GUIDED WAVE ULTRASONIC INSPECTION & VERIFICATION STUDIES OF BURRIED PIPELINES

S. Lebsack
Lebsack & Associates, The Woodlands, Texas, USA

Abstract: New DOT pipeline integrity regulations require operators to assess pipeline sections that previously could not be inspected by conventional in-line-inspection processes, i.e., smart pigs. The new rules for gas pipelines allow the use of Direct Assessment to evaluate the integrity of these lines. Over the last four years Guided Wave UT has been used to inspect interstate pipelines regulated by DOT/OPS. The method is recognized as one of the key technologies in the Direct Assessment process.

Long-range ultrasonic inspection or guided wave ultrasonic testing was commercially introduced in early 1998 for in-service monitoring of pipes and pipelines. The oil, gas and chemical process industries now use it for detection of corrosion and other metal loss defects and it has gained acceptance as a valid means of assessing the condition of pipes and pipelines where inspection preparation or access is difficult or expensive. The use of the technology is especially significant in view of the high percentage of unpiggable gas pipelines in the United States and government emphasis on pipeline integrity assessment. The technique has been extensively used in the field for evaluating the condition of pipes in the range of 2 to 48 inches in diameter and has performed well in identifying corrosion in pipes in a variety of situations. As with any new technology, a crucial stage in gaining acceptance by industry as a proven inspection and monitoring tool is the performance achieved in real field situations. Over the last two years, several validation exercises have been partially funded by The Research and Special Programs Administration (RSPA) and The Office of Pipeline Safety (OPS) in conjunction with research in this methodology. These validation exercises are serving to establish confidence in guided wave UT for regulators and pipeline operators alike.

This paper briefly reviews the guided wave process and compares some of the field data obtained with the actual as-found pipe conditions. The paper generally looks at the research underway in field applications of long-range ultrasonic technology that is contributing to the development of new and better equipment. Next generation equipment sets are already being developed and the capabilities of these units will permit more flexibility in data acquisition, improved sensitivity and extension of the inspection range.

Introduction: The long range, guided wave ultrasonic technique (GWUT) was developed for the rapid survey of pipes, to detect internal and external corrosion. The principal advantage is that long lengths, i.e., 90 to 130 feet in each direction on buried pipe and 300 feet plus above ground (also in each direction) can be examined from a single test point. The benefits are:

- reduction in the costs of gaining access to pipes for inspection, eliminating extensive removal and reinstallation of insulation, except in the area where the transducers are mounted;
- direct inspection of unpiggable pipeline sections in lieu of pig launcher-receiver installation, line upgrading or hydro testing;
- the ability to inspect inaccessible areas, such as buried pipes, cased pipes and casings, wall penetrations and under clamps and supports;
- 100% of the pipe wall is tested;

- and site trials have demonstrated that this method is capable of detecting corrosion <30% through wall and <25% of the circumferential width, i.e., 9% of the pipe wall cross-section.

The value of using GWUT to pinpoint potential problem areas along pipelines should be obvious. The use of the technique over the last 4 years has shown that this is a valid means locating corrosion in buried pipe sections. Other applications for the technology are numerous and industrial utilization is not limited to pipelines but open to situations where metal loss in piping presents an environmental or safety concern.

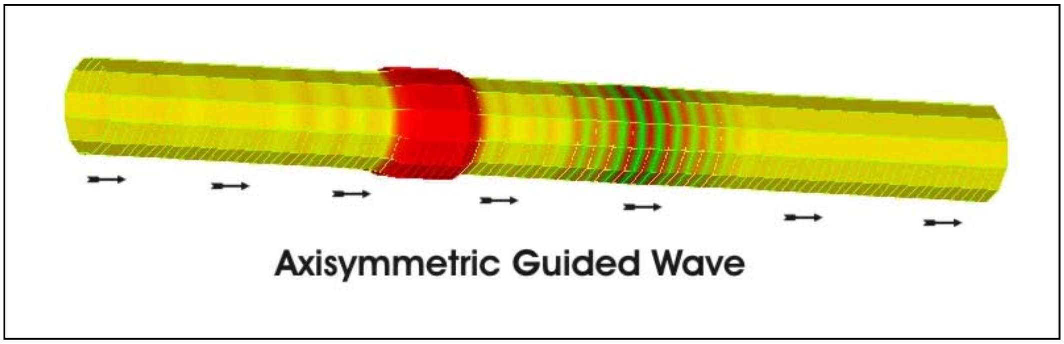

Figure 1. Finite element model of a guided wave front propagating (left to right) in a pipe section. Red band represents the main wave front. Banded area to the right is another wave mode not used in the inspection.

