METAL WALL THICKNESS ASSESSMENT OF AIR RECEIVERS BY METHOD OF ULTRASONIC TESTING (UTM).

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ABSTRACT

Metal Wall Thickness Assessment of Air Receivers by Method of Ultrasonic Testing (UTM) is reported. The Air Receivers were duly prepared for the assessment in line with the guidelines for UTM tests. The tests were carried out and results so obtained were documented in tabular and graphical arrays. The evidence of previous UTM assessments were unavailable, hence current data were referenced to the theoretically calculated base data. The results so generated, helped in forecasting the safety/integrity (fitness-for-service) by computing: The amount of metal loss anticipated before the next scheduled inspection (FCA);The remaining thickness ratio (R_t) and the length over which the thickness data may be averaged.

KEY WORDS: Air Receivers, Ultrasonic Tests, Wall thickness.

INTRODUCTION

Frequent NDT inspection in pipes seeks to assess if the pipe wall thickness has been altered (eroded/corroded) over time. Even the slightest change can affect the pipes' ability to withstand pressures and meet relevant operation requirements. Examination of pipes' walls is a central area in the NDT industry due to the fact that even a small change in the pipe's wall thickness may have grave repercussions on the pipe's ability to withstand pressures and meet preset standards.Two techniques are generally used to conduct wall thickness measurement – the Tangential Technique and the Double Wall Technique. Both of these techniques contain inherent obstacles that must be overcome in order to achieve accurate and reliable measurements [1].The pipeline's integrity is influenced by its environment, the transported medium, the type and state of the coating, the effectiveness of the cathodic protection as well as operational parameters. Flaws and anomalies in the pipe wall can grow from the outside, the inside or even from within. They can materialize during manufacturing and construction or emerge later during the operational life of the pipeline.

Corrosion and gouging are the main anomalies. They are marked metal loss and thus a significant reduction in the pipe's wall thickness. Hence the importance of measuring the remaining thickness of the pipe wall in general and the maximum allowable safe operating pressure (MAOP) of the pipeline in particular.[2]

Sensors measure the time-of-flight of ultrasonic signals which are reflected by the internal and external surfaces of the pipe wall. Based on the known velocity of the ultrasonic pulse in the coupling medium (oil or another suitable liquid) and the time of flight of the first reflected signal (t1) the distance between sensor and internal surface of the pipe wall (called stand-off) is accurately calculated. The time-of-flight of the second reflected signal (t2) is then used to determine the respective wall thickness. An average value of wall thickness is calculated for all the reflections received for a given sensor and covering a specific area. If the wall thickness varies and the stand-off remains the same, the flaw is external. If the stand-off varies with the wall thickness the flaw is internal. In addition, laminations and inclusions can also be detected. The sensors cover the full 360° circumference of the pipe[2]

In similar vein, proposed modeling of a pressure vessel under internal and external corrosion using the fitness for service (API 579) is presented. Fitness for service (FFS) assessment is a quantitative engineering evaluation of operational components. In the context of pressure vessels and piping systems, FFS assessment is performed periodically to ensure the operational safety and structural integrity. Non-destructive testing by ultrasound was used to obtain loss of thickness wall measurements for pressure vessel damaged and develop the modeling. The objective is to analyze and evaluate the values of Maximum Allowable Working Pressure (MAWP) provided by the Fitness for Service assessment using numerical thermal transient analysis using Finite Element. Results of MAWP are compared when it takes into account several variables that Fitness for Service considers, like the Future Corrosion Allowance (FCA) due to evolution of corrosion, the thickness uniform loss (LOSS) of the internally corroded areas and the changes of temperature affecting the structural integrity of the equipment. The results show that for the external corrosion the values proposed for MAWP levels 1 and 2 by fitness for service still kept the pressure vessel operating at risk according to the analyzes obtained. Furthermore, the Remaining Strength Factor (RSF) is lower for internal corrosion, indicating that for these conditions, internal corrosion is most critical than the external. Finally, it is proposed a reduction of the temperature working in order to increase the RSF. This work shows that the union of the numerical analysis with the fitness for service can be used with efficiency and objectivity in similar situations like this.[3]

Also, Pure MFL enables utility owners to:

i) **Confidently make risked-based decisions** by getting an early indication of failure mechanisms and determining the likelihood of failure associated with a pipeline.

ii) **Build an asset management program** to prioritize pipeline repair, replacement and monitoring programs.

iii) **Perform comprehensive structural analysis** based on the MFL data to understand the significance of the defects found.

iv) **Accurately assess, classify and characterize pipeline anomalies -** dramatically improve the decision-making process within their asset management program and lower costs by pinpointing areas needing repair and by minimizing verification excavations.

v) **"See" through lined pipes -** the unique differentiator of PureMFL is that it is the only MFL technology available that can provide high-resolution pipe wall loss data through thick coatings up to a 1/2-inch.

vi) **Accurately identify defect location** by becoming informed through rigorous axial location and radial determinations.

vii) **Assess metallic pipelines of variable diameters –** through a wide range of tools for manned or free-swimming deployment.[4]

Furthermore, Condition Assessment is seen as a process or processes that establish a record of the state of the critical aspects of an object at a given time. For cast and ductile iron pipes, a critical aspect is pipe wall thickness and degree pitting corrosion.[5]

Also, reversing the flow direction and operating pressure profile of a pipeline does not require a change to the existing MOP. However, the flow reversal will result in segments of the pipeline being operated at higher pressures than the previous operating levels. As a result, a threat identification assessment has been conducted to identify and assess any features and failure mechanisms that may become more susceptible due to the change in pressure profile. The effect of the line reversal was evaluated on the six primary causes of pipelines failures identified below: metal loss; cracking; external interference; dents and mechanical damage; material, manufacturing or construction; and geotechnical threats. Potential threats identified were evaluated for their suitability for service under reverse flow and the details of the validation of the individual features and threat mechanisms are described herein:

