Greater Houston
ASNT NEWSLETTER

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A Rewarding Night of Awards

Each year, we set aside GHASNT's March meeting as Awards Night. Not only is it an outstanding opportunity to recognize so many exceptional students and professionals in the Greater Houston NDT community, it is a rewarding night for all of us. We get to see the fruits of our fundraising work and unwavering support of our fellow NDT-ers assist deserving individuals whose goal it is to continue making the world a safer place through NDT. This year, we are pleased to honor the following winners:

Jerry Fulin Technician of the Year

GHASNT recognizes Level I, II, and III technicians who have gone above and beyond in their specific discipline. These technicians receive the Jerry Fulin Technician of the Year award, which, in addition to being a nice feather in their cap for a job well done, provides them with industry recognition and a chance to be nominated for ASNT National Technician of the Year representing the Greater Houston ASNT. Level I and II recipients also receive a financial gift to pursue additional studies and further their career in NDT.

This is the 1st year GHASNT has offered awards for Level I, II, and III.

This year's award recipients are:

Jason Burleson – Level I
Tyler Smith – Level II
John Chen – Level III

GHASNT's Roger Jordan and Tyler Smith, Level II Technician of the Year

Detecting and Quantifying Cracks Using Eddy Current Array

By Kimberley Hayes at Olympus

Introduction

Detecting, quantifying, and sizing indications characterized as a "crack" in critical equipment have long been the global benchmark of asset integrity programs. Therefore, the increased precision that inspection programs obtain using advanced technologies can dynamically improve the overall assessment. Cracks open to the surface have traditionally been inspected with conventional nondestructive testing methods like penetrant testing (PT) and magnetic testing (MT). As in many procedures, secondary methods may be used to verify, qualify, or quantify indications. A derivative method of MT, eddy current (EC) testing, is also widely used to detect cracks in various materials by using a similar flux leakage principle, and EC can provide increased precision to complement or replace other conventional methods by providing depth information, increased inspection speeds/productivity, minimal intrusion/waste, and digital recording. EC testing is not a new technology; it has been widely adopted to inspect for fatigue cracks in aluminum airplane skins and investigate damage mechanisms in heat exchanger tubes. Yet EC is still underutilized in the petroleum industry.

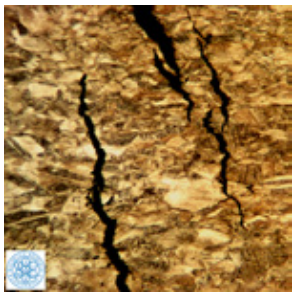
This article presents a general overview of conventional methods (PT/MT), eddy current (EC) testing, and advancements in eddy current array (ECA) technology, which offers an increased potential for detection, characterization, and productivity over conventional inspection methods. The advantages of ECA as an additional nondestructive testing method for evaluating damage mechanisms, like stress corrosion cracking (SCC), is also highlighted.

Inspection of Stress Corrosion Cracking

It is critical to understand the damage mechanisms that could potentially affect your equipment. Detection, characterization, and sizing of cracks play an important role in structural integrity assessments. The inspection process used and the metallurgy are important variables that help inspectors assess the propensity for various damage mechanisms, such as environmentally-assisted cracks. Understanding the damage mechanism and its inherent characteristics (surface/subsurface, size, orientation, and location) plays an important role when selecting one inspection method over another.

For example, it is widely understood that for SCC to occur, three factors must exist:

1 predisposed material;
2 a corrosive medium; and
3 tensile stress (load or residual).



These conditions are often found around welds, the heat affected zone (HAZ), and into the base material. In pressure vessels, process pipes, or storage tanks susceptible to SCC, the ability to detect cracks is one thing, but the ability to characterize the cracks and size their depth is critical. Narrow, branchlike ("spider web") indications characteristic of SCC, combined with the potential for scale filling the crack void, can make detection challenging for conventional surface inspection methods. SCC has a high propagation rate that can lead to catastrophic results if undetected; therefore, detecting and properly identifying SCC is critical to deciding whether or not to take an asset out of service.

Historically, conventional methods, like magnetic testing (MT) and penetrant testing (PT), have been used when inspecting for these cracks. MT/PT are reliable for many surface inspections, however, the surface preparation requirements associated with these methods pose challenges to validating the characteristics of SCC. As per API 571, in some forms of SCC *(Amine Stress Corrosion Cracking-5.1.2.2.7 a & b—Inspection and Monitoring),* MT requires surface preparation, such as grit blasting or high-pressure water blasting. It is also stated that, due to the small size of the cracks and the potential presence of scale, PT is usually not effective and should not be used for some SCC. Surface preparation can be minimized by using technologies like EC. The physics behind eddy current make this technology well-suited for overcoming the surface preparation and thin/scale-filled crack limitations. With the added value of ECA, this method should be strongly considered. EC is a well-established technology supported through the American Petroleum Institute (API) and the American Society of Mechanical Engineers (ASME).