Guided waves as illustrated in Figure 1 are induced in pipes by using a transducer collar (Figure 2) that surrounds the pipe. The wave front created propagates along the axis of the pipe interacting with features in and on the pipe such as metal loss from corrosion, welds, attachments, branches, etc. Reflected and refracted sound is returned from pipe features and read on the data screen of the inspection equipment. (Valve bodies and flanges are restrictions to GWUT.) Sensitivity is between 3% and 9% of the cross-sectional area of the pipe. The determining variable is a function of the defect shape and orientation to the wave front, i.e., features such as corrosion pits with nearly vertical side walls will yield stronger responses than saucer shaped defects. However, broad areas of localized corrosion with relatively low through wall extent are also detected.

Results: The data following was selected because the field data was verified by visual inspection of the pipe sections after they were excavated and the coating removed. Verification of the first section took place in a pipe yard where the sections had been cut and numbered so that their original position in the field was maintained. One of the cased pipe studies was verified in a similar manner as the one mentioned previously since the original pipe was replaced. The other was excavated between the two access points and inspected in the field after the coating was removed from the entire section.

Guided Wave Survey of 2000 feet of Uncoated 20" Gas Line

A large US transmission/distribution company used the Guided Wave System to inspect 2000' feet of 20 inch O.D., standard wall (.375) pipe. The line was installed in the early 1950's was operated uncoated for over 20 years without cathodic protection. Bag anodes were installed in the mid 70's. Although the operating company planned to remove and replace the line, they inspected a 2000 foot section with guided wave prior to replacing the line. The guided wave data (Figures 6 & 7) was then correlated with the as-found pipe condition to verify the anomalies identified during the in-service inspection. Examples of corrosion anomalies found on the pipe by the guided wave system are included in Figures 3, 4 & 5. It should be noted that the pipe was in such bad condition that the analyst only picked the most severe of the anomalies. Also, the bell-hole spacing was approximately 190 feet. A more effective examination would have resulted had the spacing been reduced once the condition of the pipe was established. That is to say that since the pipe had significant corrosion anomalies detected in first hole opened; better data could have been obtained by decreasing the distance between the access points along the line.

The interpretation of data from this line was difficult in that signal responses from corrosion were numerous; sometimes overlapping (Figures 3, 4 & 6). The combination of the poor pipe condition combined with the soil condition (cohesive clay in the lower sections) resulted in high signal attenuation conditions. Also, the pipe had to be cut into sections when it was removed and transported to the pipe yard. Each of the ends was marked to allow for reconstruction of the sections as they were insitu. At the time the inspections were conducted, the reconstruction exercise was not anticipated. Consequently, the original transducer collar locations could only be re-established within ± 1.5 feet based on surface measurements taken at the time of the inspection and significant features (such as welds) that correlated with specific signal responses.

The data from this study resulted in one of the most extensive verification examinations of a GWUT inspection of a buried pipeline to date. Over 650 feet of pipe has been visually mapped and compared against the as-found pipe condition. A total of 85 anomalies were identified and mapped from the as-found condition with respect to clock position around the circumference, pit dimensions and depth and axial position relative to the GWUT tool position. All of the anomalies were photographed and the raw inspection data was re-evaluated with respect to the visual data collected.

Discussion: A tabulation of all anomalies identified in this study was completed. The complete table is not included in this paper however; a summary of the results follows in Table 1. The evaluation of the performance of the GWUT technique in this verification exercise examined the following circumstances:

1. Was the anomaly within detection capabilities of the equipment?
2. Did the technician call the anomaly?
3. Was a signal response present in the data (whether called by the operator or not)?

