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AUTOMATING AND OPTIMIZING THE CML / TML DATA COLLECTION PROCESS

MIKE NUGENT, *VP of Industrial QA at AEIS*
STEVE STRACHAN, *VP of Sales at Sensor Networks, Inc. (SNI)*
ART LEACH, *Sr. Product Manager at Sensor Networks, Inc. (SNI)*

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INTRODUCTION

For the past 4-5 decades, oil refiners and petrochemical plants have 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 hundreds of thousands of manual UT readings per year.

Figure 1. Portable UT Flaw Detector

Figure 2. Digital Thickness Gage

Portable devices such as analog UT flaw detectors (**Figure 1**) and digital thickness gages (**Figure 2**) have evolved significantly over this time frame. All modern devices employ the same basic measurement principle of "clocking" the round-trip transit time, in microseconds, 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 to these instruments yielding higher resolution, RF signal display, better accuracy, temperature correction, ease of use, auto-calibrating with onboard data-logging able to store the digital data including the RF waveform, and geo-location from each thickness reading.

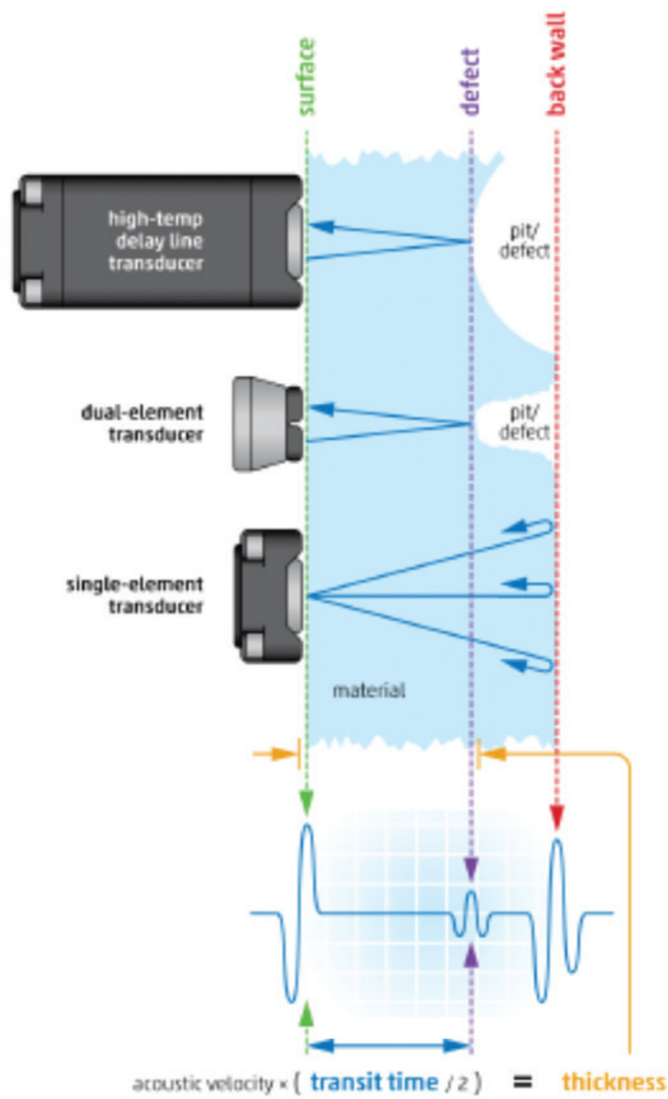


Figure 3. Various transducer configurations

Transducer technology also advanced steadily over the past few decades to include single-element, dual-element, and delay-line probes (**Figure 3**) with improved temperature stability, wider thickness ranges, better durability and improved ergonomics to minimize technician fatigue. One of the latest technological advancements 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 measurement resolution necessary for corrosion engineering (i.e., to calculate a credible corrosion rate).

