen multiple major reorganizations in an effort to capitalize on this pivot in strategic direction to create and refine more efficient and profitable ways of operating. In a study by the University of Houston (#4) over 1.33 million full time O&G jobs have been eliminated in the last three oil 'crashes'; 08-09 financial crisis, '14-'15 fracking global over-supply, and '20 COVID-19 pandemic. To add insult to injury, (#5) during COVID-19 the US Department of Energy published the global oil demand numbers of 12.5mbpd of pre-COVID-19 to that of 10.2mbpd during the doldrums of the pandemic. As a result the downstream (refining & chemical) market had to rethink their strategy on what products to produce to be able to maintain financial solvency. Reuters (#3) reported that 26 refineries and chemical plants globally had been closed, repurposed, or put to idle status in a short twelve month span with many others still trying to decide their future fates and strategic direction.

Given these trends over the last 20 years, it becomes obvious why these Oil and Gas companies are rethinking realistically every aspect of their businesses, reorganizing, strategizing, and looking for even the slightest of advantages over their competitors to reclaim the profitability lost in the last two decades.

COVID-19 ... Doing THE SAME with LESS

Oil prices are function of many different micro and macroeconomic factors, but none probably more devastating than what happened on the operational front of up, mid, and downstream asset owners due to the inability to get manual labor on site. On the E&P side of the house, producing wells were forced to slow (or close) because asset owners couldn't get technicians to site to do the simplest of things like take thickness readings at the wellhead to ensure they were safe enough to continue operation. Midstream new construction came to a standstill and asset integrity digs were postponed forcing some lines to stop flowing or requiring exemptions due to the inability to be inspected. For the downstream and refining sector, the scenario was arguably worse than anywhere else as the teams of contractors working each day at these plants were forced to stay home. Compliance inspections which were pushed from 2019 to 2020 were halted, not to mention the 2020 inspections as well, which created a massive backlog of work if/when technicians could finally get back on site.

In each of these examples, installed UT sensors were used to bridge the dearth in human work force and what each of these asset owners learned was astounding. Not only were they able to continue safe operations, but in all cases, benefitted from more accurate and timely data to improve operations to save cost and grow revenues.

Monitoring Budgeting

As one can see from the previous two sections on inspection versus monitoring and the O&G climate/trends in the last 20 years, it is easy to see why many asset owners are moving to an asset integrity plan which incorporates a wholistic inspection and monitoring strategy. Monitoring, in itself, has been another challenge