2007

Report to DOT/PHMSA Steering Committee on Collaborative Demonstration of Guided Wave Ultrasonics

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Controlled Tests & Data Analyses

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Version for Public Release
April 2007

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Background

NYSEARCH/NGA and DOT/PHMSA have an existing R & D contract, DTRS56-05-T-0002, in place to enhance and validate the TWI/FBS Teletest™ Long Range Guided Wave Ultrasonic Testing System. During 2006, the second year of this contract, several controlled tests were performed at the NYSEARCH/NGA test bed and several are also being done on live jobs at NYSEARCH member companies. Through this process, NYSEARCH has amassed the experience and facilities to test and evaluate various guided wave systems.

At the request of DOT/PHMSA, in June 2006, a task was added to the R & D contract, to conduct a collaborative demonstration of multiple guided wave ultrasonics systems under the controlled test conditions at the NYSEARCH/NGA test bed in Johnson City, NY. Engineers and R & D managers of PHMSA saw this set of tests as important because of the Federal Register Notice issued on July 29, 2005 which outlines the method for applying for use of Guided Wave Ultrasonic Testing (GUT) systems. The Federal Register guidance proscribed the manner in which GUT can be validated and applied to pipeline cased crossings.

During the initiation of the Collaborative Demonstration, PHMSA also provided a listing of organizations and names of individuals who had interest in participating in the collaborative demonstration. Representatives from DOT/PHMSA, AGA, APGA, API, INGAA, NYSEARCH/NGA and AOPL were contacted. The following parties agreed to participate in the Steering Committee: Elizabeth Skalnek and Zach Barrett, DOT/PHMSA, Joseph Soltis BP representing AOPL, Jeffrey Didas Colonial Pipeline, Kent Alms LaClede Gas representing AGA, Robert Smith DOT/PHMSA, and Daphne D'Zurko, NYSEARCH/NGA. During the tests, other parties from these organizations were also included in invitations and follow-up correspondence regarding the tests.

This demonstration, related research and other discussions each contributed to the now revised GUT review checklist found on the PHMSA Gas Integrity Management homepage at http://primis.phmsa.dot.gov/gasimp/docs/GuidedWaveCheckList030607.pdf.

Objective

The objectives of the Collaborative Demonstration were twofold: 1) to evaluate the capabilities of various Guided Wave Inspection Technology 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.

Description of Test Approach

Test Plan

After the task was officially started, conference calls were held among the Steering Committee. The first step was for each Steering Committee member to sign a Non-Disclosure Agreement from NGA because the specific details about the NYSEARCH/NGA test bed (locations of defects, features, etc at the test bed) are Confidential and are not to be released in the public domain. After some initial information that was provided to explain the test bed sections (documents containing pictures and descriptions), a test plan was issued to the Steering Committee for review. After a comment period, the test plan was issued to the participating vendors and then finalized. (See Appendix A for Test Plan)

The test plan provided information about the cased pipe sections at the NYSEARCH/NGA test bed and general information about the sections and the test site for proper planning by the Guided Wave vendors. It also laid out a specific protocol for testing at the test bed. Using the checklist (see below), the test plan listed information that was being requested as part of the vendor's test report information following the test. Finally, the test plan described the intended use of the test information and reports.

NYSEARCH staff contacted multiple guided wave vendors. Given the short timeframe before the actual demonstrations that were slated for mid-July at the test bed, three organizations accepted the invitation to test for one to two days at the NYSEARCH/NGA test bed at least two of the three cased pipe sections. There were some other vendors contacted but either the proper contact was not made or the company was not interested. [We have since learned that there are additional guided wave service providers who could have been on the contact list who were not known to us at the time.]

Each participating vendor was required to execute Indemnification agreements and make their own arrangements for travel and shipping.

Survey and Discussion on Guided Wave Checklist

DOT/PHMSA's Guided Wave checklist was circulated to the Steering Committee and the vendor participants for the Collaborative Demo. This checklist was formulated as a result of the Federal Register notice from July 2005 which requires notification from Operators when the operator plans to use a technology other than in-line inspection, pressure testing, or direct assessment to perform assessments of pipeline integrity. Prior to the July tests, the PHMSA Guided Wave checklist was formulated into a survey and NYSEARCH staff distributed to the vendors for a priority ranking of the items in two dimensions: 1) on a scale of 1 to 5 (with 5 being highest) whether the vendor agrees that an operator should receive this information during or after a Guided Wave inspection activity from the vendor, and, 2) assuming that the vendor was required as part of a PHMSA process to provide this information, the relative importance (rating them again on a scale of 1 to 5) that each line of questioning has in understanding the outcome or application of the Guided Wave inspection. Each of the three vendors provided a response to the survey and those responses were discussed as part of a Steering Committee conference call. Appendix B contains the Checklist survey and a spreadsheet summarizing the responses to the survey. From that feedback, it was clear that all three vendors consider training an important element for success. Other key parameters to provide were an explanation of how the data converts to an estimation of size of the anomaly and locations of predicted anomalies. The vendors disagreed over the importance of communicating information about frequency of calibration, signal to noise ratios and tool tolerances.

