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SLUG CATCHER INSPECTION USING THE LARGE STRUCTURE INSPECTION AUTOMATED CORROSION MAPPING SYSTEM IN LNG INDUSTRY

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ABSTRACT

Manual ultrasonic inspection can only cover an extremely small amount of the actual surface area of a large structure, such as storage tank, pressure vessel, pipeline or other similar structure. Recent developments in ultrasonic instrumentation and computer image processing have significantly improved the reliability and effectiveness of ultrasonic inspection. Presentation of the data by quantified color coded maps showing the results in plan or section views aids interpretation, for added visual enhancement the data can also be shown in three-dimensional format. When detailed statistical analysis is required the results can be output to spreadsheet application. Automated Ultrasonic corrosion mapping system has been used in the industry where the demand for quality, documentation, and repeatability of the inspection is high. The Large Structure Inspection (LSI) is a fully automated, programmable, configurable ultrasonic inspection system that rapidly provides a scan image of the remaining wall thickness in large structure. The slug catcher in Liquefied Natural Gas (LNG) industry is a large structure subject to internal corrosion and/or erosion. This paper gives an overview of Large Structure Inspection Automated Corrosion Mapping System and its application in slug catcher inspection with inspection findings.

INTRODUCTION – LNG AND SLUG CATCHER

Liquefied Natural Gas (LNG) is natural gas (primarily methane) that has been liquefied by reducing its temperature to minus 161℃ . It basically consists of liquefied methane (C1) and ethane (C2) and may sometimes have fractions of propane (C3) and butane (C4). When natural gas is cooled at atmospheric pressure down to minus 161 ℃, its volume reduces by 600 times. It can be stored and transported over long distances, by ship and then stored on land in specially – designed storage facilities. The liquefied gas can then be reheated, converting into vapor, and transported in pipelines, for distribution through a gas distribution system.

With natural gas reserves of 900 trillion cubic feet, which accounts for about 15 percent of the world's total gas reserves, Qatar takes third place in the world in gas reserves. Qatar is pursuing an expansion plan to boost LNG production capacity to 77 million tons per year and Qatargas with its ambitious plan of expansion to 42 million tons per year production will be world's leading supplier of LNG by turn of this decade.

The combined gas and liquid stream from offshore flows to the Slug Catcher. The slug catcher is a separator, where separation occurs between the heavy liquid

hydrocarbons and the gaseous lighter ends i.e. the gas is separated from the liquids. The slug catcher is made up of 8 horizontal fingers (storage tubes) coming off a manifold, 46” diameter x 34mm nominal wall thickness x 300 meters long. Material of slug catcher is APL 5L grade B meeting NACE MR0175 requirements. Slug Catcher is designed as per ASME/ANSI B31.8 Type B with design pressure 147 bar g, working pressure 80/120 bar g, design temperature -29/60℃ and working temperature 17/27℃. The slug catcher piping is welded by Gas Tungsten Arc Welding GTAW (Root) and Shielded Metal Arc Welding SMAW (Fill and Cap) welding process with post weld heat treatment (PWHT). The gas is routed from the top of the slug catcher for further processing whilst the liquids are routed to condensate flow path. Figure 1 and Figure 2 shows view of slug catcher.

Figure 1: Slug Catcher – view from inlet side

Figure 2: Slug Catcher – view from liquid header side

ULTRASONIC TESTING:

Ultrasonic testing (UT) is one of the oldest and most widely used Non Destructive Testing methods. The basic principle of UT is the use of ultrasound waves

propagating and being reflected at geometric discontinuities or boundaries in a material.

In the majority of industrial applications, manual contact ultrasonic testing is performed, resulting in measurement of a limited number of points in a structure or component. In recent years, automated ultrasonic corrosion mapping system has been applied whenever, detailed inspection of critical structures or components is required.
Some of the automated UT techniques like T-SCAN technique (C-SCAN - two-dimensional graphical presentation), P-SCAN technique (projection of a B-scan), TOFD (Time of flight Diffraction) technique are usually applied with an automatic scanning which allows a systematic relative displacement of the ultrasonic beam and the material being tested by other than manual means. Automated ultrasonic corrosion mapping is used where the demand for quality, documentation and repeatability of the inspection is high and detailed inspection is called for.