Overview of Conventional Inspection and Eddy Current Theory

Liquid penetrant testing is a surface inspection method often used on non-ferromagnetic materials. This method uses the principle of capillary actions' force from cracks open to the surface, drawing fluid that contrasts with the base material

Inspectioneering Journal article (continued on page 3)

into a discontinuity. This requires time for the penetrant to be drawn into the crack (referred to as "dwell"). Excess material is removed and a developer (light powder) is applied to re-blot the contrasting material and present visible bleed-out of the penetrant trapped in the indications. This step also requires dwell time. The visible indication is at the location of the defect, enabling intuitive defect detection and assessment ***(Figure 1).*** Due to bleed-out, challenges often exist in accurately sizing and characterizing the indication. The critical nature of the sensitivity level of the penetrant and dwell time are significant considerations. Visible penetrant is the least sensitive of the penetrant materials. Many aerospace-related inspections require Level 4 fluorescent penetrant and more than an hour dwell time to detect SCC. Sensitivity and dwell times are important considerations to achieve a good/credible inspection. An additional consideration for PT inspection is that the surface must be free of paint and very clean prior to applying the dye and developer. Visible PT requires chemicals to perform the inspection. PT creates a waste stream that must be managed, contained, and properly disposed. If the inspection area is not photographed during testing, there will be no visual record of indications located during the inspection.

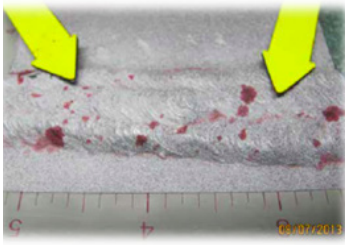


Figure 1. PT visible at an indication.

In ferromagnetic applications, **magnetic particle testing** is an effective surface and near-surface inspection technique, as it leverages the magnetic properties and disruptions in a material to its advantage. In the refining industry, an AC yoke is often used to induce a magnetic field in the specimen. When contrasting colored particles (either visible or fluorescent) are applied, they migrate to breaking flux emitting from surface disruptions. These north/south pole gaps create a visible indication at the defect. The indication must be perpendicular to the lines of flux to be detectable. In a yoke, lines of flux travel from pole to pole on the yoke's contact points; therefore, a yoke is required to assess a defect's location in two perpendicular directions to help ensure proper coverage. Wet fluorescent magnetic testing (WFMT) has long been utilized to inspect ferromagnetic materials, like carbon steel, and presents very detailed surface representations of discontinuities (Figure 2). MT yoke inspection systems are relatively inexpensive and portable. These systems typically consist of an AC yoke, fluorescent particles suspended in a medium, and a black light to excite the illumination of fluorescent dye encapsulated iron oxide particles. Access to a power supply is required to run both the black light and yoke. To perform WFMT, the inspection area must be darkened according to code when using the wet fluorescent magnetic particle method. If the area cannot be darkened, dry, color contrast methods are available, but the inspector must use particles with good contrast to the base material to help ensure good detection. Dry powder ***(Figure 3)*** comes in many colors. Taking photographs for a visual record can be challenging in these circumstances, especially with WFMT, and requires additional equipment (a camera and K-2 filter).

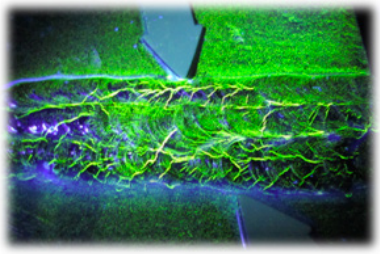


Figure 2. SCC on weld cap with wet fluorescent MT.