Test Bed Conditions

The Steering Committee representatives and the vendors were notified about the configuration and general conditions at the NYSEARCH/NGA test bed. For example, there are over (300) machine defects in the overall test bed pipes (both cased and uncased, buried sections). While NYSEARCH/NGA has detailed information about the exact axial and circumferential location of these external and internal machined defects, none of these locations were provided to the test participants. Furthermore, none of the positions of other pipe features such as welds or casing spacers/insulators were provided. Rather, it was agreed that the Steering Committee representatives who signed the NGA NDA would get the Confidential layout drawings of the relevant cased pipe sections (that specified the locations) when the test reports and results were provided. What was provided verbally to the vendors was a general sense of the range of sizes of defects (using the guided wave terminology of percent (%) cross-sectional-area (c.s.a)). This information was provided so that each vendor would have a sense of whether or not the threshold for detection by their technology could be met at the proposed test site.

It is worthy of note that two of the three 100' cased pipe sections are above-ground sections. The third is a 12" carrier pipe in a 16" casing in an underground network. In the 12" carrier pipe case, the vendors were notified that the guided wave transducer belt could be applied above-ground near the access point but between two 45-degree bends OR at the same level as the overall cased pipe section because of underground excavation vaults that had been constructed on both the North and South ends of the 12" cased pipe for the purpose of integrity inspection tests. Figure 1 illustrated both access points; in the foreground is the above-ground access point to the 12" pipe and in the background is one of the two underground vaults for direct straight-pipe access.

Figure 1. Access points for 12" Cased Pipe

The tests for the Collaborative Demonstration were held on July 17 – 18, 2006. In addition to Steering Committee reps and their invitees, three vendors were there. Both days were hot summer days with overall dry conditions. In the afternoon of both days, temperatures exceeded 90F and the above-ground pipes are likely to have had surface temperatures well over 100F.

Technology Considerations

Principles of Operation

Long range guided ultrasonic technologies employ low frequency guided waves propagated from a ring of transducers fixed around the exposed bare (or for some technologies, coated) surface of the outside of the carrier pipe. For low frequencies, liquid couplants are not necessary. Instead, air pressure is applied to the back of the ring of transducers to insure contact and symmetrical propagation of the waves around the pipe. For axi-symmetric wave propagation (and not additional advanced schemes), the wave may be envisioned as a circular sweeping motion around the pipe and the whole pipe thickness is excited by the wave motion. The propagation of the waves is governed by the frequency and the pipe wall thickness. When the wave encounters a change in pipe wall thickness (increase or decrease) a proportion of the wave energy is reflected back to the transducers, which aids in identifying discontinuities in the pipe. The challenge comes in using signal processing and signal firing techniques to distinguish between various changes in the pipe wall and differences in signal reflectors. For uniform changes such as girth welds, the change is symmetrical around the pipe and the advancing wave front is reflected uniformly. In the case of corrosion, typically the decrease in wall thickness is localized leading to scattering of the incident wave in addition to reflection. With this scattering, wave mode conversion also occurs. Mode-converted waves tend to cause the pipe to flex and the presence of these signals is a strong indicator of corrosion.

Use of Torsional or Longitidunal Waves or Both

Some guided wave vendors only use a torsional wave mode while others use longitudinal wave modes in addition to torsional. The selection of torsional or longitudinal waves or both depends on a number of factors including pipe size and optimal frequency. The optimal frequency is also dependent on a number of variables such as pipe wall thickness and coating type and thickness. While some researchers advocate use of both wave modes, particularly when using advanced processing techniques, the torsional wave mode currently seems to be the most widely used wave mode in many of the pipe conditions.

Selected Threshold for Reporting Reflections or 'Calls'

Each vendor has amassed either experience OR statistical data which formulates a curve for the Probability of Detection versus size to determine where to establish a threshold level for reporting reflections as features or defects. For average conditions, all three vendors who participated in the July demonstration agree that a defect size of 9% cross sectional area is one of the major detection thresholds. However, in ideal conditions or with use of advanced techniques, the threshold for detection can be as low as 3% c.s.a or even 1% c.s.a. During the tests, at least two of the vendors made assertions of the predicted threshold of sensitivity based on the pipe diameter and wall thickness. Prior to gaining any information about the actual sizes of the detects at the test bed, at least one of the vendors chose to select a sensitivity threshold of 3% c.s.a.. However, one vendor also noted that while there system is sensitive to 3% c.s.a., under actual field conditions, RELIABLE detection of metal loss flaws lie between 6% and 9% c.s.a.. In addition, the same vendor developed detection curves for the specific pipe sizes at the test bed showing the relationship of flaw depth to circumferential extent. The curves showed where a 4% or 5% c.s.a. sensitivity would limit defect size detectability.

