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OPERATIONS & MAINTENANCE

Non-Invasive Inspection Method For Unpiggable Pipeline Sections

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New pipeline integrity regulations allow operators to assess pipeline sections that previously could not be inspected by conventional in-line-inspection processes, i.e., smart pigs. The new rules allow other technology to be used to assess the condition of these lines or sections of lines. Hydrostatic testing may be an option in these cases but can be very costly. Clearly, other technology would be desirable if it produced results and gave the operator assurance the lines in question could meet operational requirements.

One of the emerging technologies to address this need is long-range ultrasonic inspection. Long-range ultrasonic testing 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 is gaining acceptance as a valid means of assessing the condition of pipes and pipelines where inspection preparation or access is difficult or expensive. The rise of the technology is especially significant in view of the government's emphasis on pipeline integrity assessment and the lack of a proven technique to inspect pipelines that cannot be evaluated with "smart pigs."

The technique (as represented by the Teletest® system) has now been extensively used in the field for evaluating pipes from 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 industry acceptance as a proven inspection and monitoring tool is the performance achieved in real field situations.

This article describes how this process is now being used to inspect buried and above ground pipeline sections and compares actual field data with the equipment manufactures performance claims.

The Teletest® low frequency, long range, guided wave ultrasonic technique has been developed for the rapid survey of pipes, for the detection of both internal and external corrosion. The principal advantage is that long lengths, i.e., 75 to 100 feet in each direction on buried pipe and 300 feet plus above ground (also in each direction) is examined from a single test point. The benefits are:

Reduction in the costs of gaining access to pipes for inspection, eliminating removal and reinstallation of insulation, except in the area where the transducers are mounted;

Direct assessment of unpiggable pipeline sections in lieu of hydrotesting or pig launcher-receiver installation;

The ability to inspect inaccessible areas, such as under clamps, sleeves or buried pipes; 100% of the pipe wall is tested; and

Site trials have demonstrated that this method is capable of detecting corrosion <30% wall thickness depth and <25% circumferential width.

Corrosion and other conditions resulting in metal loss in piping is generally unpredictable. Once in service, it becomes a challenge to find these conditions and monitor or repair them. Other than direct measurement with conventional ultrasonic thickness equipment or expensive radiographic procedures, global survey tools leave much to be desired in terms of sensitivity to all but the most severe conditions. Access to some pipe can present a significant problem, and in many cases, exceed the cost of the inspection or even total replacement of the pipe itself.

The benefit of using long-range ultrasonic testing (LRUT) to obtain information on pipe conditions in areas where access is restricted becomes obvious. The experience gained by PetroChem Inspection Services through the use of LRUT over the last 18 months has verified the developmental data and field experience of Plant Integrity Ltd. (PI).

Development

Developed by The Welding Institute (TWI) in the UK, the tool was commercialized as Teletest®. The equipment is sold, distributed and serviced through PI. TWI began development of the LRUT method in March 1992. UK and European agencies and a group of industrial companies funded the initial development projects. Pipeline Research Council International Inc. (PRCI) funded the final phase through its Advisory Committee, with the aim of determining the applicability to large diameter gas transmission pipelines. The final developmental phase concluded with a report from TWI to the NDT Supervisory Committee of PRCI in September 1997[3]. That report summarized a successful performance trial conducted at the GRI West Jefferson Pipeline Simulation Facility near Columbus, OH. The test was conducted on a 24-inch diameter pipe section that contained 128 known and documented metal loss defects. The test section was coated with FBE and was located above ground.

Subsequent to September 1997, PI began commercial services with the Teletest® system in the UK, Alaska, The Netherlands, and honed the equipment into a field-hardened unit capable of producing consistent results under difficult field operating conditions. Over the past four years, the PI team spent several months in Alaska each summer successfully testing road crossings on the North Slope.