I) Pipeline metal loss is managed by Enbridge through a series of comprehensive prevention, monitoring and mitigation programs. The external corrosion prevention measures include: protective external coating; a CP system installed and maintained to Enbridge standards; routine ILI using high resolution MFL and UT ILI technology; and excavation and repair programs.

ii) The internal corrosion prevention and mitigation measures include: tariff limits on sediment and water (“S&W”) content; routine monitoring, line cleaning and chemical inhibition (if required); oil batch testing; routine ILI using high resolution MFL and UT ILI technology; and excavation and repair programs.

iii) The above programs have been designed to maintain reliable operation up to the MOP along the entire NW to SA pipeline segment regardless of actual operating pressure at each particular line segment. As such, the proposed reversal of flow does not require any changes to the metal loss management programs. Based upon the metal loss related analysis and assessments summarized herein, it is concluded that the metal loss threat on the line is adequately managed and will continue to be managed at an acceptably low risk level regardless of flow direction.[6] Also, Super-heater surfaces in oil shale-fired steam boilers are subject to intensive corrosion, which causes thinning of tube wall and increased stresses. It leads to reduction of creep life of super-heater tubes and results in the necessity of super-heater repair every 3–4 years with replacement of up to 30–50% of austenitic tubes. The ability to predict accurately the remaining life of super-heater tubes allows to reduce the amount and cost of repair. The method of assessment of remaining life for super-heater austenitic steel tubes operating in conditions of intensive high-temperature corrosion is presented in this paper. The method is based on measurements of tube wall thickness and kinetic diagram of corrosion resistance of a particular steel.[7] X8CrNiNb1613 austenitic steel according to DIN 17459 in the super-heater of an oil shale PF boiler are close to the results obtained at testing of widely used austenitic steel 12Cr18Ni12Ti (ТУ 14-3-460-75). The main feature of austenitic tubes is the loss of oxide scale adhesion and its spalling in the presence of oil shale deposits on the tubes of the boiler that sharply accelerates the corrosion process in comparison with laboratory experiments. It leads to the fact that corrosion depth could be 1.2 mm after 25 thousand hours of operation and the remaining life of the tube

from X8CrNiNb1613 steel (that, according to DIN 17459, is supposed to be operated at least for 100 thousand hours) would be only 50 thousand hours. 2. Assessment of remaining life according to the suggested method which is based on measurements of tube wall thickness allows to increase essentially the accuracy of estimation and hence to avoid unscheduled outages due to tube failures and reduce amounts and

costs of repair.[7]

The Pipeline Defect Assessment Manual (PDAM) project is a joint industry project sponsored by fifteen international oil and gas companies, to produce a document specifying the best methods for assessing defects in pipelines. PDAM documents the best available techniques currently available for the assessment of pipeline defects (such as corrosion, dents, gouges, weld defects, etc.) in a simple and easy-to-use manual, and gives guidance in their use. In this paper the best practices for the assessment of corrosion in pipelines are presented. Full scale tests, theoretical analyses and assessment methods are also discussed, and the 'best' methods included in PDAM are described.[8]

3 types of defect considered in the Pipeline Defect Assessment Manual (PDAM) contains guidance for the assessment of the following types of defect: defect-free pipe, corrosion, gouges, plain dents, kinked dents, smooth dents on welds, smooth dents containing gouges, smooth dents containing other types of defects,

manufacturing defects in the pipe body, girth weld defects, seam weld defects, cracking and environmental cracking[8]

GML Level 2 assessments are permitted only if certain conditions are satisfied. The complete list of limitations in Section 4 of API RP 579 should be reviewed before proceeding with a GML Level 2 FFS assessment. Some of the limitations are:

- The original design criteria must be in accordance with a recognized code or standard (e.g., ASME Code Section VIII or ASME B31.3).
- The component must have either a design equation that specifically relates pressure (or liquid fill height for tanks) and/or other loads, as applicable, to a required wall thickness (e.g., pressure vessel or storage tank cylinder), OR must be one of the following components:
  - Pressure vessel nozzle, tank nozzle, or piping branch connection
  - Reinforcement zone of conical transitions
  - Cylinder-to-flat head junctions
  - Integral tubesheet connections
  - Flanges
  - Piping systems
- Supplemental loads that impact the thickness of the component being evaluated must be considered. Some examples include loads due to:
  - Weight of the component including contained fluid, insulation, or refractory
  - Wind, earthquake, snow and ice
  - Constraint of free thermal expansion
  - Process upset conditions

A Level 2 GML assessment may be performed using individual point thickness data or thickness profiles as described in Article 1. Thickness profiles are required if there is too much variation in the individual point thickness readings. Below is a summary of the Level 2 GML assessment methodology using thickness profiles where supplemental loading must be considered. Guidance on the use of thickness profiles can be found in API RP 579 Section 4.

GML Level 2 Assessment Summary For Cylindrical Components:

- Review the inspection history of the equipment.
- Calculate the required minimum thickness due to circumferential stress (e.g., caused by internal pressure or liquid fill height).
- Determine the supplemental loads (e.g., weight of the component and insulation, wind, earthquake). Refer to API 579 Appendix A for additional details on loads.
- Calculate the required thickness due to supplemental loads.
- Calculate the required minimum thickness due to longitudinal stress (e.g., consider thickness required for internal pressure, external pressure, and weight loads).
- Obtain the thickness profiles for the thin areas.
- Determine the critical thickness profiles for the circumferential and longitudinal directions (CTPC and CTPL).
- Select the minimum measured metal thickness from the lower of CTPC or CTPL.
- Specify the Future Corrosion Allowance (FCA). The FCA is the amount of metal loss anticipated before the next scheduled inspection.
- Compute the remaining thickness ratio. The remaining thickness ratio is based on the minimum measured thickness, the FCA, and the minimum required thickness as noted below. It is one of the inputs needed to establish the length over which the thickness data may be averaged.

$$R_t = \frac{t_{min\_measured} - FCA}{t_{min\_required}}$$

Equation 1

- Compute the maximum length that may be used for thickness averaging.
- Determine the axial and circumferential extent of the flaws using the tables and equations in API RP 579 Section 4.
- Measure the distance from a major structural discontinuity (e.g., nozzle, support skirt).

