# WHITE PAPER ON GUIDED WAVE ULTRASONICS AS AN ASSESSMENT OPTION


## ABSTRACT

The Pipeline and Hazardous Materials Safety Administration (PHMSA), the pipeline industry and standards developing organizations (SDOs) are collaborating to improve the effectiveness and expand the application of Guided Wave Ultrasonics (GWUT). This paper will illustrate how these initiatives through integrity management (IM) regulation, collaborative research and development, technology demonstrations and consultation with subject matter experts (SME) are driving these improvements. These efforts are integrating GWUT technology with External Corrosion Direct Assessment (ECDA) and Pipeline Safety IM protocols and supporting higher confidence inspection of cased crossings. Previous to these initiatives only In-Line Inspection, Pressure Testing and Direct Assessment provided assessment options for the pipeline industry.


## INTRODUCTION

There are over 2.3 million miles of hazardous liquid and natural gas pipelines in the U.S today. When transmission pipelines traverse through areas of high consequence to people, property or the environment, they must follow more stringent integrity management (IM) requirements. An IM approach identifies specific threats to the pipeline that operators must address through a plan to prevent, detect, characterize and remediate them. Pipelines traverse through wide raging terrain and must be cased when they cross under rivers, roads and rail road right of ways. When these cased crossings are located in high consequence areas (HCA), they fall under the IM requirements and must be in compliance with proscribed milestones.

With best estimates, there are thousands of cased crossings nationwide and hundreds if not thousands located in HCAs. Cased crossings are essentially a pipe within a pipe and utilize centralizers for maintaining an equal axial distance between the carrier pipe and the casing. Some are filled with wax, open to the atmosphere or sealed. Cased crossings can range from approximately 20 to over 300 feet long. These varying scenarios combined with the fact that the line cannot be dug up without major disruption to other infrastructure or public services labels them as tough to inspect areas and pose unique challenges for pipeline operators.

Historically, in-line inspection, pressure testing and direct assessment (DA) provided the only assessment options for the pipeline industry. But in some cases, obstructions in the pipeline, the expense of pressure testing, the revenue loss from downtime and the uncertainty of risk and data within the DA process detract and remove these as viable assessment options.

The Pipeline and Hazardous Materials Safety Administration (PHMSA), the pipeline industry and consensus standards organizations are collaborating to create additional assessment options for cased crossings. A comprehensive program to improve the effectiveness and expand the application of Guided Wave Ultrasonics (GWUT) is well underway and is involving a focus on IM regulation, collaborative research, technology demonstrations, consultation with SME and the integration of knowledge with SDOs.

## GUIDED WAVE ULTRASONICS: WHAT IS DRIVING THE USAGE?

INTEGRITY MANAGEMENT REGULATIONS

In 2002 and 2004, PHMSA promulgated new regulatory requirements targeting hazardous liquid and natural gas transmission pipelines in HCAs. This focusing of new pipeline regulations aimed to improve pipeline safety through:

- Accelerating the integrity assessment of pipelines in High Consequence Areas,
- Improving integrity management systems within companies,
- Improving the government's role in reviewing the adequacy of integrity programs and plans, and
- Providing increased public assurance in pipeline safety.

The majority of hazardous liquid pipeline miles in HCAs can be inspected by in-line inspection or smart pigging. Because of this, the focus on assessing cased crossings shifted to unpiggable natural gas pipelines. Natural gas IM regulations apply to gas transmission operators jurisdictional to 49 CFR Part 192. These requirements became effective February 14, 2004.

Essentially, 49 CFR Part 192 requires the integrity assessment of all line pipe in HCAs. If line pipe is in a casing within an HCA, it must be assessed in accordance with the specified requirements. The requirements list the methods approved for conducting an assessment under 192.921(a)(1-3). The list is limited to In-line Inspection, Pressure Testing, and Direct Assessment and “other technology” which GWUT is a part. To use an assessment methodology other than these 3 methods, you must provide a “180-Day Notification” as specified under 192.921(a)(4) – “other technology”.