SLUG CATCHER INSPECTION

Liquid hydrocarbon is not significantly corrosive, but under deposit corrosion could occur in bottom of slug catcher (liquid section) if solids and corrosion products are carried-over from the 32" sealine allowed to accumulate in this section. The Slug Catcher is susceptible to internal corrosion (pitting and wall thickness loss at bottom). Sulphide Stress Corrosion Cracking (SSCC) is unlikely as carbon steel meets NACE requirement.
Slug Catcher construction does not permit pigging of manifold headers or storage tubes hence the recommended inspection techniques are Non Destructive Testing (NDT) from outside, at selected areas like bottom of storage tubes and slug slope to determine the presence of any unforeseen pitting corrosion due to exposure to highly corrosive products. Risk Based Inspection analysis shows that in slug catcher, economic consequence of failure is very high. Slug Catcher failure means loss of total LNG and condensate production.

The manual ultrasonic inspection can cover only an extremely small amount of the actual surface of a slug catcher and chances of missing potential corrosion areas are high. Therefore an automated UT scanning system was explored for slug catcher inspection. Long Range Ultrasonic system with guided wave technology was tried to detect internal metal loss in slug catcher. The long range ultrasonic inspection was not successful due to noise interference possibly due to fluid flow. Large Structure Inspection (LSI) system was deployed for Slug Catcher inspection. The contract was given to Oceaneering.

SCOPE OF INSPECTION

Automated ultrasonic testing was carried out at selected locations of the Slug Catcher Inlet Manifold assembly, Storage Tube Fingers, Liquid Header and Gas Transfer Piping. Manual ultrasonic inspection was conducted at areas that were restricted due to the physical size of the scanner.

EQUIPMENT UTILISED

The following equipment was utilized for the inspection of the slug catcher.
LSI controller unit
Laptop computer
Scanning pendant
5Mhz 0.25” Ultrasonic transducer
Probe holder
500mm bridge
20mm thick V2 block for calibration

PRINCIPLES OF THE LSI SYSTEM

This is primarily an automated ultrasonic tool, consisting of a laptop computer coupled to a data acquisition system. Attached to the acquisition system is an umbilical, which comprises of ultrasonic leads, a water line and motor drive cables. This is connected to the crawler, which is adhered to the vessel by four magnetic wheels. The crawler is maneuvered along the vessel at predetermined index steps. Attached to the crawler are a scanning arm and an ultrasonic transducer assembly that sweeps the vessel taking ultrasonic measurements, again at predetermined steps. These measurements are presented as either in the form of a map of the scanned area with different colors representing different thicknesses or in an excel format.
Typical defect mechanisms that can be detected include:

Material thickness loss due to corrosion, pitting and/or erosion
Laminations produced during the manufacturing process
Hydrogen blistering
Coating breakdown
Cladding disbanding

