Automating and optimizing the CML / TML data-collection process

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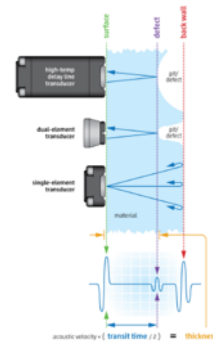
Overview: For the past four to five decades, oil refiners and Petro-Chem plants used thickness readings in their facilities. Since the PSM (Process Safety Management [1]) Regulations in 1993, the use of manual ultrasonic thickness (UT) instruments to collect data on remaining wall thickness of steel piping, tanks and pressure vessels has greatly increased. The thickness values are plotted over time to establish the metal-loss rates – due to corrosion and/or erosion and predict the asset's safe remaining life. Some sites may take over 1-million manual UT readings per year.



Portable devices such as analog UT flaw detectors (shown upper left), digital thickness gages (shown in center) have evolved significantly over this time frame. All modern devices employ the same basic measurement principle of "clocking" the round-trip transit time, in micro-seconds, and, by knowing the acoustic velocity of the test material, converting that short time interval into thickness using the following formula: ***T= t / 2 * V where T=thickness, t= time, V= acoustic velocity*.**

Example: 0.250" Thickness = 2.2 microseconds / 2 x 0.2266 in / µsec. (6.35 mm and 5.7 mm/µsec)

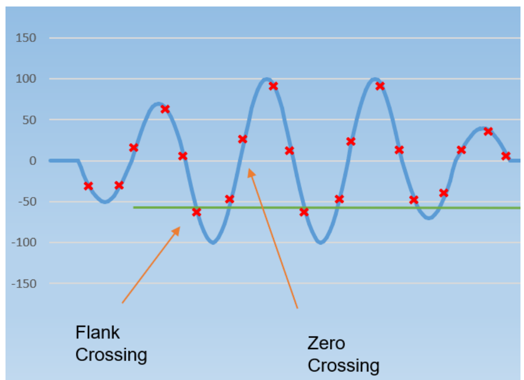
With the advent of microprocessor-based technologies in the mid-1980's, small, lightweight, low-cost, portable digital instruments of many types became available. Improved software programs also became integral factors in allowing these instruments to produce a variety of beneficial outputs, such as:

- Higher resolution
- RF signal display
- Improved accuracy
- Temperature correction
- Ease of use
- Auto-calibrating
- On-board data-logging able to store the digital data including the RF waveform

Transducer technology also advanced steadily over the past few decades to include single-element, dual-element, delay-line probes (shown upper-right image) with improved temperature stability, wider thickness ranges, better durability and improved ergonomics to minimize technician fatigue. The latest technological advancement uses 128-element phased-array UT transducers and systems to enhance area coverage, probability of detection (POD), and create real-time 2D or 3D images of remaining wall-thickness.

Advanced measurement technologies:

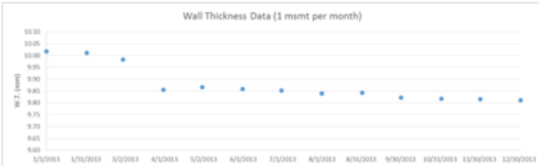
All digital ultrasonic thickness gaging capabilities are based on making very accurate and consistent round-trip transit-time measurements of the high-frequency ultrasonic pulse in the test part. Instrument electronics and software must be able to calculate or identify predictable time locations of "zero thickness" and the reflected back-wall signal, as represented by its RF waveform, to achieve the wall-thickness resolution necessary for corrosion engineering.

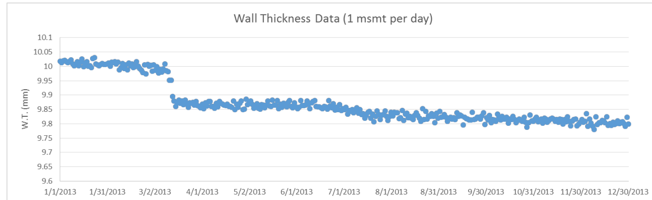


Consistent reference locations on the digitized RF waveform are required to make such repeatable and accurate thickness readings. Six-picosecond resolution (a picosecond is one trillionth, or one millionth of one millionth of a second) is possible with a 40-MHz digitizer, up-sampled by 8X, and linear interpolated with 512 possible values, which translates to a theoretical ability to resolve < 0.0001" (2.54 micron) changes in wall thickness in carbon steel.

