INTRODUCTION TO AQUA MTM ®

TECHNOLOGY

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1.0 OVERVIEW OF AQUA MTM ® TECHNOLOGY

The diagnostics of technical condition of steel pipelines not subject to an intrusive inspection method still remains a complicated problem around the globe. Transkor-K has taken the challenge to further step into research and development (R & D) to develop and eventually successfully invented the technology (Non-Contact Magnetometry Tomograpy Method (MTM)) to inspect the technical condition of the pipeline especially those which are not compatible with the intrusive inspection method.

The technology of AQUA MTM ® was developed by LLC RDC Transkor-K, based in Moscow, Russia which in collaboration with PETRONAS Carigali of Malaysia under Joint Development Agreement (JDA) project debut in 2008 which the objective is to make the existing Non – Contact MTM technology to be able to work under the subsea condition. After almost three years of continuous commitment and endeavor from the JDA team, the AQUA MTM ® technology finally has been materialized and was officially launched in end of 2011.

The basis of the AQUA MTM ® technology is a fundamental physical phenomenon; ***magneto-mechanical*** and ***magneto-elastic*** effects. This phenomenon is a direct relation of ***magnetic*** and ***mechanical characteristics*** of ferrous magnetic materials. In conditions of change of mechanical stresses concentration (σ) caused by the mechanical forces (*P)* influence such as stretching, pressing, bending and twisting upon ferrous magnetic objects, the change of their magnetic penetration (μ) will takes place – a magnetic anomaly appears.

During AQUA MTM ® inspection, the changes of local mechanical stresses are evaluated according to the vector of directivity and pipeline magnetic field strength level – on the basis of ***magneto-mechanical effect***. An integral risk factor (F), or commonly referred as ***danger degree*** of a defect/anomaly is evaluated both by its geometric parameters and the level of local mechanical stresses in the defective area.

The AQUA MTM ® inspection does not require special equipment, preparation (equipping of pipeline with pig trap, cleanout, geometry inspection, pipeline inner surface preparation, route marking), contact with a pipeline or changes of pipeline operation mode before the inspection.

AQUA MTM ® inspection is suitable for any pipeline with ferrous magnetic properties especially the non-piggable subsea pipelines or any subsea pipelines which not require an intrusive inspection method due to operation limitation.