Figure 3: Equipment in use

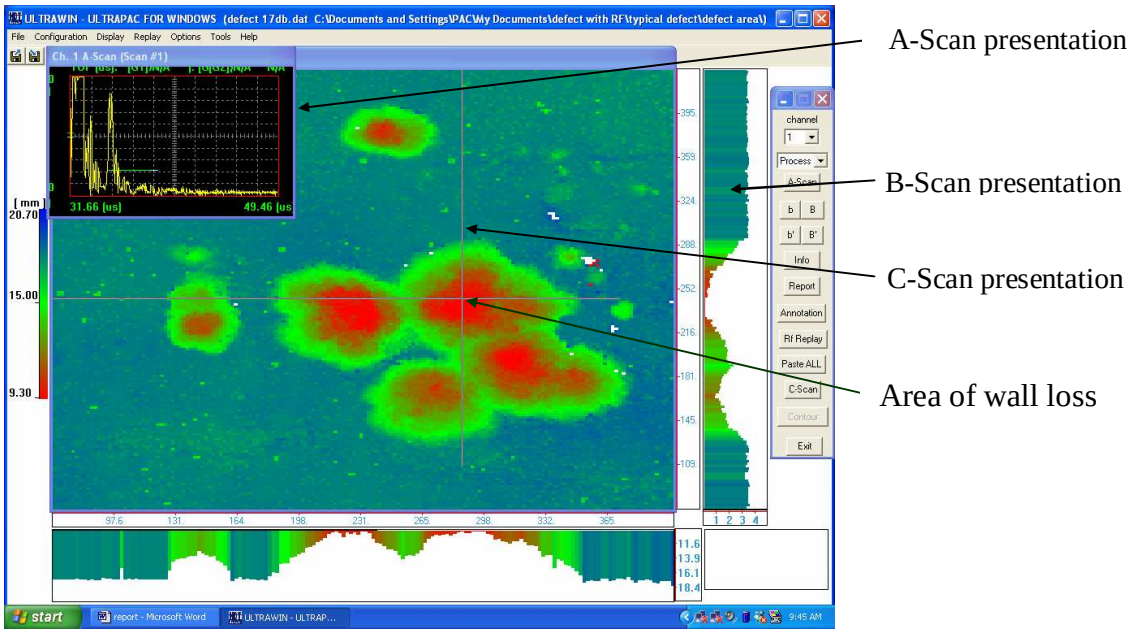

Figure 4: Example of a typical area of wall loss (red in color).

PROCEDURE

The equipment was set utilizing the software option available. This included as follows:

The use of two gates set as follows:

Gate 1: Set at a wide band at a distance to reveal any significant loss, inclusions or significant root erosion. It should be noted that the system is not designed for the detection of weld, although this is possible if the weld cap is fairly flat such as submerged arc welding.

Gate 2: Set at a narrow band to detect small areas of wall loss

Saving of data in the RF mode:

This enables the operator to review the data offline and by moving the gate settings, possibly improving the quality of the results. Furthermore, spurious or unknown data can be reviewed by cursing over the area of interest and viewing the A-scans that were used for that inspection. This procedure is only carried out as necessary as

each file saved in RF is approximately 320,000 KB ,as opposed to a scan without the RF mode having a size of 170KB.

Reporting Methodology

- LSI thickness data in excel format because results from each section of the slug catcher to be entered into the Meridium system. By using a tool in the excel program, both minimum and maximum value can be obtained.
- Using GATE 1 to give the condition on the cleanliness of the material (e.g. report on inclusions etc). If inclusions are present, a thickness reading will be given.
- Using GATE 2 to give a minimum and maximum value.
- Any recorded wall loss will be re-inspected at a higher resolution to define the anomaly. The anomaly will be sized in diameter and measurements taken from a known datum.
- All excel results to be archived and copied to CD.

RESULT

A circumferential scan of the slug catcher was inspected. The index pixel size was set at 1mm longitudinal x 10mm circumferential. The results obtained were of very good quality, with both the data provided using gate 1 and gate 2 giving interesting information. Few samples of scan with location of slug catcher inspection are as below.

SCAN 1:

Figure 5: It can be seen that color pallet of GATE 1 ranging from 26.99mm to 53.68mm. This means that data will be collected from a thickness between those figures. The curser is over a clean area of material (34.59mm), and a clear back wall echo on the A-scan can be seen. The B-scan (side view elevation) is clean with no significant loss

