USE OF LONG RANGE ULTRASONIC TESTING (LRUT) TECHNIQUE FOR HEALTH ASSESSMENT OF CRITICAL PIPING IN LPG SERVICE IN A PETROLEUM REFINERY

V.S. Desai, Mahendra Pal, Mayank Banjare, Chandana Nancharaiah, Sushil Guria and Harsh Vardhan
Indian Oil Corporation Limited, Guwahati Refinery, Guwahati, Assam, India- 781020

ABSTRACT

Process piping carrying hydrocarbons in LPG service is normally designed for a life span of 15 years. These lines are subject to corrosion, wear, mechanical pressurization and fatigue stress over a period of time during its operating period. Therefore during the design stage these factors are taken care of during finalizing of the pipe schedule (thickness) considering the cost economics. It is prudent to assess the health of these lines at a set frequency decided by the owner based on several considerations like, corrosion rate, statutory legislative requirements etc. Once the design life is crossed the inspection frequency has to be increased further to monitor the pipe health. There are certain sections of the pipelines like portions crossing under the road crossing/culverts, underground portion, where online inspection using conventional ultrasonic thickness gauging is not possible. To assess the health of these sections, advanced NDT, LRUT (Long Range Ultrasonic Testing) was successfully used. LRUT is an ultrasonic based technique where three forms of wave modes namely, longitudinal, torsional and flexural travel along the pipe. Defects of all sizes and orientations can be detected by this technique. Remaining life calculation based on API570 and observations of LRUT survey were found to corroborate with each other, accordingly, the LPG line was recommended for replacement at those locations.

Keywords: Long Range Ultrasonic testing (LRUT), Corrosion under Insulation (CUI), Distance Amplitude Correction (DAC), Corrosion Rate (MPY), Retiring Life Assessment (RLA).

INTRODUCTION

Long-Range Ultrasonic Testing (LRUT) is an advanced Non-Destructive Testing. It is one of the fast inspection tools for carrying out pipeline survey for corrosion and other degradation using ultrasonic guided waves. LRUT has been developed to detect metal loss in piping. It is a pulse-echo system, aimed at testing large volumes of material from a single test point. The technique was initially developed for detecting Corrosion under Insulation (CUI) for piping in petrochemical plant. Subsequently, it has found widespread use in other inspection situations where pipes or tubes are normally not accessible, viz. Pipes buried in soil, encased in a sleeve or located at high elevation and heater tubes.

The aim of LRUT is to test long lengths of pipe rapidly with 100% coverage of pipe wall and to identify areas of corrosion or erosion for further evaluation using other NDT techniques such as radiography or conventional ultrasonic inspection. The technique is equally sensitive to metal loss on both outside and inside surfaces of pipe.

PRINCIPLES OF OPERATION

LRUT employs low frequency guided waves, operating just above audible frequencies, propagated from a ring of transducers fixed around the pipe, photograph no.1. These low frequencies (in ultrasonic terms) are necessary to enable appropriate wave modes to be generated. At these frequencies, a liquid couplant between transducers and the surface is not necessary. Satisfactory ultrasonic coupling being achieved with
mechanical or pneumatic pressure applied to back of the transducers to maintain contact with pipe surface. Uniform spacing of ultrasonic transducers around pipe circumference allows guided waves to be generated that propagate symmetrically along the pipe axis. These may be visualized as a circular wave that sweeps along the pipe. Whole pipe wall thickness is excited by the wave motion where the pipe is acting as a wave-guide. Hence, it is termed as guided waves.

Propagation of these guided waves is governed principally by frequency of the wave and thickness of the material. Wherever the wave encounters a change in pipe wall thickness (whether an increase or a decrease), a proportion of energy is reflected back to the transducers, thereby providing a mechanism for detection of discontinuities. In case of a pipe feature such as a girth weld joint, increase in thickness is symmetrical around the pipe, so the advancing circular wave front is also reflected uniformly. Thus, the reflected wave, consisting predominantly of the same wave mode as the incident wave, is also symmetrical.

In case of pipe corrosion, decrease in thickness will be localised, leading to scattering of incident wave (in addition to reflection and mode conversion). Therefore, reflected wave will consist of the incident wave mode plus the mode converted components. The mode-converted waves tend to cause the pipe to flex as they arise from a non-uniform source. Presence of these signals is a strong indicator of discontinuities such as corrosion. LRUT is able to detect and distinguish between symmetrical and flexural waves and both types are displayed. The reflections are displayed as rectified signals in Amplitude Vs Distance ‘A-scan’ display, similar to that used in conventional ultrasonic inspections, but with a time-based range measured in tens of meters rather than centimeters.

A major complication for guided wave systems, as distinct from conventional ultrasonic inspections is the dispersive nature of guided waves; that is to say, velocity for most of the guided waves varies with frequency. This causes a variety of complications, one being that to calibrate the time base of the A-scan to read distance and not time, requires a computer program to read in a velocity for the selected test frequency from a calibration, or ‘dispersion’ curve. There is a library of dispersion curves built into the LRUT software for a range of pipe diameter / wall-thickness combinations. Girth welds in pipe produce dominant signals in A-scan and act as important markers, used to set a Distance Amplitude Correction (DAC) curve on display with which signals from anomalies can be compared.

