PORT SAID ENGINEERING RESEARCH JOURNAL
Faculty of Engineering - Port Said University
Volume (21) No. (2) September 2017 pp. 250:260

ENSURE THE INTEGRITY OF OFFSHORE RISERS AT THE SPLASH ZONE AREA & OPTIMIZE THEIR EXTERNAL INSPECTION REGIME

Amr A.Mohamed[1], Mohamed A. Kotp[2], Waleed S. Abdel Latif Hassan[3] and Ahmed Soliman Ahmed[4]

ABSTRACT

At present time with oil prices continuing to fall, most operators work hard to enforce the cost reduction philosophy and the synergy operations in their maintenance regimes to reduce their daily operational expense (OPEX), This starts from decreasing the gap between the maintenance costs and the applicability of this in the industry this led to a rapid development in the unconventional technologies and produced new advanced inspection technology. In light of the above, the use of the traditionally inspection techniques applied at the splash zone area such as general visual inspection (GVI) and local thickness measurement (UTM) are not practical as they require the removals of the marine growth, armwrap, concrete coating and in some cases the marine painting system. This require a massive preparations activities prior completion till reach the final acceptable conditions and risers reinstatements are reached. Some of the inspection areas where most of the current developments in offshore risers are being seen are in splash zone area that poses some of the biggest challenges to smooth operation in harsh environment. Where the corrosion at splash zones of offshore risers can be severe reading corrosion rates up to 1mm/Year, due to the lack of effectiveness of cathodic protection and coating damages caused either by disbandment or object impact. So it's highly recommended that this zone have a specific inspection plan combined with a special inspection program for preventing the occurrence of failure as well as following up the evaluation of any failure mechanism which eventually might be present. This paper highlights the challenges to overcome these maintenance costs related to the periodical external inspection of insulated offshore risers at splash zone area. Also the objective of this paper is optimizing the offshore riser's inspection regimes via evaluating the effectiveness of the unconventional non-destructive testing (NDT) methods for in-service inspection of insulated offshore risers at the splash zone area. The assessment will be completed using two unconventional advanced inspection techniques these are the Ultrasonic Guided Wave Technique (wavemaker GW) and the Pulsed Eddy Current – (PEC). Subsea PEC and GW have been already achieved with considerable success and encouraging results during inspections carried out in the Mediterranean Sea, This technology allows complete mapping of the pipeline corrosion status without production interruptions since no destruction or pre-treatment of the protective coatings is required. The state of the art of these nonintrusive technological solutions for inspecting the corroded areas of splash zones of offshore risers using the two inspection techniques (PEC & GW) are demonstrated through an actual case study. Keywords— offshore riser, splash zone, External corrosion, Pulsed eddy current (PEC),Guided wave (GW),Armawrapm, General visual inspection (GVI).

---

[1] Marine Engineering and Naval Architecture Department, Faculty of Engineering, Alexandria University, Alexandria, Egypt.

E-mail: Kootp2000@yahoo.com

[2] Marine Engineering and Naval Architecture Department, Faculty of Engineering, Alexandria University, Alexandria, Egypt.

E-mail: Kootp2000@yahoo.com

[3] Faculty of Science. Cairo University, Cairo, Egypt

E-mail: Waleed.Hassan@se1.bp.com

[4] Chemical Engineering and Petroleum Refining, Faculty of Petroleum & Mining Engineering, Suez Canal University, Alexandria, Egypt.

E-mail: *soims.uk@gmail.com*

1. INTRODUCTION

The riser is the most important component of an offshore platform, it is a vertical pipeline as shown in Figures 1 and that extends the full height of the jacket and is used for transporting oil or gas. Production risers carry oil or gas up from the seabed. Wellheads then take the processed hydrocarbons down to pipelines.[2] The "**splash zone"** as shown in figure 2 **[3]** is the area immediately above and below the mean water level. Offshore risers are installed in corrosive environments and are subject to more aggressive wave loading. The inter-tidal and splash zones on the riser are regions of particular susceptibility to deterioration so corrosion is more aggressive in this area and must be more carefully monitored so the need for the inspection of offshore risers is growing as the worldwide infrastructure related to pipelines and platforms is ageing. However, the ever growing harsher environments being encountered are presently posing challenges to assess the integrity of the subsea production risers with the cost effective means. Marine growth build-up is greater in the top 30m of the sea and is particularly dense in the inter-tidal region[4]. This increase mass and drag in a part of the structure, which can be more vulnerable to these effects. This may also affect corrosion rates. Accordingly, a wide range of offshore risers are subject to periodic in-service inspection in order to ensure continued safe and economic operation. The inspections are often performed by traditional nondestructive tests (NDT) methods such as routine ultrasonic (UT) and visual inspection (VT) checks[4]. These can be highly sensitive but the rate of coverage is often slow and required the direct metal contact, so that full coverage can be prohibitively expensive and extensive preparation for inspection may be required (e.g. access for internal visual inspection removal of insulation, concrete coating and neoprene coating (armawrap) removal for external inspection in addition to the re-installments costs etc.).There are also many situations where geometry or access prevents the use of conventional inspection methods. Over recent years a wide range of advanced NDT techniques have evolved. These techniques provide large area screening of the riser component for any significant degradation without removal of insulation or concrete coating or neoprene coating (armawrap) dismantles for external inspection, some of the techniques can be rapidly applied, much quicker than a more detailed conventional inspection.[2],

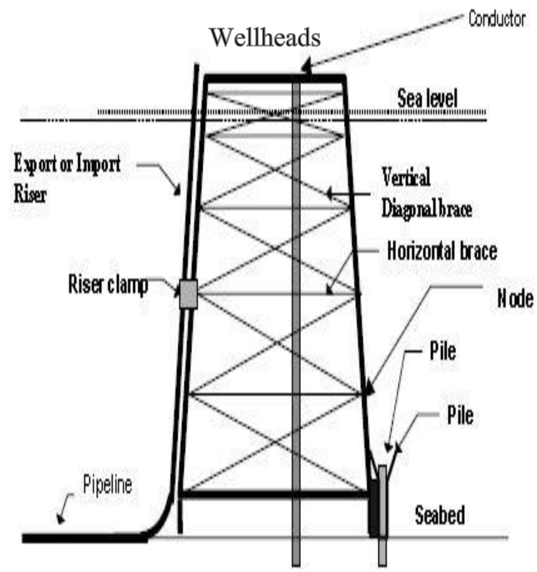

Figure 1: Export or Import Riser out of offshore platform

Figure 2: Splash zone area "Offshore platform"