- Determine the average and minimum thicknesses by numerically averaging over the length of the flaw. For cylinders, this must be done in both the longitudinal and circumferential directions.
- Compare the calculations for the remaining thickness ratio, minimum measured thickness minus the FCA, average measured wall thickness, circumferential extent of the flaw, and the distance from a major structural discontinuity, to the API RP 579 acceptance criteria.
- If the flaw is acceptable, develop an inspection strategy for the equipment.
- If the flaw is unacceptable:
  - Repair the flaw, rerate or replace the component
  - Lower the FCA (e.g., by reducing the inspection interval or mitigating the corrosion)
  - Conduct a Level 3 FFS assessment. Note that a Level 3 assessment is not required in most situations, and it requires more data and more time to conduct.[9]
  - Presently, a pressure test provides the most complete assessment of a pipeline in a single test but the sizes of anomalies that can remain are relatively large and no information is available on flaws that are developing. The ILI tools that have been developed and used extensively (deformation, HR MFL, and UT metal loss and crack detection) appear to provide the most complete integrity assessment of a pipeline for the specific anomalies that they can detect. The industry and ILI tool suppliers need to be encouraged and supported in the further development and improvement of ILI tools to assess all of the types of anomalies of concern in19 pipelines. These are in order of severity: dents with gouges or metal loss, corrosion, weld seam defects, stress corrosion cracks, and fatigue cracks.[10] The objective of this study is to use the wall thickness data for degradation analysis of feed gas filter vessel and compare the results with remaining life evaluation method provided in API 510. The exponential model for degradation fitted best to the degradation (wall thickness) data. Extrapolation of model gave the failure time for each thickness measurement location, thus providing a failure data set to be analyzed for the reliability function. The results obtained

show that the degradation model is more optimistic than API 510 methods and thus it gives a failure free period of 690.33 years which is higher in comparison to life evaluated by using API 510 short term and long term corrosion rates which were calculated to be 510.43 and 628.75 years, respectively. These results can be used as a good starting point for Risk Based Inspection studies by estimating the probability of failure based on Weibull analysis.[11]

Today, the in-line inspection of pipelines is a routine procedure. Specialised automated tools are inserted and pumped through the oil, product or gas line to be inspected. Depending on the types of anomalies and flaws to be detected, a variety of non-destructive testing methods can be applied. One such method is ultrasound (UT), a technology widely used for the inspection of liquid lines.

Advantages of UT as compared to other non-destructive testing principles applied in in-line inspection tools are: inspection of thick walls; inspection of ferritic and austenitic steels; highest level of accuracy; enhanced depth resolution; data quality suited for integrity assessment and fitness-for-purpose studies; capable of detecting and sizing metal loss, crack features and mid wall anomalies.

A major advantage of ultrasound technology regarding integrity assessment is its capability to perform true quantitative wall thickness measurements, achieving resolutions of better than 0.1 mm and accuracies of ± 0.4 mm. Ultrasound tools can thus be used to verify and record the actual wall thickness for any location within the pipe. Such an inspection records data which is of particular use in case of a pipeline uprating process.[12]

Pressure vessels, storage tanks and other safety critical components (including pipework and valves) are designed to contain liquids, gases and solids such that a loss of containment does not occur. Leaks or the mechanical or structural failure of these items of equipment may result in a major accident on-site.

The presence of flaws in critical components may result in the integrity of such systems being compromised and increase the likelihood of failure.

Non-Destructive Testing (NDT) is the application of measurement techniques in order to identify damage and irregularities in materials. NDT often provides the only method of obtaining information about the current 'health' of process plant.

If done well, NDT can provide useful information to assist in the management of plant safety. If inappropriate NDT is applied or NDT is not applied correctly, then the results are likely to give a false impression of the integrity and safety of the plant.

NDT is a measurement of a physical property or effect from which the presence of damage or irregularity can be inferred. It is not a measurement of an absolute parameter such as temperature or pressure.[13]

NDT techniques fall into two categories:

- techniques which only detect and size defects/damage present on the surface of a component; techniques which can detect and size defects/damage embodied within a component.[13]

The types of defect / flaw and degradation that can be detected using NDT are summarised as:

i) Planar defects - these include flaws such as fatigue cracks, lack of side-wall fusion in welds, environmental assisted cracking such as hydrogen cracking and stress corrosion cracks; cold shuts in castings etc;

ii) Laminations - these include flaws such as rolling and forging laminations, laminar inclusions and de-laminations in composites;

iii) Voids and inclusions - these include flaws such as voids, slag and porosity in welds and voids in castings and forgings;

iv) Wall thinning - through life wall loss due to corrosion and erosion;

v) Corrosion pits - these are localised and deep areas of corrosion;

vi) Structural deformities such as dents, bulges and ovality.[13]

Ultrasonic testing, or UT as it is commonly called, is the procedure of introducing a high frequency sound wave into the exterior side of a metal surface and reflecting the sound wave from the interior surface to produce a measurement of wall thickness.the two way duration of travel, divided by the known sound velocity through that particular metal, provides a thickness measurement equally accurate to a micrometer or calliper reading. Since ultrasound allows the precise measurement of wall thickness from the outside surface, and provides a measurement of remaining wall thickness over a wide sampling of individual points, it produces a very thorough corrosion evaluation within a short time and at reasonable cost [14].