Eddy current testing, like magnetic particle (MT), is based on the relationship between electricity and magnetism (electromagnetism). An eddy current (EC) inspection system is composed of three fundamental components: the flaw detector instrument, software, and the probe (test coil housing) and requires a higher initial investment for the equipment. The test coils are composed of a tightly wound wire (coil) in various configurations and operate on Oersted's theory of electromagnetism where a magnetic field develops from the electric current through a conductor. Specifically, an alternating current flows through the wire coil and generates an oscillating magnetic field. When the probe comes into contact with a conductive test specimen, a circular flow of electrons, called eddy currents, are induced into the part, which makes its own magnetic field ***(Figure 4)***. The part's localized magnetic field interferes with the coil in a principle known as mutual inductance. The operational basis for the technology is Faraday's law of electromagnetic induction, which states that the relative motion between a magnetic field and conductor causes voltage in the conductor. If the energized coil comes in contact with a conduc-

Figure 3. SCC on weld cap with Visible MT (red).

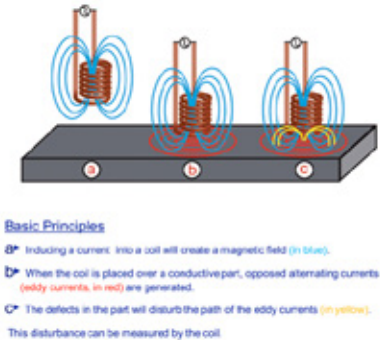


Figure 4. A diagram showing how EC works.

Inspectioneering Journal article (continued on page 4)

tive material, it impacts the electrical impedance of the coil, and the combined signal is displayed on the instrument's screen. When the coil passes over a flaw or indication, the instrument records the change in the impedance amplitude and phase angle, presenting instant feedback to the qualified inspector for assessing the indication.

The distance from the probe to the part is called "lift-off." If the lift-off is zeroed (nulled), it can be a valuable feature that enables inspectors to ignore the gap (paint to base material), enabling direct material inspection without paint removal. Using this method to measure coating thickness before performing other NDE methods, like MT, is an option often called out in industry codes. An additional element to an EC inspection system is that the AC field couples the coil to the part without the need for materials like couplant (often necessary for ultrasonic testing). This enables the inspection to be performed without additional materials, without post-inspection cleaning, and without stripping off the coating on the component being tested. Unlike MT, EC can measure the volumetric impact of a disruption and display comparative depth sizing. When precisely calibrated for material and sensitivity, indications can be accurately sized using conventional EC. The amplitude and impedance are displayed on the flaw detector, enabling a qualified inspector to assess the location and severity of the indication. This file can be easily saved for reporting, post-processing, and additional verification. Calibrating samples of known damage depths, representative of the test subject, is important for accurate crack depth sizing. Depth sizing using eddy current methods is highly dependent upon material, thickness, and crack depth. Depths using EC data are typically used for screening. The calibration is done to help ensure that the desired levels of precision can be achieved.

Although EC can be effective in detecting, sizing, and characterizing surface breaking indications (and some subsurface), the slow speed and limited coverage area of a conventional single coil EC probe has been a challenge for industry. However, the advent of eddy current array (ECA) technology has addressed these issues.

Advantages of Eddy Current Array

An ECA probe is designed with multiple eddy current coils placed side by side in the same assembly. In conventional EC, the probe is rastered to enable full area coverage and may miss some areas. With ECA's overlapping/multi-coil design, users can inspect a larger coverage area more quickly (normally about 32 times the coil coverage; ***Figure 5***). Each coil produces a signal relative to the phase and amplitude of the contact specimen. The highest resolution is observed at the surface because this is where the eddy current density is strongest. Subsurface detection may be viable if the magnetic field penetrates the component's skin sufficiently. The standard depth of penetration is defined as the depth where the eddy current density is 37% of its surface value. The depth of penetration is calculated using the test frequency, magnetic permeability, and material conductivity. Although conductivity and permeability are properties of the material and out of the inspector's control, appropriate selection of test frequency, coil type, and size are leveraged to optimize inspection.

Conventional eddy current inspection requires a skilled technician to understand the signal response on the instrument. With the multiple acquisition points from the array of coils in ECA, the data points can be displayed in a planar view image called a 'C-scan' ***(Figures 6 and 7)***. This provides an intuitive display for the inspector. Encoders can be added to present data relative to position, increasing the ability of the inspector to denote the location and severity of the detected indication and save this information for future reference and comparison.