The discrepancy between the number of operator calls and those detected by the equipment, i.e., those not identified by the operator but discernable on the data can be explained by the initial nature of the inspection. It was determined during the inspection of the first locations that the line was in poor condition. The selections made were generally thought to be individual areas whereas they actually proved to be multiple anomalies within and area. In some cases anomalies that looked like weld signals were miscalled.

Table 1

Tabulation of the As-found Conditions					
Total number of anomalies identified on pipe sections	**Anomalies below detection threshold (<9%)**	**Anomalies not detected by equipment (>9%)**	**Total anomalies detected by equipment**	**Total anomalies called by technician**	**Miscalls**
85	6	7	72	48	5
		Score	72/79 = 91%	48/72 = 66%	5/48 = 10%

The ability of GWUT to detect anomalies was similar to earlier blind verification studies with 91% detection of the anomalies found visually. However, more experience need to be developed on the characterization of signals to aid in interpreting data. This will increase the benefit of using of guided wave systems for buried pipe inspections.

Inspection-Verification of Cased Pipe Sections

ctions for the Northeast Gas Association using a Guided Wave Ultrasonic System (GWUT) were completed at three separate sites of member Companies. The purpose of the inspections was to evaluate the effectiveness of GWUT in inspecting cased pipe sections. This study was part of a larger program undertaken by NGA to determine the effectiveness of various Direct Assessment Tools that would be use to assess pipeline integrity. All three locations provided for the study were excavated for verification of the data.

Discussion: Cased pipe is difficult to inspect if it cannot be pigged. Indirect inspections such as CIS or DCVG surveys provide no information because data cannot be obtained along the area where the pipe is encased. It is possible to determine if the pipe is “shorted” in the casing however, information relating to the integrity of the line is not provided. GWUT data gives a global assessment of the pipe condition throughout the cased section. Access is required at one end of the case section (Figure 8) for inspection however; a more thorough inspection results if access from both ends is provided. The actual cased end does not need to be exposed for the inspection but the quality of the inspection data is enhanced significantly if the casing ends are exposed. A benefit of exposing both ends of the casing is that axial reference points are established and overlapping signal data provides confirming signal references.

After the inspection but prior to the verifications all participants were provided with a CAD layout of the anticipated pipe configuration as determined from the data collected. This drawing was the visual presentation of the technician’s field report. ***In all three of the verification exercises of cased pipe no metal loss anomalies were identified during the inspection process and none were found in the verification exercise.*** The anomalies that produced most of the signal responses in the cased pipe inspections were varrious coating delamination conditions, spacer belts that keep the pipe centered inside the casing and welds. Some apparent false positives were also noted in the signal data for which no explanation could be found. False positives can result from signal reverberations coming off pipe features or can be the result of dispersive sound.

The extent that coating anomalies produced GWUT signal responses was unanticipated. Areas such as those shown in Figures 9 and 10 where the coating adhesive failed produced reportable signal responses (shown in Figure 12). The signal responses at “G”, “J”, “M”, “N” and “O” were just at or below the 9% reporting threshold indicated by the green reference line (the 1st line above the dotted black line which indicates the noise level and minimum reporting threshold). Most reportable metal loss anomalies will exceed this reference line. The signal responses from actual metal loss areas can be seen in Figure 6 at “B” or “C”, both representing significant metal loss as is apparent in Figure 3 and 4.

The coating shown on the pipe in Figure 13 is factory appiled fiber impregnated asphalt whereas the coating on the pipes in Figure 12 is a plastic wrap bonded to the pipe with an epoxy tar as was most likely applied in the field. Both coatings produced signal responses that were above the reporting threshold. Even so, the technician was able to intrepret the results correctly in that metal loss was not called.

Conclusions: The most important conclusion one could draw from the data presented is that GWUT is capable of identifing problem areas in burried pipe. The severity and classification of the areas identified are subject to a number of variables including but not limited to things such as actual pipe condition, coating type and condition, soil moisture content and soil type. Anomalies identified by GWUT can be from actula metal loss in the pipe or other less urgent conditions such as coating anomalies. Wherever the character or severity of an anomaly is in question other NDT methods must be employed. GWUT is a screening tool and must be used as such.