North America Introduction

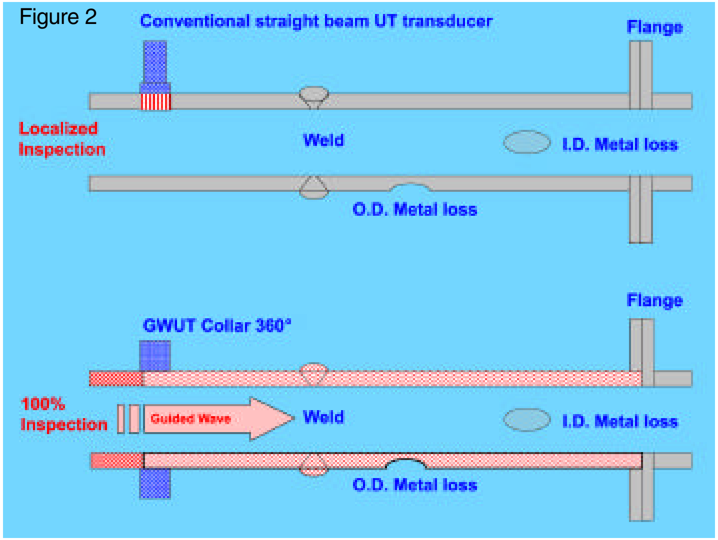
In March 2000, PetroChem Inspection Services brought the Teletest to the U.S. for two months of field-testing with their refinery and chemical plant clientele. Ultimately, those trials led to the commercial introduction of the Teletest® by PetroChem Inspection Services in the Lower 48 states, Figure 1.

Figure 1

LRUT Vs. Conventional Systems

LRUT using guided waves is different from conventional ultrasonic inspection. Straight beam UT measures pipe thickness at a small spot under the transducer, Figure 2. In order to cover a large area, the transducer must be scrubbed over the pipe surface. The Teletest® system uses a transducer collar that produces a 360° soundwave moving axially down the pipe. The pipe itself becomes the guide for the wave – thus "guided wave."

Figure 2



Guided waves propagating in the pipe wall are similar in nature to Lamb waves in plates. They are capable of propagation over hundreds of feet in plain pipe. A large number of guided wave modes are present in a GWUT shot; however, the signals are simplified and only selected wave modes are utilized by the system. This is necessary for signals from anomalies and pipe features to be interpreted.

Other wave modes that are present are canceled out by the transducer arrangement and spacing, Figures 3 and 4. Transducer arrangement and spacing is critical to achieve the highest signal to noise possible and allow for evaluation of the signals from discontinuities. The Teletest® system employs two other wave modes in addition to the primary longitudinal mode. These are the only two flexural modes that are axisymmetric. They allow the operator to discern whether an anomaly is in the top/bottom of the pipe or along the sidewalls and to distinguish

Figure 3

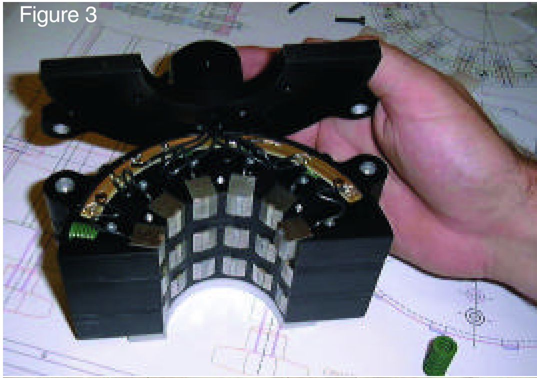
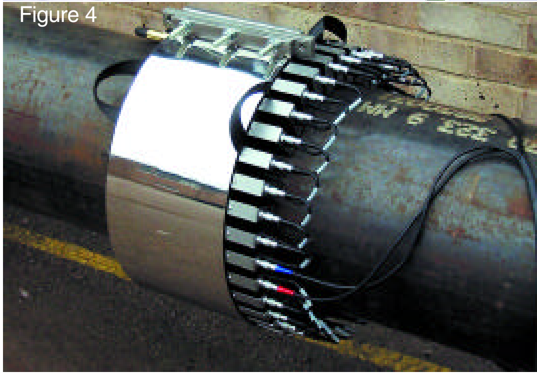


Figure 4



pipe features such as welds from actual metal loss anomalies.

