LONG RANGE ULTRASONIC INSPECTION (GUIDED WAVE UT) "AN END-USER'S VIEW"

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1.0 SYNOPSIS

The use of Guided Wave Ultrasonics for the inspection of piping is now implemented routinely for inspection of pipelines worldwide. The technique offers rapid screening of long lengths of piping for corrosion and other defects. This is always complimented by manual prove-up ultrasonics. This approach is becoming widely used and accepted by the oil and gas industry, particularly where access for inspection is difficult or expensive.

In general to-date, the technology has proved its capability for improving inspection coverage and reducing man-hours spent, albeit at a cost.

However, some obstacles have been experienced while using the Guided Wave technology, limiting the benefits of the results. These include technology limitations, inappropriate presentation of results, operator misinterpretation and the possibility of missing critical defects smaller than the reporting threshold.

This paper focuses on the practicalities of applying Guided Wave technology on piping ranging from 8" to 28" diameter, crossing environmentally sensitive areas in varying locations, including a 30 year-old painted and insulated 16" diameter refrigerated LPG transfer line. It also reviews the application of the results of the inspections in the formulation of planned, prioritized piping repair/ replacement programs.

2.0 BACKGROUND

BAPCO imports crude oil and exports refined products via Transfer lines. These lines pass above a shallow tidal area, going under several road crossings, and sit on concrete plinth supports into which are embedded the tubular supports upon which the lines rest. Also, the shipping of products is made through the Sea lines which are partially sub sea, with the remaining lengths being above ground or above sea.

The above-sea portion of these lines is subjected to severe atmospheric corrosion, to the point where, in several instances, significant external pitting corrosion is evident. This pitting has resulted in leakage. Some of these lines also suffer from internal corrosion pitting. Additionally, of particular concern are the contact points where the lines sit on their tubular steel supports, as well as other locations where the close proximity of adjacent lines has increased the atmospheric corrosion activity due to past maintenance difficulties. Access to the underside of the lines is arduous and costly in the event that scaffold has to be erected.

The visual inspection of the line's undersides often remains incomplete due to the above mentioned lack of access and the hidden portions at support positions.

Due to the potential environmental impact of line failures and in order to proactively improve the situation, attempts have been made to physically inspect and rectify corrosion damage at selected support locations. This has been done whenever individual supports have been refurbished, by removing the support and gritblasting the pipe for inspection. If serious corrosion is encountered, cut-outs and replacements have been carried out. For those locations where replacement of sections is not required, reinforcement pads have been installed (by cold work method) and supports reinstated.

Directionally, this is a reasonable method, but it suffers from several drawbacks. It is very slow and costly since the number of support locations is very high. Inspection and repairs as have previously been carried out would take many years to complete, with potential for continual disruption to operation which could not be afforded. During that lengthy period of inspection, it was also virtually certain that leaks of an environmentally unacceptable nature would occur at locations that have not been worked on yet.

Other than in a few obvious cases, it is difficult to know/ judge how close to leakage a location is until the support is removed. This will inevitably lead to expending considerable efforts and funds to "fix" locations that may not have needed fixing yet, while missing others that did.

This is where BAPCO believe that Long range Ultrasonics will be able to assist and will allow BAPCO to focus attention on the most likely leak locations.

Once that attention has been so focused, it opens up other options. Having found the most likely leakage areas, they can be prioritized for further inspection by more sensitive techniques or the sections can be replaced as considered appropriate.

3.0 GUIDED WAVE APPLICATIONS IN BAPCO

BAPCO started using this technology in 2000 when the demand for an effective inspection method for the Sea lines under the Wharf deck increased. Since then, BAPCO has used the technology several times as follows:

3.1 Sea Lines under Wharf Deck

BAPCO exports refined products via 16 carbon steel Transfer lines varying in diameter from 10” to 20” which terminate at the “T” Head and The New Island Wharves. These lines are predominately subsea, rising out of the water beneath the steel-piled, timber-decked “T” Head wharf, with valve-isolated flexible-hosed connections at either end. See *photo 1.*
The 900-1100 feet length of the above-water portions of these lines are subjected to severe atmospheric corrosion conditions, the effect of this corrosion being reduced by the past application of protective paint systems (either Coal-tar Epoxy or Vinyl Co-Polymer Pitch paint of maximum 500 microns DFT). However, due to the nature of the environment and the access restraints imposed by the supporting steel work, this paint system is not a 100% guarantee against the effects of external corrosion.