The data presented illustrates the following about GWUT technology:

1. The technique is capable of identifing a wide range of corrosion conditions in burried pipes.
2. The skill and experience of the technician is a key factor in the success of inspections.
3. Signal responses can be produced by conditions other than those relating to the condition or features of the pipe itself.
4. An extensive library of signal responses from known material conditions needs to be created for operator reference.

More valadation studies will be essential to establish insustry confidence in this technique.

Figure 2. 14-inch guided wave inspection collar. Individual transducer modules can be seen on the right side of the collar in the picture. Modules are mounted in a pneumatic bladder covered by a steel sleeve. Inflating the bladder applies uniform pressure on the transducers. There are 120 transducers in the collar shown.

Figure 3. Large isolated pits in front of a weld. See Figure 6 showing signal response from this area – 7 to 9 feet.

Figure 4. Severely corroded area approximately 3 feet in length with numerous isolated pits and areas of general corrosion. Included in the section was a very larger isolated pit (marked by arrow at top right). See Figure 6 showing signal response from this area – 14 to 18 feet.

Figure 5. Isolated pitting and general corrosion 360° around the pipe and on either side of the weld. Yellow paint indicates area identified by GWUT; red spots were from smart pig data and were marked where they exceeded 50% of nominal wall. See Figure 7 showing signal response from this area – 16 to 17 feet.

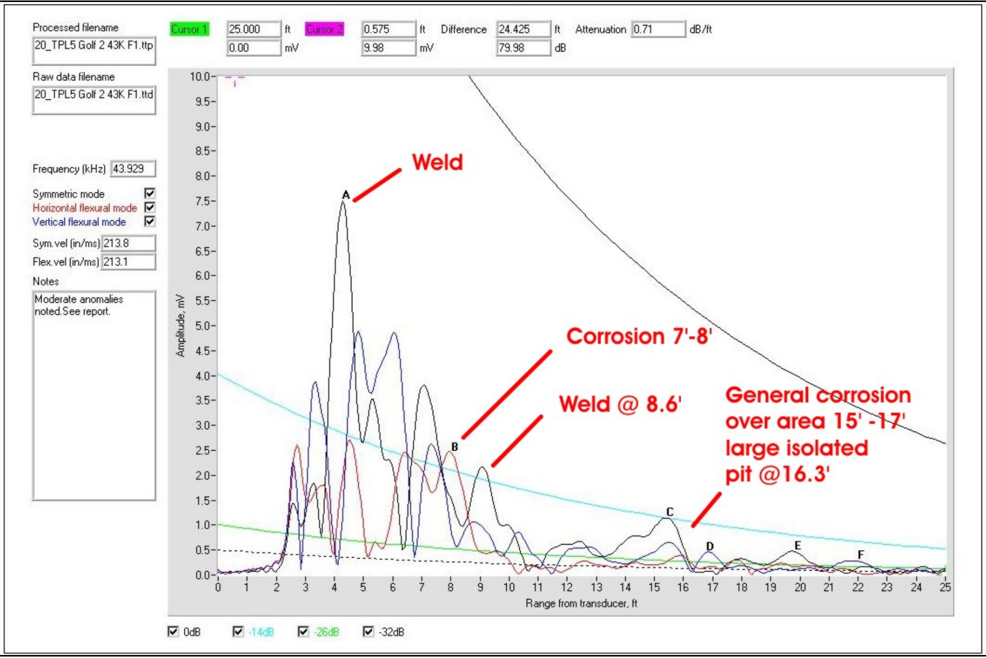

Figure 6. Signal response data corresponding to Figures 3 and 4. Signal marked at "B" represents the two large pits seen in the left-center of the picture. The weld signal follows as marked at 8.6'and is visible on the lower left side of the picture. Signals designated "C" & "D" above corresponds to Figure 4. The general area of corrosion between 15 and 17 feet is indicated @ "C" while the large isolate pit @ 16.3" aligns with "D". The long axial extent of this area can be seen in the wave form along and apparent masking of signals due to the axial alignment of the area.