2. OBJECTIVES AND PROCEDURES

The objective of this paper is to provide a satisfactory level of confidence in riser's safe and reliable operation until the next inspection the following are the most important questions that need to be addressed: whether the inspection technique is the best approach and the cost of conducting inspection must be the balanced of the inspection cost with the value. The main aims of the paper are to find a viable solution to the challenges met during the riser inspection at splash zone area and to possibly reduce the problem of concrete coating and or armawrap removal faced in the industry today, Develop and select the best suitable unconventional testing methods for in-service inspection of offshore risers at the splash zone area, these are by comprising and evaluating the effectiveness of the selected advanced inspection techniques using PEC & GW, Providing an objective source of information and offers an engineering judgment on the capability and limitations of these techniques and to provide information on their use to those involved in the splash zone riser inspection and maintenance regimes to assure its integrity and splash-zone area these are the Ultrasonic Guided Wave Technique (GW) and Pulsed Eddy Current (PEC).

3. OVERVIEW OF THE UNCONVENTIONAL TECHNIQUES

The following review [5] gives a complementary list that includes all unconventional inspection NDT techniques which might be considered as screening techniques for in-service inspection, including: see table 1

No	Abbreviation	Description
Ultrasonic /Acoustic Techniques		
1.	UGWTT	Ultrasonic Guided Wave (Teletest) Technique.
2.	UGWWT	Ultrasonic Guided Wave (Wavemaker) Technique.
3.	GUWMT	Guided Ultrasonic Wave (Magnetostrictive Sensors) Technique.
4.	CHIME	Creeping / Head wave Inspection Method
5.	M-SKIP	M-skip (Multi-Skip) uses two angled Probes producing shear waves.
6.	LORUS	Long Range Ultrasonic System.
7.	EMAT	Electro Magnetic Acoustic Transducers.
8.	VERKADE	Corrosion underneath supports (CUS) can be monitored using Verkade ultrasonic Technique involving a transmitter.
9.	TOFD	Time-of-flight diffraction.
10.	RAPID-SCAN	Rapiscan is a fast and versatile ultrasonic C-scan inspection system.
11.	AE	Acoustic Emission.
12.	QAE	Quantitative Acoustic Emission.
Radiographic Techniques		
13.	LIXI	It is real time radiographic equipment for Screening for corrosion in pipes.
14.	SCAR	Small Controlled Area Radiography
15.	THRUVU	Direct digital gamma radiography system
16.	NEUTRON	Neutron backscattering
Electromagnetic / Electrical Techniques		
17.	SLOFEC	Saturated Low Frequency Eddy current.
18.	PEC	Pulsed Eddy Current.
19.	MFL	Magnetic Flux Leakage.
20.	MICROWAVE	Microwave signals.

Table 1: List of unconventional inspection NDT techniques[5]

4. OBJECTIVE OF ADVANCED INSPECTION TECHNIQUES.

It is essential to be clear about the reasons for performing an in-service unconventional inspection using advanced inspection techniques. The objective of unconventional inspection has to be determined in advance. This may have an impact on the approach to the inspection as well as follow-up detailed inspection. The decision to carry out in-service unconventional inspection will normally depend on a number of different factors. A primary advantage is likely to be risk reduction at reasonable cost for safety critical elements such as offshore risers.[6]

5. POTENTIAL BENEFITS OF USING UNCONVENTIONAL TECHNIQUES

Reduction of Risk: Many of the in-service / unconventional techniques can provide fast coverage of large volume. Rather than use sampling for general trends, it is possible to obtain detailed qualitative and somewhat quantitative information about the condition of the risers. **Inspection of inaccessible areas**: Many applications, hitherto considered inaccessible, can be inspected using some of the unconventional techniques thus reducing unexpected failures and associated consequences including health and safety and environmental hazards and loss of production. **Minimize manual activities:** Many of the in-service / unconventional techniques require minimum preparation including insulation removal, surface preparation and scanning. **Avoids Item shutdown:** Many of the in-service / unconventional techniques can be deployed while risers are in operation. Most or all of the inspection work can be carried out in advance of the shutdown. Thus, shutdown duration may be reduced, being restricted to mechanical work if needed. This also simplifies planning.[5]

6. SUMMARY OF DIFFERENT APPROACHES AND ASSOCIATED CHALLENGES

Ultrasonic thickness measurement (UTM) is a method[1] of performing non-destructive measurement (gauging) of the local thickness of a solid element (typically made of metal, if using ultrasound testing for industrial purposes) basing on the time taken by the ultrasound wave to return to the surface. This type of measurement is typically performed with an ultrasonic thickness gauge. Ultrasonic waves have been observed to travel through metals at a constant speed characteristic to a given alloy with minor variations due to other factors like temperature **Ultrasonic Guided Wave (Wave-maker) Technique [7];** Long Range Guided Wave Ultrasonic is an Ultrasonic Techniques which potentially allows a large volume of pipework to be inspected from a single transducer position. Figure 3 shows the conceptual difference between the normal ultrasonic wave and the inspection area coverage by GW versus normal UT.[5]