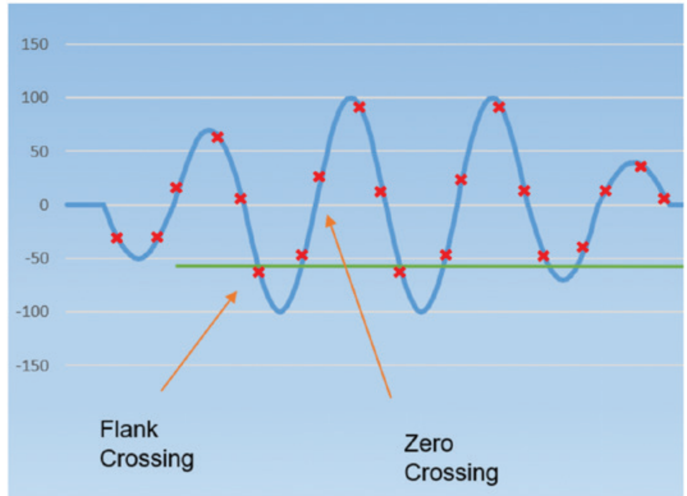


Figure 4.

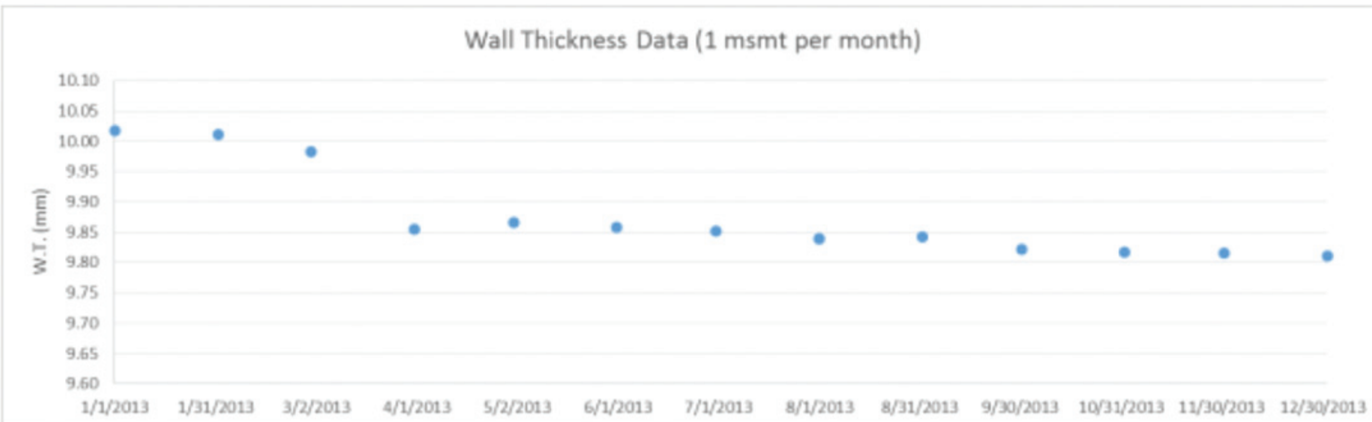


Figure 5. Monthly wall thickness measurements

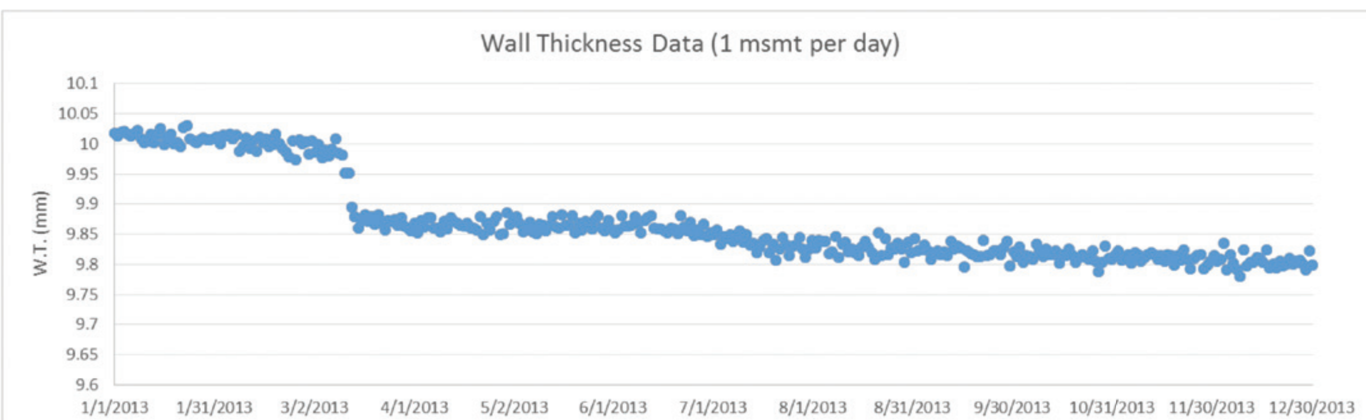


Figure 6. Daily wall thickness measurements

Consistent reference locations on the digitized RF waveform are required to make such repeatable and accurate thickness readings (See **Figure 4**). 