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Buried Ultrasonic Sensors for Midstream Asset-Integrity Corrosion Monitoring

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ABSTRACT

In response to new Pipeline & Hazardous Material Safety Administration (PHMSA) and Department of Transportation (DOT) regulations asking owner/operators to be more diligent in 'monitoring' their assets due to internal and external pipeline corrosion. Many operators are using both wired and wireless ultrasonic sensors for both buried and above ground assets between regularly scheduled in-line inspections (ILI). By doing so, operators are able glean important wall thickness data, which they otherwise wouldn't have without incurring significant costs from excavation, mass screenings such as ILI, etc. In addition, these operators can now use this data to map corrosion rates based on operational activity, mechanical activities, cleanings, chemical inhibitor utilization, etc. All of which help to paint the asset integrity and health of the asset under consideration which can extend its life of keep from leaks, spills, or other events. The ease of deployment coupled with the durability and flexibility of the different sensor platforms is allowing single point, multi-point, or area monitoring of critical asset locations to be monitored to allow operators to maintain their normal inspection intervals. Sensors are being deployed predominately for two different scenarios:

New Construction: For areas which have been identified as low spots or potential troublesome locations during pipeline plotting.

Asset Integrity Monitoring: For areas which have been identified by smart pigs or ILI. If a section has leaked or is in need of fix, sleeve, or repair, sensors are installed in the area where the asset failed previously. For pitting or 'low spots' which have been identified by the mass screening, sensors are placed on the areas which are marked to monitor the anomaly. This allows the asset owner to keep regularly scheduled ILIs as they are monitoring these low spots between inspections.

Effectiveness of Mechanical or Chemical Cleaning: Using readily available corrosion data to confirm the presence/mitigation of corrosion activity at different locations along the asset. Essentially saving time and money by confirming, "Am I cleaning too much, or not enough?" or "Am I using enough (or the proper) chemical inhibitor, or too little?"

In any of the above examples, these sensors can provide critical data around episodic or gradual ware of the asset due to microbiologically induced corrosion, chemical inhibitor effectiveness, and frequency

of required cleaning. This paper will cover the sensor technology, deployment, and case studies around how the technology has helped owner/operators better protect their critical midstream assets.

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

INTRODUCTION

Many asset owner/operators struggle to identify the root cause of fluctuating corrosion rates due to unreliable or infrequent data. Midstream groups across the country are tasked with monitoring thousands of miles of pipelines using this same data. Many times, the only data these teams have to rely on are inspection reports from ILI (In-line Inspection) and NDE (Non-Destructive Examination) techniques such as manual ultrasonic testing and/or radiographs. While these techniques can provide valuable “snapshots” of the condition of particular locations, limitations and inherent error with these techniques can compound leading to ill-advised decision making.

For example, ILI runs are time consuming, expensive, and purely episodic in nature (they are only done when regulation calls for it, or there is an event that triggers a closer look at the asset integrity of a line). Therefore, the quantity of data and sample size of integrity data is few and far between. So, making short- or medium-term decisions around the effectiveness of asset integrity or cleaning measures (much less real time) are simply impossible.

When it comes to manual inspection during asset integrity digs or direct assessments, as with any manual task, there is margin for error. In the case of manual UT thickness gauging, there are a seemingly endless list of opportunities for this margin of error to be introduced and/or exacerbated. Thus, in our equation above, how many times do I need to send a technician to obtain data which is useful? Listed below are a few potential examples of how error can be introduced across the value chain of a manually taken UT thickness reading.

- Was the technician at the correct location (CML/TML)? Was the technician even there at all?
- Did the technician scan the area or take a single point reading?
- Did the technician calibrate the handheld device?
- How was the unit calibrated? Was it calibrated on the same device as the last time the reading was taken? Is the same sensor/probe being used? Same UT gel/couplant? Same inspector? Did one inspector press harder or softer than another? Was the probe flat or did it rock?
- In practice it is a documented issue that if five different technicians inspect the same TML, all five technicians will produce a different result to the tune of anywhere from 0.001” to 0.050” in reading differential.
- Once the reading is taken, how is it documented? Audibly? Written down? Stored on the device? Does it ever actually make it back to the report?
- Is the reading then included on a report? How is it input into the Inspection Database Management System (IDMS)? Manually? What is the margin of error of inputting the data from typing a wrong key or misinterpreting a paper on a notepad with smeared ink from sweat and glove handwriting? How often do transcription errors occur in a process so laborious?