Photo 1: *Layout of Sea Lines under Wharf’s deck.*

Of particular concern are the contact points where the lines sit on their tubular steel supports, as well as other locations where the close proximity of structural steelwork has reduced the effective application of protective paint systems (*photo 2*). Although the presence of varying degrees of internal corrosion losses is a distinct possibility, and this must be reported on, the main focus of the exercise of applying Long Range UT is to detect external corrosion at supports and obstructions.

Photo 2: *Sample of tubular steel support and the close proximity of lines under T-Head.*

In order to inspect all these lines, BAPCO practice is to walk the accessible sections of the lines for visual inspection and hydrotest them periodically. As mentioned above, the sections under the "T" Head are complex with very difficult access to the lines. To access all sections of the lines, extensive scaffolding would have to be erected.

The GW exercise was expected to provide accurate, comprehensive, easily understood, timely reports of the results of that inspection. It was also expected to identify and categorize the locations of corrosion activity (within a specified and mutually agreed limit of detection), including confirmation by follow-up examination of these locations, utilizing complementary NDT methods where necessary.

3.1.1 Examined Lines Location

The lines inspected are situated beneath the Wharf "T"-Head jetty timber decking, with typical head clearance to decking of 7 feet. Dependant upon tides, the lines sit some 15'-20' above sea level. Natural lighting is minimal due to the overhead timber decking.

The lines are supported at intervals of approximately 22 feet, sitting on tubular steel supports which are tied into the surrounding structural steelwork. Typically, 4-5 lines sit on each support between piles. The clearance between individual lines was considered adequate for installation of the transducer (minimum 3" diametrically), except at supports and positions adjacent to the vertical structure support piles, where the lines occasionally sit hard against the steelwork. In addition, the jetty structure also contains fire-break walls, through which the lines pass (4 in total).

3.1.2 Accessibility

Normal access across the lines is by one of the 4 permanent transverse grating walkways, coming off the main grating walkway (*photo 3*).