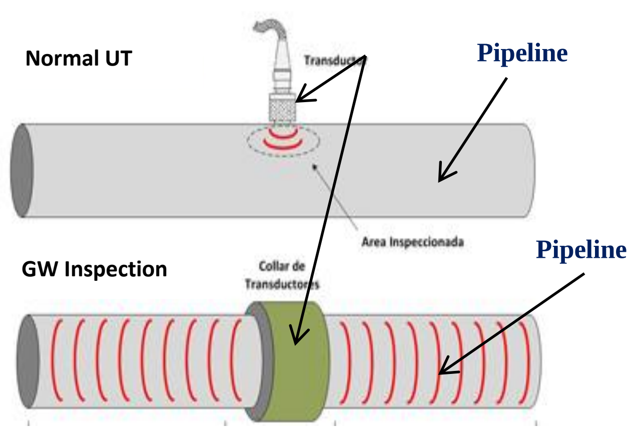

Figure 3: Testing using normal ultrasonic test & using GW technique.[1]

A unit of piezoelectric transducer is clamped around the pipe and the guided waves (GW) are sent simultaneously in both directions along the pipe with 100% screening coverage within its diagnostic length. Ultrasonic transducers send a symmetrical wave of ultrasound energy axially along the length of the pipe; features generate a series of reflections of this sound which are detected at the tool. A feature with a symmetrical change in wall thickness such as a weld generates a symmetrical reflected signal, whereas a localized thickness change causes a flexural signal to be returned which is recorded differently. [5]

7. ULTRASONIC GUIDED WAVE THEORY

Guided Wave testing (GWT) is one of latest methods in the field of non-destructive evaluation. The method employs mechanical stress waves that propagate along an elongated structure while guided by its boundaries. This allows the waves to travel a long distance with little loss in energy. Nowadays, guided wave (GW) is widely used to inspect and screen many engineering structures, particularly for the inspection of metallic pipelines around the world. In some cases, hundreds of meters can be inspected from a single location. Guided wave testing uses very low ultrasonic frequencies compared to those used in conventional UT, typically between 10~100 kHz. higher frequencies can be used in some cases, but detection range is significantly reduced. The acoustic properties of these wave modes are a function of the pipe geometry, the material and the frequency. [5] Figure.4 & Figure 5 show the **G**uided **w**ave **t**esting of pipelines, a technician (right) performs a Guided Wave test. Mechanical stress wave is generated via transducer array mounted around the pipe surface. The electrical signal is driven by the portable electronic unit. After the collection, the result is displayed on the computer for further analysis, where an array of low frequency transducers is

Figure 4: An example of pipeline inspection using guided wave testing (GWT).

attached around the circumference of the pipe to generate an axially symmetric wave that propagates along the pipe in both the forward and backward directions of the transducer array. The Torsional wave mode is most commonly used, although there is limited use of the longitudinal mode. The equipment operates in a pulse-echo configuration where the array of transducers is used for both the excitation and detection of the signals. At a location where there is a change of cross-section or a change in local stiffness of the pipe, an echo is generated. Based on the arrival time of the echoes, and the predicted speed of the wave mode at a particular frequency, the distance of a feature in relation to the position of the transducer array can be accurately calculated. GWT uses a system of distance amplitude curves (**DAC**) to correct for attenuation and amplitude drops when estimating the cross-section change (**CSC**) from a reflection at a certain distance. The DACs are usually calibrated against a series of echoes with known signal amplitude such as weld echoes. Once the DAC levels are set, the signal amplitude correlates well to the CSC of a defect. A typical result of GWT is displayed in an A-scan with the reflection amplitude against the distance see figure 5