Per the PHMSA regulations, the use of GWUT in a casing is considered "Other Technology" requiring the 180-Day Notification. This is mainly because the NACE International consensus standard for External Corrosion Direct Assessment (ECDA) referenced in PHMSA regulations requires 2 complementary indirect inspection tools for conducting an assessment under the standard. The ECDA standard will be discussed later in this paper. PHMSA received approximately 41 of these "Other Technology Notifications" addressing the use of GWUT on cased crossings by the end of calendar year 2007. PHMSA anticipates more notifications in 2008 until the ECDA standard for cased crossings is revised appropriately and accordingly for GWUT and until PHMSA incorporates the revised standard in 49 CFR Part 192. Natural gas transmission operators have until 2012 to assess all HCA miles which includes cased pipe.

PIPELINE EXTERNAL CORROSION DIRECT ASSESSMENT METHODOLOGY: NACE INTERNATIONAL STANDARD RECOMMENDED PRACTICE

PHMSA regulations recognize DA as one of the methods for assessing the integrity of natural gas pipelines. DA is limited to assessing pipelines for the integrity threats of external corrosion, internal corrosion, and stress corrosion cracking (SCC).

DA typically involves a four step process including integrating pipeline physical characteristics and operating history (pre-assessment) with data from multiple field examinations (indirect inspections) and pipe surface evaluations (direct examinations) and validating the assessment process (post assessment).

The ECDA methodology is supported by the availability of several indirect inspection methods such as close-interval surveys, Alternating Current attenuation surveys, Direct Current and Alternating Current Voltage Gradient surveys, Pearson surveys, and Cell-to-cell surveys. Tools and methodologies continue improving for addressing hard to evaluate areas. These are stated in the ECDA process are pipe in casings, underwater crossings, pipe in corridors with electrical interference (electrified railways and high voltage lines), as well as pipe beneath pavement.

The NACE International ECDA standard proscribes how to conduct a feasibility assessment and the selection of indirect assessment tools for cased pipe. Table 2 in the standard provides the guidance for selecting indirect inspection tools and specifically addresses conditions under which some indirect inspection tools may not be practical or reliable.

Unfortunately, all listed indirect inspection tools in Table 2 are classified as not applicable or not applicable without additional consideration for casings. Because it does not recognize two indirect inspection tools for conducting ECDA in a casing, PHMSA does not believe it would be appropriate to accept using guided wave, a single tool, for assessing casings without a Notification for "Other Technology".

An "in the works" revision of the ECDA standard will address the necessary specifics for applying GWUT to cased crossings. PHMSA will incorporate the revised standard into 49 CFR Part 192 accordingly as long as the technology is applied appropriately given its capabilities and drawbacks.

In summary, the introduction of natural gas pipeline IM regulations with their associated milestones and deadlines and the appropriate revision of the NACE International ECDA standard remain clear and strong drivers for utilizing GWUT as an assessment option.

## HOW IS PHMSA AND THE PIPELINE INDUSTRY IMPROVING AND EXPANDING GWUT AS AN ASSESSMENT OPTION?

A successful GWUT assessment of cased pipe is dependant on having a process in place to produce credible, repeatable, consistent results. PHMSA and the pipeline industry are working hard to improve confidence in these results through collaboration in research, technology demonstrations and by providing further guidance (via the "IM check list") on determining the important considerations for the PHMSA review.

COLLABORATIVE RESEARCH & DEVELOPMENT

The PHMSA Pipeline Safety R&D Program is strengthening industry's ability to effectively meet promulgated integrity management regulations by providing near-term technology solutions and communicating them to pipeline stakeholders. The program contributes directly to the PHMSA mission by pursuing three program objectives:

1. Fostering development of new technologies that can be used by operators to improve safety performance and to more effectively address regulatory requirements,
2. Strengthening regulatory requirements and related national consensus standards,
3. Improving the state of knowledge of pipeline safety officials so industry and regulatory managers and pipeline safety field inspectors can use this knowledge to better understand safety issues and to make better resource allocation decisions leading to improved safety performance.