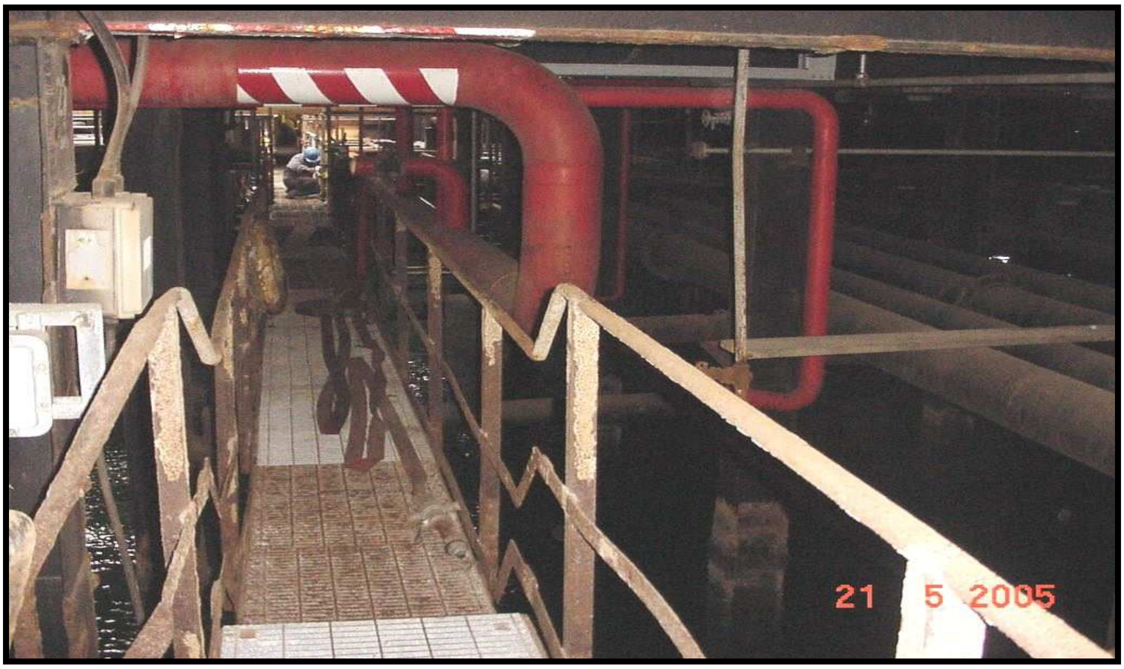

Photo 3: *The main grating walkway under T-Head.*

The lines are situated some 2-3 feet below these walkways. Access to the lines for the purpose of this inspection exercise was made by temporary crawler boards, which were required to be moved by the NDT Contractor from location to location as required. There is no access to the lines from underneath, other than that which can be reached from above.

3.2 Transfer Lines between Refinery and Sitra Tank Farm (Wet Gap)

The 15 subject carbon steel lines are of varying diameters from 8” to 16” plus a 4” Khuff gas line and two LPG lines of 4” & 8”. The length is approximately 1100 feet. Externally, they are not painted. Line wall thickness is typically scheduled 20. See *photo 4.*

Photo 4: *Layout of Transfer lines at Wet Gap.*

3.2.1 Examined Lines Location

The Transfer lines run mostly above ground with few locations of buried sections under road crossings and one section of approximately 600 feet passing over a low tidal channel of sea water called the "Wet Gap", where the lines sit on concrete plinth supports into which are embedded the tubular supports upon which the lines rest (*photo 5*). The exercise was carried out to the portion of the lines passing through the Wet Gap as it is considered an environmentally sensitive area.

Photo 5: *Supports of transfer lines at Wet Gap.*

3.2.2 Accessibility

Loose (tied-down) scaffolding boards were used at transducer locations. Otherwise normal access was by walking on the lines (*photo 6*). There is access to the lines from underneath, however this means wading in 1' to 2' of mud which is arduous.

3.2.3 Scope of Examination

There are approximately 800 pipe-on-support locations. It was required that the Contractor be able to examine the lines to the extent that identified defects can be categorized in terms of the urgency of any remedial action. The subsequent repairs would be undertaken support-by-support, rather than line-by-line, unless the identified repairs required a line to be taken out of service. In that instance, all of the results of inspection for that line were to be made available to allow a one-off repair exercise to be undertaken.

Photo 6: *Access to the transfer lines at Wet Gap.*

The reporting of the inspection findings was intended to give sufficiently concise data to allow clear categorization as follows:

- **A** > 50% volumetric loss which requires short term action
- **B** 20 – 50% volumetric loss which needs to be re-examined in "X" years
- **C** < 20% volumetric loss which indicates no short term concern

3.3 Refrigerated Liquefied Petroleum Gas (RLPG) Line

The last major maintenance exercise on this line was between 1992-1993, in which the line was blasted and painted in stages, with a change of insulation from formed sections to injected polyurethane foam (PUF). Since then, the inspection activity on this line system has centered around selective insulation removal and visual inspection with ultrasonic wall thickness gauging. The intention was to challenge this convential approach in an environment (Wharf environment) where atmospheric corrosion of poorly painted/ insulated locations is likely to be severe.

3.3.1 Accessibility

This is a 16" paint coated and PUF insulated line and the majority of this line is normally inaccessible (*photo 7*), the exceptions being the locations at a blowdown drum platform and above deck sections at the loading arms. Access for positioning of the transducer for this exercise necessitated building a scaffold walkway and 10 working platforms along a distance of approximately 2500 feet.

Photo 7: *General view of the RLPG line.*

3.3.2 Transducer Positioning

In order to position the probe ring, the insulation and paint coating had to be removed from the line at approximately 250 feet intervals. It was found that during the trial, the Guided Wave signal could only be reliably interpreted for distances of up to 50 feet upstream and downstream of the transducer position. This also depended upon the proximity of the probe ring position to the line supports. The ideal location for the probe ring would be centrally between sets of supports. The conclusion is that access and insulation/ paint removal would have to be provided at 100 feet intervals at best, with shorter distances where the measured position is too close to the supports (*photo 8*).