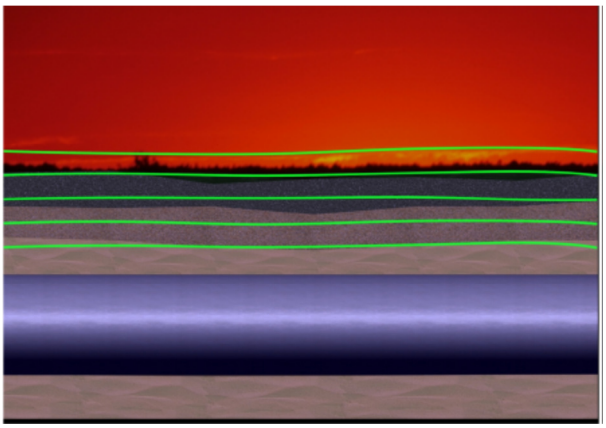


Figure 1: Magnetic Properties of ferrous magnetic pipe WITHOUT SRESS

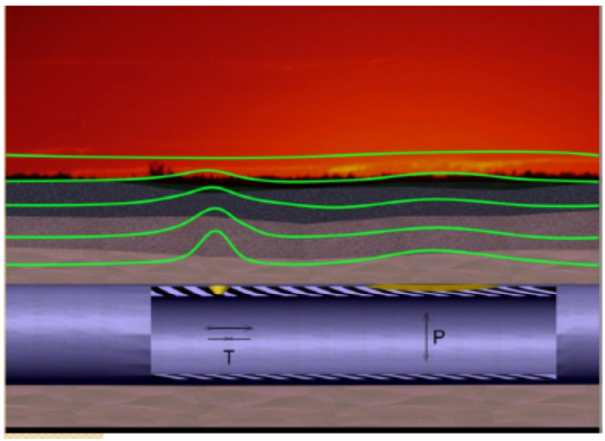


Figure 2: Magnetic Properties of ferrous magnetic pipe WITH SRESS

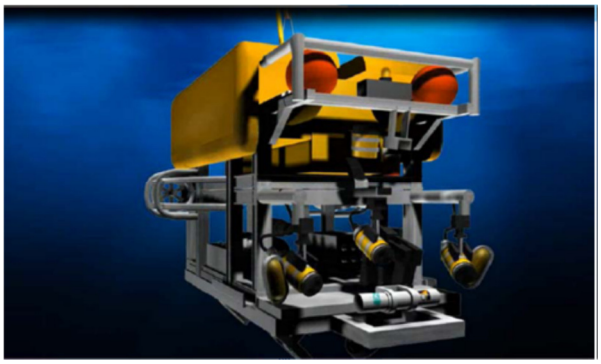


Figure 3 : AQUA SKIF with Remote Operated Vehicle (ROV)

