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## SHORT RANGE GWT USING ELECTROMAGNETIC ACOUSTIC TRANSDUCERS (EMAT) PG.2



# SHORT RANGE GWT USING ELECTROMAGNETIC ACOUSTIC TRANSDUCERS (EMAT)

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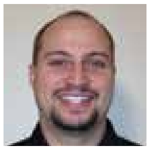

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Pipeline and plant operators frequently encounter challenges inspecting short inaccessible sections of pipelines that are obstructed by pipeline supports or through wall penetrations, air to soil interfaces at riser locations and various other obstructions. These difficult-to-inspect locations are often adjacent to exposed and easily accessible areas that can be comprehensively examined using Visual Examination techniques and/or Conventional Ultrasonic Thickness (UT) testing, although even for the exposed sections conventional inspection can be a time-intensive endeavor and not comprehensive.

These inaccessible pipeline segments often are configured in close proximity to valves, bends and other appurtenances that limit the ability to use conventional Guided Wave Testing (GWT). Structural Integrity has acquired and developed new technology in the form of a short range GWT technology that leverages Electromagnetic Acoustic Transducer (EMAT) Sensors to improve the ability and resolution to non-destructively examine these areas. Our 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 between 1.0mm and 3.0mm.
- 100% volumetric inspection can be completed.
- Pitch-Catch configuration eliminates near field allowing placement of sensors adjacent to obstructions.
- Normalization gate provides self-calibration for guided wave applications.
- 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 left). These small forces, known as Lorentz forces, cause the small mechanical perturbations that constitute the guided wave.

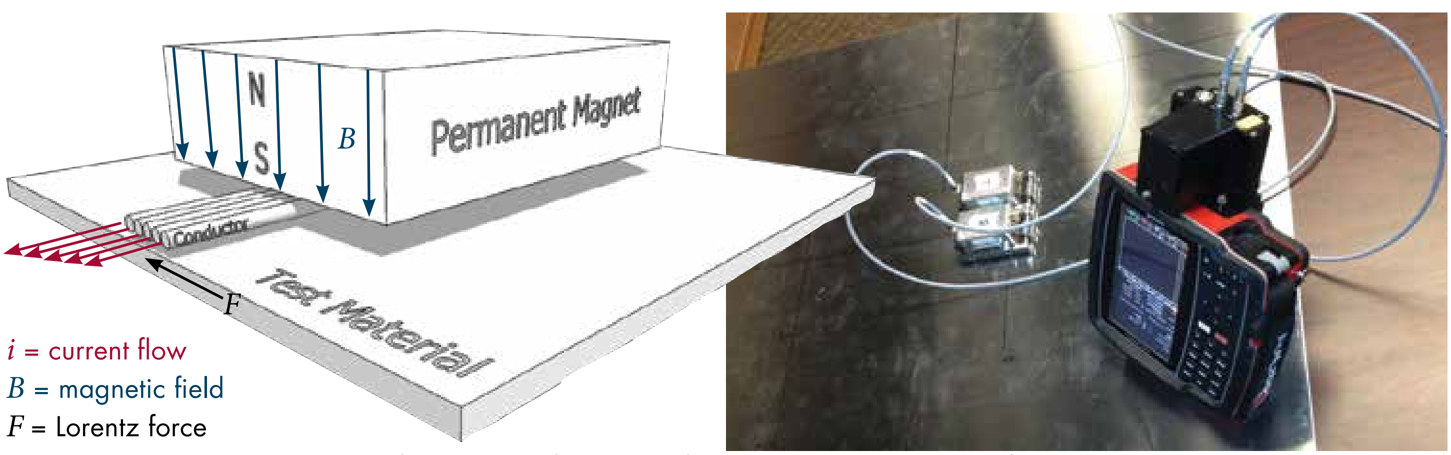


**Figure 1** (Left) Schematic of the Lorentz force and (Right) photograph of inspection system

Structural Integrity's portable, handheld EMAT inspection system is shown in Figure 1. 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.

