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Monitoring Buried Pipe with Permanently Installed Guided Wave Systems

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ABSTRACT

Guided Wave ultrasonic inspection offers definite advantages for assessing the condition of buried piping or piping that is difficult to access for inspection. In the case of buried piping, excavation costs easily exceed the cost of the inspection. Guided Wave monitoring systems (PIMS) are now available for situations where periodic monitoring is appropriate. These systems eliminate re-excavation costs for re-inspection and offer enhanced sensitivity in subsequent monitoring inspections. These systems are applicable and cost effective for hydrant fuel systems. PIMS are now being used extensively by the pipeline industry to monitor buried and cased pipe sections and by U.S. nuclear power plants to monitor the condition of buried service water systems.

The typical installation follows a guided wave inspection of a pipe segment that requires periodic monitoring. The technical advantage is that the initial guided wave inspection provides a baseline to which future inspections can be compared. Changes as small as 1% in the pipe condition can be detected after the initial baseline inspection.

This paper describes the conditions for the use of a monitoring system, their technical advantages, installation procedures and longevity.

Keywords: Guided wave, Guided Wave Ultrasonic Inspection, corrosion monitoring, Permanently Installed Monitoring System, pipeline inspection, pipe integrity monitoring, long range ultrasonic inspection

INTRODUCTION

With over ten years of commercial inspection applications, Guided Wave Ultrasonic Inspection (GWUT) has become a widely used technique for inspecting pipes and pipelines across a wide spectrum of industrial applications. Guided wave techniques are by their nature; qualitative and therefore are used properly for pipe screening. The current generation of equipment and software provides rapid assessment of relatively long pipe sections that would otherwise be inaccessible without erecting staging or providing excavations.

Typical applications include corrosion surveys, buried and cased pipe inspection, unpiggable pipelines, soil to air interface inspections, wall penetrations and encased pipe inspections. GWUT is accepted by PHMSA (Pipeline and Hazardous Material Safety Administration) as a stand-alone inspection of regulated pipeline sections when applied using mandated prescriptive guidelines incorporated into an approved procedure.

Any facility operator that has had to erect extensive staging or excavate to provide access for pipe inspection and/or maintenance knows that the access costs can easily exceed the cost of the inspection or maintenance. By using GWUT, access costs are significantly reduced allowing the operator to direct maintenance and inspection budgets on specific problem areas. Further cost reductions are now possible with the availability of new GWUT monitoring equipment.

The PIMS (Permanently Installed Monitoring System) are mounted at strategic inspection points. Future inspections are performed by accessing a plug placed in an easily accessible location eliminating the need for future staging or excavations to perform routine inspections. In the last two years, the US Nuclear Fleet has installed over 150 PIMS collars and one nuclear utility has 80 planned for 2011 and 2012. US Pipeline operators have adopted the GWUT PIMS systems for cased pipe sections at road crossings and in other pipe sections where the lines are unpiggable or more frequent monitoring is needed without making a complete pig run. Refineries and chemical plants employ the systems.

Basic GWUT Technology

Unlike conventional ultrasonic inspection (UT), GWUT uses low frequency ultrasonic waves (15 – 80 KHz) that are directed down the axis of the pipe in a uniform wave front that interrogates 100% of the pipe circumference. The sound energy interacts with corrosion or other features including, welds, attachments, clamps, supports, and any place that the cross-section of the pipe changes, or the acoustic properties of the material change. An important distinction between conventional UT and GWUT is that GWUT is looking at the total volume of the pipe *cross-section* as opposed to small areas between the ID and OD of the pipe wall.

Figure 1: GWUT equipment setup in an excavation.

The equipment set consists of a pneumatic collar that holds the transducers, the GW Pulser/power supply unit, and a laptop with the GW analysis and report software. (Figure 1) These units are interconnected by cables. Standard collar sizes range from one-inch to 36 inches. Larger collars are made by combining the standard collars. A “shot” is initiated from the laptop and typically only takes a few minutes to complete. New systems take a shot that collects data over a range of frequencies which are used in the analysis process to characterize the returned signals.

Axial distance achieved by GWUT is a function of the pipe environment. Above-ground gas filled pipe yields the greatest distances, i.e., up to 600 feet in each direction from the collar. Shot distances for buried and coated pipe range 40 to 80 feet but can be reduced to as little as 15 to 20 feet where pipe is buried in clay soils and/or coated with fresh coal tar or bitumen coatings.