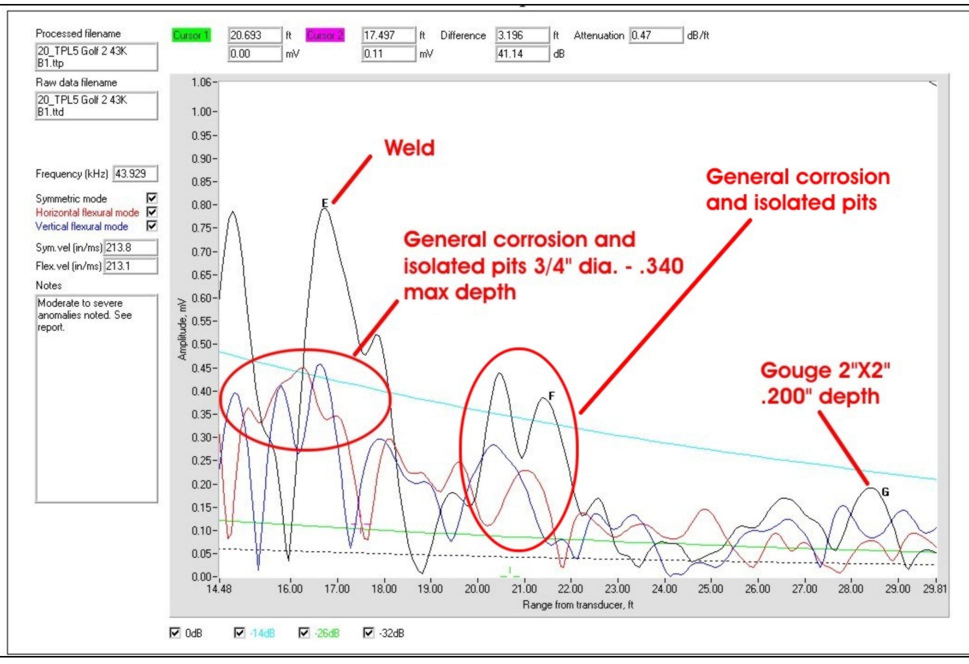

Figure 7. Signal response data corresponding to Figure 5. Signal marked at "E" represents the weld. Note amplitude of red and blue (flexural) signals under the weld signal below "E". These represent the pitting condition that was present around the weld. Numerous pits were > 50% through wall as indicated in Figure 5. Flexural signals close to or associated with a weld can be difficult to characterize.

Figure 8. GWUT Tool position set-up for inspection of a cased road crossing. Casing end-seal has been removed.

Figure 9. Surface corrosion delineates areas where coating has seperated from the pipe. Good coating adhesive is represented by black areas remaining after stripping the coating material. Areas such as this indicating water migrating under the coating correlated with many of the signal anomalies.

Figure 10. Dis-bond and minor surface corrosion over 180º between 40' and 41'. Similar areas corresponding to anomalies I, J & K (Figure 12) from Location 4 were noted between 35' and 39'. The weld is visible just before the 41' mark and corresponds to the typical weld signal @ "L" in Figure 12.

Figure 11. 18 to 21+ feet from datum @ Location 1 showing weld just past 20' and bare pipe on either side of the weld. Signal responses for the coating transition to bare pipe were present but at low amplitude from Location 1. From Location 2 the transition from bare pipe to factory wrap coating @ 34' (yellow band – right center) corresponds to the arrow marking an undesignated signal peak in Figure 13. Note coating patches missing lower left on pipe. Signal trace data representing this area is shown in Figure 13.