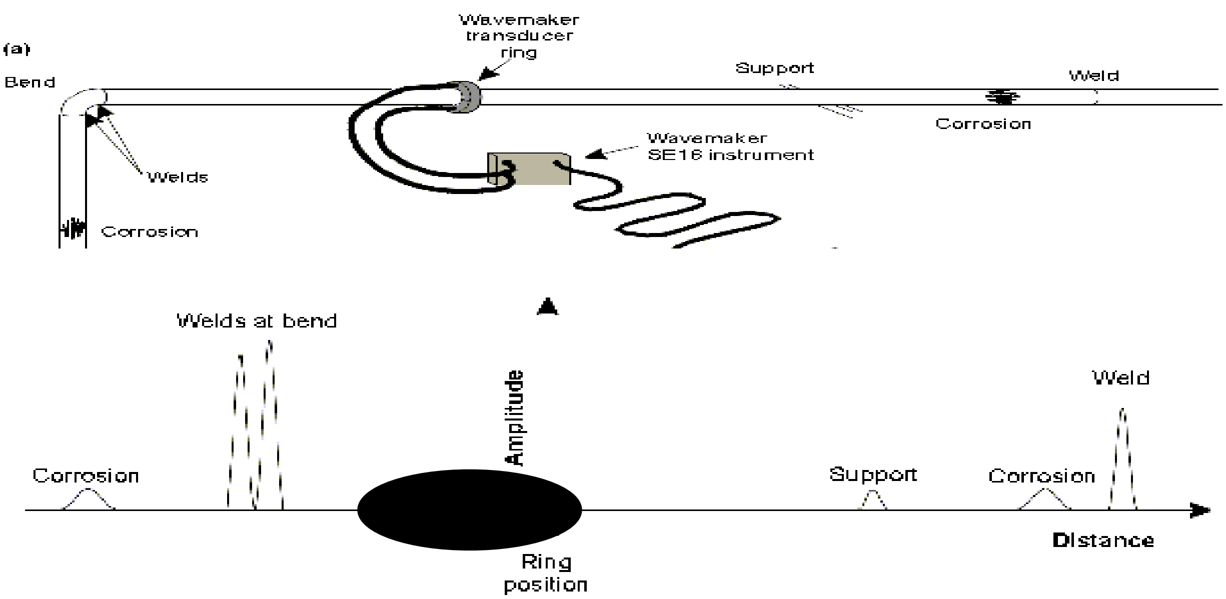

Figure 5: Guided wave - Installation diagnostic diagram

8. PULSED EDDY CURRENT – PEC

Pulsed eddy current (PEC) is a screening tool for inspecting remaining wall thickness under coatings and insulations see figure 6. A coil is placed over the insulated pipe and a current pulse is sent through the coil. When the current is interrupted eddy currents are generated in the material, which decay in time. Measuring the rate of decay of the eddy currents determines the wall thickness. High wall thickness results in a slower decay [8]. The PEC wall thickness is an average over its 'footprint', i.e. the area where eddy currents flow. The size of the footprint area depends on the distance between probe and metal surface. The footprint is approximately a circle with a diameter depending on the distance between probe and steel surface. A rough rule of thumb is smallest detectable defect diameter is 50% of the lift-off, i.e. in 50mm of insulation the smallest detectable defect diameter is around 25mm. The PEC wall thickness readings are an average value over this footprint area. As a result, PEC can only detect general wall loss. Localized corrosion such as pitting is not detected by PEC. In principle PEC cannot differentiate between internal and external defects. PEC can be deployed on-stream for detection of erosion corrosion, flow accelerated corrosion and corrosion under insulation in carbon steel or low alloy ferromagnetic metals with wall thickness between 2-35mm.

9. THE PULSED EDDY CURRENT (PEC) THEORY

The PEC sensor generally contains two electric coils, one as transmitter and one as receiver. The probe is positioned close to the metal to be inspected. The figures below show the principle of the PEC system.

The application of a voltage pulse to the transmitter coil generates a primary magnetic field. The voltage (then the current through the coil) is switched off and the steel demagnetizes. The rapid expiring of the magnetic field produces electrical eddy currents within the steel. The electrical effect produce a secondary magnetic field in the steel and it's picked up by the receiver coil; this field is picked up by the receiver coil as an induced voltage. The signal is amplified and the result as a function of time is referred to as the PEC signal. The behavior of the eddy currents in the material is fairly complex, being a combination of various modes, each with its own spatial distribution within the substrate. The strongest modes are concentrated near the surface, but they decay quickly with the depth into the material. The modes that are scattered throughout the thickness of the steel take longer time to decay. The software evaluates the integral of the signal over time, until the signal reach zero: the given result is the indication of the steel wall thickness. For the result optimization a detailed data post processing is possible after the collection of the readings. The area covered by measurements (footprint) by PEC sensor has approximately 100mm diameter as seen in Figure 7; the step between each shift has been determined being 50mm in both directions for the following reasons: The readings overlap, so ensuring the full coverage of the inspected area. The overlapping of the readings allows to obtain abundant data, allowing to recognize possible wrong measurements and to check again immediately the interesting area.[9]

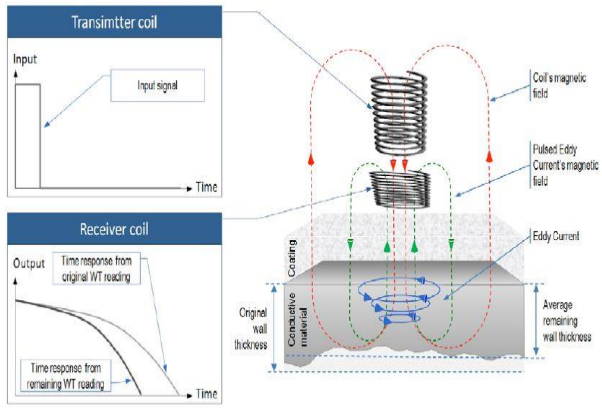

Figure 6: PEC - Principle of PEC system operation

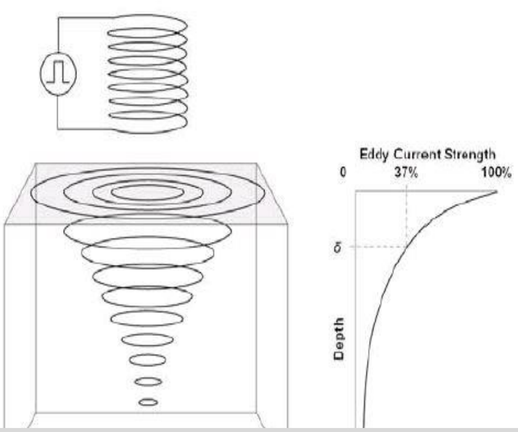

Figure 7: PEC - Eddy Current Field Depth of Penetration & Density for a specific test frequency

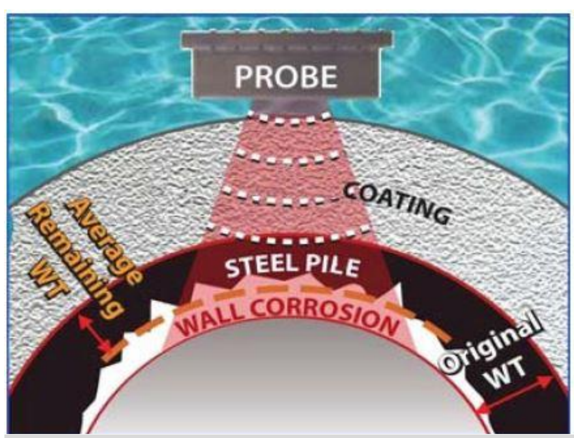

Figure 8: PEC Principle sketch

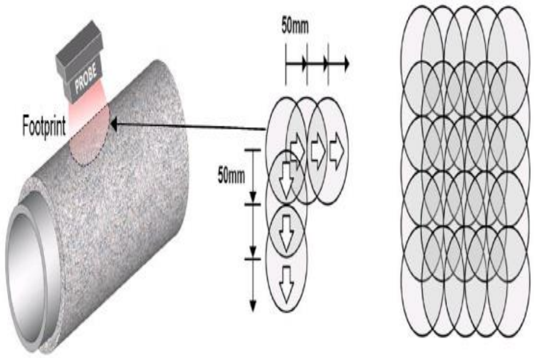

Figure 9: PEC - Footprint on the pipe, bidirectional steps and complete covering by multiple bidirectional steps