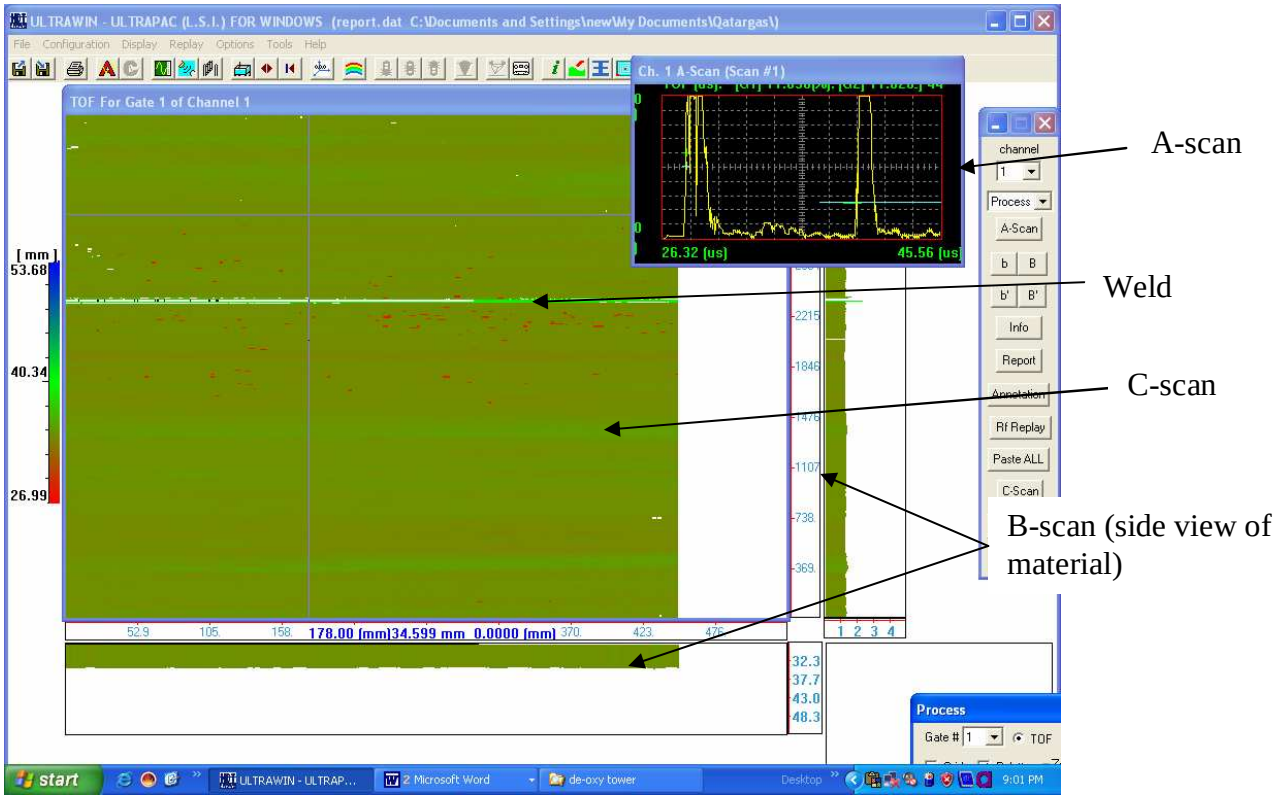

Figure 5: Sample scan

Figure 6: Same scan as per figure 5 with the same gate setting, but this time cursing over a red area. An echo is evident before the back wall echo, and by using the A-scan and B-scan modes, and this can be revealed as an inclusion in the material