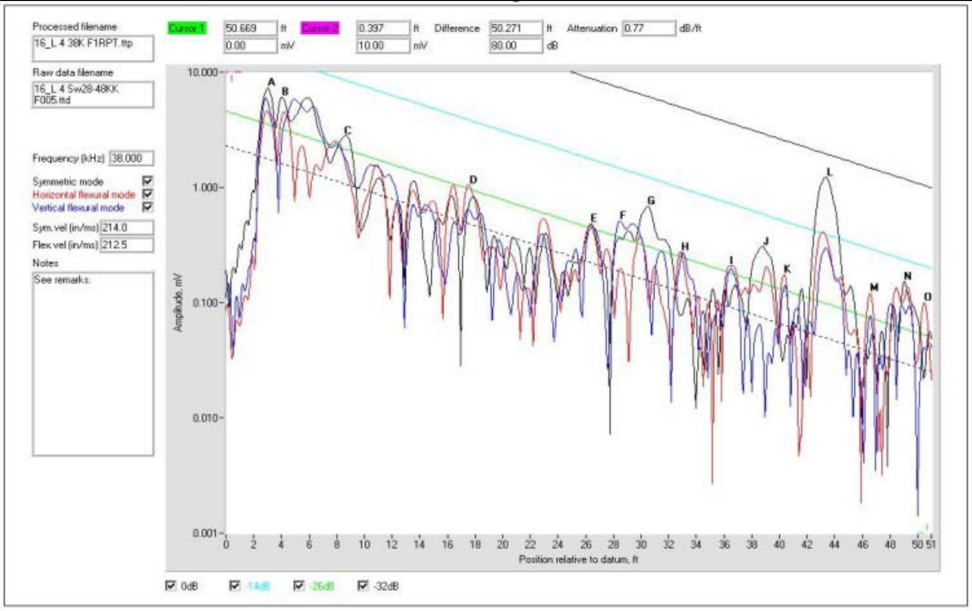

Figure 12. Signals trace data corresponding to Figure 10. Area of interest is @ "L" (41') showing signal response from the weld visible in Figure 10. Signals marked I, J & K represented coating dis-bond areas similar to that which can be seen in front of the weld in Figure 10.

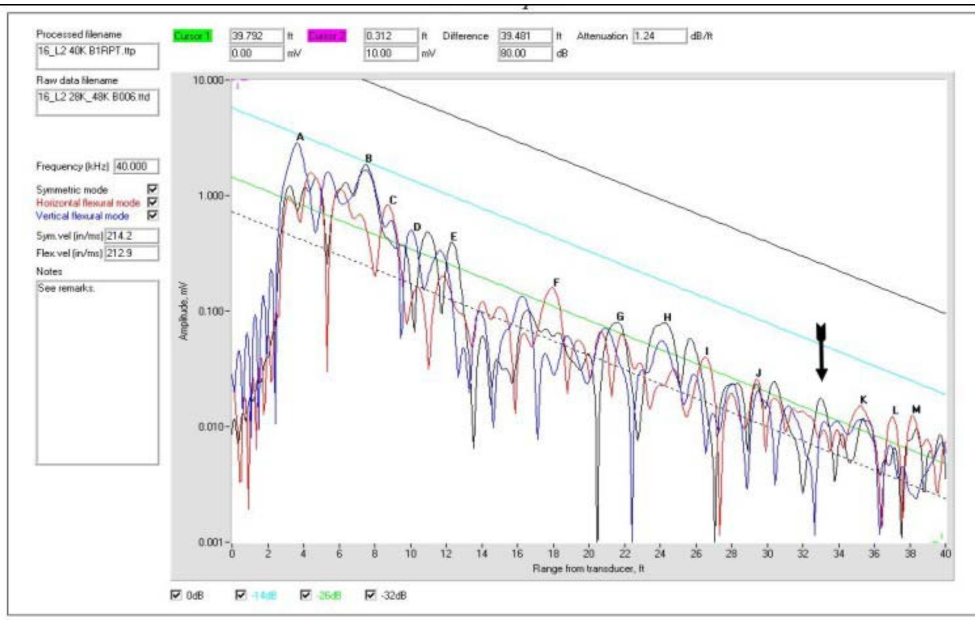

Figure 13. Signal traces corresponding to Figure 11. Arrow at 31.5' marks signal from the coated to uncoated pipe marked by the yellow paint band in Figure 11. The weld seen in Figure 11, which was not marked during the inspection, may be associated with this signal response. Signal peaks designated "K" and "L" are thought to be associated with the coating dammage visible to the left of the weld in Figure 11.