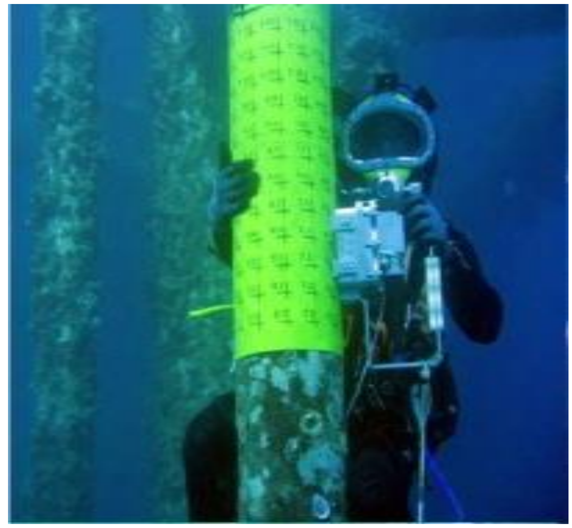

Figure 10: Divers during reading inspection with PEC probe and yellow template for the properly positioning

10. GW - PEC FIELD RESULTS

This section concluded the inspection activities performed by the long range guided wave (GW) & Subsea PEC system within great variety of environmental conditions offer important evaluation and confirmation on the efficiency of the inspection method. Some of the interventions carried out are outlined in table 2

NDT Method	**g-PIMS R2P06-834**
Location	Mediterranean, Egypt.
Inspected structure	Gas & condensate riser, Platform structure.
Diameter	30 mm concrete
Nominal WT	14” Gas Riser (NWT 15.9 mm) & 6” Condensate Riser (NWT 7.9 mm).
Coating Thickness	80mm concrete & Armawrap.
Water Depth	91m water depth
Job description	The Long Range Guided wave (GW) scope of work comprises of inspection of ±02 meters of tow (2) offshore gas and condensate risers using g-PIMS, g-PIMS monitoring clamps had installed on risers that have significant defects to monitor the affected areas. The permanent clamps are installed at critical locations with a communication umbilical run to the nearest walkway or safe area where a Lemo connector is placed. Future inspections are carried out by a platform inspector plugging into the Lemo connector with a G3 Wavemaker, interrogating the clamp and recovering data. There is no requirement for scaffolding or overside work. Risers have been inspected with the manual handled system, at several locations using g-PIMS and subsequently verified using UT.

NDT Method	**PEC**
Location	Mediterranean, Egypt.
Inspected structure	Gas & condensate riser, Platform structure
Diameter	30 mm concrete
Nominal WT	14” Gas Riser (NWT 15.9 mm) & 6” Condensate Riser (NWT 7.9 mm).
Coating Thickness	75 m 80mm concrete & Armawrap.
Water Depth	91m water depth.
Job description	Provide thickness measurements on 14” gas and 6” condensate risers using subsea PEC at the splash zone area (±2 m water level) without any concrete coating or armawrap removals. 360° inspection covers all the accessible Locations. More than 1,000 reading have been collected.

Table 2: Intervention data for PEC and GW

11. 14” GAS RISER RESULTS USING G-PIMS.

The initial scans performed on this riser revealed the fact that while in operation, there is a significant level of vibration on this line generating background noise in the same range as that used for the GWT scans. This vibration was not noted during the 2009 scans as the platform was out of service at the time those scans were performed. Based on the comparison between the 2009 and current scan results, we note the following, Data range extends to approximately 2m beneath the sea level. As was the case in the 2009, this general level was originally noted to have a wall loss of at worst 40% in some areas with the remainder being of lesser wall loss values. This general level of signal is still at most in the medium range while increasing by approximately 5% at most to a level of 45%. As such, we are noting a slight increase in the indication signal amplitudes, there is an additional region of suspected minor level wall loss noted below the sea level which has been highlighted, One additional indication has been noted in the clamp located above the ring location, This indication was also not present in the 2009 scans. It is suspected that this indication is at least partially caused by the vibration in the line coupled with the loss of spacer material at this same position (visually verified) between the clamp and the pipe wall, This localized variation in the coupling of the clamp to the pipe wall together with the vibration of the pipe is expected to be responsible at least for part of this noted indication, Based on the above, short interval monitoring of this line is warranted. The figure below shows a direct comparison of the current scan performed with that from March 2009. Also highlighted in this figure are the noted changes between the two scan results.

12. 6” CONDENSATE RISER RESULTS USING G-PIMS.

The operation of this line did not appear to introduce additional noise into the line as it had with the 14” riser, Figure 11 shows a direct comparison of the current scan performed with that from March 2009. Also highlighted in this figure are the noted changes between the two scan results. Based on the comparison between the 2009 and current data, we noted the following: Data range extends to approximately 1.6m beneath the sea level. Note that this figure is approximate as the exact distance from ring to sea entry could not be safely measured. In general, the indications that were noted in the 2009 scan results are all present. Added to this is an extension in the length and severity of the indication that had been noted beneath the mortar below the seal level. An increased reflection appears in this region corresponding to a suspected wall loss of approximately 50%. Based on the above, short interval monitoring of this line is warranted.

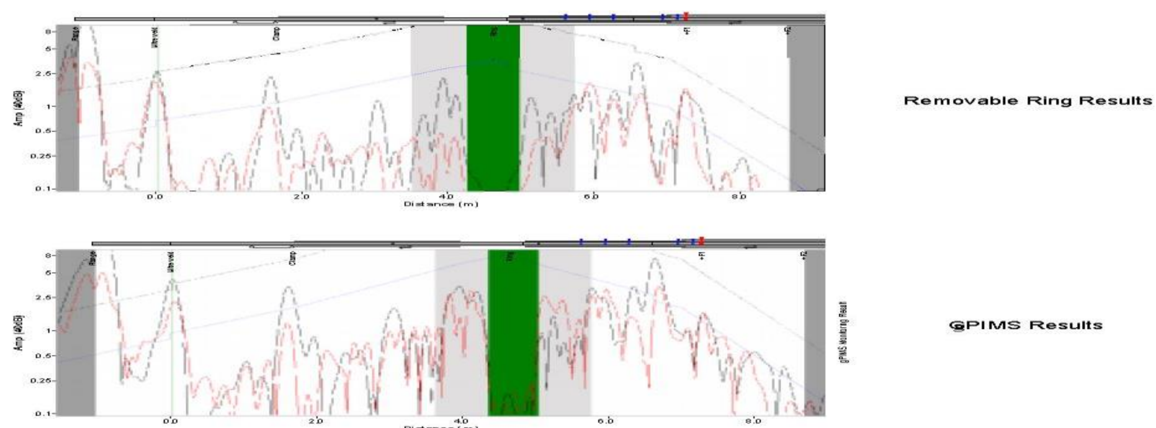

Figure 11: direct comparison of 2009 and current results from 14" gas riser-Results from at FR 7.6 and 0 BW