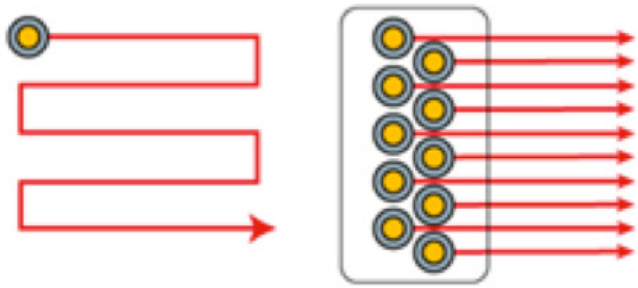


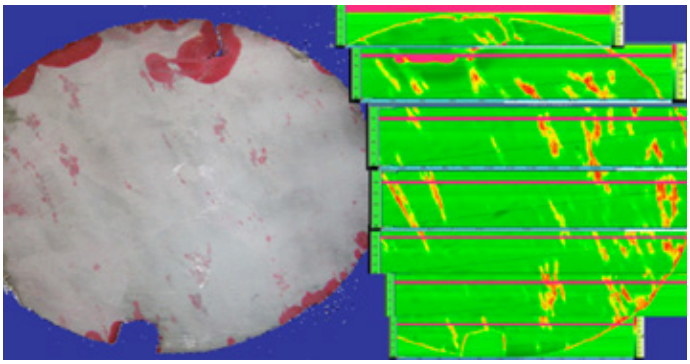
Figure 5. Left-Single-coil EC raster scan and on Right-Multiple coil (ECA) coverage of same area.

An eddy current array inspection system is also composed of three components: an ECA inspection instrument, software, and probe (rigid: flat or shaped, or flexible), and is characterized by its portability, the number of channels, frequency range, and software.

Application

We recently used both ECA and PT to inspect a heat exchanger shell made of carbon steel with 304 stainless steel explosion-bonded cladding that was suspected of having SCC. The results demonstrate that the C-scan presentation enabled the operator to clearly detect and size the corrosion as well as the larger

notches ***(Figure 6)***. Visible penetrant can be seen in ***Figure 6*** (left) along with seven ECA rastered C-scans stitched together of the same part (right). Color palettes are often linked to the amplitude of the eddy current signals; however, when required, color palettes can also be linked to the phase angle of the signal. Color pallets range from a gradual rainbow palette to a precise, two-color "go/no-go" pallet. Selection can be changed to represent visible PT or black/white MT ***(Figure 7)***.



C-scan image of the heat exchanger shell captured using ECA.

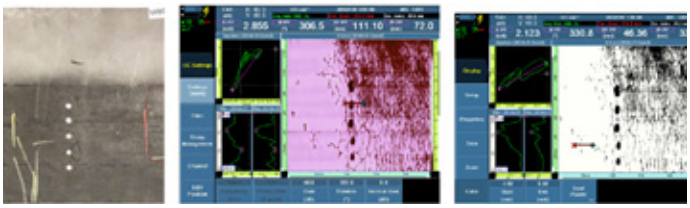


Figure 7. Inspected plate (left), penetrant color palette (middle), and visible magnetic particle inspection (right).

Detection

MT has a maximum sensitivity for linear discontinuities oriented perpendicular to lines of flux and a maximum detection in both directions. An ECA probe can detect both parallel and perpendicular defects (but not oblique indications). However, an SCC ECA probe used in reflective mode can provide omnidirectional inspection. This enables faster inspections and helps ensure directional coverage. System setup, sensitivity, and calibration can further increase or decrease the probability of detection (PoD). For corrosion detection on carbon steel, a frequency around 150 kHz is often used. Gate/threshold alarms can enforce audio/visual alarms to help ensure an accurate evaluation from an inspector.

Characterization/Qualification

ECA enables users to assess surface-breaking cracks and measure their depth in many cases, a feature that is not an option with MT/PT. The amplitude displayed on the instrument's screen has a direct relationship to the depth of the flaw. The amplitude can be gated based on acceptance criteria and can be adjusted for sensitivity. When an appropriate probe and settings are calibrated, short flaws, like SCC, can be accurately detected. ECA is a comparative evaluation and attention must be paid to the initial calibration.

Productivity

ECA can detect defects through non-conductive paints, optimizing cost in turnaround time and coating removal/re-application. Aside from time and waste, this is especially important because the coating stripping process can potentially damage the component being inspected and increase corrosion exposure. Since the probe is coupled directly through the alternating current and paint can be nulled, this risk is mitigated. These features help reduce waste from stripping and spent cans; costs which are often overlooked. Once the ECA system is calibrated, the inspection is near-instantaneous, reducing inspection time (up to 15 times less than PT). There is no post-cleaning and inspected parts do not need to be demagnetized, which also saves time. As previously mentioned, ECA presents a circular field which enables multiple directions to be presented perpendicular to the lines of flux. This omnidirectional detection capability further reduces inspection time and can scan at a speed of 3 inches per/second, which is 32 times faster than conventional EC, and sweep larger areas.