Of the various conventional and advanced non-destructive examination (NDE) methods, five are widely used for the examination of pressure vessels and tanks by certified pressure vessel inspectors. The names and acronyms of these common five methods are:

i) Visual Examination (VT)
ii) Liquid Penetrant Test (PT)
iii) Magnetic Particle Test (MT)
iv) Gamma and X-ray Radiography (RT)
v) v) Ultrasonic Test (UT)

VT, PT, and MT can detect only those discontinuities and defects that are open to the surface or are very near the surface. In contrast, RT and UT can detect conditions that are located within the part. For these reasons, the first three are often referred to as "surface" examination methods and the last two as "volumetric" methods.[15]

MATERIALS AND METHOD

MATERIALS

1. Air Receiver Plant Number CR/AR-1. SWL =110PSI; Proof Load =165 PSI. E= 207x $10^6 N/M^2$
2. Air Receiver Plant Number SP/AR-1 SWL =110PSI; Proof Load =165 PSI. E= 207x $10^6 N/M^2$
3. Air Receiver Plant Number 2HM/AR-1 SWL =110PSI; Proof Load =165 PSI. E= 207x $10^6 N/M^2$
4. Air Receiver Plant Number PL/AR- 1 SWL =110PSI; Proof Load =165 PSI. E= 207x $10^6 N/M^2$
5. Dakota UTM
6. Turbine oil or machine oil
7. Smooth sand paper.

METHODS

The Air Receiver vessel to be assessed is mapped out geographically, thus: North Pole, Cancer, Equator, Capricorn and South Pole. For the purpose of point traversing, Longitudes 0^0, 45^0, 90^0, 135^0, 180^0, 225^0, 270^0, 315^0 and 360^0 are mapped out and intersection with the North Pole, Cancer, Equator, Capricorn and South Pole are marked out.. These points so marked out are thoroughly cleaned with smooth emery cloth in order to remove coatings, rust and any form of impurities. These points are further cleaned with Acetone in order to remove any form of grease. Turbine oil or machine oil is now applied to those points. The Dakota UTM is now switched on and confirmed for zero accuracy placing the Probe(prismatic feeler or sensor) on the calibration block of the UTM. The Dakota UTM is now ready for use. Readings are now taken for each of the marked positions on the Air Receivers. Care is taken to ensure proper contact of the UTM Probe to the metallic body of the Receiver and reading taken at the steady state of digital display. Readings are taken for each position until all the marked positions are traversed.. the data so generated are tabulated in Tables 1.1, 1.2, 1.3 and 1.4 respectively for the four Air Receivers. The generated wall thickness values for each Air Receiver are plotted graphically as shown in Figures 1, 2, 3 and 4 respectively and the minimum wall thickness value is identified. Theoretical metal wall thickness derived from the Safe Working Load (SWL) and Proof Load parameters is designated as t_{calc}.. Decision criteria : If $t_{min} > t_{calc}$, Accept Results (that is Air Receiver is fit for service). If $t_{min} < t_{calc}$, Reject Results (that is Air Receiver is not fit for service). For the fit-for-service verdict, the Remaining Thickness Ratio (RTR) is now computed with a basic assumption that the Future Corrosion Allowance (FCA) is equal to tcalc, hence equation 1 is modified to :

$R_t = (t_{min} – t_{calc})/t_{calc}$ Equation 2.

Results so obtained are tabulated and discussed. Based on these results and discussions, conclusion is drawn.

RESULTS

TABLE 1.1: AIR RECEIVER ULTRASONIC DATALOG

		0^0	45^0	90^0	135^0	180^0	225^0	270^0	315^0	360^0
1.1 CA/AR-1	N/POLE	6.69	Circum 293.5 cm	L=180 cm	N/H=103 cm	S/H= 104.5 cm				
	Cancer	6.41	6.48	6.49	6.54	6.52	6.54	6.44	6.54	6.41
	Equator	6.77	6.75	6.67	6.67	6.69	6.69	6.66	6.70	6.77
	Capricorn	6.63	6.58	6.63	6.59	6.60	6.72	6.58	6.60	6.63
	S/Pole	6.74								

SOURCE: [16] .B: All values are in mm unless otherwise stated.

TABLE 1.2: AIR RECEIVER ULTRASONIC DATALOG

		0^0	45^0	90^0	135^0	180^0	225^0	270^0	315^0	360^0
1.2 SP/AR-1	N/POLE	7.71	Circum 243.5 cm	L=171 cm	N/H=92 cm	S/H= 92 cm				

	Cancer	5.25	5.28	5.29	5.26	5.21	5.24	5.31	5.29	5.25
	Equator	5.34	5.45	5.50	5.43	5.26	5.24	5.29	5.31	5.34
	Capricorn	5.26	5.26	5.29	5.23	5.23	5.26	5.29	5.29	5.26
	S/Pole	7.88								

SOURCE: [16] N.B: All values are in mm unless otherwise stated.

TABLE 1.3: AIR RECEIVER ULTRASONIC DATALOG

		0^0	45^0	90^0	135^0	180^0	225^0	270^0	315^0	360^0
1.3 2HM/AR-1	N/POLE	8.11	Circum 199 cm	L=122 cm	N/H=70cm	S/H= N/A				
	Cancer	6.50	6.49	6.54	6.57	6.49	6.55	6.59	6.48	6.50
	Equator	6.51	6.55	6.59	6.52	6.66	6.77	6.59	6.56	6.51
	Capricorn	6.52	6.69	6.49	6.57	6.56	6.54	6.53	6.52	6.52
	S/Pole	N/A								

SOURCE: [16] N.B: All values are in mm unless otherwise stated.