PHMSA and the pipeline industry have invested heavily in GWUT R&D with 6 projects since 2002 at a level of $2.4M by PHMSA with $2.7M of industry co-funding. Several goals are sought by this investment in the following areas:

1. Increasing signal response over longer inspection distances
2. Focusing of multiple wave forms
3. Investigating basic defect characterization
4. Long-term monitoring via magnetostrictive sensors
5. Evaluating GWUT equivalency to hydrotesting
6. Investigating EMAT for launching and detecting guided waves

Table A1 in the Annex illustrates the collaborative investment since 2002 made by PHMSA and the pipeline industry. Much more was done by individual GWUT service providers and industry operators and is not captured in this depiction.

The status of these investments is available to the public at http://primis.phmsa.dot.gov/matrix/ and provides useful information on how these improvements were made.

TECHNOLOGY DEMONSTRATIONS

Technology demonstrations are a means of evaluating the merit of technologies that are reaching the prototype stage. Demonstrations expose the technologies to the environment in which the technology must be operated successfully. Demonstrations also promote the deployment and utilization of new technologies through observations and participation by pipeline operators, equipment vendors, standards organizations, and pipeline safety officials.

When these demonstrations occurred, GWUT was not considered “a prototype” technology, but still requiring further validated to build defect libraries conducive for higher confidence in produced results. To address this, PHMSA and the pipeline industry are holding multiple formal and informal technology demonstrations. Some while carrying out the scopes of research projects described in the previous section and at test beds where defect libraries are controlled. These demos are building confidence in detection capabilities and drawing a finer line where this technology should and should not be applied.

Two formal and more than a dozen informal demonstrations were held by the PHMSA program and its research partners since 2002. The most notable one occurred July 17-19, 2006 in Binghamton, New York. This demonstration occurred at the NYSEARCH/Northeast Gas Association (NGA) technology test bed specifically designed for testing GWUT and robotic technology for unpiggable gas pipelines. The following objectives were designed and sought by an industry and government steering committee:

1. To evaluate the capabilities of various GWUT providers in a known setting on cased pipes; and,
2. To exchange information among regulators, operators and technology providers and to determine what technical parameters are important for operator selection and/or evaluation of Guided Wave technologies.

Figure 1: Photo from the NYSEARCH/NGA test bed.

Figure 2: Photo from the NYSEARCH/NGA test bed.

Figure 3: Photo from the NYSEARCH/NGA test bed.

Figure 4: Photo from the NYSEARCH/NGA test bed.

The July 2006 demonstration put much of the research in perspective on how those efforts are advancing GWUT detection and characterization capabilities. Much was learned by the industry and government about what variables affect the performance of GWUT when applied to cased crossings. In addition, this event helped refine the natural gas IM check list down from 39 points to 18 specific points and grouped in issues for pipeline operators, technology vendor personnel, the application process on cased crossings and technology hardware. The checklist is described more in the next section.

The main demonstration output identified several important parameters or variables that influence the application of GWUT technology. Those parameters include:

1. Coating type
2. Coating thickness
3. Nearby pipe features that can absorb signal energy
4. Integrity of casing spacers
5. Knowledge of the positions of welds and other features such as casing spacers
6. GWUT vendor operator training
7. Wave type(s)
8. Temperature effects
9. Varying GWUT vendor application and consideration of parameters 1-8

Finally, this work raised additional questions and the need for continued dialogue between pipeline regulators, operators and with the GWUT vendor community. The following dialogue should address:

- How operators can best judge what defect selection threshold is acceptable for a guided wave job.
- For a range of operating pressures, what is the threshold for acceptability in the size and shape of a pipe defect.
- Whether commercial use of guided wave technology should also provide more education to operators and regulators about the current limits of the technology.
- Whether advancements are reducing the defect selection threshold to smaller sized defects.
- How sizes and shapes of defect impact guided wave performance.
- What additional improvements can be made to raise the reliability and applicability of guided wave ultrasound to natural gas pipelines.

The full July 2006 demonstration report is available at http://primis.phmsa.dot.gov/rd/techdemo.htm and provides a wealth of important information about applying GWUT to cased crossings.

These demonstrations served to validate GWUT hardware and software improvements under existing research, identified the most influential technical parameters that refined the natural gas IM GWUT checklist and finally advanced the state of knowledge for the regulators and pipeline operators who participated.