Increased PoD, accuracy of detection, and increased repeatability optimize the inspection and provide confidence in the results. Post-processing data analysis helps speed up inspection time and sample verification as an inspector can do bulk acquisitions and assess/report off-line. For ferromagnetic materials, special considerations are required; however, the one inspector can perform both ferro and non-ferromagnetic inspections with the same probe configuration, utilizing two separate instrument setups. The result is that the investment in equipment is minimized as is the hours and labor associated with the inspection process.

Reporting

Setup, calibration, and scan files can be easily archived, recalled, and verified by an owner/operator or secondary authority. Onboard data storage throughout the inspection facilitates convenient post-inspection reporting.

Challenges

The dominance of legacy inspection methods has plagued the quantity of qualified eddy current inspectors, but this limitation can be overcome with increased demand. In addition, the

perceived per hour cost difference between MT/PT services versus ECA has slowed the adoption of ECA as a mainstream inspection method. If direct and indirect costs (e.g. paint stripping and reapplication, potential damage during the stripping process, material disposal, and potential dwell time) of other methods are properly weighed against the aforementioned value propositions (increased detection, characterization, sizing, digital archives, and productivity) of ECA, you will see that ECA presents significant savings. Decisions should be based on the full quality of inspections, rather than simply the base costs.

Conclusion

As inspection technologies advance, industry should adopt solutions that present advantages over older inspection strategies. In this article, we demonstrated the advantages that ECA inspection has over PT/MT in detecting stress corrosion cracking. These advantages include an increased probability of detection, reliability, and overall cost and time savings.

Kimberley Hayes: About the Author

Business Development Manager, Olympus

Kimberley Hayes has more than 20 years of experience in chemical processing and nondestructive testing, and is a Business Development Manager at Olympus. She is responsible for executing strategic and tactical initiatives to support the oil and gas market and new product development for the Americas. Before joining Olympus, she was as a BDM at Magnaflux focused on magnetic and penetrant testing. She has an MBA from Pepperdine University and a BS from Jacksonville State. She participates on technical review committees with the American Petroleum Institute and is a recent member of the Special Working Group on NDE Resource Support ASME, Section V.

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ACCP Level II	MT GI B, MT GI Y	Gene Perz
ACCP Level II	VT GI D	James Basham
ACCP Level II	VT* GI D	Shadi Aldawas
ACCP Level II	VT* GI D	Brandon Ware
ASNT NDT Level III	UT	Andrew Levron
ASNT NDT Level III	MT	Chase Robinson
ASNT NDT Level III	MT, PT, UT, VT	Dustin Whitehead
ASNT NDT Level III	UT	Allison Pepperjohn
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GOLF

OUTING

What's a little rain among friends and fellow NDT-ers? Despite being washed out, GHASNT's annual golf tournament (and our biggest fundraiser of the year), which took place on April 17, 2017, was a wonderful day of just plain fun at Timber Creek Golf Club in Friendswood, TX. Huge thanks go to GHASNT's Tournament Directors Skip Hoyt and Becky Judkins and the many volunteers for always making this an event everyone looks forward to - rain or shine!

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GREATER HOUSTON

One of the ways we say thank you to our members and sponsors each year is GHASNT's annual Vendors Night at South Shore Harbour Resort.

The event is always the right mix of business and pleasure, offering free food and drink alongside lots of great conversation, demonstrations, and networking, make it an evening that is a must-attend local event.

ASNT VENDORS NIGHT

Jerry Fulin of Scholarship Award Recipients

Scholarships

Each year, GHASNT provides scholarships for students pursuing a program of study at a junior college or NDT training facility within the Houston area. Students must be pursuing a degree, and though the focus is on NDT, other welding, engineering, and science-related programs utilizing NDT disciplines may also be considered. There are two scholarships available: the Charles N. Sherlock Memorial Scholarship, and the Gerald E. Smith Memorial Scholarship. To be eligible for either, applicants must enroll in an NDT-related course at a university or college.