## INSPECTION OF PIPELINE UNDER SUPPORTS

As an example application, we have shown that Short Range (SR)-GWT can be used to successfully detect Stress Corrosion Cracking (SCC) under clamped supports. We performed SR-GWT on two 10" diameter, three 6" diameter, and three 2" diameter stainless steel (SS) piping segments with artificially fabricated Outer Diameter Stress Corrosion Cracking (ODSCC). The piping contained both circumferentially and axially oriented ODSCC. We also saw that several of the ODSCC flaws contained simulated external corrosion pitting and several additional flaws contained external corrosion pitting with no ODSCC. The defect manufacturing process that was used produced realistic closed-face cracks.

As shown in Figure 2, two different EMAT configurations were used to detect axial and circumferential cracking. For circumferentially oriented ODSCC, a normal incidence technique was used with the transmitter and receiver placed directly adjacent to one another and several inches back from the support clamp edge. For axially oriented cracking, an oblique incidence pitch-catch technique was used with the transmitter and receiver placed on opposite sides of the support clamp.

A total of 38 flaws in the various test samples were evaluated with the SR-GWT EMAT technique. Several of the ODSCC flaws also contained simulated external corrosion pitting and several additional flaws contained external corrosion pitting with no ODSCC. A detection rate of 100% was achieved for all examined flaw areas (several areas contained multiple flaws) using the high-frequency guided wave technique. Figure 3 shows an example SR-GWT encoded data scan.

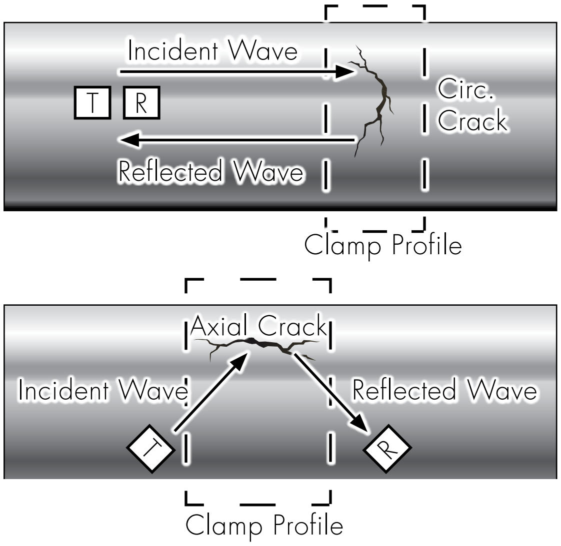


**Figure 2** Schematic of the EMAT test configurations used for detecting ODSCC.

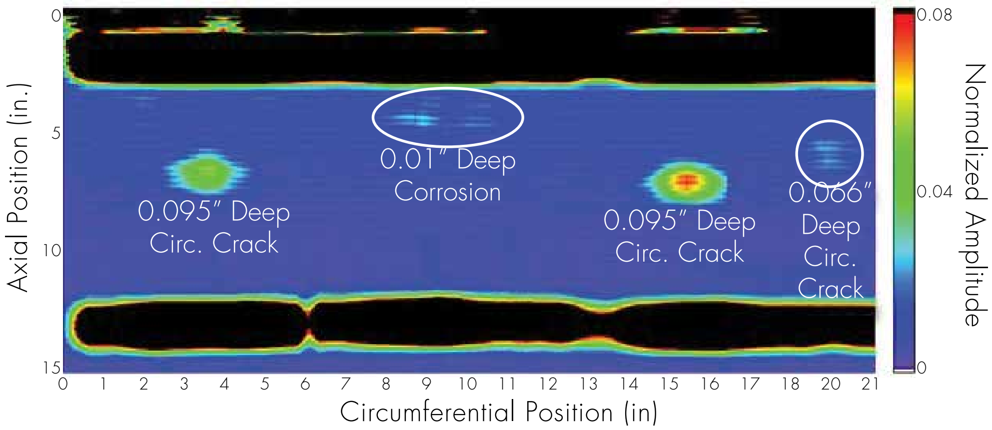


**Figure 3** Unrolled pipe display or "C-Scan" showing the detection of several ODSCC and corrosion defects under a clamped support on a 6" diameter pipe.

