Structural Integrity Associates, Inc.®

NDT Service Offerings for Oil and Gas Pipeline

STRUCTURAL INTEGRITY MISSION STATEMENT

Structural Integrity Associates, Inc. will be recognized as the most trusted independent provider of innovative, best in value, fully integrated engineered solutions to the Energy industry.

ABOUT STRUCTURAL INTEGRITY

Structural Integrity Associates, Inc., is a leading engineering and consulting firm dedicated to the analysis, control, and prevention of structural failures. Founded in 1983 in San Jose, CA, we have since opened branch offices throughout the United States and Canada, and established overseas affiliates.

We pride ourselves on innovation marked by a creative multi-disciplined approach to component evaluation and repairs. Our services are supported through the development of increasingly sophisticated tools reflecting a unique blend of technical expertise with the latest computer, analysis software, and NDE technologies.

Over the years, Structural Integrity has established itself as an innovative and responsive resource for addressing virtually any challenge in the analysis, control, and prevention of failures in critical equipment. Our experience ranges from R&D to engineering, metallurgy, and fabrication, and from petrochemical applications to nuclear and fossil-fueled power plant support. With multiple offices and many experts throughout the U.S., we can quickly and effectively help your engineering needs.

CORPORATE SNAPSHOT

- **Employee-owned company founded in 1983 in San Jose, CA**
- **Branch offices throughout the United States and Canada, as well as overseas affiliates**
- **250+ employees providing consistent innovation and service**

ABOUT STRUCTURAL INTEGRITY'S INTEGRATED ASSESSMENT SERVICES

Ensuring the continued safe, reliable operation of key infrastructure involves an understanding of the potential degradation mechanisms, knowledge of the optimal inspection methods to quantify the condition of the asset, and the engineering expertise to analyze the information to make an informed decision as to the remaining operability of a component or system. This is what we refer to as ***Integrated Assessments***.

Operators increasingly require greater assessment and engineering expertise to determine if their pipeline/piping assets are fit for service. By integrating expertise in materials degradation, structural mechanics, and regulatory requirements with advanced inspection technologies, Structural Integrity is uniquely positioned to assist operators with difficult to assess projects.

ABOUT STRUCTURAL INTEGRITY PIPELINE SERVICES

OUR SERVICES INCLUDE

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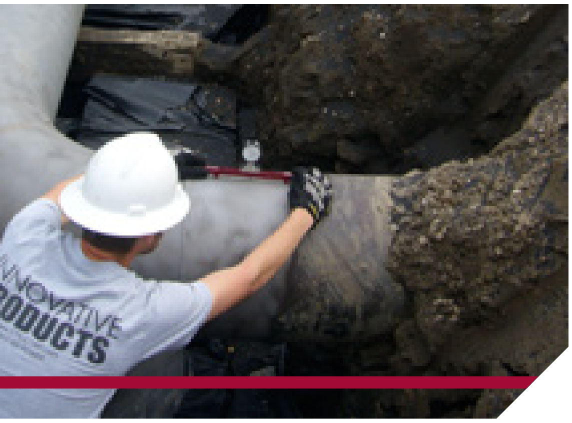
CORPORATE MILESTONES

- **1983** – Company Founded in San Jose, CA
- **1985** – Opened Infometrics; NDE Products Business
- **1989** – Established Fossil Plant Services in Uniontown, OH
- **1991** – Acquired IST, Inc. and Focused Array UT Inspection Technology in Ft. Lauderdale, FL
- **1995** – Opened Charlotte, NC Office
- **2000** – Opened Denver, CO Office
- **2002** – Established Materials Science Center in Austin, TX Office
- **2002** – Opened Stonington, CT Office
- **2004** – Acquired GWT Technology; Established Pipeline Services Group
- **2005** – Opened Structural Integrity Canada in Toronto, Ontario
- **2008** – Opened Chattanooga, TN Office
- **2011** – Acquired the Inspection Services Group from FBS, Inc.
- **2012** – Preferred vendor with Utilities Service Alliance (USA)
- **2012** – Acquired TubeTrack (Power Plant Data Management Software)
- **2013** – Achieved two million hours worked without a lost time injury
- **2013** – Structural Integrity's 30 Year Anniversary
- **2013** – Established affiliate in Europe
- **2013** – Acquired ANATECH Corporation



Bell-hole Inspection: In order to better characterize potential areas of degradation identified from in-line inspection (ILI) tool runs and to properly support the Direct Examination phase of Direct Assessment projects, trained NDE and corrosion specialists should implement a thorough inspection program for excavated pipeline segments.

Structural Integrity has developed a comprehensive bell-hole inspection program with some of the most highly-trained and certified NDE specialists in the industry.

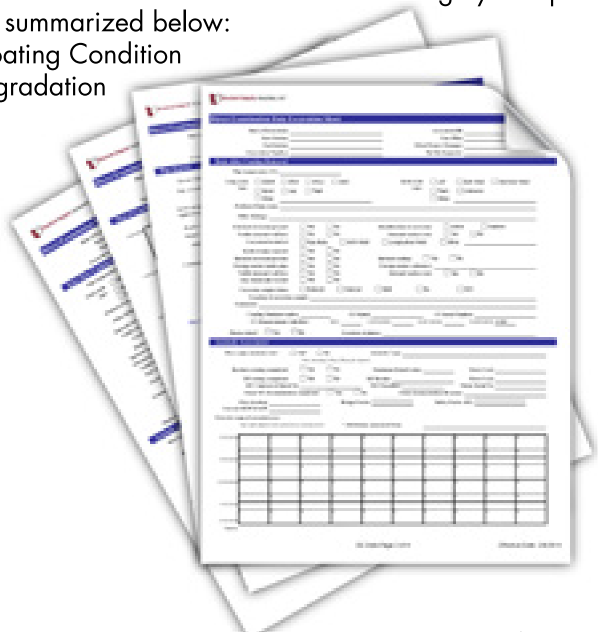
- Maintains specialized data reporting tools to document the findings of these inspections
- Implements the guidelines and data collection requirements specified in NACE, ASME, API, and other industry standards
- Applied this inspection program in a number of different pipeline segments and facilities including gas compressor stations, oil terminal stations, fossil generating plants, and nuclear power plants.