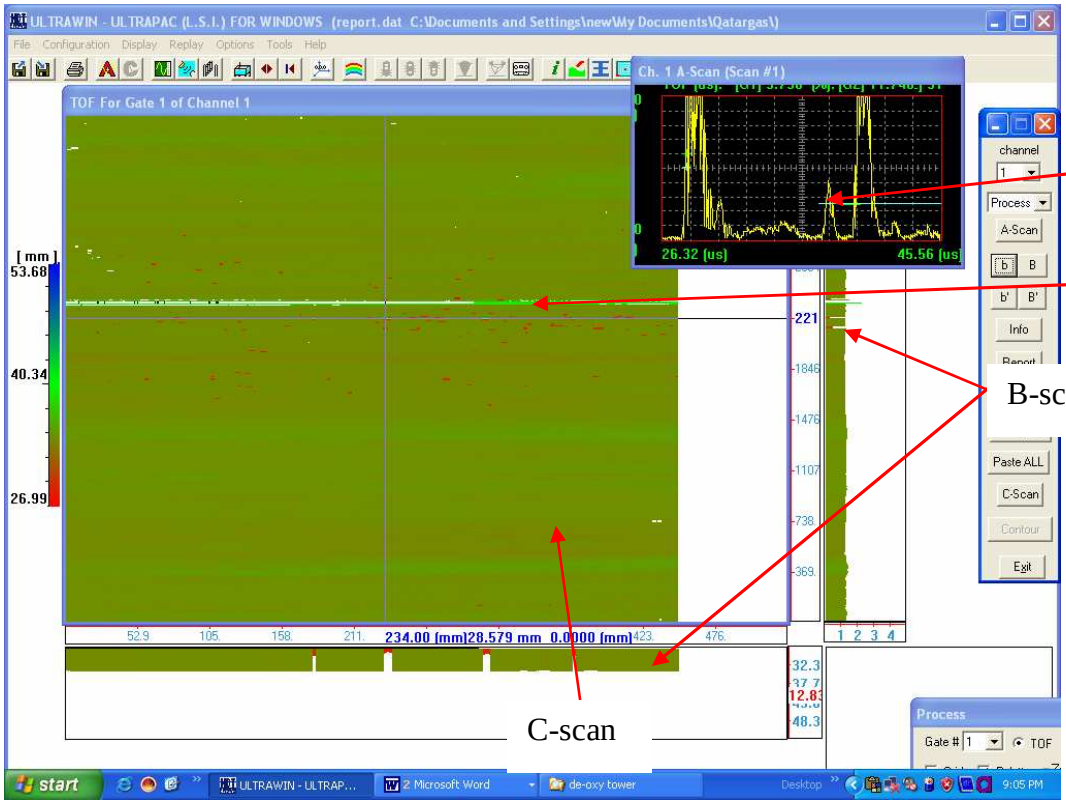

Figure 6: Sample scan

SCAN 2:

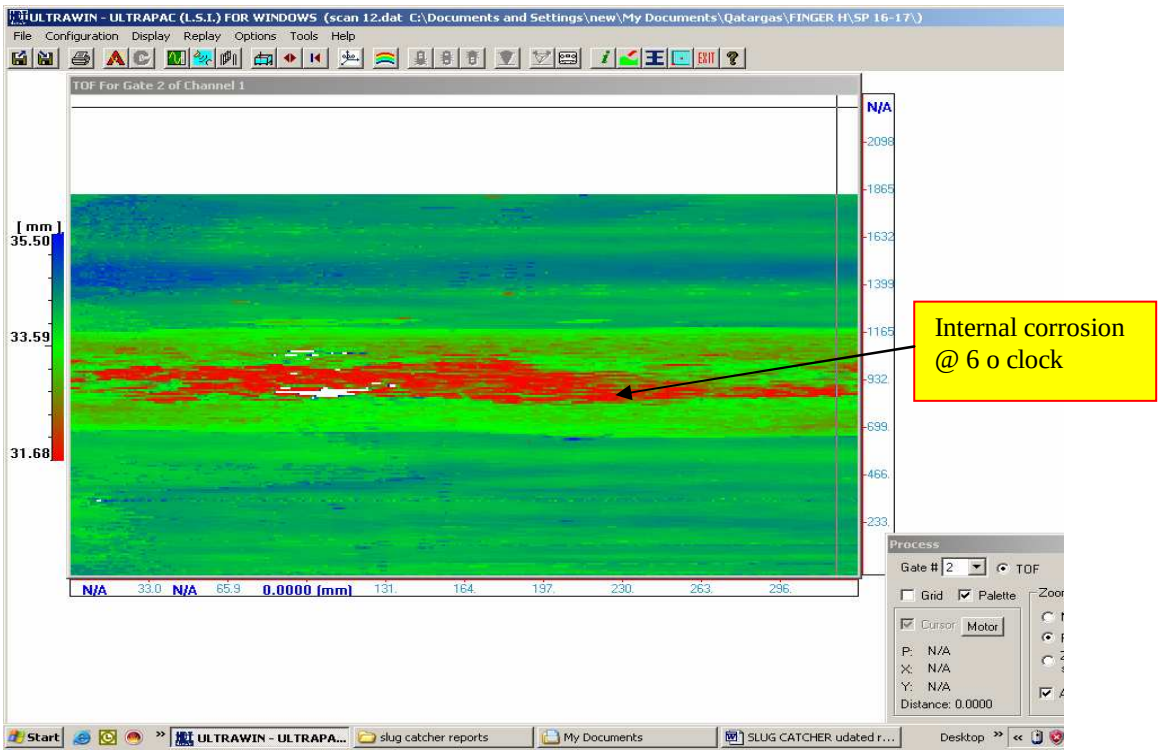

Figure 8: Scan location - Half circumferential scans (3 to 9 o'clock position)

Internal corrosion (isolated and general localized pitting) was found at 6 O'clock position of the storage tube fingers close to liquid manifold and therefore scope of work was increased to full scanning of underside of pipes. The slug catcher inspection was completed in 86 days with total approximate cost of US $135,000.

The Material Selection philosophy for Qatargas has considered the slug catcher to handle Dry Phase of sour gas and condensate. All the water in the stream from wells is expected to be removed by the Glycol Dehydration units located offshore. However, in the event of malfunctioning / outage of dehydration units, water is expected in the slug catcher. It is evident that hydrate formation has happened on several occasions in the past indicating presence of water in the stream. However, the free water is expected to be inhibited by the Corrosion Inhibitor addition being done in offshore.

The inspection findings established predominant corrosion between 5 to 7 O' clock position and running over substantial length closer to the liquid header. This corresponds to the probable location of deposits and free water zone. The slug catcher has a 1:200 slope towards the liquid manifold end and any deposit is likely to accumulate in this region. The level of Corrosion Inhibitor (CI) injected Offshore is adequate for mitigating corrosion in the Carbon Steel piping and is being monitored closely. However, Corrosion Inhibitor may be ineffective for Under Deposit Corrosion. Removal of deposits is not feasible due to construction feature and therefore injection of additional Corrosion Inhibitor is not considered to be beneficial.

The new projects handling wet gas have considered S-bends and internally cladded storage finger and Liquid manifold which are an improved design.

BENEFITS

1. The inspection is performed with very high speed. It is relatively fast compared to some other systems (up to 500mm/second sweep).
2. A color coded C-Scan map (with associated A- and B-Scans) of the area of interest is produced from the scan data and is easily interpreted.
3. The resolution of the system can be increased to produce highly accurate defect detection and sizing.
4. Auditable 100% coverage of the pre determined area (given adequate surface conditions) is assured.
5. Operator error can be minimized.
6. Archive of results is possible.
7. System has electronic data and can be replay off line.
8. Having the option to monitor areas of concern with the same calibration parameters as previously used.
9. The transducer is seated in a bubbler housing, thus the water (required as a coupling medium) is retained in the housing, which allows an ultrasonic echo to be maintained on an uneven surface condition, and more importantly, obtain data in close proximity to welds.
10. System can be used on a range of temperatures up to 150℃.
11. Hard copy results can be printed.

LIMITATIONS

1. For adequate detection of back wall (internal) defects, the outer surface should be clean and free from loose impediments such as insulation or other debris. Debris could cause the ultrasonic signal to scatter, therefore not reaching the inner surface. In this scenario, a back wall echo may not be strong enough to allow credible data to be recorded. This is a pre requisite for all methods of ultrasonic inspection.
2. Areas in the close proximity to nozzles, saddles or other impeding obstructions may require alternative manual inspection due to physical size of the scanner.
3. 110-240 volt power supply is required.

CONCLUSION

The application of LSI in the above cases has yielded very good results upon which future inspection strategies could be based. The chosen contractors proved themselves very competent in the field with a professional approach.

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