As seen in the tests (and to be discussed in later sections), there is a tradeoff in the selection point for making 'calls' of anomalies. For example, with a truly conservative approach, such as only selecting data where the reflection suggests a defect with a size of

9% c.s.a. or larger, many typically sized defects would not be seen. In the case of the test bed, there were NO defects as large as 9% c.s.a. so it becomes a moot point. However, there were some defects on these cased sections that had a c.s.a. of >3% and one with a c.s.a. of > 6%. [The reason for the range of sizes on the cased pipe sections was not based on a limit to a specific technology but rather a decision on the part of the gas operators who designed the test bed for the range of defects (minor, moderate, severe) that they would want technologies to be able to detect.] As one lowers the sensitivity threshold or call reporting point, there is more chance to pick up reflections that are in the noise. So more minor or moderate sized defects may be picked up but also with that comes a higher probability for false calls. For a gas operator, false calls result in customer interruption and excessive cost to remove or expose a pipe that is in good working condition.

Weld Positions

Welds on pipe, such as girth welds, are good reference points for guided wave technology service providers. While weld positions are not always readily available to the operator, they can be used as a point of calibration. In this test, however, the positions of welds and other features were not provided.

Casing Spacers/Insulators

There were several casing spacers/insulators in place in all three sections of cased pipe at the test bed. In one of the three cased sections, the EXACT positions of the cased spacers were known by NYSEARCH/NGA and analyzed as part of the data review. For the other two sections we have close estimates of spacing but not exact positions because of installation and/or documentation issues. The 16" above-ground cased section is the section where casing spacers position documentation is exact.

While some calls were made that suggest that the reflection was a casing spacer/insulator, none of the vendors put a priority on calling spacers. This is mainly because casing spacers do not necessarily indicate any information about defects or pipeline integrity except in cases where the casing spacer is at the same position as the defect. In the latter case, there is sometimes a problem is distinguishing between a casing spacer and a defect.

A casing spacer that is secure and tightly coupled to the pipe is apparently distinguishable. However, how that spacer is differentiated was explained differently and is approached differently by varying vendors. For example, one of two vendors who commented on the detection of spacers felt that a tightly coupled casing spacer results in a detectable reflection; the other felt that a tightly coupled casing spacer did not affect the ultrasound.

Effects of Coatings

The cased sections that were tested during the Collaborative Demonstration provided a means for testing the varying impact of coatings. The 16" above-ground cased section has a thick, 0.154" coal tar epoxy coating that is more representative of the older vintage coated pipe and majority of older coatings in the LDC network. The 12" below-ground coal tar epoxy coating is much thinner, 0.020" thick, and is a more modern sprayed-on enamel that is not as common in the LDC installed pipe inventory. (NYSEARCH does not have much information to comment on prevalence for the majority of pipes/coatings owned and operated by transmission pipe companies.)

During the test, there was one new variable introduced that may have impacted the thicker coating on the *above-ground* 16" cased pipe. That was the extreme heat of the coating on the day of the test. Since ambient air temperatures were in the high 90s (ºF), the exposed coating temperature easily could have exceeded 100ºF. One vendor reports that for those tests, signal attenuation was considerably higher that day and attributes that partly to the temperature of the coating and the potential change in viscosity of that coating. [It is worth noting that in most underground conditions, this situation would not occur on a hot day.]

In general, because of attenuation on thicker coatings, guided wave performance is better on the thinner coatings. Based on a number of controlled and well as live field tests that NYSEARCH/NGA participated in during 2006, it is the author's opinion that coal tar epoxy and polyethylene coatings seem to create significant attenuation to limit the range of the guided wave technology to ½ or less of the claimed ranges of 100 – 150' by creating noise and lack of clarity in the signal reflections.

Dead Zone Near Transducer Belt
The guided wave technology service providers have acknowledged a "dead zone" where data cannot be collected. This dead zone varies but can range from a few inches to a few feet from the centerline of the transducer belt. Therefore, it is important to be able to have sufficient space away from the area of interest (such as the casing) to avoid having the dead zone in an area where there could be pipe integrity issues.