The bell-hole inspection program includes
A collection of data elements:

- Coating condition and adhesion assessments
- Pipe-to-soil potential measurements
- Measurement of coating thickness
- Mapping of coating degradation (blisters, disbondment, etc.)
- Measurement of under-film liquid pH
- Soil resistivity measurements
- Identification of corrosion defects
- Mapping and measurement of corrosion defects
- Corrosion product data collection (if applicable)
- Thorough Ultrasonic Thickness (UT) testing for the exposed piping
- Photo documentation
- Evaluation of remaining strength of the pipe segment
- Root cause analysis

These elements are gathered and documented in Structural Integrity's inspection form, a portion of which is summarized below:

- Summary Details and Coating Condition
- Map of Any Coating Degradation
- Pipe Condition
- (post coating removal)
- Repair Data



Structural Integrity bell-hole form.

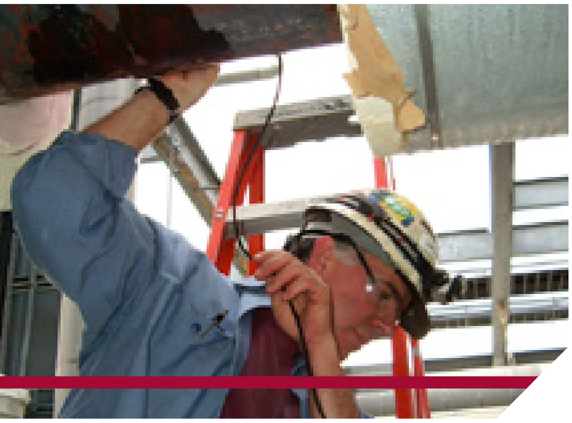
Guided Wave Testing (GWT): Guided Wave Testing (GWT) provides the ability to rapidly screen long lengths of piping to detect internal or external wall thinning and is a proven method for assessing the condition of buried, insulated, or otherwise inaccessible piping in the nuclear, fossil, natural gas, oil, and other industries. GWT is typically applied to metallic piping components ranging in diameter from 2"- 48" although custom collars can be developed for other sizes. Inspections are performed by placing a collar consisting of an array of transducers around the pipe circumference at each test location to launch guided wave modes which travel axially upstream and downstream of the collar location. When the guided wave modes encounter changes in the pipe's cross-section (i.e., corrosion, welds, branches, etc.), some of the energy is reflected back to the transducer collar where it is received for analysis. Through the use of state-of-the-art technology, comprehensive personnel training, superior written procedures, and in-house expertise, Structural Integrity's Guided Wave Technologies group has demonstrated its position as an industry leader in the development and application of advanced guided-wave testing services and solutions. Some examples of applications for which Structural Integrity typically provides GWT include:

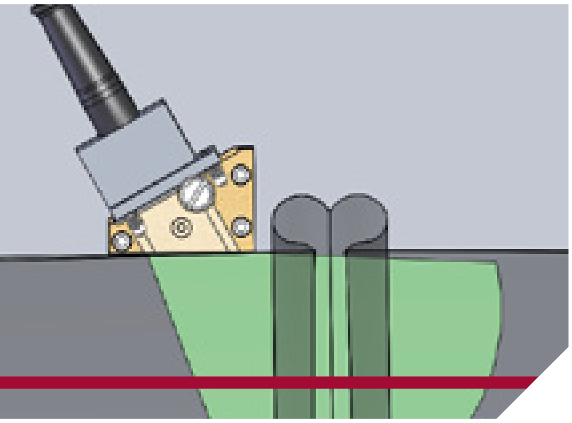
- Cased and non-cased piping segments at road/rail/river crossings
- Above-ground insulated or inaccessible piping
- Buried piping
- Pipeline inspection for corrosion under insulation
- Pipeline inspection for touch point and crevice corrosion (such as corrosion under supports)
- Weld location determination
- Permanently installed monitoring

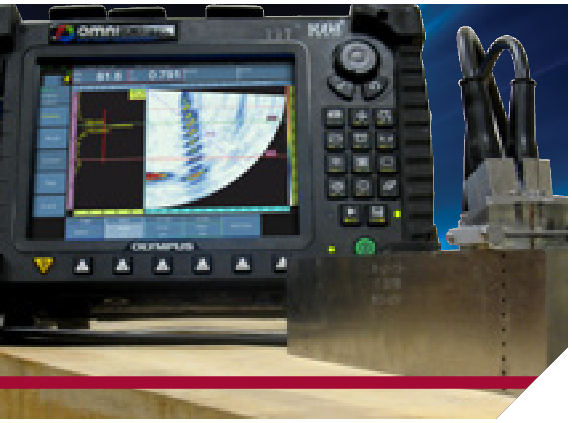
Structural Integrity has been at the forefront of guided wave technology from the very early stages and has continued its pioneering efforts through the early adoption of other GWT technologies such as permanently installed guided wave collars for structural health monitoring (SHM). These collars are environmentally sealed and suitable for both buried and non-buried applications, allow for condition-based monitoring, and have shown significant potential for improvement in sensitivity and inspection coverage. Furthermore, Structural Integrity has diversified its GWT technology capability through the ownership and operation of all the major equipment brands; each with unique capabilities that may be suited to a specific application.

With an experienced engineering team dedicated to the development of new GWT solutions for piping and other critical components, a world-class team of technicians to implement the technology, and some of the industry's most advanced reporting capabilities; Structural Integrity is continuously adding value to its GWT service offerings with a strong focus on quality. Structural Integrity's GWT specialists are also qualified to conduct bell-hole examinations in accordance with industry standards and are certified in accordance with ASNT and EPRI guidelines for a variety of other advanced ultrasonic NDE methods.

GWT transducer collar mounted on a piping component.







Advanced Ultrasonic Testing:
Structural Integrity specializes in the development and application of advanced ultrasonic testing technologies including Linear Phased Array (LPA), Annular Phased Array (APA), 2-D Matrix Array, and time of flight diffraction (TOFD). These techniques have been utilized on multiple oil and gas pipeline projects as well as in the power generation industry for detecting and sizing internal corrosion and stress corrosion cracking. We employ a team of engineers and UT specialists dedicated to the development of techniques and procedures for clients who are dealing with difficult configurations, challenging/unique materials, and complex examinations in demanding working environments.