TABLE 1.4: AIR RECEIVER ULTRASONIC DATALOG

		0^0	45^0	90^0	135^0	180^0	225^0	270^0	315^0	360^0
1.4 PL/AR-1	N/POLE	5.89	Circum 245 cm	L=168 cm	N/H=95cm	S/H= 95 cm				
	Cancer	6.01	6.06	6.02	6.06	6.12	5.92	5.97	6.01	6.01
	Equator	6.03	6.04	6.06	6.13	6.09	5.97	5.99	6.05	6.03
	Capricorn	6.10	6.06	6.05	6.08	6.10	5.97	6.01	6.08	6.10
	S/Pole	6.06								

SOURCE: [16] N.B: All values are in mm unless otherwise stated.

TABLE 2

S/NO	DESCRIPTION OF ITEMS/GOODS	MAKER'S NUMBER	PLANT NUMBER	NATURE OF TEST/INSPECTION CARRIED OUT	SUMMARY OF FINDINGS	REMAINING THICKNESS RATIO (R_t)	CURRENT STATUS OF EQUIPMENT
1.1	Air Receiver			Ultrasonic	Minimum		

	SWL = 110 PSI Proof Load = 165 PSI E = 207 X $10^6 N/M^2$	-	CR/AR-1	metal thickness test. 26 traverses viz: North pole (1), Cancer (8), Equator (8), Capricorn (8) and South pole (1)	wall thickness from measured values (t_{min}) = 6.41mm. Theoretical metal wall thickness (t_{calc}) = 2.12mm. $t_{min} > t_{calc}$. Accept result.	2.02	In Good working condition
1.2	Air Receiver SWL = 110 PSI Proof Load = 165 PSI E = 207 X $10^6 N/M^2$			Ultrasonic metal thickness test. 26 traverses viz: North pole (1), Cancer (8), Equator (8),	Minimum wall thickness from measured values (t_{min}) = 5.211mm. Theoretical metal wall	1.96	In Good working condition

				Capricorn (8) and South pole (1)	thickness (t_{calc}) = 1.76mm. $t_{min} > t_{calc}$. Accept result.		
1.3	Air Receiver SWL = 110 PSI Proof Load = 165 PSI E = 207 X $10^6 N/M^2$			Ultrasonic metal thickness test. 26 traverses viz: North pole (1), Cancer (8), Equator (8), Capricorn (8) and South pole (1)	Minimum wall thickness from measured values (t_{min}) = 6.48mm. Theoretical metal wall thickness (t_{calc}) = 1.43mm. $t_{min} > t_{calc}$.	3.53	In Good working condition

					Accept result.		
1.4	Air Receiver SWL = 110 PSI Proof Load = 165 PSI E = 207 X $10^6 N/M^2$			Ultrasonic metal thickness test. 26 traverses viz: North pole (1), Cancer (8), Equator (8), Capricorn (8) and South pole (1)	Minimum wall thickness from measured values (t_{min}) = 5.92mm. Theoretical metal wall thickness (t_{calc}) = 1.78mm. $t_{min} > t_{calc}$. Accept result.	2.33	In Good working condition

SOURCE: SUMMARY FROM TABLE 1 AND APPENDIX.

From Fig.1 in Appendix, t_{mm} = 6.41mm; t_{calc} =2.12mm.

$t_{mm} > t_{calc}$ that is 6.41mm > 2.12mm. Hence we accept results.

Applying Equation 2, $R_t = (t_{min} - tcalc)/t_{calc}$ =(6.41 -2,12)/2.12 = 2.02

In similar vein, from Fig. 2 in Appendix, t_{mm} =5.21mm; t_{calc} =1.76mm.

t_{mm} >t_{calc}, that is 5.21mm > 1.76mm. Hence we accept results.

Applying Equation 2, R_t = (5.21 – 1.76)/1.76 = 1.96.

Also, from Fig. 3 in Appendix, t_{mm} =6.48mm and t_{calc} =1.43mm.

t_{mm} >t_{calc}, that is 6.48mm > 1.43mm. Hence we accept results.

Applying Equation 2, R_t = (6.48 – 1.43)/1.43 = 3.53.

From Fig. 4 in Appendix, t_{min} = 5.92mm, t_{calc} = 1.78mm. t_{min} > t_{calc}. Hence we accept results. Applying Equation 2, R_t = (5.92 – 1.78)/1.78 = 2.33.

DISCUSSIONS

Fig. 1, 2, 3 and 4 are the graphical representations of Data in Tables 1.1, 1.2, 1.3 and 1.4. What can be deduced from these graphs is that the wall thickness of each of the Air Receivers is not uniform as one traverses the vessels. The wear and tear is due to corrosion and may be defects due to non-uniformity at point of construction. It may be safe to equally hazard a guess that this non-uniformity of vessel wall thickness may be due also to non-uniformity in the corrosion pattern within each of these vessels.

From Fig.1, the Air Receiver, appear to have almost the lowest wall thickness along longitude 2700. In a similar vein, Air Receiver 2 in Fig. 2 appears to have the lowest wall thickness along longitude 180^0. On the other hand, Air Receiver 3 in Fig. 3 do not have a clear distribution of lowest wall thickness along a specific longitude. Contrary to Air Receiver3, Air Receiver 4 in Fig.4 displays a clear lowest wall thickness along longitude 225^0.

Prior to this UTM test on the listed Air Receivers, there was no record of previous wall thickness assessment for these vessels. Since the amount of metal loss anticipated before the next scheduled inspection (FCA) must be referenced to a specific datum, in the absence of previous wall thickness assessment data, it was pertinent and safe to reference FCA to the theoretical value of vessel wall thickness t_{calc}

The interval for statutory inspections/assessments requiring wall thickness evaluations of Air Receivers for most countries ranges between 2 to 3 years. In Nigeria, it is 2 years..