Results of Tests

The tables below summarize the results from the findings of the tests performed on July 17 – 18. For illustration on one such test, see Figure 2. The detailed summaries, spreadsheets and layout drawings were provided to the Steering Committee as Confidential documents. The technology providers were also provided detailed results but the exact locations and sizes of defects that are present at the NYSEARCH/NGA test bed have not been provided to the vendors or any party who did not sign the NDA.

12" Below-Ground Cased Pipe

	Vendor A 1	Vendor B 1	Vendor C	Vendor A 2	Vendor B 2
Acc Weld Callouts	2 out of 2	1 out of 2	0 out of 2	2 out of 2	1 out of 2
Acc Defect Callouts	3	4	2	12	9
Size of Acc Defect	2 @ > 3% 1 @ >1% & < 3%	2 @ >3% 2 @ >1%	1 @ >3% 1@>1% &<3%	2 @ > 3 % 5 @>1% & <3% 5 @ < 1%	1 @ >3% 5 @ >1% & 3% 3 @ <1%
Missed Defects	16*	13*	17*	7**	9**
Size of Missed Defects	2 @ >3% 5 @ >1% & <3% 9 @ <1 %	1 @ >3% 5 @ >1% & <3% 7 @ < 1%	2 @ >3% 6@ >1%& <3% 9 @ <1%	2 @ >3%* 1 @>1% & <3% 4 @ < 1%	2 @ >3% 2 @ >1% & <3% 5 % <1%
False Indications	0	2	1	Many***	5

Note – when sum total number of accurate and missed defects differ by vendor, it is because of callouts that were incorrectly labeled or the callouts did not cover the full pipe section range

***** four missed defects outside of casing
****** two missed defects outside of casing for Vendor A, three missed defects outside of casing for Vendor B
******* Vendor A's secondary analysis involved the use of post-processing procedures to remove structured noise from the signals. This approach is considered preliminary and is not commercial.

16" Above-Ground Cased Pipe

	Vendor A 1	Vendor B 1	Vendor C	Vend A 2	Vendor B 2
Acc Weld Callouts	1 out of 2	1 out of 2	0 out of 2	N/A	1 out of 2
Acc Defect Callouts	5	3	3	N/A	9
Size of Acc Defect	2 @ >3% 3@ >1% & <3%	1 @ >3% 1 @ >1% & < 3% 1 @ < 1%	1 @ >3% 1@ >1% &< 3% 1 @ < 1%	N/A	4 @ >3% 3 @>1% & <3% 2 @ <1%
Missed Defects	14	16	11	N/A	9
Size of Missed Defects	2 @ >3% 6 @ >1% & <3% 6 @ < 1%	3 @ >3% 5 @ >1% & < 3% 9 @ < 1%	1 @ >3% 5 @ >1% &< 3% 5 @ < 1%	N/A	3 @ >1% & <3% 6 @ <1%
False Indications	2	1	0	N/A	2

20" Above-Ground Cased Pipe

	Vendor A 1	Vendor B 1	Vendor C	Vendor A 2	Vendor B 2
Acc Weld Callouts	N/A	1 out of 2	1 out of 2	N/A	N/A
Acc Defect Callouts	N/A	3	1	N/A	N/A
Size of Acc Defect	N/A	3 @ >1% & <3%	1 @ >1% & <3%	N/A	N/A
Missed Defects	N/A	-	2	N/A	N/A
Size of Missed Defects	N/A	-	2 @ >1% & <3%	N/A	N/A
False Indications	N/A	1	1	N/A	N/A

Casing Insulator/Spacer Callouts

Only in some cases, for two of the three vendors, casing spacer/insulators were cited. In those cases, for the most part, those callouts were not accurate and were more a prediction of an un-explained cause for a reflection. The focus of the tests was not to find spacers but to find defects. The proximity of the defects to the spacers may have compromised the accuracy of the defect callout. An example of shielding, to be discussed later, is a missed defect having a size of > 3% cross sectional area (c.s.a.), that was located between a casing spacer and a link seal. These types of features can create too much noise/clutter. The lack of clear information then prevents the vendor from making a confident call.