Phased Array Ultrasonic Testing (PAUT): PAUT is widely used in several industry sectors including aerospace, power generation, petrochemical, pipeline construction and maintenance, structural metals, and general manufacturing. This method is an advanced NDT method that can be used for weld inspection, bond testing, thickness profiling, and in-service crack detection. The greatest benefits of phased array technology over conventional ultrasonic inspection come from its ability to use multiple elements to steer, focus and scan sound beams with a single transducer assembly. The ability to electronically control parameters such as refracted beam angle and focal distance allow for improved defect detection, sizing capability, and speed of testing. It also allows for greater flexibility for the inspection of complex geometries and visualization of inspection results.

For example, LPA technology provides the ability, by proper phasing, to steer the ultrasonic beam through a series of different angles covering a sector typically over a range of up to 60°. The linear array is used primarily to influence beam direction, electronically focus the beam, or a combination of the two. A true spatial representation of the linear array data requires that the data be presented in polar coordinates. The amplitudes of the waveforms, plotted sequentially at each digitization point along each waveform, are typically presented in colors such that the presentation provides instant recognition of the position of a reflector as well as its significance in terms of reflection amplitude. These plots have become known as sectorial scans, or S-scans, because they represent sectors of the cross-section of the component in the plane of the beam. A typical S-scan image is provided in Figure 3. In this case, the image represents a calibration block containing a stack of side drilled holes, with a drawing of the block shown at the left and the representative S-scan image to the right.

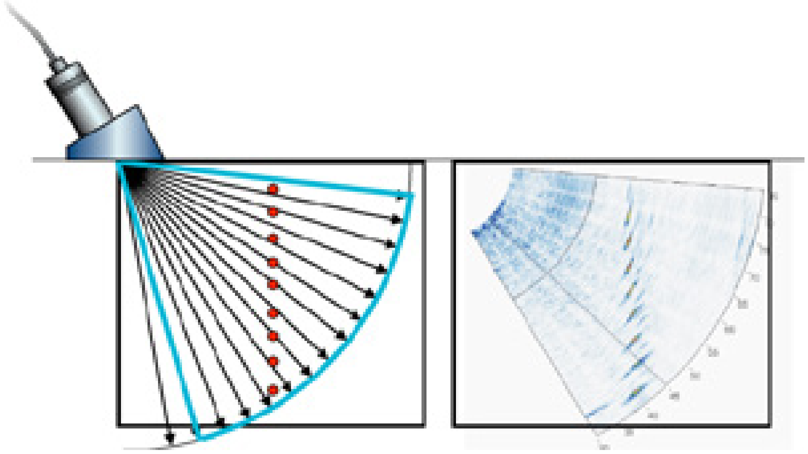


Figure 3: Linear Phased Array (LPA) ultrasonic S-scan image of a series of side drilled holes down a calibration block with angle sweep of 30° to 85°.

Automated Phased Array: As one solution for the detection and sizing of ID corrosion in oil and gas piping, Structural Integrity can deploy an automated, encoded linear phased array ultrasonic examination technique. The examinations are conducted using an automated x-y scanner that can be adapted to varying diameters and utilizes a linear array containing up to 64 elements and time delay phasing to direct and focus the sound beams to the desired location. This phased array pulse-echo technique utilizes longitudinal waves and is capable of recording thousands of thickness readings per square foot. The thickness readings are saved in a spreadsheet format for statistical analysis purposes and historical recording, as well as to generate visual representations of the examination area through C-scan (Top View), B-Scan (Side View), and D-Scan (End View) imaging (Figures 4-6).

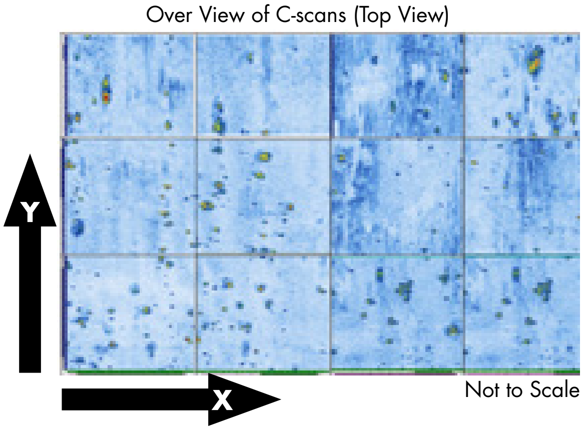


Figure 4: Sample C-scan image (Top View) obtained on a carbon steel pipeline component with internal wall thinning using the automated scanning approach. Image shows a map of the entire examination area with changes in color relating to variance of thickness. The Green (X-axis) represents the Index position of the phased array probe and the Blue (Y-axis) represents the scan position.

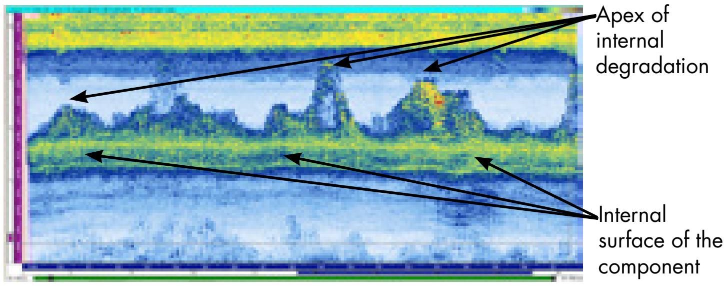


Figure 5: Sample B-scan image (Side View looking along the Blue Scan axis) obtained on a carbon steel pipeline component with internal wall thinning using the automated scanning approach. The Purple Ultrasonic axis represents the actual thickness measurement showing true depth at each point.