# SIPEC PULSED EDDY CURRENT SENSOR FOR ROBOTIC IN-LINE INSPECTION OF LINED PIPING

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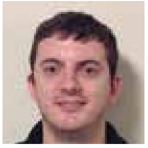

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Pulsed eddy current (PEC) is a nondestructive testing (NDT) technology traditionally used to inspect for corrosion under insulation (CUI). Unlike traditional Eddy Current Testing (ECT), PEC uses a transient excitation pulse induced in the conductive test material by a driver coil. As the magnetic pulse is injected, transient eddy-currents diffuse inward into the material and result in a time-lag in the response of the material to the induced magnetic field. The duration of the time-lag is related to the material properties and thickness of the metal, thus providing a method for estimating the remaining wall thickness. Inspectors using existing PEC systems traditionally acquire point-by-point measurements by manually scanning the sensor over the insulation jacket, with each point measurement requiring several seconds of stationary data acquisition.

Structural Integrity Associates recently completed the development of a new dynamic PEC sensor, electronics, and data processing and analysis algorithms that enable PEC data to be acquired while the sensor is in motion. Utilizing the high measurement frequency and dynamic data acquisition capabilities of Structural Integrity's Pulsed Eddy Current (SIPEC™) technology, along with Diakont Advanced Technology's RODIS robotic in-line inspection (R-ILI) delivery system, the industry's first SIPEC in-line inspection was successfully completed on an internally-lined 42-inch diameter pipe. Subsequent scans were acquired on an unlined 36-inch diameter pipe; in this case, spacers were used to simulate the presence of a liner. The data and results of this novel application of SIPEC are presented herein.

Our patent-pending SIPEC™ sensor design and data processing algorithms enable detection and approximate sizing of flaws at up to 0.625 inches of sensor lift off. Our SIPEC™ inspection system currently offers the following advantages:

- Inspection through internal liners (up to 0.625 inches of lift off).
- Rapid data acquisition (up to 20 measurements per second).
- Dynamic data acquisition (scanning speeds up to six inches per second).
- Differentiation between inner diameter (ID) and outer diameter (OD) flaws.
- Approximate spatial sizing (axial, circumferential, remaining wall thickness).
- Measurement of approximate liner thickness.

## BACKGROUND

The test spool on which the inspection was performed consisted of a carbon steel pipe, with a 42-inch diameter, 0.500-inch nominal wall thickness, half-inch thick internal fiberglass liner. This piping configuration is representative of that used to transport seawater from oil tankers' ballast water tanks to water treatment facilities as the tankers are loaded with crude oil. The test spool was fabricated with flaws of various morphologies, including concavities and flat-bottom holes representative of general corrosion. In addition, the liner was fabricated with several repairs where rectangular portions of the liner had been removed to fabricate flaws and subsequently replaced and sealed, resulting in an irregular ID surface for scanning.

## DATA ANALYSIS

Our SIPEC™ acquisition software displays an unrolled pipe C-scan data image in real-time, indicating the axial and circumferential locations of any indications (i.e. potential flaws). The software also features a real-time cross-section view that indicates the circumferential position of lowest remaining wall thickness reading. Our SIPEC™ post-processing software adds an interactive rolled pipe display that includes a three-dimensional rendering of the data overlaid on the pipe, as well as a zoomed view for analyzing indications. Multiple scans were recorded on both the 42-inch and 36-inch diameter test spools.

We targeted two flaws on the 42-inch diameter test spool were targeted for scanning. The first was a 6.375-inch by 6.875-inch ID concavity with a maximum depth corresponding to 0.140-inch (28%) remaining wall thickness. Figure 1 shows a real-time unrolled pipe C-scan display of the ID flaw. From left to right, Figure 2 shows zoomed C-scan, rolled pipe C-scan, and cross-section displays of the ID flaw. The second flaw was a 7.750-inch by 8.125-inch OD concavity with a maximum depth corresponding to 0.133-inch (27%) remaining wall thickness. Figure 3 shows a real-time unrolled pipe C-scan display of the OD flaw. From left to right, Figure 4 shows zoomed C-scan, rolled pipe display, and cross-section displays of the ID flaw.