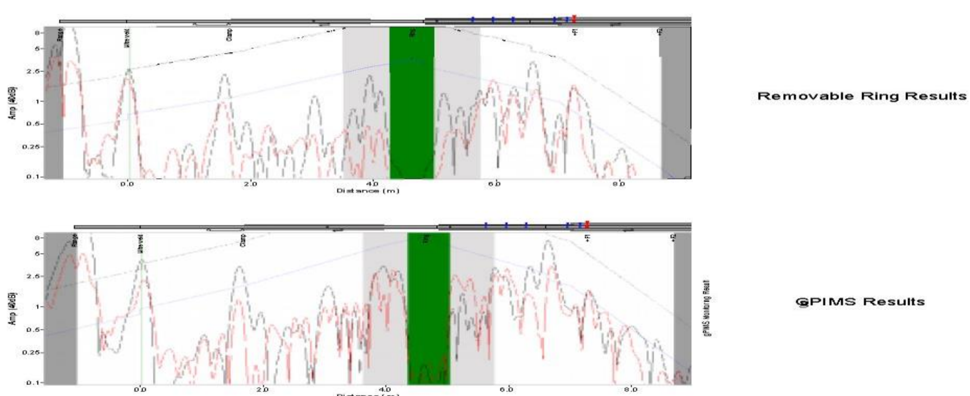

Figure 12: direct comparison of 2009 and current results from 14" gas riser-Results from at FR 7.6 and 0 BW

13. 6” Condensate Riser - PEC results:

The post processing doesn’t make any evidence of deep corrosion in the inspected areas as shown in Figure 13. Based on the inspection results the section of pipe inspected is generally in a good condition, with a minimum value of average remaining wall thickness around 92-98% randomly distributed, Some not critical wall loss has been found at 1.6-1.7 m height and at 1.9-2.0 m height along longitudinal direction, all around the section between 11-01 hours, with value in a range of 78-84% and worst critical point at 1.6 m height with a remaining WT of 77.8%. The wall thickness matrix in the next paragraph provides further details of the measurements performed as well as the conversion in absolute value.

Vert. Pos. (Y)	Longitudinal Position (hr)											
[mm]	1	2	3	4	5	6	7	8	9	10	11	12
2200			97.1			95.0			94.5			97.0
2150												
2100			94.4			90.2			90.6			90.7
2050												
2000	83.8		88.6			81.3			80.9		84.7	85.7
1950	82.4		88.9			90.7			87.5		78.6	79.6
1900	86.6		86.3			91.7			88.0		83.8	83.0
1850	94.4		94.1			93.6			92.5		85.0	93.5
1800	94.8		94.3			95.3			94.7		86.5	94.6
1750	94.5		96.8			94.9			94.4		93.6	95.8
1700	96.1		89.8			93.3			92.2		94.3	81.4
1650	88.9		90.1			94.1			88.3		94.8	79.4
1600	77.8		90.2			92.4			88.8		82.0	83.0
1550	82.5		90.4			92.1			88.5		84.4	83.4
1500	83.7		90.1			91.6			88.3		85.0	83.8
1450	84.6		91.5			91.4			87.9		84.7	83.5
1400	85.1		91.2			90.2			88.3		84.1	84.0
1350	85.5		90.9			89.9			87.4		84.7	84.3
1300	84.8		91.6			89.7			87.7		84.5	84.5
1250	86.1		91.4			89.5			87.9		84.8	85.0
1200	85.9		91.2			89.6			87.7		85.3	84.8
1150	86.6		91.8			89.4			87.5		85.5	85.1
1100	86.2		92.2			88.9			87.6		86.1	85.0
1050	86.8		92.6			88.7			87.4		85.5	85.6
1000	86.5		92.5			88.3			86.7		85.8	85.4
950	87.0		92.7			88.5			86.6		86.0	85.9
900	86.3		92.3			87.5			86.3		86.1	86.0
850	87.3		92.7			87.4			86.7		85.3	86.5
800	87.6		92.5			86.9			87.4		84.4	86.3
750												
700	89.2		93.3			85.7			86.9		84.4	86.2

Vert. Pos. (Y)	Longitudinal Position (hr)											
[mm]	1	2	3	4	5	6	7	8	9	10	11	12
2200			7.7			7.5			7.5			7.7
2150												
2100			7.5			7.1			7.2			7.2
2050												
2000	6.6		7.0			6.4			6.4		6.7	6.8
1950	6.5		7.0			7.2			6.9		6.2	6.3
1900	6.8		6.8			7.2			6.9		6.6	6.6
1850	7.5		7.4			7.4			7.3		6.7	7.4
1800	7.5		7.4			7.5			7.5		6.8	7.5
1750	7.5		7.6			7.5			7.5		7.4	7.6
1700	7.6		7.1			7.4			7.3		7.4	6.4
1650	7.0		7.1			7.4			7.0		7.5	6.3
1600	6.1		7.1			7.3			7.0		6.5	6.6
1550	6.5		7.1			7.3			7.0		6.7	6.6
1500	6.6		7.1			7.2			7.0		6.7	6.6
1450	6.7		7.2			7.2			6.9		6.7	6.6
1400	6.7		7.2			7.1			7.0		6.6	6.6
1350	6.8		7.2			7.1			6.9		6.7	6.7
1300	6.7		7.2			7.1			6.9		6.7	6.7
1250	6.8		7.2			7.1			6.9		6.7	6.7
1200	6.8		7.2			7.1			6.9		6.7	6.7
1150	6.8		7.2			7.1			6.9		6.8	6.7
1100	6.8		7.3			7.0			6.9		6.8	6.7
1050	6.9		7.3			7.0			6.9		6.8	6.8
1000	6.8		7.3			7.0			6.9		6.8	6.7
950	6.9		7.3			7.0			6.8		6.8	6.8
900	6.8		7.3			6.9			6.8		6.8	6.8
850	6.9		7.3			6.9			6.9		6.7	6.8
800	6.9		7.3			6.9			6.9		6.7	6.8
750												
700	7.1		7.4			6.8			6.9		6.7	6.8