The GWUT display appears similar to the “A-Scan” display of a conventional UT unit except that the “X” axis representing axial distance away from the collar position displays the upstream and downstream data simultaneously. (Figure 2) The “Y” axis represents signal amplitude. The collar position is presented in the center of the display field as a typical shot will collect data in both upstream and downstream directions. Welds are used to set the rate sound energy decays or attenuates since they represent a constant increase in the pipe cross-section of 23-25%. The weld default value can be reset manually if supporting information is obtained from actual welds along the pipe section being inspected. Sound attenuation is represented by a DAC or Distance Amplitude Curve. The DAC is a line of equivalent signal strength drawn over the axial distance. The DAC provides a means of comparing signal amplitudes as they decrease with the distance from the collar position.

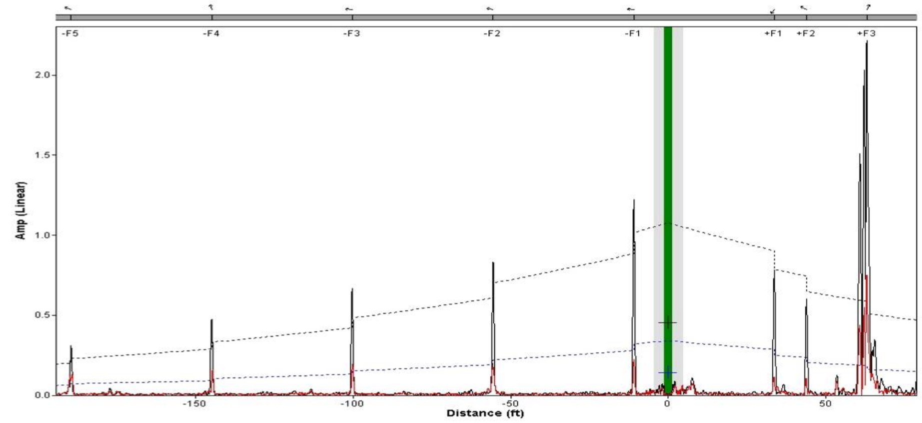


Figure 2: GWUT “A Scan” display of an above-ground pipe run on supports.

Signal responses from two wave modes are displayed on the GWUT graphic display or “A-Scan”. Symmetric responses are shown as a black trace. Flexural response is shown as a red trace. The Symmetric response is the primary wave mode transmitted in the initial pulse whereas the flexural response is a mode conversion that occurs when the symmetric wave encounters a change in the pipe cross section, i.e., a corrosion anomaly, a weld, an attachment, etc. The relative amplitude of the two signals is used to characterize the nature of the response. When this information is viewed with respect to the different frequencies collected during the shot, differences between welds, attachments, and corrosion anomalies can be characterized by a qualified technician.

Anomaly size detection limits range between 3 and 5% of the cross-sectional area of the pipe (metal only). The limiting factor in determining flaw size accurately is signal-to-noise ratio and the sound attenuation rate. Estimates of flaw length and depth are usually accurate to within ±15% of the reported dimension however, GWUT estimates of flaw sizes trend to the conservative. Flaw sizes at or less than 1% CSA are achievable once baseline information is obtained and used for comparison.

Planning and Pre-assessment

Planning to use GWUT as a tool in a structured integrity program is not much different from any of the other survey tools that are employed to locate potential corrosion sites on inaccessible piping. Site visits or walk-downs are the most effective way to prepare an inspection plan. Included in the walk-down is a review of existing as-built drawings and in some cases a file search of older drawings if the required information is incomplete. Simple projects may be planned without the site visit; however current ISO’s and/or as-built drawings are essential. It is also extremely helpful to provide photographs of above-ground to buried transition points along with the drawings. These preliminary steps may seem unnecessary, but accessing buried pipe for inspection is costly and additional digs can impact the budget significantly when not anticipated in the original scope of work.