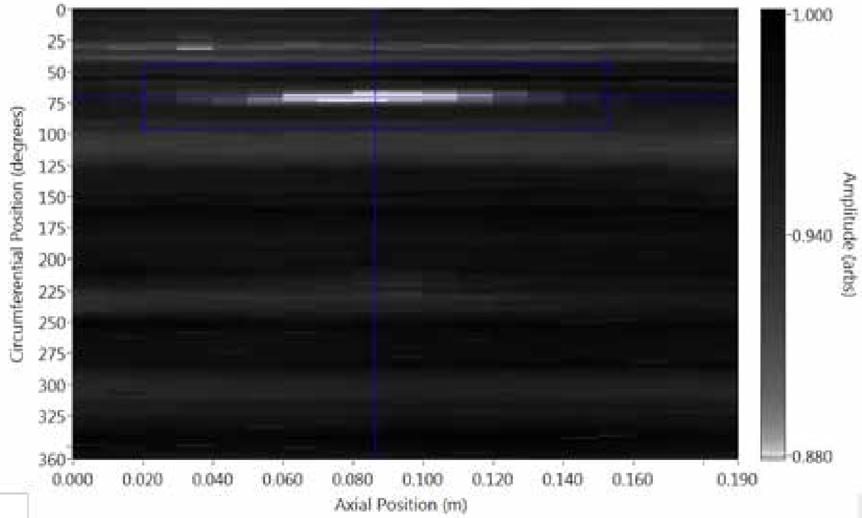



**Figure 1** Real-time unrolled pipe C-scan display identifying the location of the 42-inch diameter pipe ID flaw and the seam weld.

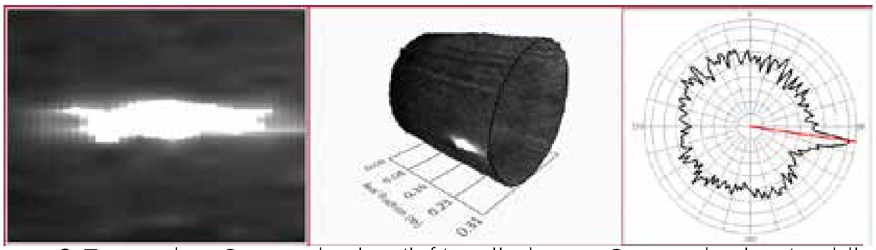


**Figure 2** Zoomed in C-scan display (left), rolled pipe C-scan display (middle), and cross-section view (right) of the 42-inch diameter pipe ID flaw.

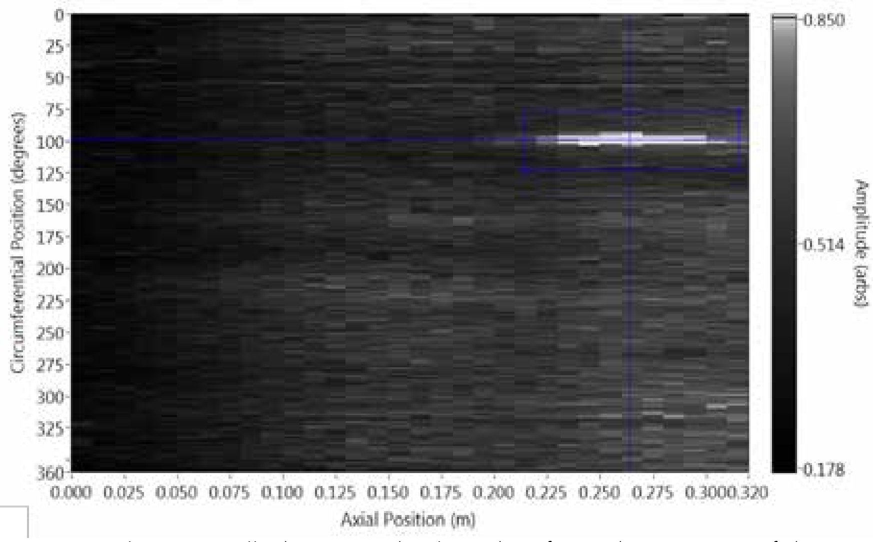



**Figure 3** Real-time unrolled C-scan display identifying the position of the 42-inch diameter pipe OD flaw.

**Figure 4** Zoomed in C-scan display (left), rolled pipe C-scan display (middle), and cross-section view (right) of the 42-inch diameter pipe OD flaw.