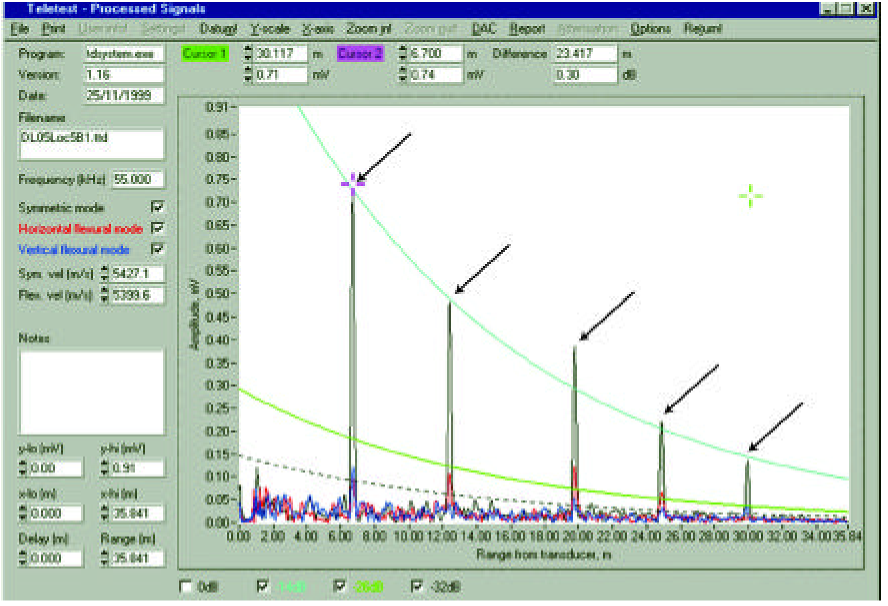
Performance Factors

Field experience over the last 18 months has verified the manufacturer's claims for both sensitivity and sound transmission capability. PetroChem's experience during the last six months has focused on inspecting buried pipelines accessed from a "bell hole" dig. On average, inspection distances of between 70 and 100 feet have been achieved. Many times greater distances could be recorded but the technician elected to cut the examination distance due to difficulties in interpretation beyond a specific distance. This is a routine decision made by the technician during each test.

In situations where pipe is aboveground, inspection distances have ranged well in excess of 200 feet and at times more than 300 feet. However, in these situations the operator must use good judgment in determining at what point the data is no longer useful. This is a condition of deteriorating signal to noise ratio over distance and one of the more important aspects in using guided waves.

Other factors that affect sound attenuation are liquids in the pipe. The higher the liquid viscosity is, the greater the attenuation. Where pipe is severely corroded or pitted, the signal will drop dramatically immediately beyond the problem area. Pipe that has numerous elbows, bends, or smaller diameter branches will not yield the same distances as a straight section of pipe. It is important to mention that pipe geometry does not normally restrict inspection with Teletest,® but the distances obtained will be reduced as the complexity of the pipe geometry increases.

Figure 5



Sensitivity

Teletest® is a screening tool. Its use yields valuable information about a pipe that is not otherwise accessible or access is cost prohibitive. In pipeline "bell hole" digs, the information envelope is expanded from the pipe exposed in the dig, normally 10 to 15 feet, to 165 feet assuming 75 feet as an average distance for sound

Table 2:

#	Smart Pig Results	Anomaly Size	Anomaly Size	Teletest ®
1	Wheel Count 391935 - Map Station 257+68 -External corrosion between 3:00 and 10:00 positions	5:00 o'clock - 1 in. X 1.25 in., 0.160 in. deep	7:00 o'clock - 1in. X 1 in., 0.200 in deep	Moderate Anomaly
2	Wheel count 391937 - Map Station 257+66 - 1st Girth Weld	Girth weld		Weld
3	Wheel count 391945 - Map Station 257+57.5 - External corrosion	8:00 o'clock - 1.5 in. X 1.25 in. by 0.080 deep.		Minor Anomoly
4	Wheel count 391987 - Map Station 257+16 -	2nd Girth Weld		Weld
5	Wheel count 392018 - Map Station 256+85.6 - External corrosion	5:00 o'clock, 0.75 in. X 0.50, 0.100 in. deep		Minor Anomoly

transmission in buried pipe sections. An important point to note is that LRUT techniques do not provide a direct measurement of pipe wall thickness, but are sensitive to a combination of the depth and circumferential extent of any metal loss. This is due to the transmission of a 360° circular wave front traveling axially along the pipe. The wave front interacts with changes in the annular cross-section of the pipe. A signal response is produced where the cross-section is reduced (metal loss) or changes character (at a weld or other pipe feature). This is shown schematically in Figures 5 and 7.

Detectable flaw areas are calculated as a percentage of the pipe wall cross-section. Teletest® is equally sensitive to internal and external wall loss but cannot distinguish between the two. The effect of multiple flaws is additive. Under normal field conditions the unit can detect metal loss anomalies that are approximately 9% of the annular cross section of the pipe. Tests during development of the Teletest® proved that this level of sensitivity was achievable with 95% probability whereas 3% anomalies could be detected with 75% probability. This would apply to buried pipe sections, but under more favorable conditions, such as gas filled, aboveground piping has shown higher sensitivity levels, especially as the diameter of the pipe increases.

Understanding anomaly size can be confusing since anomalies are expressed in terms of the percentage of the pipe cross-section area. Therefore, a 9% metal loss area in a 10-inch (STD 0.375-inch) diameter pipe would represent 0.560 square inch reduction in the annular cross section of the pipe. This area configured at 30% through wall would be 0.11-inch deep by 4.97-inch long. Since LRUT is a volumetric exam the probability of detection would not change if reconfigured to five areas whose sum equaled the original area of 0.560 square inches. As mentioned previously, detectable anomaly sizes may be reduced by as much as 50% in pipe diameters greater than 20-inch.

Applications

The initial commercial use of the system by PetroChem concentrated on process piping in refineries and chemical plants. The primary applications were assessing the soil to air interface of berm penetrations and road crossings. Typically, these pipe sections had never been checked due to the difficulty and expense of exposing them, yet had been suspect due to the nature of their environmental conditions.

The following list summarizes the applications that were tried and found within the capabilities of the LRUT technique using the Teletest® system:

- Berm penetrations of uninsulated pipe;
- Road crossings and berm penetrations of sleeved and insulated pipe;
- Above ground insulated piping;
- Spirally welded pipe (gas collection field);

- Coiled heater tubes (4" O.D. X 40');
- Insulated pipe—pinpointing weld locations under insulation, (Figure 5);
- Wall penetrations of piping in compressor stations (sleeved and encased pipe);
- Locating smart pig anomalies in a buried pipe section; and
- Corrosion assessment of buried pipe sections (Unpiggable).

During the past 18 months, PetroChem has performed services encompassing all the applications listed above. In the following sections, the operating circumstances, limitations and unexpected findings are reviewed.

Process Piping Applications

Work on process piping has taken two basic directions. The first is corrosion under insulation programs. The LRUT method is adept for these surveys because it reduces pipe access costs, especially in overhead piping and pipe racks. The second is miscellaneous piping running on the ground usually to and from storage tanks. These piping systems are typically insulated and make numerous road crossings passing through sleeves. Storage tanks have emergency retaining berms surrounding them and the pipe passes through these as well. In both cases, road crossings and berm penetrations, piping is susceptible to corrosion and difficult to inspect. PetroChem performed an extensive in plant survey for a major U.S. chemical producer. Table 1 represents the results of that survey. Conventional UT was used to verify anomalies that could be accessed. The data in Table 1 is a tabulation of the anomalies that were verified. Anomalies under roads, in berms or pipe sleeves are not included in the tabulation unless they were verified.