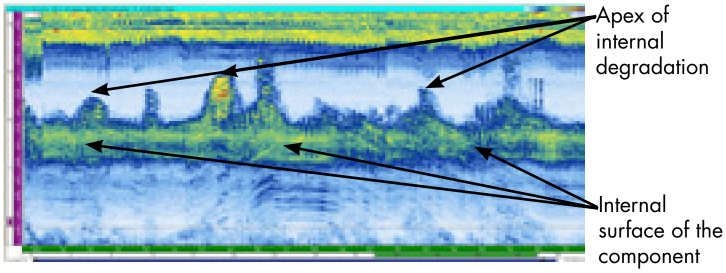
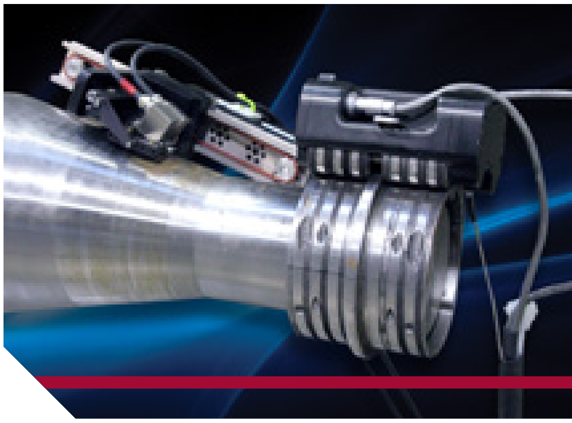
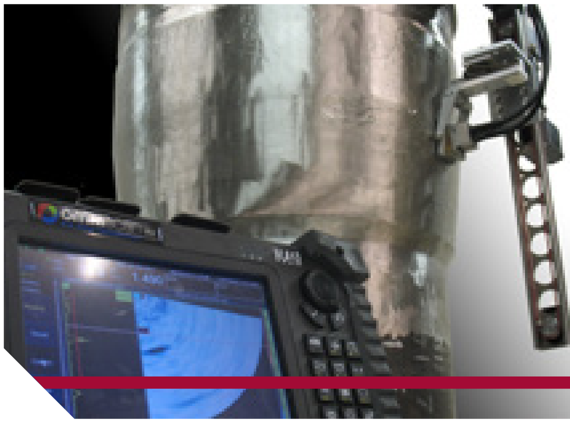


Figure 6: Sample D-scan image (End View looking along the green Index axis) obtained on a carbon steel pipeline component with internal wall thinning using the automated scanning approach. The Purple Ultrasonic axis represents the actual thickness measurement showing true depth at each point.





Photograph of Hydro-Form Scanner

Encoded Phased Array: The main difference between Automated PAUT and Encoded PAUT is that when performing Encoded PAUT, the probe is manually scanned along the component (non-mechanized and non-automated). Encoded phased array units use an encoder for collecting probe position data in addition to the UT scan data and also allow multiple-view scans to be implemented for data analysis and reporting. Encoded PA units can collect full A-scan waveform data, and store and manipulate displays to give B-scan, C-scan, and/or D-scan interpretations. This type of examination also works well for establishing a permanent document for archiving purposes.

Structural Integrity maintains a variety of units that can collect this type of data and have recently integrated PAUT roller probes into our encoded phased array service offering to continue to improve our inspection processes and capabilities. These portable wheel probes provide the capability to quickly scan an area of piping to obtain thousands of UT thickness measurements per square foot. An example C-scan image, generated using data collected with the the roller probe, showing internal corrosion detection and mapping for a section of piping is included in Figure 7.

Manual PAUT can also be performed to offer the same data processing and viewing capabilities as Encoded PAUT but without position tracking/encoded capability. **Encoded Manual B-Scan** can also be performed and permanently document areas where internal degradation has been found. One approach for performing these examinations is to scan the area with conventional UT to identify and locate areas of degradation, and then encode this area utilizing Phased Array or Conventional B-scan for permanent documentation.

Photograph of GE Array Probe.

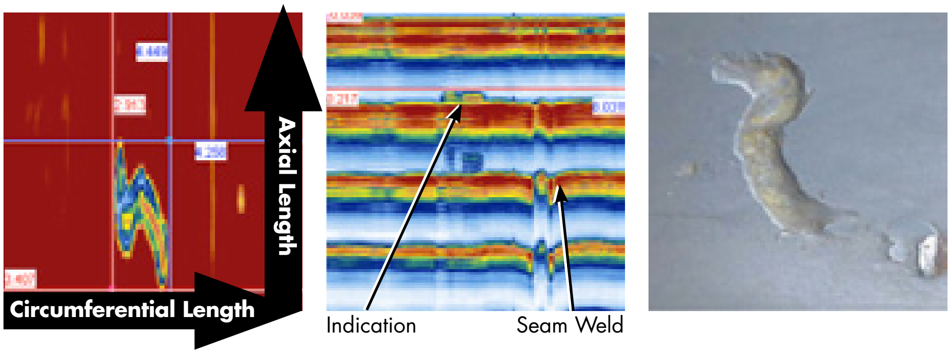
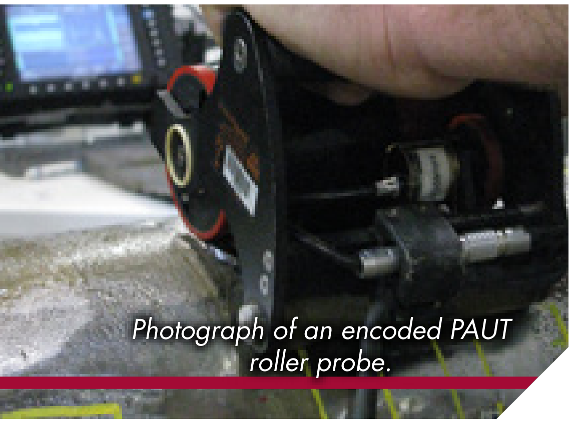


Figure 7: (Left) C-scan image showing the detection and characterization of internal degradation using the PAUT roller probe. (Right) Photograph of the internal degradation detected.



Photograph of an encoded PAUT roller probe.

Time of Flight Diffraction (TOFD): Structural Integrity has developed custom solutions for detecting and sizing stress corrosion cracking (SCC) using both LPA and TOFD approaches. SCC occurs in piping due to the combination of environment and stress. SCC in the pipe body typically forms as colonies containing a number of cracks (see Figure 8). A high length to depth ratio is typical, often in the range of 20-50:1. Crack depth sizing can be a challenge using conventional techniques due to a low through-wall dimension as well as the close proximity with adjacent cracks within the colony.