Figure 2 DOT and Industry Reps observe
Application of transducer belt on 16” pipe

Data Interpretation and Dialogue Among Steering Committee

Overview

In reviewing the initial results (first analysis of test bed sections by the three vendors), the Steering Committee was interested in learning whether the vendors had chosen a conservative threshold for callout reporting and whether there was additional data from the July 17 – 18 activity that could be called as defects. Two of the vendors re-visited the data and for one of the two vendors (Vendor A), there was no additional data that would be called from a ‘traditional’ standpoint. However, Vendor A chose to use some new and previously un-tested signal processing software and did re-visit and perform a secondary, less conservative analysis. The second vendor (Vendor B) simply used the existing data and found that with less conservatism on the existing data, that there were several more defects that could be called. The third vendor (Vendor C) did not respond to the request. For both of the vendors who did re-visit the data, more accurate defects were called, less defects were missed and there were more false calls. For Vendor A who used new, un-tested signal processing software, the number of false calls was large whereas for Vendor B the number of false calls jumped from one to two in the 16” above-ground case and two to five in the 12” below-ground case. [Besides emphasizing that the signal processing software was seen as a new, non-commercial technique to try to“de-noise” the data, Vendor A also asserted that the data collected in July was not high quality data to begin with. Also, they would prefer for the ‘false calls’ to be labeled as artifacts of the un-tested signal processing i.e. processing that creates signals where no defect exists.]

Another point to stress for these tests is that the data is being presented based on the conditions that existed on the days of the test. On other days in other conditions, advanced processing techniques could have been more or less successful. Given that multiple vendors did attempt the same tests in basically the same weather on two consecutive days, only the methods that were working on those days are being considered in this report.

Dialogue on Appropriate Minimum Callout/Sensitivity Threshold

In the situation tested at the test bed, there were only a few defects on the cased sections that had % c.s.a. of greater than 3%. As seen in the results, many of the accurate defects called were the ones either greater than 3% c.s.a. or greater than 1% c.s.a. What concerned the Steering Committee is that for the two vendors who chose to re-visit the data and provide a secondary data analysis, for the 12” below-ground pipe, there were still (2) defects with a c.s.a. of greater than 3% that were missed. This lead to a discussion of factors that may have caused a problem with detection in those areas as well as a discussion of the criticality of a 3% c.s.a. defect and what the appropriate sensitivity threshold should be.

Shielding Investigation

As part of the discussion on missed defects from the less conservative re-visited or secondary analysis, the Steering Committee began to question whether the guided wave results from the tests were illustrating another phenomenon; that of responses being “shielded” by nearby pipe features. With that concern in mind, NYSEARCH staff did a more specific review of the placement of all the defects in the cased sections that were tested and conducted an analysis of the distance of actual defects to nearby features. That Confidential analysis (revealing defect designations and the actual distances from nearby features) is provided to the Steering Committee under the NDA. For the defects that were greater than 3% c.s.a. and missed as described above, there is the following information to report: 1) For the first missed defect with a 4.12% c.s.a., the defect was outside of the casing and was near a 45 degree bend and 6” away from a weld, and, 2) For the second missed defect with a c.s.a. of 3.86%, the defect was actually between a casing spacer and the link seal (inside but near the end of the casing spacer).

When considering shielding of defects sized smaller than 3% c.s.a., the analysis shows that in the case of the 12” pipe, out of the (7) defects that were missed in the **secondary less conservative analysis**, the remaining (5) defects (other than those >3% c.s.a) that were missed by one vendor could be considered shielded (because of being either close to a casing spacer, weld, link seal by up to 12”). At the same time, a small defect (<1% c.s.a) that is actually UNDER a casing spacer was not missed by that vendor. For the second vendor, all of the defects that were <3% c.s.a. and missed could also all be considered shielded. [For the 16” pipe and the initial more conservative data analysis, for Vendor A, 10 out of 14 missed defects could be considered shielded and for Vendor B, 12 out of 16 missed defects could be considered shielded.]

As noted above, the vendors qualified their predictions even before the test reports were issued. One vendor suggested that the sensitivity threshold for reliable detection in actual field conditions was 4 or 5% c.s.a. (using the pipe sizes and wall thicknesses that were present at the test bed). However, there was still optimism about seeing defects with 3% or even down to 1% c.s.a. . It was also suggested at one point that what may have compromised the 3% c.s.a. detectability assertion in the July tests was the fact that the defects in this test situation are machined defects and have smooth surfaces as opposed to the rougher surfaces of natural corrosion defects (most prior experience comes from actual corrosion defects).

Vendors’ response to Shielding Information/Hypotheses

Two of the three vendors provided responses to the information provided here about shielding. Neither of the two accepted shielding as the primary cause for missed defects. Also, neither were particularly convinced that a 3% c.s.a. sensitivity or higher sensitivity threshold should the focal point of the discussion or evaluation. One vendor reacted with the point that to address the significance of missed defects, one needs to consider that for the operating pressures and the sizes under question that any failure of defect with a size of 4% c.s.a would fail by leakage and not rupture. The point here is that an inspection technique does not necessarily need to require sensitivity less than 4% c.s.a. because of the way that a defect with a size of lower % c.s.a. would affect the pipe (even if there was high wall loss and extreme operating pressure). For example, they see flaws with a 3% c.s.a. on a 20" diameter pipe with 0.375" wall thickness having little consequence to pipe integrity at practical operating and test pressures.