When compared with the results of the Rach Project[2], Figure 6 results were roughly similar but better than those reported by PI. The trials were conducted 'blind' without knowledge of the defects present and the results were evaluated by an independent team from Bureau Veritas, Paris, France. This figure shows the results from the Teletest® technique on 36 individual defects. The plot is in terms of depth and circumferential extent of the defects and indicates whether each was detected or not. The figure shows that under blind trial conditions the Teletest® technique performs as expected from the development work. [1]

Pipeline Inspections

Developing proficiency on pipeline sections with the Teletest® equipment required different techniques than originally employed on above ground piping. Buried pipelines accessed through "bell holes" presented variables in their condition that elevated the task of evaluation. Moisture and soil type along with the condition and age of the bitumastic wrapping, (see cover) were three factors noted that affected sound transmission in buried pipelines. These conditions required the technicians to be diligent in selecting the correct inspection frequency and only interpret data with acceptable signal to noise ratios.

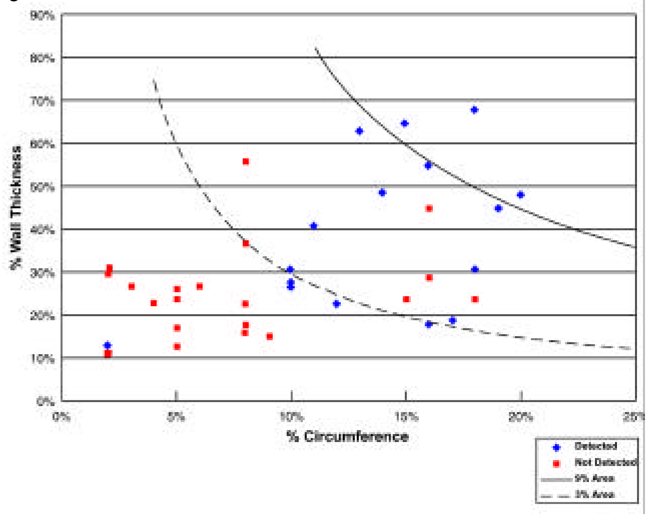
In order to inspect buried pipe, numerous

Table 1

Data Correlation w/Straight Beam UT						
Anomalies Found /Verified						
	No. of Lines	Total Footage	Minor*	Moderate**	Severe**	NRI***
Totals	130	5795'	34/28	52/48	18/17	26
False Calls			6 - 17.6%	4 - 7.7%	1 - 5.5%	

*Minor - defect greater than 3% but less than 9%.
**Moderate& Severe - defecst greater than 9%
***NRI - No reportable indications

Figure 6:



"shots" must be made to determine the frequency that yields the best signal to noise ratio. In addition, ghost signals resulting from mode conversions can appear to look like anomalies. These usually are verified by checking the response from other data sets at frequency ranges above and below that of the suspected anomaly. A real anomaly will usually be present at more than one frequency while reverberations and ghost signals will disappear. A feature to allow more rapid "tuning" during operations is being incorporated into the next generation of the equipment.