This year's recipients are as follows:

Name	School
Brandon Hernandez	Ocean Corp.
George Rodriguez	Ocean Corp.
Michael Tran	Ocean Corp.
Kristofer Christoferson	Ocean Corp.
Brook Ann Beesley	Ocean Corp
Delsi Arana	Wharton
Joe Garza	Wharton
Matthew Ortiz	Wharton
Jacinto Torres	Wharton
Arnulfo Mendoza	Wharton
Tim Riemer	Texas A&M
Manuel Gutierrez	Texas A&M
Xavier Benitez	Texas A&M
Maximiliano Ortiz	Texas A&M
Able Solis	Texas A&M
Dale Stein III	Texas A&M
Amador Ramirez	Lone Star College

Texas A&M Scholarship Winners

GHASNT Scholarship Winners at Lone Star College

Scholarship Winners Awarded at Ocean Corp

Wharton Students Receive Scholarships from GHASNT

More HEART

Dave Bajula, ASNT 2016-2017 President and long-time member of GHASNT, is back in this issue with the second article in his HEART series.

In case you missed the previous article in the Winter 2017 issue of GHASNT's newsletter, HEART is an acronym that stands for five fundamental attributes I believe are necessary ingredients in the successful application of all NDT testing. These attributes are honesty, excellence, accuracy, respect, and teamwork. This month, I look at accuracy.

Merriam-Webster defines accuracy in the following three ways:

- freedom from mistake or error
- conforming to truth or to a standard or model
- degree of conformity of a measure to a standard or a true value

How does this apply to us in NDT? It goes without saying that accuracy in our inspection work is paramount for the decisions required to assure the safety and integrity of the components we inspect. Based on my 30-plus years of experience, the importance of accuracy comes down to our ability to produce results free from mistake or error.

> "We are duty bound to report accurately the results of our NDT inspections."

Accuracy should not be confused with precision. However, precision is also important, especially in the context of repeatability. For years, one of the big oil companies has mandated that a minimum of three thickness readings be taken for each Corrosion Monitoring Location (CML) at each inspection interval. As an example, if a particular CML inspection point was proven to be .205 and I received data from the technician showing .202, .206, and .204, I would characterize this as both accurate and precise. If I received data from the technicians showing .190, .194, and .188, I would categorize this as not very accurate; however, with good precision. If I received data showing .184, .202, and .215, I would conclude that the technician and/or the techniques are neither accurate nor precise.

In NDT testing, it would be hard to address the accuracy requirements without identifying the expected tolerances. Tolerances are the permissible limits (variations) from truth or

real value. In ultrasonic testing, we generally refer to accuracy tolerances within various physical limits, such as transducer frequency. Specifically, the best expectation for sizing of any particular flaw would be within one-half wavelength (λ). In Nondestructive Testing Handbook: Ultrasonic Testing, wavelength is defined as $\lambda = V/F$ (ASNT, 2007). If you want to increase your ability to achieve the most accurate results, then increasing your frequency is one way to do it.

Our challenge when doing inspections is to be as accurate as possible within the expected tolerances. Where we may not be able to completely control the variables due to limitations on the physics of a particular method, technique, or equipment choice, we must strive to minimize inaccuracies due to human factors. This starts by performing the inspections with strict adherence to the procedures, specifications, standards, or codes that are provided. When using prequalified procedures, standards, and techniques, accuracy is then completely dependent on our skill, including the care and diligence we exercise in the performance or our inspections.

We are duty bound to report accurately the results of our NDT inspections. The consequence of a critical component or part failure is too great and the inspections we perform are used to ensure safety and save lives.

In summary, accuracy is an important part of nondestructive testing, and I would continue to challenge all of you to be diligent in the performance and reporting of your inspections.

Contact:

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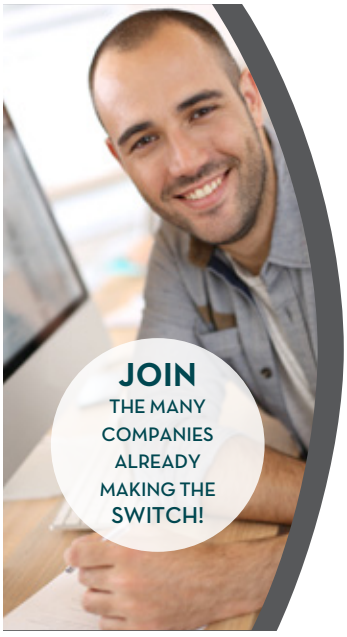
May 16-20, 2017	ICPIIT – 15 (Galveston, TX) asnthouston.com
May 23-26, 2017	AFPM Reliability & Maintenance Conference (New Orleans, LA) – afpm.org

Sweet Financials

We all know that "keeping the books" can be a thankless, grueling task. At the March meeting, we were so pleased to present GHASNT's own Tom Roberts with a jar full of jelly beans and, yes, a cash register, in appreciation for all his years of helping us keeping our financials in sweet shape.

Thanks, Tom!



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