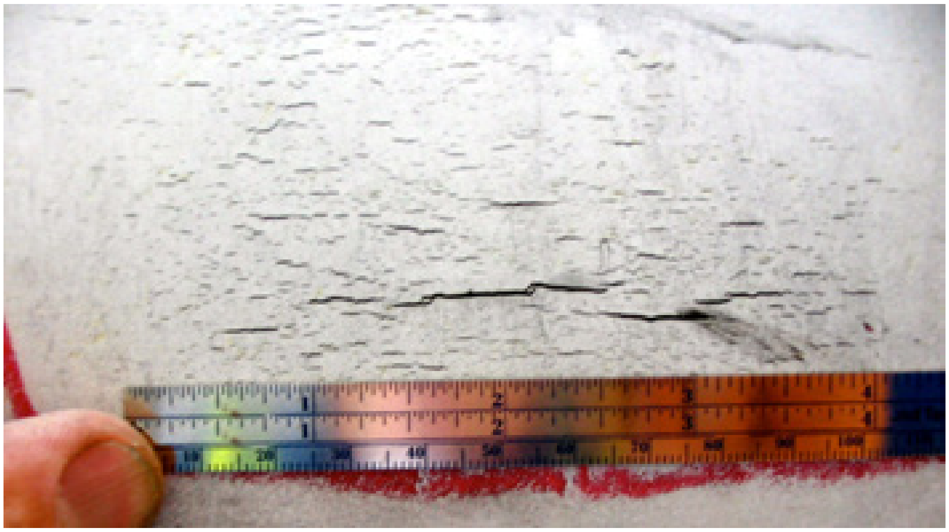
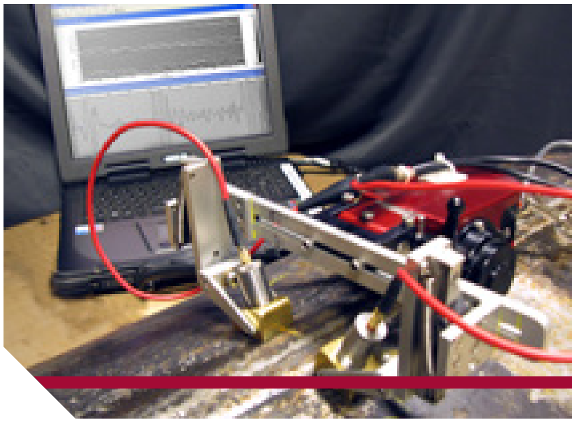
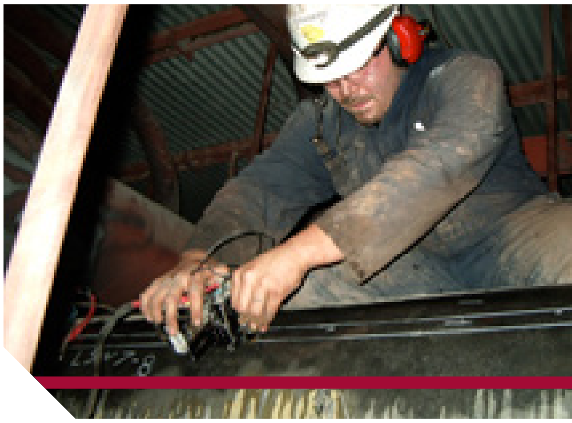
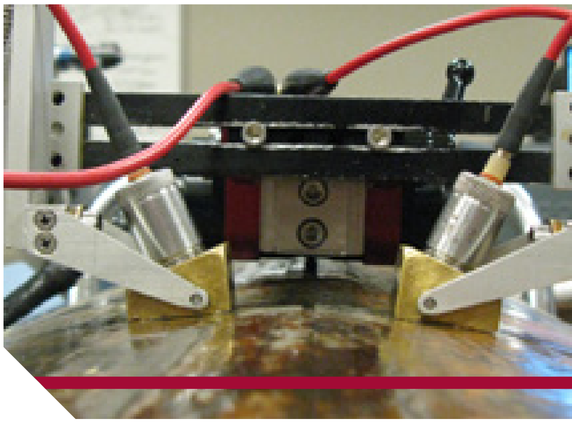


Figure 8: Depiction of typical SCC.

Structural Integrity uses several different sizing techniques depending on size, orientation or other conditions. Structural Integrity's proprietary micro-TOFD system uses high frequency, small diameter transducers with very low probe center spacing. This system is designed to locate the diffracted energy from the crack tip. Micro-TOFD has been shown to be effective on thin wall materials and relatively small cracks. This system requires two probes, one on either side of the crack. LPA techniques can also be effective in measuring crack depth. Structural Integrity uses a transducer array and timing delays (phasing) to direct and focus the beams at the desired location. This technique can use longitudinal waves or shear waves. The transducer array is housed in a single probe permitting sizing when only one side of the flaw is accessible. The technique may be pulse-echo, thru-transmission, or pitch-catch as applicable and can be used for both ID and/or OD initiated crack-depth sizing.







EMAT Inspection

Pipeline and plant operators frequently encounter challenges inspecting short inaccessible pipeline segments that are obstructed by pipeline supports, through wall penetrations, air to soil interfaces at riser locations and other various obstructions. In addition, even accessible areas that can be examined using Visual Examination techniques and/or Conventional Ultrasonic Thickness (UT) testing could benefit from a more thorough and rapid screening technique such as EMAT as conventional techniques can be time intensive and cost effective to complete a comprehensive inspection.

These inaccessible pipeline segments are often configured in close proximity to valves, bends and other appurtenances that limit the ability to use conventional Guided Wave Testing (GWT). Structural Integrity has implemented a short-range GWT technology that leverages Electromagnetic Acoustic Transducer (EMAT) Sensors to improve the ability and resolution to non-destructively examine these areas. Structural Integrity's EMAT inspection system offers several advantages:

- The sensors can be placed on rough and/or corroded surfaces. Rust/scale that could detach from the surface and stick to the magnetic sensors should be removed to avoid damage to the sensor coil.
- No couplant is required.
- The sensors work through paints, Fusion Bonded Epoxy (FBE), and other thin coatings. The amount of acceptable sensor liftoff for carbon steel materials depends on excitation frequency but typically has a maximum around 3.0mm.
- 100% volumetric inspection can be completed.
- Pitch-Catch configuration eliminates near field allowing placement of sensors adjacent to obstructions.
- Minimal indicators from content points
- Due to operation in a higher frequency regime, greater resolution of defects can be obtained than conventional GWT;

Technology Overview

The EMAT probe consists of a permanent magnet and a conducting coil that is pulsed with an AC voltage signal. The interaction of the current flowing in the coil and the magnetic field produced by the magnet results in small forces in conductive materials (Figure 1 below). These small forces, known as Lorentz forces, cause the small material displacements that constitute the guided wave.