NATURAL GAS “GWUT CHECK LIST”: TARGET ITEMS FOR GO, NO-GO PROCEEDURES

PHMSA and the pipeline industry are constantly evolving and improving their knowledge base for effectively using GWUT on cased crossings. This is similar in how ECDA is a continuous improvement process. Targeted guidance improves over time and sometimes takes multiple iterations.

PHMSA released its first targeted guidance via a Federal Register Notice on July 29, 2005 about the use GWUT on cased crossings in meeting integrity management regulations. The guidance proscribed the manner in which GWUT is validated and then applied to pipeline cased crossings.

See the following link for more information http://ops.dot.gov/new/New_2005/05-15022.pdf

Further guidance was then provided on the Natural Gas IM website about how to construct 180-Day Notifications for using “Other Technology” such as GWUT for these assessments. The initial guidance was to include statements and attachments documenting how 39 people, process and equipment type points were addressed concerning GWUT’s usage on cased crossings. These 39 points were structured along an in-line inspection mentality which was the common thinking at that time. PHMSA would then review each notification on the merits of the individual submittal.

The collaborative research, technology demonstrations and discussions with subject matter experts drove revision to the checklist from 39 points down to 18 focused points grouped in issues for pipeline operators, technology vendor personnel, the application process on cased crossings and for the technology hardware.

The following are the 18 categories on the natural gas IM checklist as of March 2008:

1. Generation of Equipment and Software
2. Inspection Range
3. Achieving a complete inspection of the pipe
4. Sensitivity
5. Frequency
6. Signal or Wave Type
7. Distance Amplitude Correction (DAC) curve is required for each inspection
8. Dead Zone
9. Near Field Effects
10. Coating type
11. End Seal
12. Weld Calibration – welds are used to set DAC curve
13. Validation of Operator Training
14. Equipment – should be traceable from vendor to contractor.
15. Calibration, Onsite – diagnostic test on site and system check on site.
16. Use on shorted (either direct or electrolytic) casings
17. Direct examination of all indications above the testing threshold is required.
18. Timing of direct examinations of indications above the testing threshold.

Each category contains a descriptive narrative to assist operators and GWUT vendors on the appropriate parameters to include in a 180-Day Notification. Many of these parameters address the physical depiction shown in Figure 5. GWUT technology has inconsistencies between service providers as well as detection strengths and weaknesses. These understandings resulted in a "Go" or "No-Go" approach for cased crossings. Improvements in people, process and equipment will further improve confidence when applying this to cased crossings. A finer line could then be drawn on where this technology should and should not be applied.

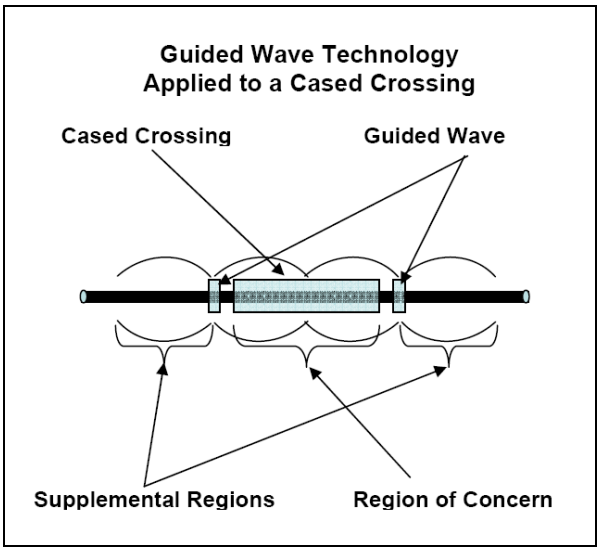


Figure 5: Depiction of the region of concern.

Please visit the following website http://primis.phmsa.dot.gov/gasimp/notifications.htm for a complete description of 180-Day Notifications and the necessary additional information via the natural gas check list that should be provided when using GWUT on cased crossings.

## CONCLUSIONS/PATH FORWARD

This paper clearly illustrates the multiple actions PHMSA and the pipeline industry are undertaking to improve and expand GWUT as an assessment option for cased crossings. This comprehensive approach is integrating advances from research and field testing with growing stakeholder experience, IM regulations and consensus standards.