Today's challenge: However, the process of sending NDT technicians into plants to collect and manage the data has not changed as much over that multi-decade time frame. It is still a labor-intensive process affected by difficult and highly variable work environments, safety risks and data-corruption issues. In addition, the management of data, both good and corrupt, has led to a separate issue in managing this information.

Accurate manual thickness trending is also challenging due to variability in technician qualification and experience, temperature changes, instrument differences, calibration and measurements not taken on the same exact spot. Cases have been reported where pipe-thickness measurements showed an increase in value between two readings [2]. Clearly, a more robust solution was required – especially for trending high-value strategic or tactical TMLs.



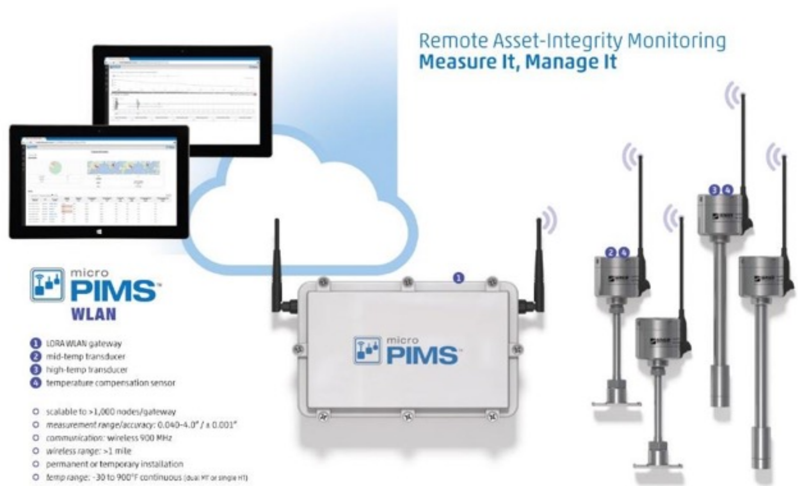


Even if accurate readings are taken at monthly intervals (left image plot), episodic events caused by process upsets or turnaround-related issues will be poorly understood. If accurate readings are taken and time-stamped daily (right) corrosion engineers are better able to correlate metal-loss rates to actual plant operating conditions.

The use of bi-directional programmable dataloggers in the UT thickness instrument helps alleviate this but can also cause confusion for the UT technician in the field taking the thickness readings at specific locations. It is so easy for a UT technician to lose his/her place in the pre-loaded inspection route and the result is incorrect thickness readings in the wrong TML location within the database.

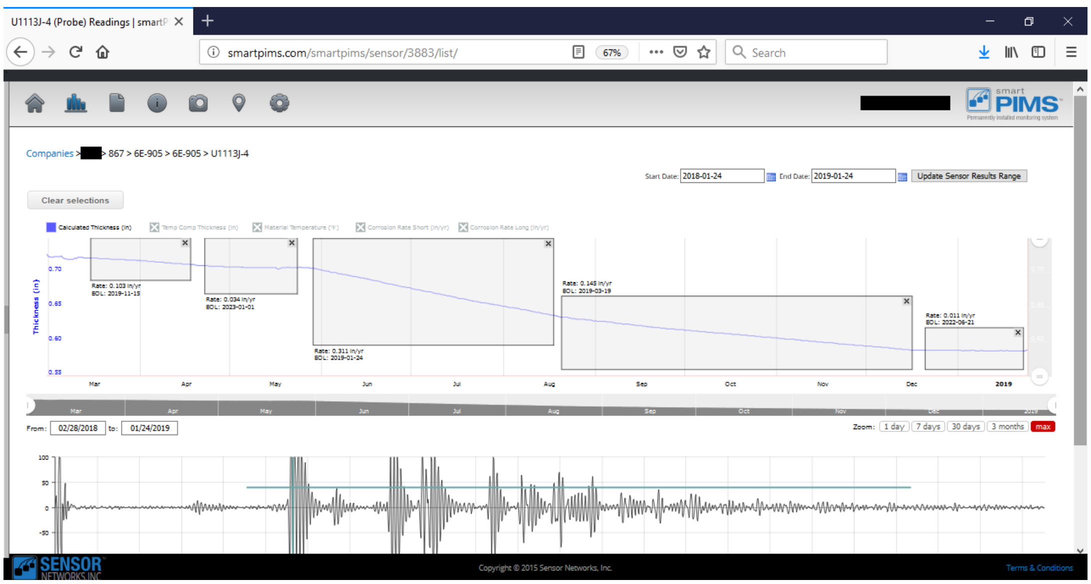
Even with the advantage of programmable data loggers, the norm is still to write down thickness readings on paper. Thickness readings that are manually entered into corrosion monitoring software programs are also prone to keying errors and misalignment of data.