Also, that same vendor made the point that the federal regulations do not require methods in alternate integrity assessments that exceed the flaw detection sensitivity of hydro-testing. Then, using a table as shown in Figure 3, they demonstrated that for the sizes of the defects that were missed (discussed earlier) and the diameter and wall thickness of the pipe in question (12" diameter and 0.375" wall thickness), that the estimated ratio of failure pressure to MAOP is higher than the highest likely required ratio for Federal Code 49 CFR Part 192 Subpart O for hydrotesting.

Class location	1	2	3	4
MAOP for 12.75" x 0.375" grade B pipe	1482 psig	1235 psig	1029 psig	823 psig
Pf/MAOP for 3"W x 1"L x 50%d	1.69	2.02	2.43	3.03
Pf/MAOP for 2"W x 1"L x 80%d	1.44	1.73	2.08	2.59
49CFR Part 192 , Highest likely Test pressure/MAOP	1.25	1.25	1.5	1.5

(Pf/MAOP = failure pressure ratio calculated by RSTRENG)

Figure 3 Calculated Failure Pressure to MAOP ratios based on RSTRENG Program

In addition, the vendor pointed out that the published literature, as well as current research indicates that the probability of flaw detection for relatively short flaws (i.e., on the order of one inch) increases as flaw length increases when the width and the depth of the flaw (i.e., the csa) are constant. Therefore, a one inch long flaw with a csa of 3% that is undetected may be detectable if the flaw length increases. Therefore, the vendor makes the point that it is important to assess the shape of the flaw in addition to the % c.s. a. This reaction provides an interesting follow-up item but it is emphasized in reaction to the results. Little discussion or presentation were made by any vendor during the course of the preparatory work or during the July tests that brought in the issue of the significance of shape of the defect. This may simply illustrate that the understanding of how defect size and shape impact guided wave signals is still evolving.

The other vendor who commented on the shielding investigation does not feel that the simple presence of a casing spacer will mask a defect. If the spacer generates a response to the guided wave, it could mask defects which are underneath the spacer and therefore miss the defect. If there is no response from the casing spacer, then the reflected signal is only governed by the defect and the signal to noise ratio. Also, this vendor prefers that the discussion about defect sensitivity and selection threshold be based on curves for Probability of Detection (PoD) for each size pipe. However, the limitation of making any conclusions about PoD in these or related tests at the test bed or in any specific field jobs is that you need a statistical sampling of defects and guided wave responses to fully define the PoD curve.

Conclusions

The objectives of the Collaborative Demonstration were to evaluate the capabilities of the technology in a known setting and exchange information among regulators, technology providers and operators. With this report and supporting documentation, this objective has been met. There are certain qualifiers about the range of sizes of defects that the technologies were tested in but a lot has been learned about technique, capabilities and limitations and the impact of ongoing advancements. For the second objective, a healthy exchange has started between the entities based on: 1) the guided wave checklist and related survey, 2) the two days of demonstration and dialogue, and 3) the responses from all sides to the data reports.

Each vendor that participated in the July 17 – 18 was working with either a different make of the same basic guided wave technology OR a different software/processing version of the same technology. At least one vendor used advancements that are in process through an R &D program and therefore, was using some incomplete versions of advanced hardware and software. In all cases, however, each vendor was given the same opportunity and information to work with at the test bed.

In the first analysis of the data by the vendors, there were little to no false calls, some defects called accurately but many defects missed. However, when you look at the issue of selection threshold (9%, 5%, 4% and 3% c.s.a), it is clear that a majority of the machined defects at the test bed were below the 3% c.s.a. size.

The secondary, less conservative analysis had more accurate predictions of defects, fewer missed defects, more false calls and missed the same larger (> 3% c.s.a.) defects.

One of the issues that arise from this activity is how critical is a defect with a size of 3% c.s.a. Based on the deliberate design of the NYSEARCH/NGA gas engineers who selected the defect sizes for the test bed, that particular subset of the gas industry is indicating that 3% c.s.a. is critical. Others do not necessarily agree and cite pipe strength calculations and federal standards as references.

Given the stated selection threshold limits of 4% and higher, if one were to only consider performance for defects with those sizes, then for this activity, the vendors did considerably well because they still found defects as small as (less than) 1% or in the size range from 1% to 3%.

A controlled site offers some advantages to live jobs. In this case, the NYSEARCH/NGA test bed was intended to replicate real-world features (such as welds, bends, casing spacers, soil conditions, pipe depth, etc), but it also has some conditions which are different and impact the performance of the technology. Those conditions include: low environmental noise, machined defects, above-ground pipe with coating that can be affected by temperature and a limited pipe network. However, it should be noted that while there was information provided to show a close proximity of defects to pipe features such as welds and casing spacers, the defects themselves were spaced at least 3’ apart in most cases. This 3’ spacing was incorporated into the test bed design in early 2005 at the designation of various technology vendors including parties that represented the guided wave technology.