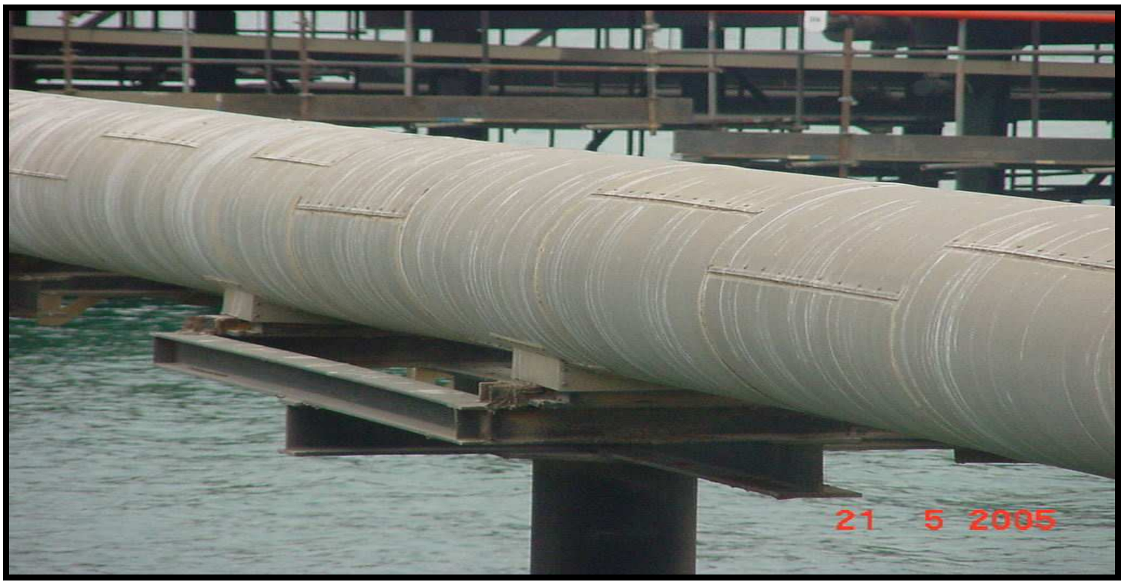

Photo 8: *Type of supports for the RLPG line.*

3.4 AB Pipelines (Crude Transfer Lines)

Crude transfer pipeline consists of 3 pipes; one 28” (AB3) and two 12” (AB1 & 2) diameters (*photo 9*). They transfer crude oil from Saudi Arabia to BAPCO Refinery. BAPCO is responsible for the section where they come ashore at Jasra to the Refinery (approximately 25 km). AB 1 was constructed in 1945 and AB 2 in 1947. Since then, only minor maintenance works were required. However, the land section of AB3 was constructed in the early 70's and recently, some leaks have developed at a low point of the pipeline at the 6 o'clock position. This is considered to be due to water drop-out.

Photo 9: *View of the AB Pipeline.*

The lines are above ground after they come out of the sea except at the buried sections of the road crossings (*photo 10*). This made the exercise of Guided Wave easy and accessible.

Photo 10: *Sample of AB pipeline road crossing.*

3.4.1 Scope of Inspection

The inspection initially concentrated on the section of the 28" line which had evidenced leakage due to internal corrosion. The need was for accurate defect location, to be proved up with manual UT. This would enable a repair package to be formulated.

Once the mechanism of corrosion was concluded, the remaining inspection centered on trying to find similar defects in other low and non-low areas, in effect to go some way towards proving or disproving the corrosion mechanism theory. In its entirety, the inspection was performed at the following locations:

1- Main road culvert including two road crossings.
2- Two low sections of approximately 1000 feet long each.

3- Three sleeved highway crossings.

3.5 Process Heaters

Several vertical furnaces which have return headers within the refinery are currently inspected using Thru Gauges, a mechanical system for measuring the internal diameter of furnace tubes, and manual ultrasonic gauging using flaw detectors with an A scan display. Both methods have their limitations, and a much quicker and more efficient means of inspecting these tubes was required.

During a scheduled plant T&I, the opportunity was taken to prove that Guided Wave Ultrasonics is a viable technique for inspection of Furnace Tubes.

The assessment was made utilizing specially made fixed rings, with extended length transducers. The rings were specially made for this test, as there was limited access and the furnace tubes were of non-standard size (*photo 11*).

***Photo 11*:** Tubes layout inside the furnace.

Initially, due to time constraints, only tubes that had previously been scanned manually and which had indications of wall loss were selected for the test. However progress was so good that all the required tubes on all furnaces were completed before unit start-up.