*Continued on next page*

# SIPEC PULSED EDDY CURRENT
## CONTINUED

RESULTS

Consolidated results from the 42-inch and 36-inch test spool are shown below in Table 1. All of the flaws that were targeted for scanning were detected and depth-sized to within a maximum error in measured defect depth of 0.056-inches. The average error in defect depth estimation was 0.029-inches.

It is important to note, especially as it pertains to flaw depth sizing, that data acquisition was completed at lift-off distances between the sensor face and ID surface of the pipe of 0.625-inches and 0.600-inches for the 42-inch diameter and 36-inch diameter pipes, respectively. Furthermore, each flaw was auto-scanned only once in a high-speed scan mode. Typical R-ILI protocol consists of a high-speed detection scan after which the detected indications are investigated with a low-speed, high-resolution scan for each indication in the data in order to facilitate classification and sizing.

| | | | | Remaining Wall Thickness | | |
|---|---|---|---|---|---|---|
| Flaw Identifier | Flaw Type | Lift Off | Detected | Measured | Actual | Error |
| 42″-ID-1 | Concavity | 0.625″ | Yes | 0.375″ | 0.360″ | -0.015″ |
| 42″-OD-1 | Concavity | 0.625″ | Yes | TBD | 0.133″ | TBD |
| 36″-ID-1 | Flat-Bottom Hole | 0.600″ | Yes | 0.156″ | 0.100″ | -0.056″ |
| 36″-ID-2 | Flat-Bottom Hole | 0.600″ | Yes | 0.187″ | 0.180″ | -0.007″ |
| 36″-ID-3 | Flat-Bottom Hole | 0.600″ | Yes | 0.126″ | 0.165″ | 0.039″ |

**Table 1** Consolidated detection and depth sizing results.

The results of the industry's first PEC R-ILI indicate that the SIPEC sensor is capable of flaw detection and depth estimation at high scan speeds and appreciable sensor lift off. A unity plot displaying our measurement of ID defect depth is shown in Figure 5. The novel SIPEC™ sensor design and data acquisition and processing algorithms represent an evolution from static, point-by-point data acquisition schemes employed by traditional PEC technology to rapid, dynamic data acquisition. These evolutionary developments have enabled the SIPEC™ sensor to meet the requirements for R-ILI deployment.