Let’s look at the process for midstream asset integrity INSPECTION. ILIs are long range non-destructive mass screening techniques only performed periodically (and as spread out as possible) because of the cost associated with not only the process but downtime of the assets being out of service. When an ILI is performed (using a smart pig using ultrasound, MFL (Magnetic Flux Leakage),

etc.) and anomalies are found, a direct assessment (or dig) must take place at each of the locations under question. After a couple days of excavation and prepping, a technician is sent into the hole to take manual thickness data to compare to the manual results to the ILI. Depending on a host of different variables, ultimately the operator must decide between two options:

- A) The pipeline is fit for continued service as is and can be buried (perhaps instead of a for example, seven-year ILI interval, now five will be required due to the wall thinning and unknown general corrosion rate)
- B) The segment under investigation is fixed, sleeved or repaired (now the same inspection interval is grated because the remediation had taken place

In either case, these are expensive propositions. Moving from a seven to five-year inspection interval could mean potentially hundreds of thousands to millions of dollars of extra cost associated with ILI over the useful life of that segment of pipeline.

Electing to fix, sleeve, or repair means additional cost in downtime, materials, labor, and inspection cost.

Until recently, these were the only two options for owner/operators. Today, many owner/operators are opting for a third option which allows them to continue operating on their normal inspection interval even when anomalies are identified, without having to take immediate remediation. Why? Because they are electing to MONITOR these locations using buried UT sensors.

In this third option, the workflow is simply, perform ILI, execute direct assessment, mark locations under question, decide which ones to place sensors to monitor, and bury. So, when it comes time to report the ILI findings and there are anomalies present and the regulating body asks what remediation tactic was used, the answer is quite simply, we are actively monitoring it with buried UT sensors. If we see an active or episodic anomaly, we can send cleaning tools, inject inhibitor, etc. to hopefully remediate. If we cannot, we don't need to run another tool, all which is necessary is to dig exactly where the sensors are and at that time replace the pipe segment.

In many cases, owner/operators are being proactive and deciding that when they do a direct assessment, considering they have already spent the money digging the hole, examining the location, to invest in a couple sensors to leave behind. This further can be documented to regulators that forward-looking monitoring is taking place at regular intervals.

First let's have a look at ultrasonic technology and how it is applied in an 'installed' (permanent or temporary fashion).

Installed Ultrasonic Sensors

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. See figure 1 below:

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

Where

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 instrumentation is deployed, data can be remotely accessed via the Internet.
- 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.
- Data can be collected on a more frequent basis (>1X per day) for automated systems. This allows for more accurate corrosion-rate trending through statistical data analysis.
- 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.
- The data is easily accessible. Wireless installed sensor systems can make use of various forms of data backhaul including the facility wired or wireless intranet, industrial wireless networks, satellite, or cellular networks for remote collection points, allowing real-time data/asset health availability.

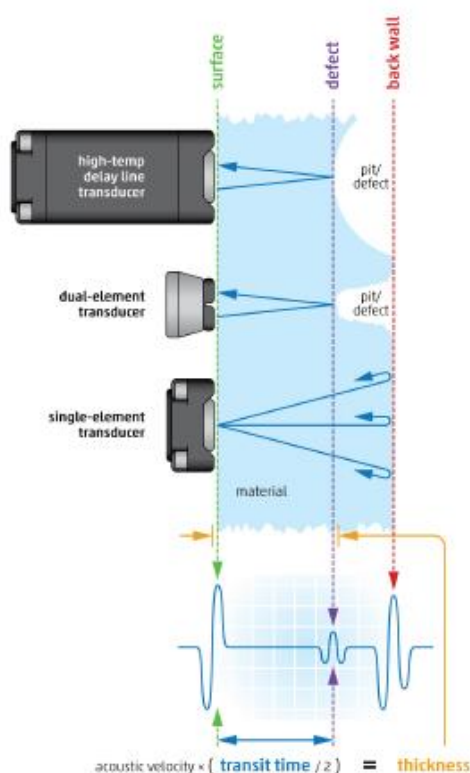


Figure 1: Principles of Ultrasound

Monitoring During New Construction

During the planning stages for new pipeline construction, much work goes into planning for where the actual pipeline is laid. Things like environmental, residential, topography, and a myriad of different factors must be taken in to account to ensure the pipelines long term viability and safety. Many owner/operators are getting ahead of the curve by looking for areas which they think might be prone for future potential corrosion attacks. For areas which have been identified as low spots or potential troublesome locations during pipeline plotting make for ideal locations to place sensors while it is being constructed and put into the ground (or left topside). Many of these locations also just so happen to be in similar locations as the cathodic protection locations, which makes data collection much more streamlined.

See below figure 2. This is a perfect example of a gradient change from the top of the hill in the background to the foreground where the pipeline not only was moving steadily downhill, but also had to be laid below an existing line. As the pipeline continued into the foreground it went back up to the top of another hill, making this location a perfect location to monitor for internal water or buildup which could potentially become corrosive in the future.



Figure 2: Newly constructed pipe with sensors installed at the low spot of the pipeline segment

In many cases during new construction monitoring planning, a different type of sensor is used as there are no exact locations but rather a general 'area' which is to be monitored. In these such situations an area monitoring sensor is recommended (figure 2 below). These area monitoring strips have multiple elements all localized together which form a pattern or shape to collect multiple readings from the same general area. In the case of the 1x15 array or 3x5 matrix, there are 15 discrete sensor readings taken when data is collected.