Structural Integrity's portable, handheld EMAT inspection system is shown in lower left. The electronics unit is approximately the same size as a conventional UT scope and each probe (transmitter and receiver) is roughly the size of a closed fist.

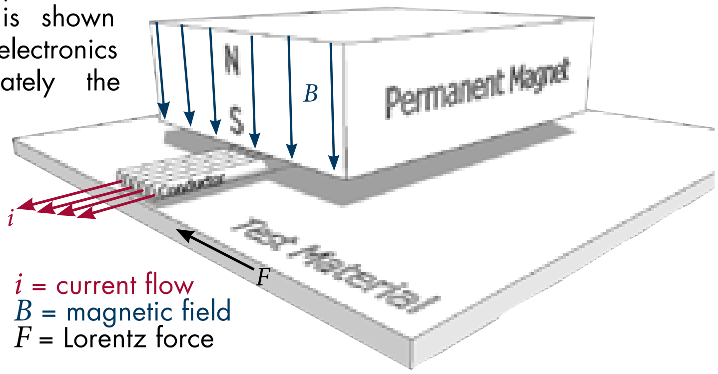
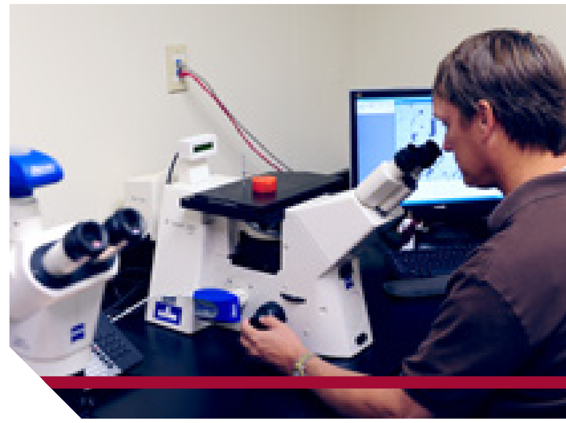


Figure 1: (Above Schematic of the Lorentz force and (Left) photograph of inspection system

Materials Characterization
Structural Integrity is well established as an industry leader in materials evaluation and failure analysis. Our metallurgical experts, located at our state-of-the-art Materials Science Center in Austin, Texas, are well-equipped to tackle the toughest industry problems affecting material performance. Our field metallurgy team excels in materials characterization due to the ability to apply laboratory-based expertise to field hardness testing, material identification, damage assessment, and failure evaluations. Structural Integrity's experience begins with proper surface preparation to allow for improved confidence in testing results, and extends to proper interpretation of data, which leads to the most appropriate recommendations that we can make to our clients.



Positive Material Identification (PMI) is the analysis of a metallic alloy to establish composition by reading the quantities by percentage of its constituent elements. Structural Integrity performs PMI using an Innov-X Systems Alpha Series or similar X-ray Fluorescence (XRF) Spectrometer. XRF does not detect elements below atomic number 20 including carbon, aluminum, and silicon. The analyzer normalizes the results to equal 100 percent.

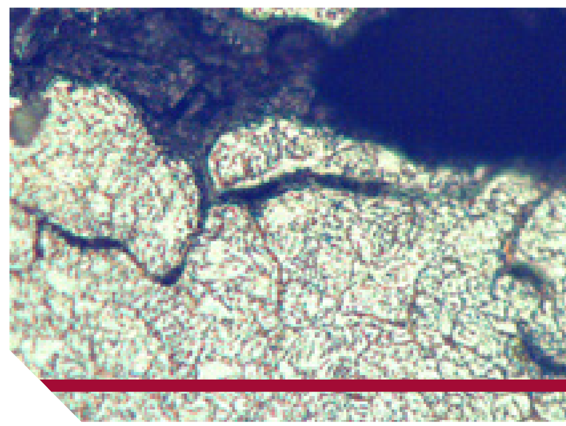
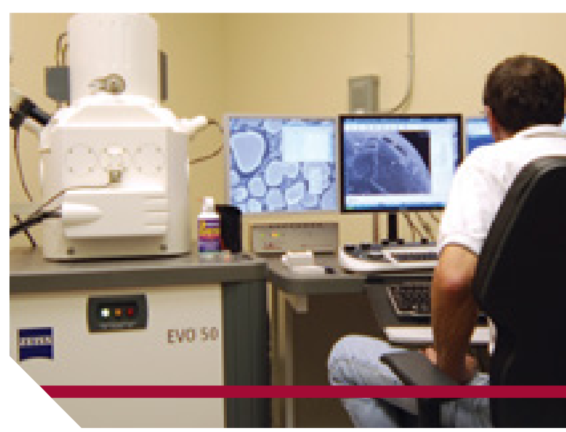
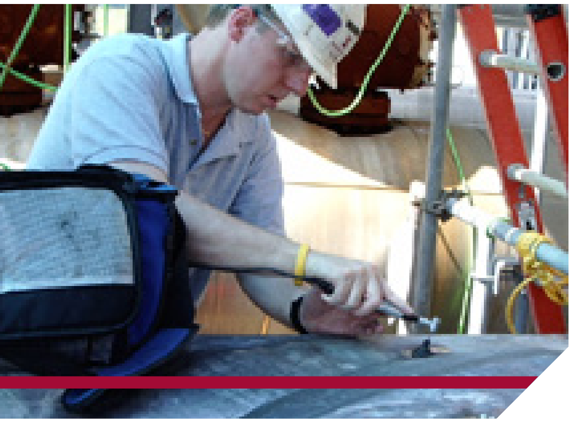


Figure 11: Innov-X Systems Alpha Series for PMI testing.

Figure 12: Micromotor polishing and grinding system for surface preparation.





Metallurgical Replication is a field-implemented technique that allows for the in-situ nondestructive evaluation of material microstructure and metallurgical condition. Similar to laboratory practice, grinding and polishing are carried out in progressively finer steps to remove scratches and the deformed surface layers that can interfere with detailed microstructural interpretation. We then etch the surface with a suitable etchant to reveal the microstructural features of interest, after which, a thin piece of acetate film is moistened in acetone and applied to the prepared surface. The acetate conforms to the surface 'duplicating' the surface features. The acetate is subsequently removed and mounted for microscopic examination. This inspection technique is limited to the surface being replicated.

Hardness is the resistance of a material to permanent indentation made by a stronger material. It is important to recognize that hardness is an empirical test and not a material property.