SCREENING PHILOSOPHY

LRUT does not provide a direct measurement of wall thickness, but is sensitive to a combination of the depth and circumferential extent of any metal loss, plus the axial length to some degree. This is due to the transmission of a circular wave along the pipe wall, which interacts with the annular cross-section at each point. It is the reduction in this cross-section to which the guided wave is sensitive.
Figure 2 illustrates that the technique is sensitive to flaw area as a proportion of the pipe-wall cross-section.

It is equally sensitive to internal and external flaws. The effect of multiple flaws is additive.

**CATEGORIZATION OF LRUT INDICATIONS**

LRUT indications were primarily categories 1, 2 & 3 as ‘Minor’, ‘Moderate’ and ‘Severe’, in terms of amplitude respectively. Distance amplitude curves (DAC) were superimposed on the LRUT indications for comparison purpose.

**Category 1 (Green):** Responses lower than -26dB line, Estimated cross sectional area wall loss in the range of 3% to 9% (formerly Minor).

**Category 2 (Red):** Responses above the -26dB line, but are lower than blue line at -20dB (formerly Moderate), Estimated cross sectional area wall loss in the range of 9% to 15%.

**Category 3 (Blue):** Responses exceeding -20dB blue line, Estimated cross sectional area wall loss > 15%.

**LRUT REPORT & OBSERVATIONS:**

<table>
<thead>
<tr>
<th>Distance relative to datum</th>
<th>Indication Description</th>
<th>Priority</th>
<th>Approx Thickness (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>-4.54m</td>
<td>Cat 1. Low</td>
<td></td>
<td>4.7</td>
</tr>
<tr>
<td>-3.77m</td>
<td>Cat 1. Low</td>
<td></td>
<td>4.2</td>
</tr>
<tr>
<td>-2.54m</td>
<td>Cat 2. Med</td>
<td></td>
<td>3.5</td>
</tr>
<tr>
<td>-1.67m</td>
<td>Cat 3. Low</td>
<td></td>
<td>2.7</td>
</tr>
<tr>
<td>-1.33m</td>
<td>Concrete Interface</td>
<td>Low</td>
<td>-</td>
</tr>
<tr>
<td>-0.65m</td>
<td>Pipe Support</td>
<td>Low</td>
<td>-</td>
</tr>
<tr>
<td>1.44m</td>
<td>Flange</td>
<td>Low</td>
<td>-</td>
</tr>
</tbody>
</table>

Photograph No.2: Dia. 3” under ground LPG piping from South side

Photograph No. 3: Dia. 3” under ground LPG piping from North side

Fig. 4: Isometric sketch of Dia. 3” under ground LPG piping at road crossing
REMAINING LIFE ASSESSMENT (RLA)

Basis for this retiring life calculation is API RP 574 and ASME B 31.3. The design data of the subject pipeline is as follows:-

- Material: SA 106 Gr. B, Sch 40, Dia. 3 Inch;
- Thickness: 5.49 mm;
- Design Pressure (Pump shutoff pressure): 15 kg/cm$^2$ (g);
- Design Temperature: 70 °C

**Corrosion rate calculation formulae:**

\[
\text{Corrosion rate (mm/yr)} = \frac{t_{\text{initial}} - t_{\text{actual}}}{\Delta \text{Time in yrs}}
\]

**Calculation for minimum thickness required:**

(A) Initial design thickness \((t) = \frac{P \times D}{2(SE + PY)}\)

Where, 
- \(P\) = Initial design gauge pressure = 15 kg/cm$^2$ (g);
- \(D\) = Outside diameter of pipe = 88.9 mm;
- \(S\) = Stress value for material from Table-A-1 of B 31.3 = 20 ksi;
- \(E\) = Quality factor from Table-A-1-A of B 31.3 = 1.0;
- \(Y\) = Coefficient from Table 304.1.1 of B 31.3 = 0.4.

\[
t = \frac{15 \times 88.9}{2 \times (20 \times 1000 \times 0.07 + 15 \times 0.4)} = 0.474 \text{ mm}
\]

(B) Corrosion allowance + Erosion allowance\((C) = 1.5 \text{ mm.}\)

\[(C) t_{m} = t + C = 0.474 + 1.5 = 1.96 \text{ mm.}\]

Tolerance on SA 106 Gr. B is 12.5 % under;

Therefore; Minimum thickness required \(t_{m} = \frac{1.96}{0.875} = 2.247 \text{ mm.}\)

**Remaining life (in years) calculation formulae:**

\[
\text{Remaining life} = \frac{t_{\text{actual}} - t_{\text{required}}}{\text{Corrosion rate}}
\]
As per LRUT survey:

Remaining thickness = 2.7 mm as on 10th Feb’ 2011
Original thickness = 5.49 as on 10th Aug’ 2003
Δ Time in yrs = 7.5 years

Corrosion Rate = \( \frac{5.49 - 2.7}{7.5} \) = 0.372 MPY

Remaining Life = \( \frac{2.7 - 2.247}{0.372} \) = 1.21 years

Remaining life calculations was done by taking the minimum thickness found out in LRUT survey. The minimum life was found out to be 1.21 years. The LPG line was recommended for replacement and same were replaced as per LRUT findings.

CONCLUSION

Remaining life calculation based on LRUT survey was found reliable and accurate and is helpful for health assessment of inaccessible piping. In comparison with other methods of monitoring, Inspections can be carried out more frequently with LRUT because Scaffolding is not necessary, pipes do not have to be dug up, only a small area of insulation has to be removed, Plant does not have to be shut down, on average 60m of pipe can be inspected from one location, internal and external corrosion are detected simultaneously and the complete pipe circumference is inspected.

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REFERENCES

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