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 linearly 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, managing all the data, both good and corrupt, continues to be very challenging.

Accurate manual thickness trending is also challenging due to variability in technician qualification and experience, temperature changes, instrument differences, surface conditions,

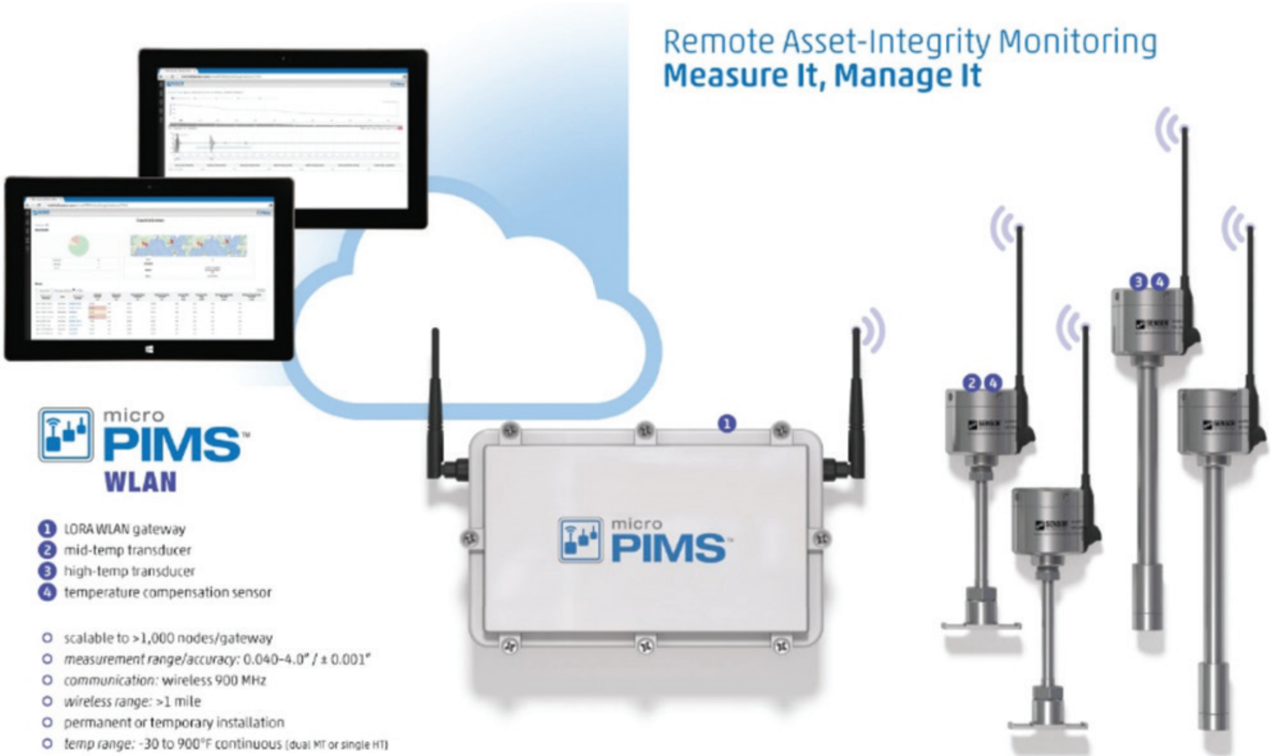


Figure 7. Typical system topology of a wireless UT sensor network.