In the Shielding part of the "Results" section of this report, the discussion leads to the conclusion that if shielding were considered (features up to 12" away from a defect), that there would be a rationale for many of the missed defects in this test, even in the secondary, less conservative analysis. However, the technology vendors do not feel that shielding is a worthy explanation. They see it as a more complicated issue of defect size and shape, and defect texture (machined versus natural). They may also see the conditions at the NYSEARCH/NGA test bed as worse case. What this unveils is a general diversity in opinion about the criticality of defects with varying sizes and shapes.

Guided wave as a screening technology

As discussed in this report, there are several important parameters or variables that influence the application of the guided wave technology. Those parameters include: 1) type of coating, 2) thickness of coating, 3) nearby pipe features that can absorb signal energy, 4) integrity of casing spacers, 5) knowledge of the positions of welds and other features, 6) training, 7) wave type, 8) heat effects and several others. What we learned in this activity is that the relative weighting of those parameters varies by vendor. However, it appears as if the most common limitations are the type and thickness of the coating.

We also learned during this activity that extending the use of guided wave technology to sizing defects is possible but that the capability for sizing defects is still limited. There is work being done by several parties to advance this capability but based on the information from this limited test, there is no evidence that suggests that the guided wave technology as it is available today has a reliable capability for sizing defects.

Recommendations/Next Steps

There are some areas where this work raises additional questions and need for dialogue. It is recommended that further dialogue is needed to 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

APPENDIX A

APPENDIX A

<u>Test Plan for Collaborative Demonstration of Guided Wave Ultrasonics Technology</u>
July 2006

Objectives of Collaborative Demonstration:

1) To evaluate the capabilities of various Guided Wave Inspection Technology 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.

General Information on Planned Tests:

1) Technologies will be applied to as many of (3) potential cased crossings test sections at the NYSEARCH/NGA test bed in one 6-hr period (one test day available with one extra day if tests are prohibited by very bad weather)
2) Three cased sections contain the following Pipe parameters:
    a. approximately 80’ of cased pipe for each section; two above-ground, one below ground
    b. Below Ground 12” CTE steel pipe with 16” casing – Section A
    c. Above Ground 16” CTE steel pipe with 20” casing – Section B
    d. Above Ground 20” bare steel pipe with 24” casing – Section C
3) All three sections have machined defects at various points around the circumference and axially along the pipe; the positions of those machined defects will not be provided to the vendors but will be provided to the Steering Committee for purposes of evaluation
4) Pipe wall thickness for all three sections – 0.375”
5) All three sections have circumferential welds at pipe joints. All pipes were manufactured with seam welds.
6) All three sections have casing spacers and at the edge of the casings on North and South End; link joints
7) Sections B & C can allow direct placement of the GUT transducer belt on the pipe directly North and South of the casing
8) Section A allows direct placement of the GUT transducer belt on the pipe directly North and South of the casing if applied on the pipe in the N and S vaulted excavations. The North end of Section A also contains an above-ground access point but the signal must pass through two 45 degree bends; one above-grade and one below-grade
9) All three sections of pipe have straight configurations
10) Sections B and C have pipe support through embankment/bedding
11) Section A pipe is supported by backfill
12) None of the casings in the three sections are filled with any material
13) Two of three sections have CP on the carrier pipe. For Section A, the CP is removable. Section B has no CP. Section C has CP that is provided through galvanic anode

14) An electric supply is available at the Rectified station which can be made available to all three sections through use of extension cord(s)
15) None of the pipe sections contain pressurized media
16) NYSEARCH/NGA will provide illustrations of test bed data collection access points. Sample photos from the test bed are provided in Appendix A. I didn't see an Appendix A attached to this email. I assume it will be provided at a later time?