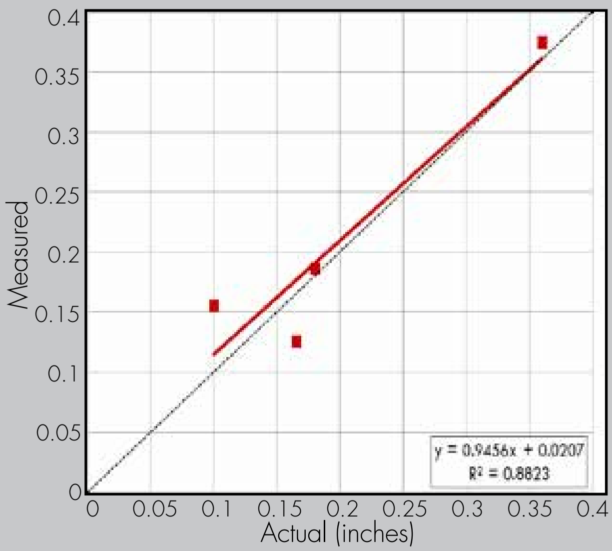
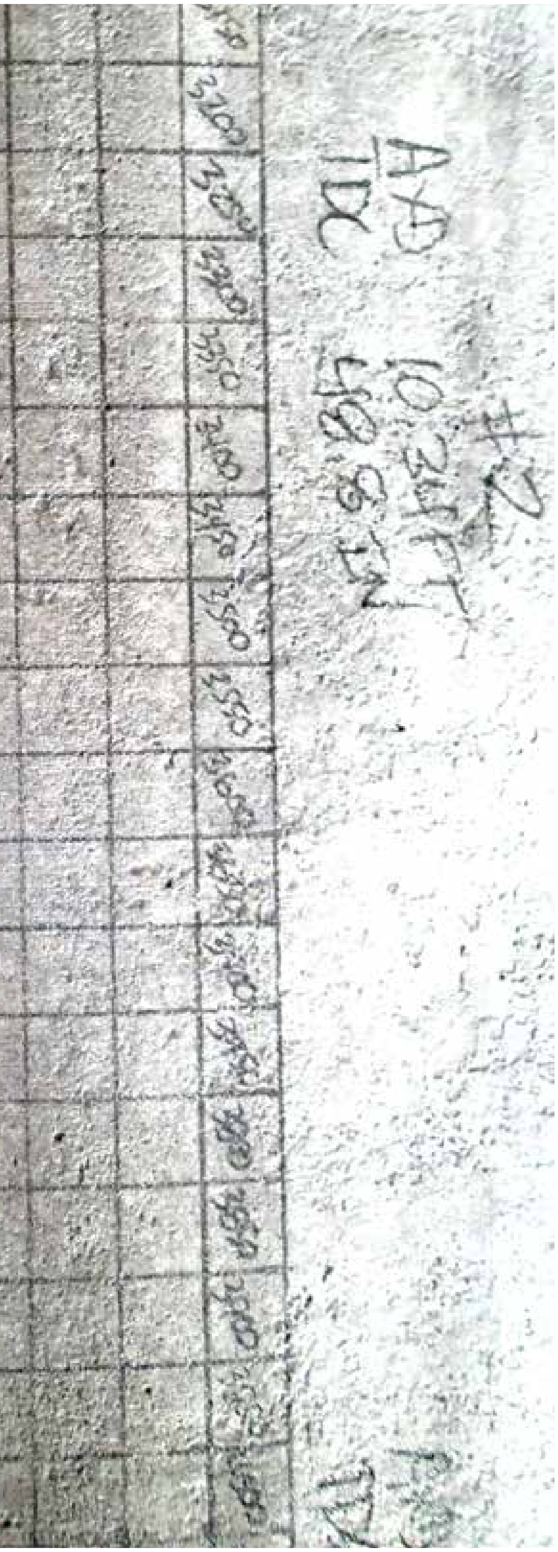
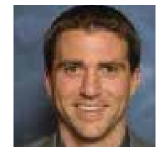



**Figure 5** Unity plot for depth measurements of the ID defects listed in Table 1.

# PRCI STUDY OF NDE TECHNOLOGIES FOR SIZING CRACK-LIKE INDICATIONS





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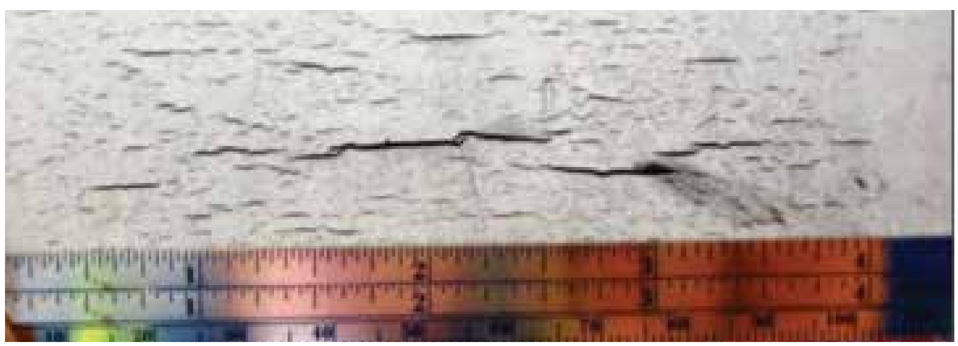
Pipeline operators are increasingly finding pipeline degradation in the form of crack-like defects from stress corrosion cracking (SCC), selective seam corrosion, hook cracks in certain vintage ERW pipelines and other select seam types, and mill defects among other mechanisms. Furthermore, operators are continuously challenged to identify and employ NDE techniques that can reliably determine the axial depth profile of these cracks. While magnetic particle testing (MT) provides a robust and inexpensive method of detection, it is unable to determine the through wall depth of the cracks. The geometry, location, and proximity of linear indications and other features can create a significant challenge and degree of variance in an NDE technologies' ability to size crack-like defects.