Fig 13: PEC results sample

14. PEC INSPECTION RECOMMENDATIONS

The results of inspection make in evidence the good condition of underwater section of risers; it’s a different situation on the above water area, where both risers have significant loss of material as per map in the previous figures. The lacks of previous PEC inspections suggest creating and maintaining periodical monitoring of the 14” and 6” risers corrosion process; based on that, it could be convenient monitoring every 12 months wall loss to minimize every risk and hazard consequent to corrosion process., a first new monitoring is strongly suggested earlier (6 months) to check if any fast corrosion process is in act. In case of future Armawrap reposition or substitution, we suggest to performing a spotted UT testing, comparing the results with the previous values listed in this report.

15. POSSIBLE DEFECTS & DEGRADATIONS

Different screening techniques for screening inspection have different defect detecting and sizing capabilities, and they may have to be applied selectively to specific geometries. Planning a screening inspection will therefore almost certainly require detailed consideration of the types and locations of defects which may be present. Examples of defects or degradation which may be required to be detected and characterized include, but are not limited to:

1. General corrosion over the whole area.
2. Corrosion under supports
3. Corrosion under insulation
4. Local corrosion
5. Pitting.

It is important to consider the different and possibly unusual defect morphologies which can occur (e.g. microbiological induced corrosion) since these aspects can influence the selection and capability of screening inspection techniques.[5]

16. PRACTICAL PERFORMANCE COMPARISON FOR GW & PEC

Standing on the field trails and completed lecture survey [5, 10, 11], the inspection effectiveness score is computed using weighted score of the following parameters:

1. GW & PEC Inspection Effectiveness.
2. Capabilities of GW & PEC.
3. Sensitivity & Minimum Detectable Defect.
4. GW & PEC Access Restrictions.
5. GW & PEC Applications.

Technique	Inspection Effectiveness			Other significant considerations
	General Corrosion	Pitting	Erosion	
Guided Wave maker (GW)	High	Low	High	Only applicable to pipes (not suitable for vessels). Applicable to CUI (provided probe array can be mounted on a section of bare pipe).
Pulsed Eddy Current (PEC)	High	Low	Medium	CUI capability. Application is slow.

Table 3: Screening Technique Inspection Effectiveness[5]

Technique	Wall thickness [mm]	Material	Temperature Range
Guided Wave maker (GW)	Up to 75 mm	Inspectable Materials include all metals. Coatings: Polyurethane foam, Mineral wool, Epoxy coated, Tar epoxy coated, PVC coated, Painted.	Up to 180°C
Pulsed Eddy Current (PEC)	2-35 mm Insulation thickness up to 200mm	Carbon steel Low alloy ferromagnetic metals.	-150 to 500°C

Table 4: capabilities of screening techniques[5]

Technique	Access restrictions	Limitations
Guided Wave maker (GW)	Approximately 50mm clearance around pipes to attach ring transducers	Access to a surface is needed (25cm length). Cannot pass through flanges Pipes coated with attenuative coatings can reduce range.
Pulsed Eddy Current (PEC)	A clearance of 1.5 x the insulation thickness.	The PEC wall thickness is an average over its ‘footprint’. The size of the footprint area depends on the distance between probe and metal surface.

Table 5: GW & PEC Access Restrictions[5]

Technique	Applications	Inspection Time
Guided Wave maker (GW)	Most suitable for inspection of long, un-flanged lengths of pipe diameters from 16mm - 1800 mm.	About 1 minute per measurement. 30m coverage from one location is realistic.
Pulsed Eddy Current (PEC)	PEC is a screening tool for inspecting remaining wall Thickness under coatings and insulations.	Each spot measurement Takes 2-4 seconds 2000 points per 10 hour shift.

Table 6: GW & PEC Applications [5]

17. RECOMMENDATIONS

General; Riser system external corrosion management and monitoring systems should efficiently be carried out in such a way as not to allow riser deteriorate to a point where there is a high risk of failure for high consequence systems (High Pressure Gas systems). So, optimizing the inspection systems of the risers at the splash zone areas can greatly reduce the task efforts and assure riser's integrity. According to the last inspection results (Reference to Appendix),The Integrity Management best practice for splash zone of risers is the combination of periodic inspection GW & PEC where GW is a screening tool while subsea PEC is measurement tool to confirm the integrity of localized areas but both don't require removing the Aramwrap. GW technique is rapid screening technique that has advantage above traditional UT wall thickness inspection for the sake of avoiding the removing of Aramwarp in the splash zone areas as its self a risky job and when they are applied with common sense they can save time, reduce risk and can be a major financial cost saver. The paper concluded that new risers could be designed with space allowance in the splash zone area for the application of guided waves sensor collar to provide continuous monitoring system and assurance accordingly. In the meantime, GVI to be applied frequently on the risers at the splash zone areas to assure the integrity of the protective wrapping or coating at the splash zone areas and PEC to be applied in case of any defect identified. This GVI to be carried out by diver or ROV assistance in splash zone area (± 2 M of sea level). **Guided wave Inspection Technique;** Corrosion damage is always a loss of the cross-section. Because this guided waves technique is a screening tool, an indication is sized in percentage Estimated Cross-sectional Loss (ECL). Further investigations are required to better characterize the interactions between guided waves propagating along a pipe and other more complex types of supports, such as clamps and saddle supports (i.e.: vibration greatly affect), In particular, the formation of corrosion deposits at the touch points between a pipe and its supports is likely to significantly alter the mechanical and geometrical properties of the contact interface and to lead to variations in the echo from contact supports. A better characterization of the dependence of the echo from contact supports from the presence of corrosion deposits at the contact interface could prove crucial for the early detection of touchpoint corrosion. **Subsea PEC Inspection Technique;** To monitor risers, caissons or subsea piping at any given moment an on-stream measurement can be taken with PEC. In the splash zone the probe can be handled with a riser tool, rope access operators or even a diver. The subsea part obviously is the territory for divers or for ROV's. On forehand the number of measurements or grid is agreed with the client. One cycle of a measurement will take a few seconds although ROV use will slow down the inspection speed. **GVI**; Visual inspection is simple and less technologically advanced compared to other methods. Despite this, it still has several advantages over more high-tech methods. Compared to other methods, it is far more cost effective. The GVI results reveal and confirm the riser's integrity at the time of the inspection. This means that if the installed Armawarp were in acceptable condition and their integrity had been confirmed consequently the riser integrity is also confirmed.