The GWUT contractor should provide an inspection plan showing the most advantageous locations for inspection points. These points may not be possible due to the existence of other utilities, paved areas, road crossings, etc. This reinforces the need for an on-site walk-down so that local conditions and structures that may not be apparent on drawings can be considered in the inspection plan. In addition to the proposed inspection points, the inspection plan should detail the pipe preparation required, and pipe sections that may not be appropriate for GWUT. In those cases, alternate NDE methods should be proposed. The inspection plan is an essential element in preparing an accurate budget for a project.

GWUT Field Inspection Procedures

Preparing pipe for GWUT requires that the collars be placed on clean metal. At least twelve inches (minimum) of coating or insulation must be removed 360º around the pipe at each test location. The pipe surface must be clean and free from any loose debris, corrosion or scale in the area where the collars are placed. Well bonded paint or epoxy coatings (FBE) do not have to be removed however; when the monitoring collars are to be installed all coatings must be removed. Power brushing may be necessary if the surface is oxidized or lightly pitted. GWUT collars require a minimum of four inches of vertical clearance, 360º around the pipe, for proper placement. When inspecting from an above ground location into a buried section, soil should be removed approximately one to two feet below the ground surface and the coating stripped.

The quality of GWUT results can be affected by acoustic noise in the piping system originating from operating equipment and/or work being performed on the pipe system. In most cases, any extraneous noise in the shot can be mitigated but may result in longer shot times due to the increased signal processing that is required.

The exposed surface of the pipe is visually inspected at each inspection point and where inspections are performed to verify/quantify any anomalies exposed for verification. The pipe coating condition (if present) is documented. External corrosion present at any inspection point may restrict the use of GWUT if the condition is severe. Generally, light pitting is not problematic however; placing the GWUT collar over corrosion pits (ID or OD) is not recommended. A new location void of any irregularities should be used if at all possible. It is standard practice to use conventional straight beam UT or B-Scan to scan the area where the collar is placed. This ensures that ID corrosion or erosion is not present under the collar. Additionally, there is an area of about 36 inches on each side of the centerline of the collar that includes the *“Dead Zone”* and *“Near Field”.* Standard practice also requires that these areas be inspected with conventional UT or B-Scan. Alternatively, if the collar can be moved within the excavation, these areas may be inspected with a second GWUT shot approximately six feet away from the first.

Data collection at each location usually takes less than 30 minutes and results are available almost immediately. In some cases additional analysis may be required. Typically, preliminary data is presented to the client on site and a final report delivered later after secondary reviews of the data have been completed. Should significant anomalies be identified, final onsite disposition can be completed if immediate remediation of the pipe is indicated.

Installing a GWUT Monitoring System (PIMS)

All of the foregoing steps are required prior to the installation of the PIMS collar. The PIMS collar is placed on the pipe in the exact same position as the portable equipment collar. (Figure 3) The collar electronics are verified and then the collar is sealed in place within a polyurethane boot filled with epoxy filler. Once the epoxy cures (30 minutes), additional baseline shots are taken and compared to the shots taken with the portable equipment. The data is checked and if acceptable, the pipe area adjacent to the new PIMS collar can be recoated and the excavation can be backfilled. Backfilling the excavation must be done to preclude any damage to the collar or the extension cable that connects the collar to the surface plug. The surface plug must also be installed in a location that is out of traffic areas to avoid damage to the plug or the cable.

Figure 3: Left, GWUT PIMS collar installed before filling the excavation. Right, PIMS above-ground test point connection.

When the excavation has been backfilled and the connection point secured, additional baseline data is taken and again compared with the data acquired when the excavation was open. The real advantages of using the PIMS system become apparent at this point. All of the acoustic interfaces existing in the excavation are no longer present, i.e., the transition between the uncoated pipe and the coated pipe and the soil-to-air interface. (Figure 4) The removal of these variable conditions reduces the associated attenuation, increasing the sensitivity and clarity of the data.