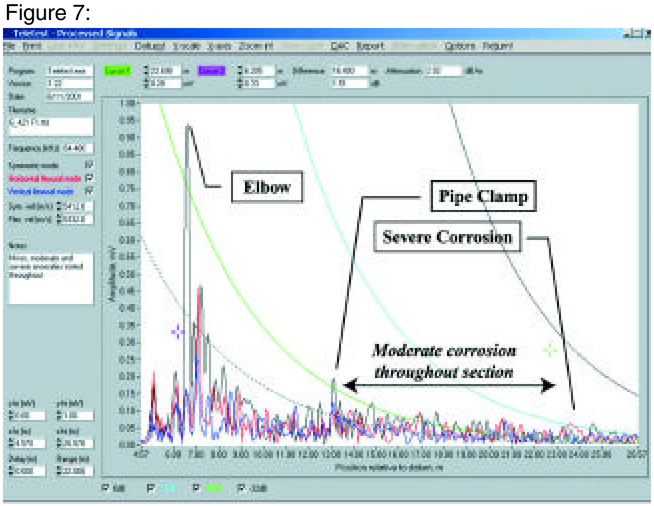
Field Test On Condemned Pipeline

A test was conducted by a major southeastern gas pipeline operator. The line had been condemned and was out of service. Smart pig data was available on the 300-foot section of a 16-inch OD Schedule 10 (0.250-inch) inspected by PetroChem with the Teletest® system. Table 2 summarizes the results of the test.

Field Trial On Buried Pipeline

The following Teletest® graphic data set is from a line operated by a large Northeast refiner/pipeline operator. The section of line from 42.6 feet to 82 feet was previously known to have extensive corrosion. The condition was detected over and extended distance in the last portion of the test length. A pipe clamp and the area of severe corrosion were correctly recorded (blind) during this test. Note that the area of severe corrosion is more than 75 feet from the setup point. The graphic data demonstrate the corrosion impact, Figure 7. The signal strength drops rapidly beyond the

Figure 7:



pipe clamp as indicated by the steep decline of the DAC reference curves. The dotted black line on the left, the green trace, turquoise trace and solid black trace on the far right show these references. From left to right these lines represent the 3%, 9%, 14% and 100% reference levels.

Conclusion

Pipeline inspections using LRUT were more problematic than those conducted on aboveground piping whether insulated or not. However, after understanding that soil, moisture, coating age and actual pipe condition are variables that can affect test results; test procedures were initiated to minimize their effects. PetroChem has verified the performance claims of PI. In actual practice, the Teletest® system will detect conditions that are below the stated sensitivity levels. However, the ability to exceed the stated performance levels of the equipment is based on the technician's skill and experience.

The use and ultimate success of LRUT techniques, irrespective of equipment manufacturer, is largely dependent on the training and field experience of the technician. Ultrasonic signal recognition skills are paramount. PI has taken a responsible position in marketing their equipment by requiring that end users take at least 40 hours of instruction from their field personnel. PetroChem has also recognized the importance of operator skill in delivering a reliable service to industry. PetroChem technicians are required to have a strong background in shear-wave inspection. Many have passed the Electric Power Research Institute (EPRI) test for detection and sizing intergranular stress corrosion cracking and passed the ASME Section XI PDI initiative for ultrasonic operators inspecting piping in American nuclear power stations. They are also required to work with an experienced Teletest® crew for a minimum of three months before being allowed to conduct examinations independently.

LRUT technology is significant to pipeline operators at this point in time. There are more than 2 million miles of pipelines in the United States. The Office of Pipeline Safety has stated that 30% of these lines cannot be inspected with smart pigs. With the current legislation now pending, pipeline operators will be required to assess the integrity of lines that are unpiggable. This may require the use of direct assessment or hydrotesting. Guided Wave UT technology offers a cost-effective method of compliance when used with the direct assessment method. While there is no one technology that can cover all inspection situations, GWUT coupled with CIS and other emerging technologies, will be important tools in maintaining any pipeline integrity program. ***P&GJ***

Author's Note: *Scott Lebsack has over 25 years working in the field of Non-Destructive Inspection and Testing. He is executive vice president for PetroChem Inspection Services and responsible for developing new business and services related to pipeline inspection. Prior to joining PetroChem, he was the NDT Division Vice President for Society General de Surveillance (SGS) in Geneva, Switzerland. He joined PetroChem after it acquired the U.S. Division of SGS, SGS Industrial Services. For the last 15 years he has focused on identifying inspection technologies that could be applied to specific industry problems.*

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