Figure 13: UCI MIC 20 harness tester.

Structural Integrity uses three different portable hardness methods, based on the material and component being inspected.

UCI Hardness Method (MIC 10 or MIC 20): UCI testers are portable electronic devices that use a spring to apply a force to a Vickers indenter that is attached to the end of a resonating rod. As the resonating rod and Vickers indenter penetrate the test sample, a frequency shift occurs in the rod. The amount of frequency shift is measured and can be related to the penetration depth of the Vickers indenter into the sample. The results are electronically converted to other hardness scales.

Rebound Method (MIC 20 or Equotip): Rebound testers use a carbide ball hammer that is spring powered. An electronic sensor measures the velocity of the hammer as it travels toward and away from the sample surface. The Leeb value is the hammer's rebound velocity divided by the impact velocity times 1000. The result is Leeb hardness from 0 to 1000 that can be related to other hardness scales such as Rockwell and Vickers. The Equotip and MIC 20 equipment manuals recommend not using the rebound method on components that are less than 0.787 inch thick.

Brinell Method (Pin Brinell or Telebrineller): The Brinell method measures the permanent width of indentation produced by a carbide indenter applied to a test specimen at a given load. Typically, an indentation is made with a Brinell hardness testing system and then the indentation diameter is measured manually with a specially designed Brinell microscope. The resulting measurement is converted to a Brinell value using the Brinell formula or a conversion chart based on the formula.

Figure 14: Brinell Method harness testing equipment.

OD Surface Profilometry: Due to the irregularities associated with general corrosion and extensive regions of pitting over the outer surface, ultrasonic testing is less than practical as an effective tool for determining external wall loss. As an alternative to performing manual pit depth measurements of externally corroded areas, Structural Integrity can deploy a handheld surface scanning laser system that can capture and reconstruct the profile of the degradation using adjacent material thickness measurements to establish and normalize the underlying material thickness. This process is often much quicker than collecting manual depth measurements with pit gauges when setup time, inspection, data analysis, and reporting are considered. While this approach cannot account for internal surface corrosion or pitting, it can be used to accurately reconstruct the outer surface to depict and measure the material loss from the OD. Post processing of the profile image allows the analyst to identify regions of significant wall loss where localized thickness measurements can then be taken using ultrasound. The combination of the local UT data points and the OD surface reconstruction provides a reliable representation of the test location. The Handyscan REVscan has a resolution of 0.004 inch (0.1 mm) and an accuracy of 0.002 inch (0.05 mm) and can record 18,000 data points per second. The laser system and representative reporting images are provided below.

Figure 9: Handyscan 3D laser scanner.

The data collection and analysis software generates on-site results that can quickly be exported to an Excel report displaying 3D color mapping, worst case profile, and unwrapped 2D views. Reconstruction of the surface is real-time, with color coding used to provide a visual relevance for material loss. Off line analysis can be used to make discrete readings of loss, or the full map data file can be exported using standard file formats to allow other subsequent analysis to be conducted.

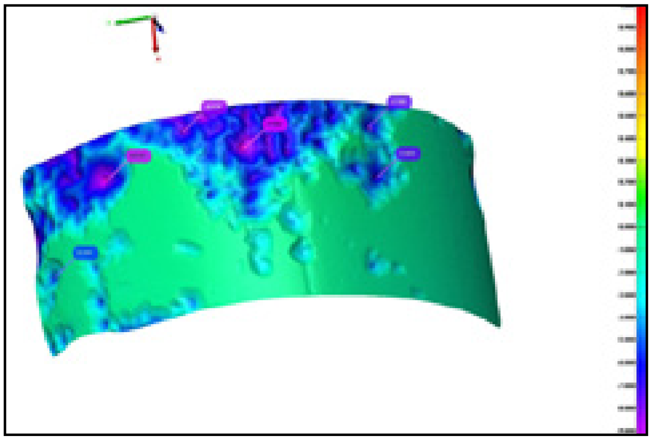
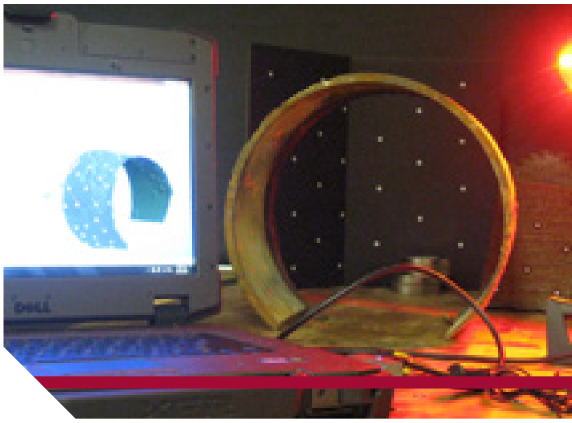
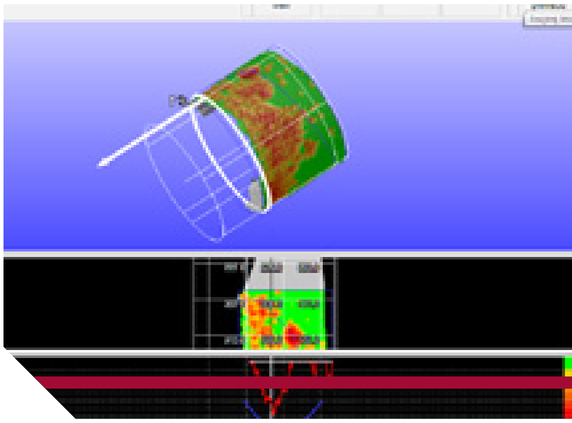
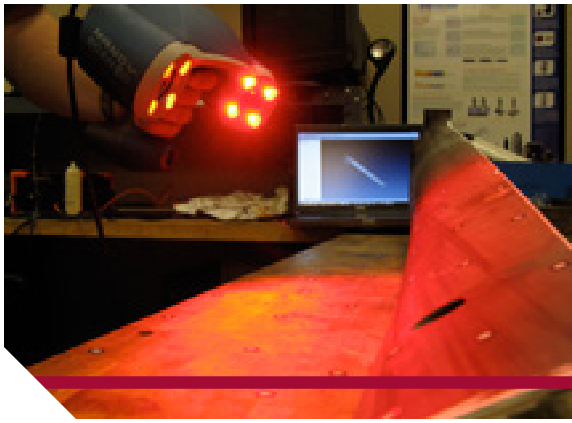
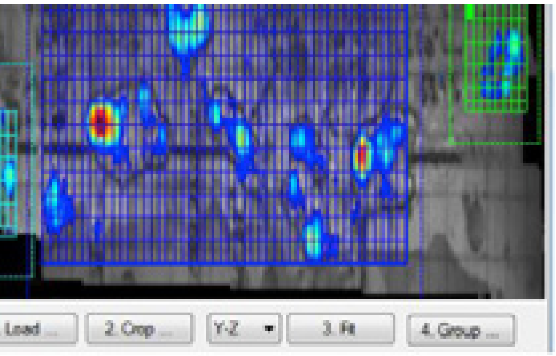


Figure 10: Example laser profilometry image result.