As part of a Pipeline Research Council International (PRCI) research project, Structural Integrity is currently the prime contractor of a project established to further investigate and define the capabilities and limitations of different NDE methodologies typically used and/or identified as feasible to size crack-like features. The project consists of developing and implementing a process to evaluate the applicability, accuracy, and sensitivity of different NDE methodologies in sizing crack-like defects. The primary task includes development and implementation of a test plan to support blind, round-robin NDE testing on selected PRCI crack-like defect samples and subsequent destructive testing to verify the crack depth size and accuracy of the different technologies used. Currently, NDE evaluation of the samples is underway with over seven different service providers/ technology developers scheduled to complete inspection.

As part of the final deliverable, a guidance document will be created that provides the level of discrimination performance that can be expected from various in-ditch NDE technologies applied to sizing linear indications Furthermore, criteria for crack characteristics affecting performance will be documented.

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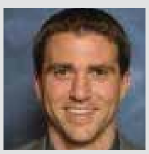
# AUTOMATIC SHUTOFF VALVE / REMOTE CONTROL VALVE STUDIES



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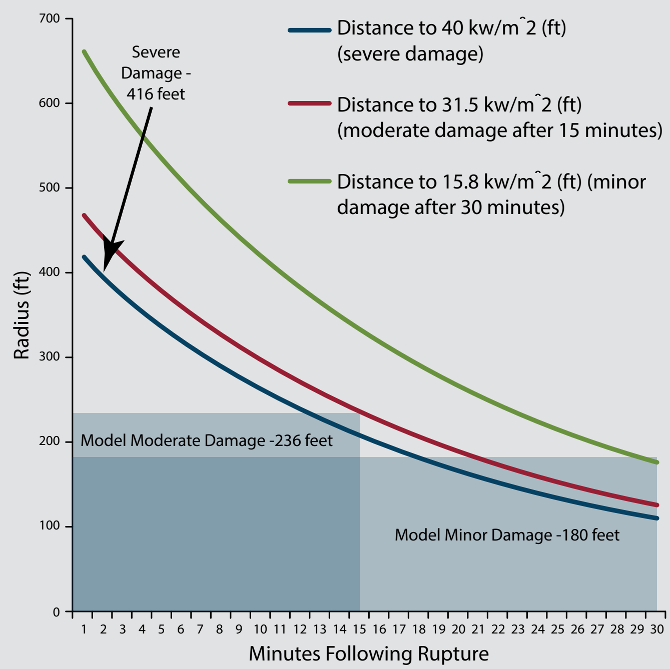
A Remote Control Valve (RCV) is a main line valve that can be operated from the SCADA control room, making it a much faster method of stopping the flow to a break than driving to a manually operated valve. An Automatic Shutoff Valve (ASV) is a main line valve that would automatically close when a line rupture is detected based on certain flow/pressure conditions, reducing the flow of gas to the break. The transmission integrity management regulation requires operators to determine if, based on a risk analysis and consideration of several specified factors, that an ASV or RCV would be an efficient means of adding protection to a high consequence area in the event of a gas release.

We have has helped several of our clients complete analyses that include a detailed model of a failure and the resulting heat flux to estimate the radii at which damage to personal and/or commercial property would likely occur. Figure 1 below is an example of a model for the PG&E pipeline rupture at San Bruno. We have experience estimating costs associated with damage at the hypothetical rupture relative to the savings of installing an ASV/RCV and resultant benefit to public safety helping our clients make an informed decision regarding the benefit and optimal location of an RCV or ASV.

**Pipeline Rupture Heat Flux, 120 miles of 30 inch pipe, 386 psig**

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