The remaining thickness ratio (R_t) for Air Receiver 1 is 2.02.this value of R_t is referring therefore to the multiple duration of inspection/assessment. Thus for Air Receiver 1, the results are indicating that this vessel has a guaranteed safety/integrity operating period of 2.02 x 2years = 4.04 years without fear of failure. In similar vein, Air Receivers 2, 3 and 4 have (in the absence of any force majeure) 3.92, 7.06 and 4.66 years guaranteed safety/integrity operating periods which favourably exceeds the duration of the next inspection.

CONCLUSION

The UTM wall thickness assessment precisely measure and indicate the wear pattern of the internal surfaces of vessels. The results so generated, helps in forecasting the safety/integrity (fitness-for-service) by computing:

a) The amount of metal loss anticipated before the next scheduled inspection (FCA).

b) The remaining thickness ratio (R_t) .

c) The length over which the thickness data may be averaged.

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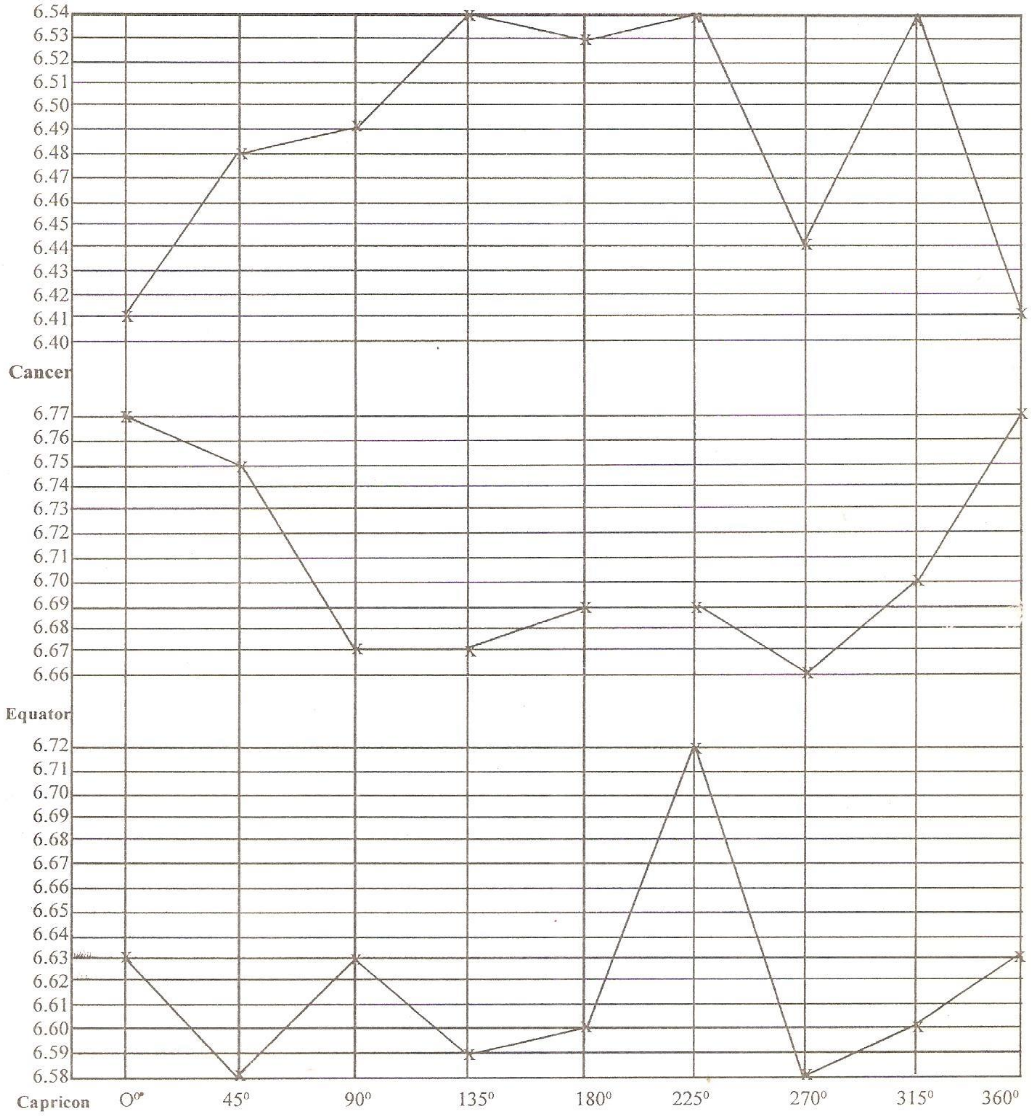
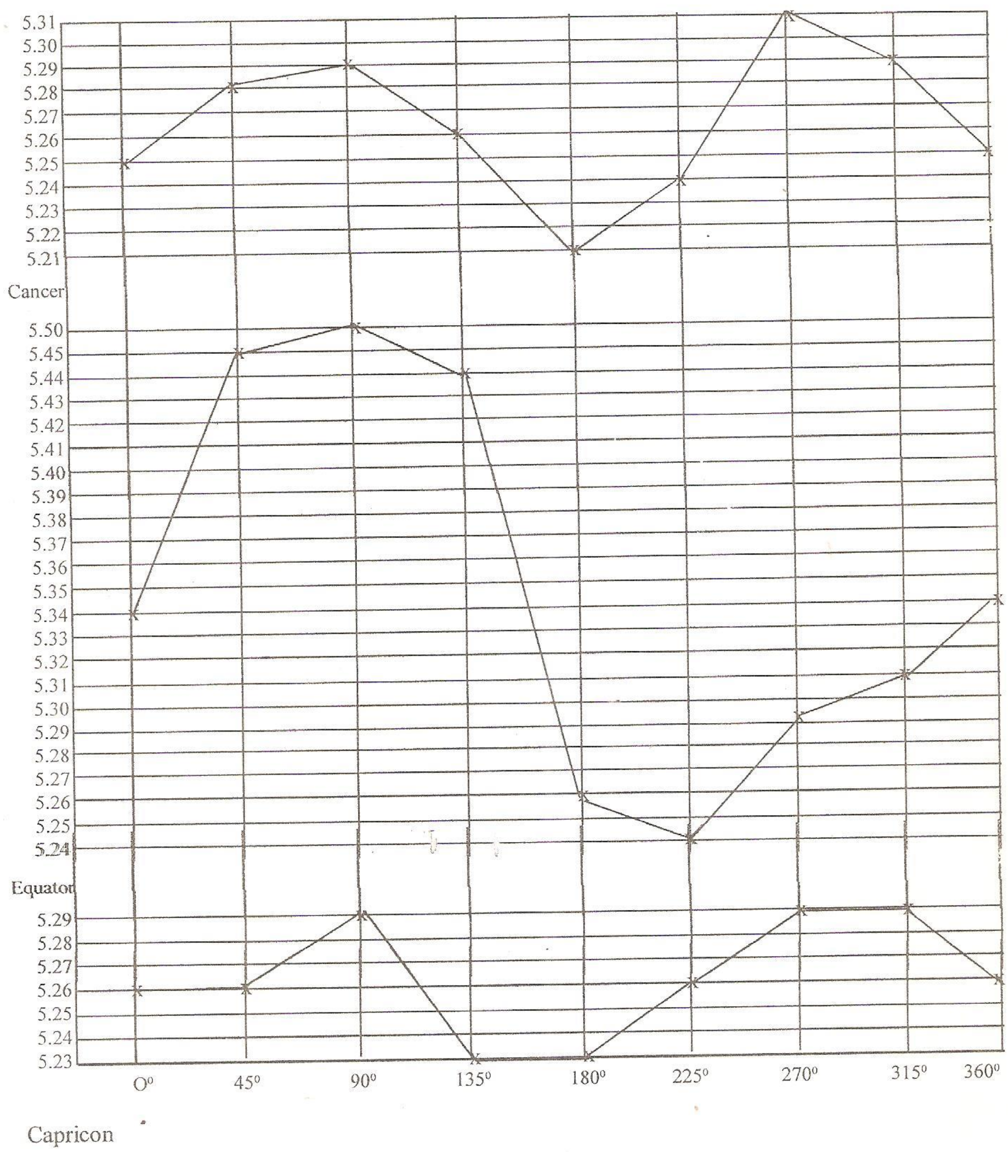
APPENDIX