Installed Sensors: A technology-driven solution: Today, small, low-cost, wireless, battery-powered UT and temperature sensors can be permanently installed on high-value TMLs. This enables improved safety, higher-fidelity UT thickness data, collected at a higher frequency and trended to extremely accurate rates accessible via a cloud-based web portal. This lowers the need for the number of TMLs allowing NDT personnel and budgets to be better utilized elsewhere. Case studies of several plants show that – when embraced – this new technology yields significant benefits.



Typical system topology of a wireless UT sensor network.

Thousands of sensor nodes take thickness readings at user-defined time intervals – hourly, daily or weekly – and communicate them to the gateway which connects to a cloud-based web portal with data management and analysis software.



Shown above: Time-gated widows can accurately calculate metal-loss rates and correlate that data to specific episodic events such as chemical inhibitor use.

The metal loss plot, shown above, was 0.001" for a seven-day period which, if left unabated, would be 0.060" year. Installed sensor systems can accurately identify trends more rapidly therefore enabling faster intervention.

By using a cloud-based solution for data collection, storage, trending and reporting, anyone with authorized access can see the on-line report from anywhere at any time. No more waiting for data to be manually processed and auto-alarms can be set for minimum thickness or accelerated corrosion rates.

Thickness data for each TML can be output from the cloud-based software. Data can be easily imported into mechanical integrity, corrosion monitoring or other types of software which utilize the wall-thickness data to predict next inspection due dates, retirement dates and RBI calculations.

ROI for Installed Sensors:

Deployment of permanently or temporarily installed ultrasonic sensors to either replace or augment manual inspections is not a new idea. The first versions of installed sensors were hard wired, introduced over twenty years ago, were extremely niche as they were expensive and quite limited in capability. As with any technology, components get smaller, have more computing power, and ultimately become more affordable. This is true for installed sensors – especially with the acceptance of internet and cloud solutions. Over the last ten years, the installed sensor concept has seen rapid technological advancements with sensor systems available in a multitude of packaging, shapes and sizes:

- Single point, multi-point, and area coverages
- Wired or wireless
- Extremely high (1,100-deg F) or low temperatures (-30-deg. F)
- Buried or above ground
- Permanent or temporarily installed

Given all the improvements in this arena, it is easy to see why many asset owners and end users have embraced the concept and found places to leverage this technology. Today, customers around the world and across many industrial segments (O&G, PG, P&P, Mining, etc.) are looking for ways to save cost, improve efficiency, reduce safety risks and let technology do the hard work. In each of these examples, customers are reviewing the economic value and benefits by deploying installed sensor systems.

Unfortunately, for those looking for a simple ROI equation, it is not as straight forward as we would like. It is nearly impossible to directly compare ROI calculations from manually deployed thickness gage data to that of automated sensor data collection, as both methods are inherently different. Each method has its own unique advantages and disadvantages. When performing a comparative ROI analysis on manual vs. automated thickness monitoring locations or corrosion monitoring locations, unfortunately it is not simply:

$$\text{Cost (M)} = ((\$A+\$B) * X)) + (\$C*X)$$

Cost (M) = Cost of manual inspection
$A = Cost of time, equipment, labor to send technician
$B = Cost of reporting, data management/input
X = Number of readings per year
$C = Cost of pre-work to obtain data (Ex. Removing insulation, erect scaffolding, etc.)

$$\text{Cost (AS)} = (\$D+\$Y) + \$C$$

Cost (IS) = Cost of automated sensor
$D = Cost of hardware/software per sensor
$Y = Cost of sensor installation

Ultimately, the above equations do not consider three main variables which must be dollarized when deciding when and where to deploy the two data-collection strategies – Data Quality, Data Quantity, and Safety. We will call this TRUE cost. Each asset owner must be able to dollarize and quantify the value of these three criteria for every TML/CML in their facility to fully understand which locations would benefit from a manual inspection versus an automated approach. Thus, in each example, the question is:

"Does it make sense sending technicians to manually collect data from a location X number of times at $Y, or should I install a permanent sensor to obtain X (or at the same cost, a large number of readings) at $Z"

X = the number of desired readings
$Y = **TRUE TML/CML cost** for manual inspection
$Z = **TRUE TML/CML cost** of installing a sensor

FFS, IOW, CCD, RBI: Permanent Installed Monitoring Systems (PIMS) have been in refinery and petrochemical plants for over a decade. As with any new technology, there has been a learning curve in proper installation practice, miniaturization of apparatus, enhancement and evolution in software and reduction in installed costs of these systems. In conjunction with the advances in installed sensors, advances in Fitness for Service (FFS), Corrosion Control Documents (CCDs) and Integrity Operating Windows (IOWs), along with the maturation of Risk-Based Inspection (RBI), all rely heavily on the use and trending of equipment thickness readings. The economics and validity of random or non-cataloged thickness has been discussed in other forums and the focus on the application of targeted thickness readings for a few specific applications such as FFS validation and monitoring, Materials Operating Envelope (MOE) monitoring correlations and critical-area monitoring in anticipation of turnaround or replacement.

One application of installed UT sensors are monitoring the operational conditions of equipment with the corrosion rates of a unit or corrosion circuit in a unit. One such unit with many critical process variables is a Hydrofluoric Acid Alkylation Unit. The HF Alkylation Process is designed to generate a valuable gasoline-blending component from other refinery products that are too volatile and too light to be used in gasoline. Unsaturated butylene and propylene olefins are chemically combined with isobutane (iC_4) in the presence of a catalyst, hydrofluoric acid (HF). This chemical reaction produces alkylate, which is a high octane-blending component.

Corrosion by HF Acid is an aqueous type of damage mechanism which can result in high general or local corrosion rates to carbon steel, sometimes greater than 1,000 MPY (25.4 mm/yr.). This can be accompanied by hydrogen blistering, hydrogen stress cracking and/or HIC/SOHIC.

The recommended materials used in HF Alkylation service in refining is Carbon Steel (CS), except where temperatures may exceed 150 - 180 deg. F (65.6 – 82.2 deg C). Then, copper-nickel alloys and UNS N04400 will be used as an upgrade. All of these alloys can be susceptible to HF Acid corrosion under the right conditions, and temperature is a key variable on material performance. In addition to measuring wall loss of a component over a period, the ability to identify when the wall loss occurred and the metal temperature and/or condition at that time is highly valuable information in the material upgrade decision process. Manual thickness readings generally lack any temperature component; just a date or estimated day so tying wall loss to temperature is difficult if not impossible.

This is another example of how installed UT Sensors car provide data that cannot be obtained by manual UT readings. In addition to the higher-quality data, a focused thickness interrogation program may cost anywhere from $25 to $75 per data reading in a specific TML over a period of time. After approximately 20-50 readings, the cost of an installed sensor is not only economically justified, but more data can be obtained without the additional cost or risk of manual intervention.

Installed Sensors benefits worker safety programs

Finally, but first on many people's minds, is worker safety. Using installed sensors reduces the need for UT inspectors or technicians to go into the units to perform spot UT thickness measurements. This reduces the number of unit entries and thus reduces the possibility of a person having a work-related injury due to slips, falls, burns, or other instances normally occurring within industrial environments. Most of all it reduces the possibility of human injury or loss of life in the event of a serious facility incident.

Conclusions: Technology drives safety and productivity

Over the past decade, manual Ultrasonics and Radiography are being displaced by installed ultrasonic sensors to measure asset integrity for wall-thickness degradation. These applications are commonplace and are showing technical, economic, planning and safety advantage over manual methods. In addition, accuracy and precision of these measurements are much greater than the manual methods. They allow a continuous monitoring rather than a periodic snapshot view of asset health. Asset managers desire a more real-time view of the health of their plant equipment similar to the KPI view that they get from monitoring process variables.

References:

1. 29 CFR 1910: OSHA Process Safety Management
2. O'Brien, J. "Chevron NDE Performance Demonstration Exams" API Inspection Summit, January 26-29, Galveston Island Convention Center, Galveston, TX.

The authors:

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