Important Note: Before deciding whether to perform a screening inspection, it must be established whether the required information can be obtained from the inspection.

18. OPTIMIZATION OF INSULATED OFFSHORE RISER INSPECTION REGIME

1. Preform General visual inspection (GVI) covers the splash zone area of the riser (+ 3m waterline).
2. If the GVI results revealed that there is a breakdown or damage in the protective coating and or the Armawrap. Go step (4).
3. If the GVI results revealed that the installed Armawarp or the paint system was in acceptable condition and their integrity had been confirmed, consequently the riser's integrity shall be confirmed at the time of the inspection.
4. Apply the Guided wave inspection technique (GW).
5. In case of any sign of corrosion or thickness reduction. Go step (7).
6. In case no sign of corrosion or thickness reduction found extend the inspection frequency upon this condition and note that the next inspection frequency is standing on the company Technical Authority.
7. Apply the subsea pulsed eddy current inspection technique (PEC) to identify the reduction % and thickness in mm.

8. Perform Fitness for service study (FFS) and check the remaining thickness then rectify if required.

19. ABBREVIATIONS

ADT	Air Diving Team
CVI	Close Visual inspection
CML	condition monitoring location
CUI	corrosion under insulation
DPR	Daily Progress Report
GVI	General Visual Inspection
g-PIMS	Guided wave permanent installed management system.
GW	Guided wave
LT	long term
MOC	management of change
MAWP	maximum allowable working pressure
MDR	manufacturer's data reports
MT	magnetic-particle technique
NDE	nondestructive examination
NDT	Non-Destructive Testing
NWT	Nominal Wall Thickness
PQR	procedure qualification record
PT	liquid-penetrant technique
PEC	Pulsed Eddy Current
PPE	Personal Protection Equipment
RBI	risk-based inspection
RTP	reinforced thermoset plastic
RAT	Rope Access Team
ST	short term
SOW	Scope of Work
SMYS	specified minimum yield strength
UT	ultrasonic examination (method)
KP	Kilometer Point
PEC	Pulsed Eddy Current; typically used also for the relevant probe using the PEC method
Pig	Pipeline Inspection Gauge: is a tool that is sent down a pipeline for the internal inspection.
Probe	the device which permits to transmit and receive the magnetic field to/from the steel.
Profiler	acoustic instrument employed to explore the strata beneath the sea floor.
ROV	Remotely Operated Vehicle
Saddle	Support and centering system on the pipe
WT	Wall Thickness

20. REFERENCES

1. Glascock, J.D., R.D. Felkner, and G.M. Holmes, *Method for the ultrasonic inspection of pipe and tubing and a transducer assembly for use therewith*. 1996, Google Patents.
2. Cook, H., et al. *Riser Integrity Management for Deepwater Developments*. in *Offshore Technology Conference*. 2006. Offshore Technology Conference.
3. Leong, A., et al., *Overwrap composite repairs of offshore risers at topside and splash zone.* Proc. Int. Comm. Compos. Mater.(ICCM-18), Jeju Island, Korea Int. Comm. Compos. Mater, 2011.
4. Davey, V.S., et al., *Non-destructive Examination of Underwater Welded Steel Structures: IIS/IIW Document V-1097-97 (IIS/IIW-1372-97).* Vol. 1372. 1999: Woodhead Publishing.
5. Hardie, F., *Evaluation of the effectiveness of non-destructive testing screening methods for in-service inspection.* Doosan Babcock Energy Limited, 2009.
6. Slomp, E. *Subsea PEC: the NDT diverless robotic system for the pipeline corrosion inspection by the PEC method*. in *Abu Dhabi International Petroleum Conference and Exhibition*. 2012. Society of Petroleum Engineers.
7. Cawley, P., et al., *Practical long range guided wave inspection-applications to pipes and rail.* Materials evaluation, 2003. **61**(1): p. 66-74.
8. Reber, K. and A. Bönisch. *Inspection of unusual pipe types with eddy current technologies*. in *PPS A Seminar, Aberdeen November 17th*. 2010.
9. Tian, G.Y., et al., *Multiple sensors on pulsed eddy-current detection for 3-D subsurface crack assessment.* IEEE Sensors Journal, 2005. **5**(1): p. 90-96.
10. Goldsmith, B., E. Foyt, and M. Hariharan. *The role of offshore monitoring in an effective deepwater riser integrity management program*. in *ASME 2007 26th International Conference on Offshore Mechanics and Arctic Engineering*. 2007. American Society of Mechanical Engineers.
11. Gallen, C., et al., *Towards development of a rapid and effective non-destructive testing strategy to identify brominated flame retardants in the plastics of consumer products.* Science of The Total Environment, 2014. **491**: p. 255-265.