t_{mm} = 6.41mm; t_{calc} . 2.12mm; $t_{mm} > t_{calc}$; i.e 6.41 > 2.12mm; (Accept Result)

Fig. 1 Graphical Array for CR/AR-1 (Data from Table 1.1)



t_{mm} = 5.21mm; t_{calc} = 1.76mm; $t_{mm} > t_{calc}$; i.e 5.21 > 1. 76mm (Accept Result)

Fig. 2 Graphical Array of SP/AR-1 (Data from Table 1.2)

t_{mm}=6.48mm; t_{calc}.1.43mm; t_{mm}>t_{calc}; i.e 6,48>1.43mm (Accept Result)

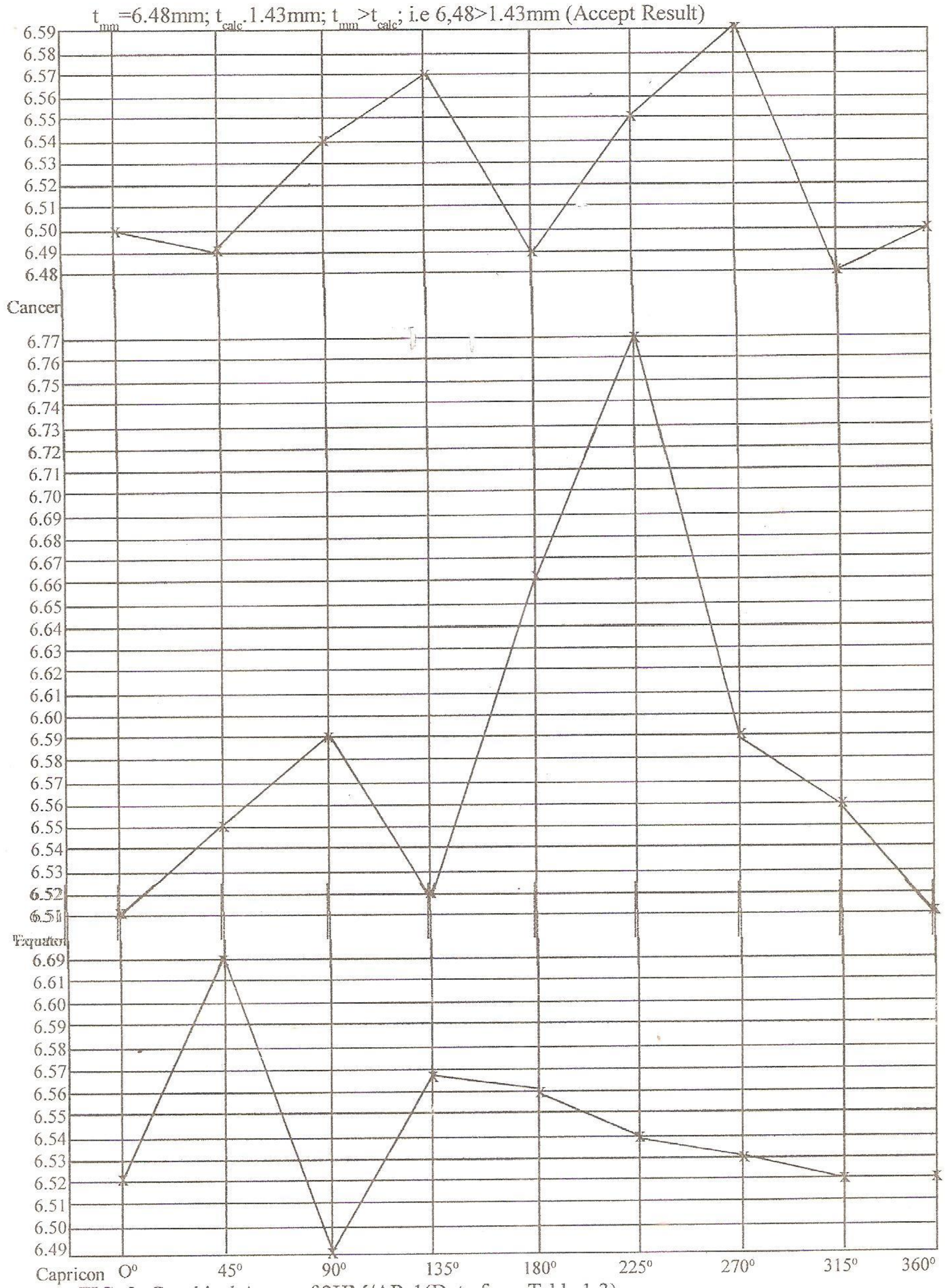
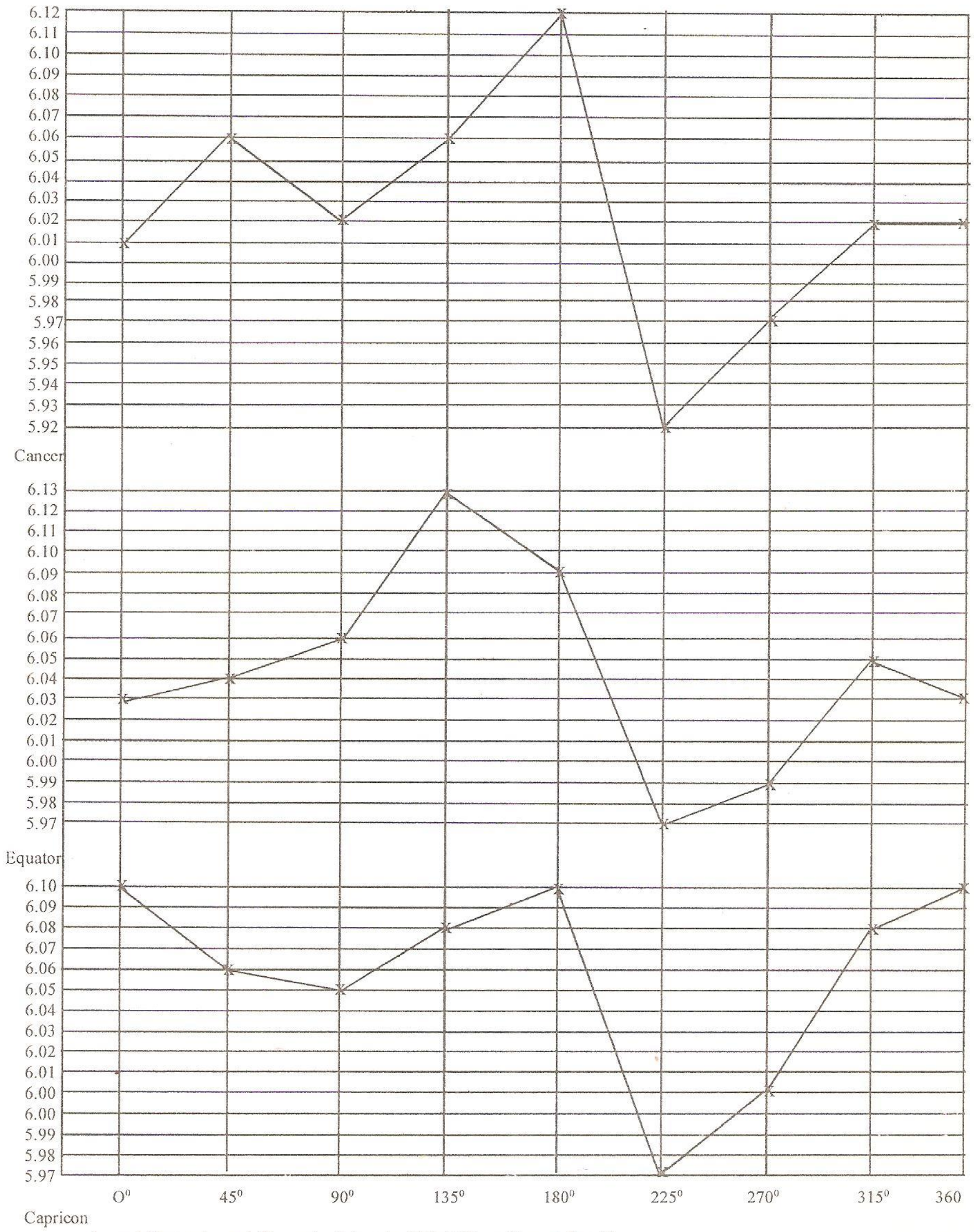


FIG. 3 Graphical Array of 2HM/AR-1(Data from Table 1.3)



t_{mm} = 5.92mm; t_{calc} = 1.78mm; $t_{mm} > t_{calc}$; i.e 5.92>1.78mm (Accept Result)

Fig. 4. Graphical Array of PL/AR-1 (Data from Table 1.4)