In comparison with the BAPCO produced manual UT thickness measurements, there was general concurrence between the GW survey results and the BAPCO reported thicknesses. The exercise proved that GW is an efficient, quick and reliable screening tool for this type of inspection. The technique allows fast screening of tubes, thereby releasing valuable resources for focusing on detected areas requiring manual ultrasonic wall thickness scanning only.

4.0 CONCLUSION

The application of guided wave in the above cases has yielded solid results upon which future inspection strategies could be based. The initial GW application included a correlation of GW results versus actual defects found when the defective piping was physically examined. The accuracy of the comparison for what after all is considered a screening tool was such that confidence in the subsequent exercises was high. This was further endorsed by cross-referencing of the results obtained by different contract operators on the same line length. The objective of this exercise was twofold, i.e. to compare result accuracy and to use that comparison as a means of approving additional operators.

There is little doubt that in the above cases the technology proved itself to be robust in as much as the progress of the inspections was not hampered by the technical difficulties which so often arise with the less-conventional methods. In the above cases, we were looking to screen long, difficult to access piping systems for volumetric wall thickness losses and the technique achieved this.

The use of the technique saved BAPCO high potential costs. This can be evaluated by taking in consideration many aspects. The availability of a planned program of pipes replacement means saving huge amount of money that may be needed in the case of a sudden, unexpected leak of critical transfer lines or shipping lines. Additional costs may include ship demurrages, lost profit opportunity and process delay. More important is that the pollution of the environment may be proactively avoided along with the efforts and costs needed to clean the affected areas and recover products.

It is concluded that the GW experience to date has been both cost effective and has yielded results from which sound practical plans for future inspections and repairs have been made. The chosen contractors proved themselves very competent in the field with a professional approach.

5.0 ADVANTAGES & LIMITATIONS OF GUIDED WAVE APPLICATION

As a result of the above GW applications, BAPCO has gained valuable information on where the Guided Wave UT can be used effectively, considering the benefits and the likely limitations/ obstacles. These are summarized in general as follows.

5.1 Benefits

- The erection of scaffolding is only needed at specific locations where the probe rings are to be fitted.
- GW application provides a baseline or fingerprint for assessing future trending of pipeline deterioration.
- It allows for the examinations of supports locations without the need to lift the pipes.
- It highlights the locations that need more detailed examinations
- The use of the technique allows the inspector to focus attention on areas that are most likely to lead to a failure.

5.2 Limitations/ Obstacles

- GW does not size defects in terms of volumetric loss whether it is deep or shallow. Back-up convential NDT is required to size the defects.
- It does not distinguish between active and passive corrosion which in some cases may lead to unnecessary action.
- It does not distinguish between external and internal corrosion which needs visual examination of the detected location. This may lead to additional costs such as erecting further scaffolding at these locations to assess the location and extent of corrosion.
- Removal of insulation/ coating at less than desired intervals because of the signal distance range limitation.

6.0 RECOMMENDATIONS

The effectiveness and usefulness of the Guided Wave UT is dependent on several factors which need to be taken into consideration which include the following:

1. The GW technology must be applied appropriately and the operator must be competent and experienced in field applications. In some instances, critical defects may be missed due to operator misinterpretation of results. Several contractors have well established themselves in the application of GW and are known in the oil and gas industry. The user should either employ a contractor of known ability or prove the capabilities and experience of the chosen contractor. In either case, it is essential to ensure the competency of the operator.

2. Regardless of how well the operator performs in the field, inadequate reporting will reduce the ability of the client to implement future maintenance plans based on the inspection findings. The final report content must be in a form which enables the client to make informed judgments and decisions to move forward with an effective maintenance strategy. It is therefore essential that the client sits down with the

operator before the field work begins and clearly states the deliverables expected of him and the format required. In our case, defect criteria were set in order to categorize the defects to allow a prioritized maintenance program. In addition, dimensioned sketches were specified which included clear marking of external features (e.g. pipe support, sleeve end-plate …etc) and marking the probe ring position for future reference.

3. The progress of the field work and more importantly the reporting must be assessed on an appropriate time basis (e.g. daily) to ensure that all parties are moving forward together.