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 (thickness monitoring locations).

Even if accurate readings are taken at monthly intervals (**Figure 5**), episodic events caused by process upsets or turnaround-related issues will be poorly understood. If accurate readings are taken and time-stamped daily (**Figure 6**) corrosion engineers are better able to correlate metal-loss rates to actual plant operating conditions.

Figure 8. Cloud-based web portal.

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 in 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 can lower the need for the number of TMLs, allowing NDT personnel and budgets to be better utilized elsewhere. Case studies of several plants have shown that, when embraced, installed sensors can yield significant benefits.

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

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 in real time. No more waiting for data to be manually processed and auto-alarms can be set for minimum thickness or accelerated corrosion rates.

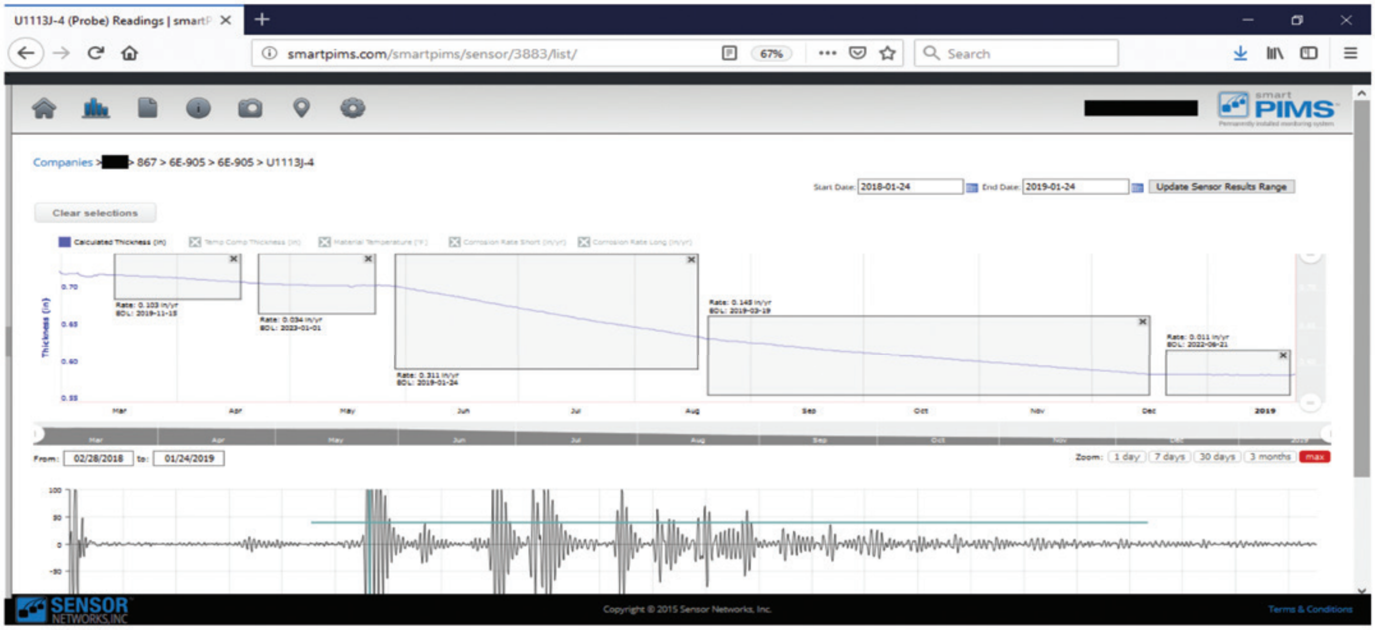


Figure 9. Time-gated windows can accurately calculate metal-loss rates and correlate that data to specific episodic events such as chemical inhibitor use.