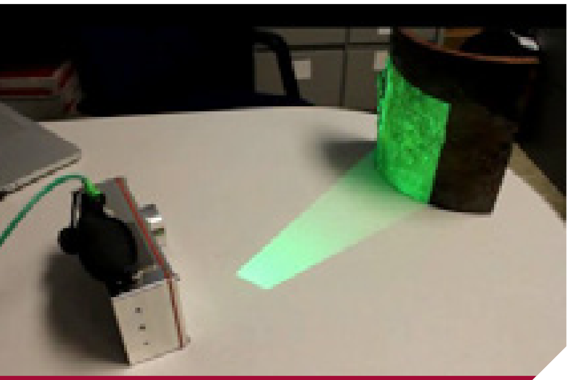




Three-Dimensional Defect Mapping (3DDM)

Structural Integrity has recently added Technical Toolboxes Inc. (TTI) 3D Toolbox to our NDE service offering, which leverages Seikowave's structured light 3-Dimensional scanning tools.. The 3D Toolbox is a complete measurement system for inspecting oil and gas pipeline and other facility infrastructure. Included with the 3D Toolbox is the eVox LCG 3D imaging system: a compact 3D measurement system with 40mW optical power which uses real-time measurements and unique algorithms to process accurate measurements of three-dimensional objects and surfaces. The figures below provide an overview of this system which can be used for mapping and quantifying external defects such as external corrosion, dents, and gouges.

Similar to laser profilometery, detailed defect information (geometry, depth, etc.) can be captured along with a digital image retained for permanent record. However, the speed and efficiency of data collection along with the ability to import into advanced analysis tools such as RSTRENG® and Finite Element Analysis (FEA) models is extremely beneficial. Multiple scans can be concatenated and stitched together for analyzing larger areas and/or for capturing greater resolution of defects. Digital records with depth values in high resolution grids along with river bottom profiles and other data formats can be viewed and exported for further analysis.

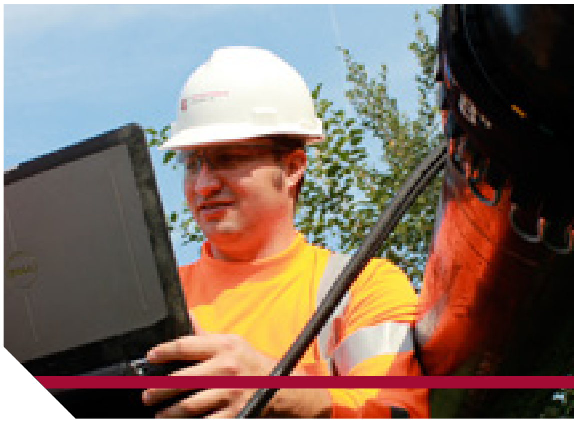


Structural Integrity NDT Personnel

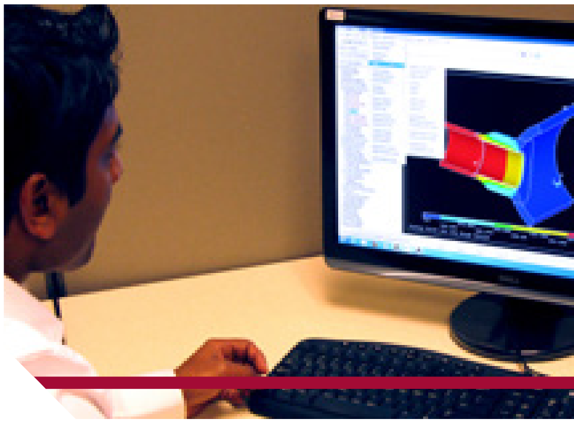
Structural Integrity houses one of the most highly skilled/certified and diverse inspection teams in the industry with personnel certified in all key NDT disciplines (UT, MT, PT, ET, RT, and GWT). In addition to a detailed certification program, Structural Integrity's internal NDE certification program meets all of the guidelines provided in ASNT SNT-TC-1A for the training and certification of NDE personnel and, in some cases, exceeds the requirements set forth in this standard. Specifically, all certified UT personnel have met the classroom training, testing, and field experience requirements to a level that is commensurate with or exceeding the ASNT SNT-TC-1A standard. In additional to their SI certifications, many of SI's personnel also hold ASNT certifications and PDI qualifications and have also completed a wide-range of manufacturer training programs. Structural Integrity maintains multiple full-time, senior Level II and Level III NDE inspection team leads that are certified in accordance with this program.

These programs include but are not limited to:

- ASNT Level III in UT, MT, PT, MT, and RT,
- EPRI Performance Demonstration Initiative (PDI) Certifications in the Nuclear Power Generation Industry,
- EPRI Performance Demonstration (PD) Certifications in the Fossil Power Generation Industry,
- Guided Ultrasonics Ltd. (GUL) Level II and Level I Certifications,
- GUL Road Crossings and Buried Pipe Certifications,
- GUL gPIMS Training,
- Level I and Level II CSWIP Certifications,
- SwRI MsS Level I Certifications, and
- Innerspec Level II EMAT Certifications.



Several of Structural Integrity's inspectors/engineers have published multiple scientific articles in peer-reviewed journals and have also patented several new NDE techniques and tools in addition to being heavily involved in all major industry committees for establishing inspection protocols and certification standards (i.e., ASME, ASNT, and NACE). As a standard offering, we also have experience in writing client specific NDT procedures for detecting and characterizing flaws for a variety of applications and types of degradation.



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