Protocol for Testing:

1) Each Vendor should notify NYSEARCH/NGA prior to the tests if they need to have the coating removed from the test sections in order to apply the transducer belt. My guess is that they (vendors) will all require the coating be removed so that the transducers contact bare pipe.
2) Each Vendor should notify NYSEARCH/NGA prior to the tests regarding whether they need to have the Cathodic Protection system de-activated.
3) Hardhats should be worn at all times while at the NYSEARCH/NGA test bed facility. Visitors to the test bed cannot be on-site without a NYSEARCH/NGA or NYSEG representative present.
4) Each Vendor will be asked to attempt in the time allotted (and influenced by weather) to collect data for all three sections. If time becomes a limiting factor, at least the 12" CTE section should be tested from both N and S ends
5) For a test to be considered complete on a particular section, data should be collected from both North and South Ends
6) The data collection process should allow time at the beginning for sufficient calibration.
7) The vendors will be given time at the beginning of the data collection process to explain to observers and members of the Steering Committee how the technology is being used and what methods are being used for calibration and data collection
8) The vendors will be given time to take data, make an initial assessment and then provide a PRELIMINARY indication of major features such as welds, large defects and other features that appear as large signals
9) The vendors will be given time for a dedicated discussion after the data collection process on PRELIMINARY findings, methods and any issues presented by the test environment.
10) For Section A, the Vendor/technician may go into the pit to attach the transducer belt to the pipe. However, data collection equipment should be kept at the ground surface.
11) For Section A, when the vaults are NOT in use, the vault doors should be kept closed.

PHMSA/OPS Checklist Intended for Evaluation of Required Information Exchange between Gas Operators and GUT Technology Providers:

For the Collaborative Demonstration, the Steering Committee is requesting that the following information be provided either during or after the test.

1. Inspection parameters to be used such as frequencies, modes, amplitudes.

2. Signal to noise ratios (at proposed frequencies and modes) and expected attenuation rates
3. Expected test range (under current conditions)
4. Defect size sensitivity threshold for each pipe size/type; minimum performance expectations
5. Algorithm status such as age, updating and past performance and if/how validated.

6. Method of converting area of metal loss into length and depth determination.
7. How the guided wave technology provider is going to classify anomalies and what approved methods are they going to use (B31G, etc.)
8. QA method to be used to validate results.
9. Inspection and equipment procedures with calculations, tool tolerances, and procedures
10. Defect location and tolerances on distance from sensor
11. Location *and dimensions* of known indications such as welds, spacers, bends, etc.
12. Filters used on sensors and in the algorithm.

Equipment Issues

13. Equipment calibration history
14. Test and calibration of equipment prior to first test on site. How long between calibration tests, especially prior to testing at new site?
15. Frequency of calibrations during testing
16. Tool tolerances and signal attenuation at various ODs and WTs

Training Issues

17. Training and qualification of field personnel for equipment, procedures and wave frequency determination
18. Training and qualification of personnel performing data interpretation for filter screening, conversion of wave signals and interpretation of signals to metal loss (pit depth and length)
19. OQ training and other certification of testing and interpretation personnel
20. Testing and interpretation personnel experience on this type of inspection

Report Expectations:

It is anticipated that a report will be provided with predictions of welds, defects, features such as casing spacers within 30 days from the conduct of the tests.

The report should address as many items from the PHMSA/OPS checklist (above) that are practical and possible given the activity. The report should also provide a clear reference point for each set of data from both North and South ends of each test section.
The report should describe the technical approach, all findings, any issues or concerns raised by the test data and/or facility and any suggestions regarding continued dialogue or additional activities. The vendor is welcome to attach a Confidence level with each finding.

Sponsors' Intended Use of Report:

The sponsors and Steering Committee do not intend to compare the results of the various vendors to each other. Rather, each vendor's results will be compared to the actual conditions at the NYSEARCH/NGA test bed. Also, in any reference to a vendor in a report for the Steering Committee or NYSEARCH/NGA sponsors, the names of the vendors will not be supplied (rather words like "Vendor A, Vendor B will be used.). Also, results from each vendor will not be shared with other vendors participating in the activity.

APPENDIX B

PHMSA/OPS CHECKLIST SURVEY

		Vendor A	Vendor B	Vendor C
	Test Results*			
A -	**Aquiescence to vendor providing operator with survey info. during/after a GUI activity.**			
B -	**Relative importance each survey question has in identifying the application of the GUI.**			
	Guided Wave Contractor	**A,B**	**A,B**	**A,B**
1	Inspection Parameters	3,5	5,5	2,2
2	Signal to noise ratios	5,5	3,?	2,2
3a	Sensor type, spacing and location	1,1	3,0	3,1
3b	Expected Range**	4,4		
4	Single/Dual Sensors	?,?	5,5	1,1
5	Algorithm Status	5,5	5,5	3,2
6	Performance and range guarantee	1,1	0,0	3,3
7	Conversion of metal loss to length and depth determination method	5,5	5,5	5,5
8	Anomaly classification criteria	1,1	5,5	5,5
9	QA method	5,5	5,5	4,4
10	Inspection and equipment procedures	5,5	5,5	5,5
11	Defect location and tolerances on distance from sensor	5,5	3,3	5,5
12	Location and dimensions of known indications	5,5	4,?	4,4
13	Filters used on sensors and in the algorithm	5,5	3,3	3,2