More dialog and investigations are required to develop a holistic assessment approach for GWUT that provides high confidence in the remaining integrity of cased crossings. To reduce regulatory complexity, the NACE International ECDA standard should be revised to comprehensively address GWUT and cased crossings.

PHMSA and the pipeline industry must better refine where this technology should and should not be applied. If improvements are made in sizing defects and through wall determinations then ASME International should address this subject within the ASME B31.8S standard. In addition these efforts may better correlate how defect cross sectional area could be compared to hydrotesting. Collaborative research is still underway to investigate these ideas.

However, advances in other technology such as some of the robotic efforts for unpiggable natural gas pipelines will complement GWUT within a holistic approach or replace GWUT as a more effective detection and characterization tool.

Through PHMSA's partnership with the National Association of State Pipeline Representatives, education is underway on the many activities improving the over all process to determine cased crossing integrity. States must use the PHMSA requirements as the minimum standard in their state. This means these collaborative actions have an enormous impact on the states. PHMSA is also educating other Federal agencies within the Department of Transportation about the challenges that cased crossings bring. The strategy would be to reduce the creation of new cased crossings and slow potential new mileage in HCAs.

Finally, PHMSA, the pipeline industry, SDOs and SMEs must work together to raise awareness of GWUT improvements, hold public venues where stakeholder knowledge levels are raised and further collaborate with research. These efforts will bring further clarity to the integrity of cased crossings and confidence in GWUT to assess them.

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## REFERENCES

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*PHMSA, Natural Gas Integrity Management Program Notifications website, http://primis.phmsa.dot.gov/gasimp/notifications.htm*

*PHMSA, Natural Gas Integrity Management Program GWUT Checklist, http://primis.phmsa.dot.gov/gasimp/docs/GuidedWaveCheckList110107.pdf*

*NACE International Standard Recommended Practice RP0502-2002, Pipeline External Corrosion Direct Assessment Methodology, 2002*

*PHMSA R&D Technology Demonstration website, http://primis.phmsa.dot.gov/rd/techdemo.htm*

*Final Report, Guided Wave Ultrasonic Inspection of Cased Crossings - Northeast Gas Association/NYSEARCH Test Bed, July 17-19, 2006, Binghamton, New York, http://primis.phmsa.dot.gov/rd/demos/GuidedWaveUltrasonicsDemonstrationReport.pdf*

## ANNEX A

## COLLABORATIVE GWUT RESEARCH SINCE 2002

**Table A1: Collaborative GWUT Research Since 2002**

| # | Project Title | PHMSA | Co-Share | Total | Net Improvement |
|---|---|---|---|---|---|
| 1. | Enhancing Direct Assessment with Remote Inspection through Coatings and Buried Regions | $222,170 | $255,262 | $477,432 | EMAT Untrasonics Inc. software and hardware improvements for automatic inspection through wide ranging coatings. |
| 2. | Validation and enhancement of long range guided wave ultrasonic testing: A key technology for DA of buried pipelines | $531,331 | $622,750 | $1,154,081 | TWI software and hardware improvements for 360$^{o}$ focusing and for basic characterization of defects. |
| 3. | Long Term Monitoring of Cased Pipelines Using Long-Range Guided-Wave Technique | $500,000 | $506,400 | $1,006,400 | Investigating signal response improvements and long term monitoring from using magnetostrictive sensors. Applied for U.S. Patent. |
| 4. | Demonstration of ECDA Applicability and Reliability for Demanding Situations | $274,254 | $388,000 | $662,254 | Investigating comparison of GWUT data with hydrotest equivalency. INGAA formulating formal process. |
| 5. | High-power, Long-range, Guided-wave Inspection of Pipelines | $272,420 | $332,935 | $605,355 | Increased inspection distance by approx. 10%-25%. Applied for U.S. Patent. |
| 6. | Enhancement of the Long-Range Ultrasonic method for the Detection of Degradation in Buried, Unpiggable Pipelines | $655,564 | $633,325 | $1,288,889 | Petrochem hardware & software improvements to incorporate multi wave focusing |
| | **Totals:** | **$2,455,739** | **$2,738,672** | **$5,194,411** | |