Figure 10. The metal loss plot, shown above, was 0.001" for a seven-day period which, if left unabated, would be ~0.050"/year. Installed sensor systems can accurately identify trends more rapidly therefore enabling faster intervention.

Thickness data for each TML can be an 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

Deploying 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 and introduced over 20-years ago and extremely niche as they were expensive and quite limited in capability. As with any technology evolution, 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 from deploying installed sensor systems.

Unfortunately, for those looking for a simple ROI equation, it is not as straightforward 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:

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.)

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 monetized 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 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 advancements 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), 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 is monitoring the effects of operating conditions on equipment by measuring the corrosion rates in strategic areas of a unit or corrosion circuit. 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.

HF Acid corrosion is an aqueous type of damage mechanism that 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

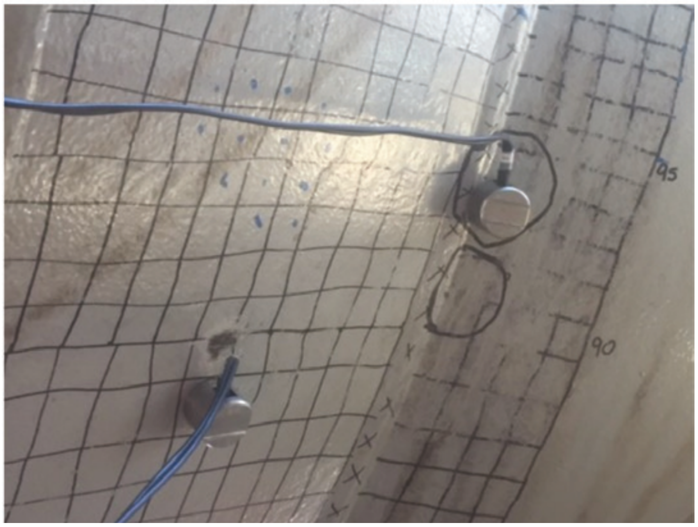
accompanied by hydrogen blistering, hydrogen stress cracking, and/or HIC/SOHIC.

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 might be used as an upgrade. All of these alloys are 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 can be 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 just one example of how installed UT Sensors can 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 at 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.

TECHNOLOGY DRIVES SAFETY AND PRODUCTIVITY

Finally, but first on many people's minds, is worker safety. Using installed sensors reduces the need for UT inspectors or technicians to enter units to perform spot UT thickness measurements. This can reduce 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 can reduce the



possibility of human injury or loss of life in the event of a serious facility incident.

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. ■

For more information on this subject or the author, please email us at inquiries@inspectioneering.com.

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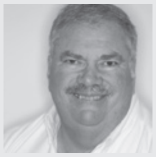
CONTRIBUTING AUTHORS

ART LEACH

Art Leach is the Sr. Product Manager for Sensor Networks, Inc., located in State College PA. Art has more than 40 years' experience in the Ultrasound field encompassing medical ultrasound probes and industrial probes and applications. Art is a graduate of the Ohio Institute of Technology and an alumnus of Penn State University.



MIKE NUGENT

Mike Nugent is VP of Industrial QA at AEIS in South Plainfield, NJ and has over 35 years in the Refining, Chemical and Power Industry as an Owner User and Service Provider Engineer and Manager. He has a Bachelor's and Master's from Stevens Institute of Technology where he has been an Adjunct Professor for the past 20 years. Mike has spent most of his career in operating plants and is a Fellow in ASNT. He is on the Board of Advisors for SNI since the company's inception in 2014.

STEVE STRACHAN

Steve Strachan is VP North American Sales for Sensor Networks, Inc. in Houston, TX. Steve is a graduate from Pennsylvania State University. Prior to joining Sensor Networks, Inc. Steve worked for GE Inspection Technologies as a graduate of the Commercial Leadership Program and worked as a Sales Regional Manager and Product Manager for Ultrasound, Digital Radiography and Handheld XRF (PMI). Steve is based in Houston, TX.