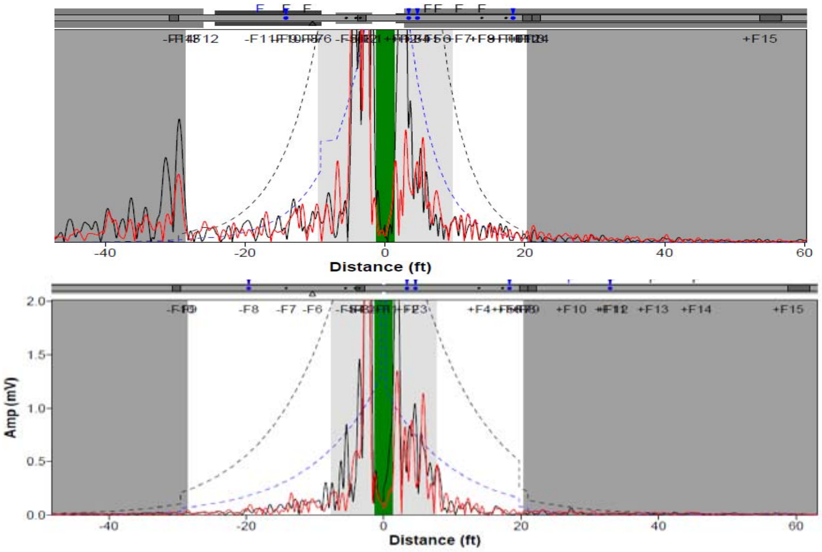
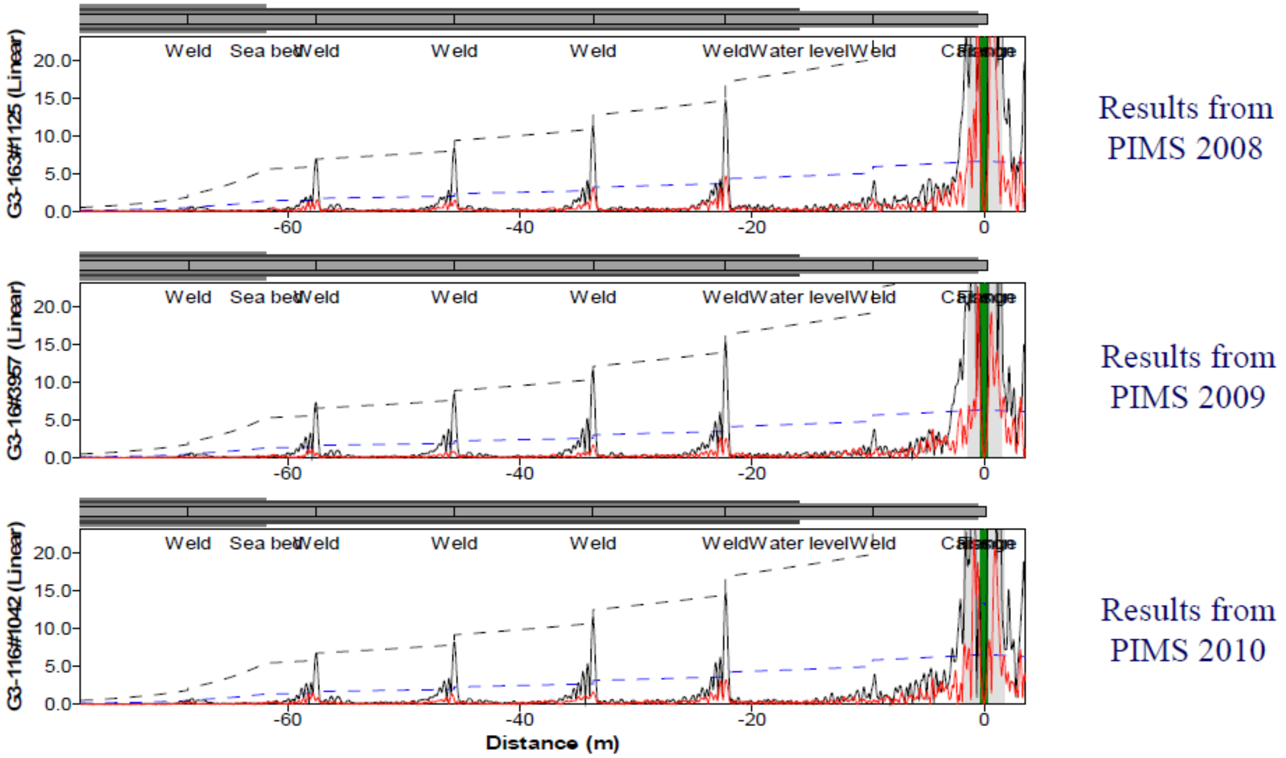


Figure 4: Comparison between data set from the open excavation (top) and after backfilling (bottom). Note the elimination of the soil-to-air interface response at approximately 30' (left side) on the bottom A-Scan display and the slope of the DAC curve (upper dashed line) is less than that of the open excavation (top).

Studies have shown that the repeatability successive monitoring shot is excellent. (Figure 5) Once the baseline data have been collected, the ability of GWUT to detect very small changes in the condition of the pipe makes it an excellent tool for monitoring corrosion. Above ground installations can detect changes as small as 0.20% CSA. (Figure 6) The sensitivity to changes is less in buried pipe at 1% but significantly below the original CSA detection threshold of 3 to 5%.



Results from PIMS 2008

Results from PIMS 2009

Results from PIMS 2010

Figure 5: Year to year monitoring results from PIMS system installed in a sub-sea environment. Data repeatability is excellent illustrating the ability to distinguish any small changes in the condition of the pipe.

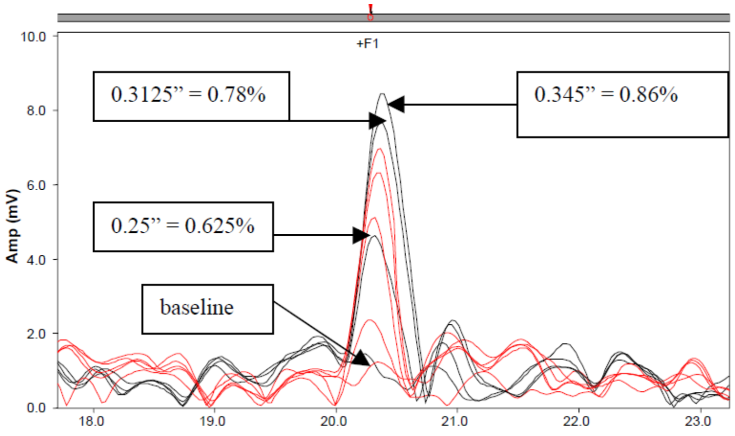


Figure 6: Overlay of GWUT data representing an initial baseline of clean pipe. Progressively larger anomalies have been added and the data overlain to illustrate the increased sensitivity after the initial baseline inspection. The initial anomaly was a 0.25" hole through wall representing a CSA change of 0.625%. Successive enlargements of CSA 0.155% and 0.08% are detected.

Data on the longevity of the GWUT PIMS is not available except through accelerated environmental testing. The expected lifetime is estimated to be 20 to 25 years. New collar designs are expected to be released in the near future that eliminate the need for epoxy encasement of the transducer collar. (Figure 7) The new designs will expedite and simplify the installation process and their anticipated life expectancy is also longer due to the elimination of the epoxy materials.

Figure 7: New design PIMS collar does not require any epoxy resins to install and has a more robust subsurface connection point.

Installation of these systems requires a trained and certified technician that has the manufacturer's endorsement. On a technical level, collecting all of the original baseline data should be done by an advanced GW technician who is acknowledged as such by the equipment manufacturer. In addition, training in the mechanics of the installation is required to ensure the function and longevity of the equipment.

The cost of GWUT PIMS may appear high but the cost advantage and savings become obvious when examined over a three to five year monitoring cycle. As the frequency of monitoring increases, the initial equipment cost becomes negligible and can be justified by the fact that excavations are no longer required to check the condition of the pipe. Monitoring costs are also reduced since the shot time is reduced since the installation of the collar is no longer required. The number of monitoring locations checked in a single day is increased by a factor of three to four compared with normal field operations using removable collars.

CONCLUSIONS

Guided wave inspection and more recently monitoring equipment (PIMS) have become important tools for the oil, gas and power generation industries in the US. Applications are found in extreme environments, from deep sea applications to the miles of piping in refineries and chemical plants, or oil-gas collection fields. The technology passed the research-experimental stage over ten years ago when the equipment became commercially available and was recognized by regulatory authorities as an important technology for assessing pipe integrity and safety in many industrial situations.

The use of PIMS equipment is now recognized as a tool providing periodic monitoring of critical piping while eliminating the cost of repetitively accessing the pipe. Very small changes in the pipe condition can be tracked enabling the actual growth of damage to be monitored while remediation activities are planned on a scheduled timeline. These systems are being used with increasing frequency as the advantages they offer to industrial operations, integrity, and safety management become recognized.

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