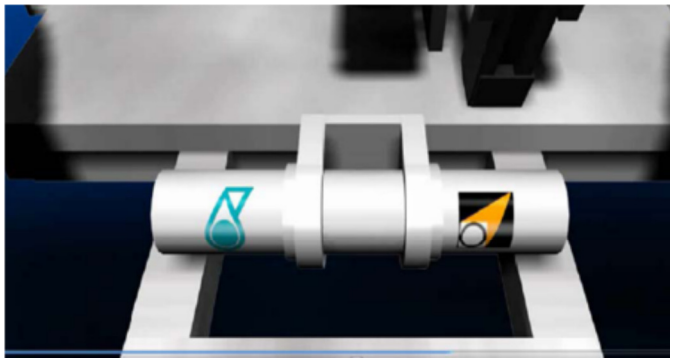


Figure 4 : AQUA SKIF attached to the ROV

Figure 5 : Deployment of AQUA MTM ® inspection from service vessel

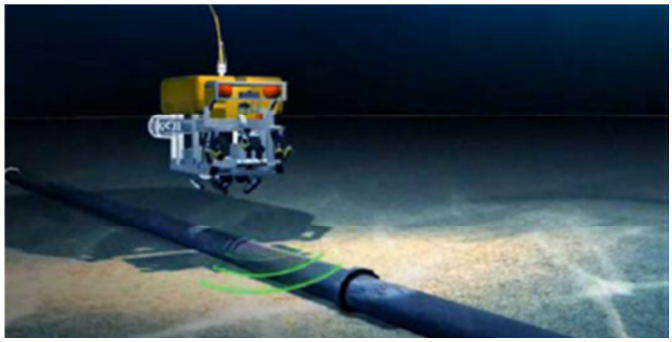


Figure 6 : AQUA MTM ® inspection on action

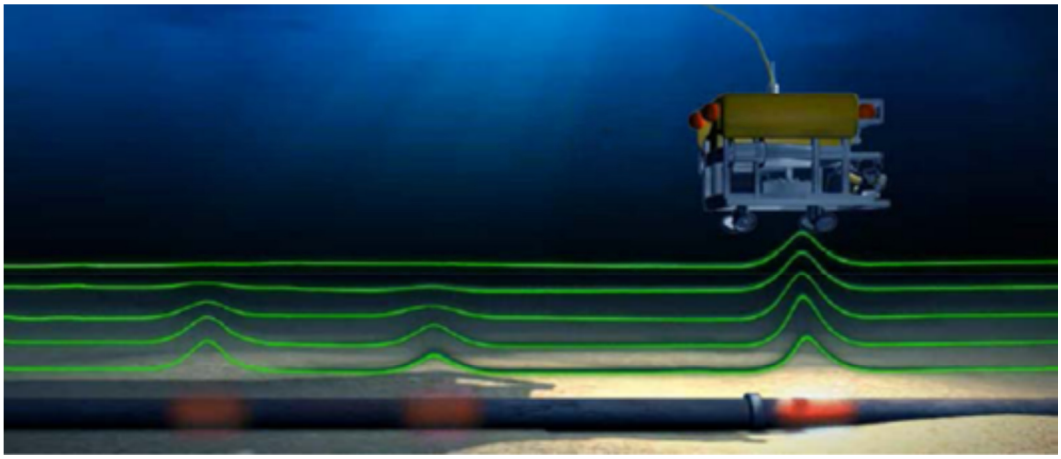


Figure 7 : AQUA MTM ® inspection on action

2.0 AQUA MTM ® ACCEPTANCE CRITERIA

Item	Parameter Description	Criteria / Limitation
1	Maximum operating depth	Maximum of 200 m
2	Maximum distance from the magnetometer to the inspected pipeline	Maximum 15 Diameter of the pipe
3	Maximum deviation of SKIF :- • Along X-axis, ex • Along Y-axis, ey • Along Z-axis, ez	 < 0.5 D < 0.5 D < 0.5 D
4	Stability of scanning (admissible angle around axis) • Around X-axis, αx • Around Y-axis, αy • Around Z-axis, αz	 $\leq 5^{o}$ $\leq 5^{o}$ $\leq 5^{o}$
5	Minimum diameter of inspected pipeline	75 mm (3”)
6	Maximum diameter of inspected pipeline	No limitations
7	Minimum pipeline wall thickness	3 mm (1/8”)
8	Maximum pipeline wall thickness	No limitations
9	Pipeline magnetization level	≤ 100 A/m
10	Maximum operating pressure	No limitations
11	Maximum speed during inspection	2.5 m/s (6.5’ per sec)

3.0 AQUA MTM ® ADVANTAGES

3.1 Does not require special equipment, preparation (equipping of pipeline with pig trap, cleanout, geometry inspection, pipeline inner surface preparation, route marking)

3.2 Does not require direct contact with a pipeline or changes of pipeline operation mode before the inspection.

3.3 It provides corrosion (and other) monitoring of defects development

3.4 It allows comparing sections with different types of defects by relative level of stress deformed condition and substantiating a repair schedule on the basis of serviceability calculations for the actual operation conditions of an object

3.5 It makes the technical audit and calculations of conditions for insuring dangerous industrial objects available

3.6 Suitable for any pipeline with ferrous magnetic properties especially the non-piggable subsea pipelines or any subsea pipelines which not require an intrusive inspection method due to operation limitation

4.0 REQUIREMENT FOR TECHNICAL FACILITIES OF AQUA MTM ® INSPECTION

The essential parameters of Aqua MTM ® are based on MTM parameters of quality :-

- Probability of Detection (POD)
- Probability of Identification (POI)
- Confident Level (CL)

Definitions of these and other parameters for AQUA MTM ™ application are given in Section 6.

4.1 AQUA MTM ® Guarantee

i) AQUA MTM ® inspection can be provided for 100% of pipeline length.

ii) AQUA MTM ® equipment (AQUA SKIF) is able to inspect horizontal pipeline with 100% of quality. Application of this equipment for riser inspection is not guaranteed, because of odometer (a device of AQUA SKIF underwater unit which is responsible for measuring distance and making the strobe fixing signal) is designed for horizontal movement of the unit, not vertical (See AQUA SKIF Specification in section 7.5).

iii) Within the range of mechanical stresses on defective sections of (**30 % - 85 %) of SMYS** the detection of anomalies associated with metal defects (POD) of any type is guaranteed with probability **more than 80 %** for the total pipeline length.

iv) **Maximum POD (> 85%)** is achieved at the level of stresses on defective sections of **(55 % -65 %)** of SMYS.

v) POD and POI values are proved if the condition of real MTM scanning complies with MTM Specification requirements. For this purpose parameter of Quality Control (QC) is determined after the scanning. Moreover, these guarantees are applied if calibration has been provided for each inspected pipeline.

vi) The dependence between magnetic reply and real mechanical stresses should be determined and verified in calibration pits. **Without calibration** the confident level (CL) of AQUA MTM ® quality **become lower by (10 % - 15 %)** than original values even with QC > 0.8.

Please refer to Table 1 on next page. This table was extracted from document; *MTM Specification and Requirement for MTM Inspection for Pipelines, Version 1.1 July 2011* produced for Aqua MTM project.

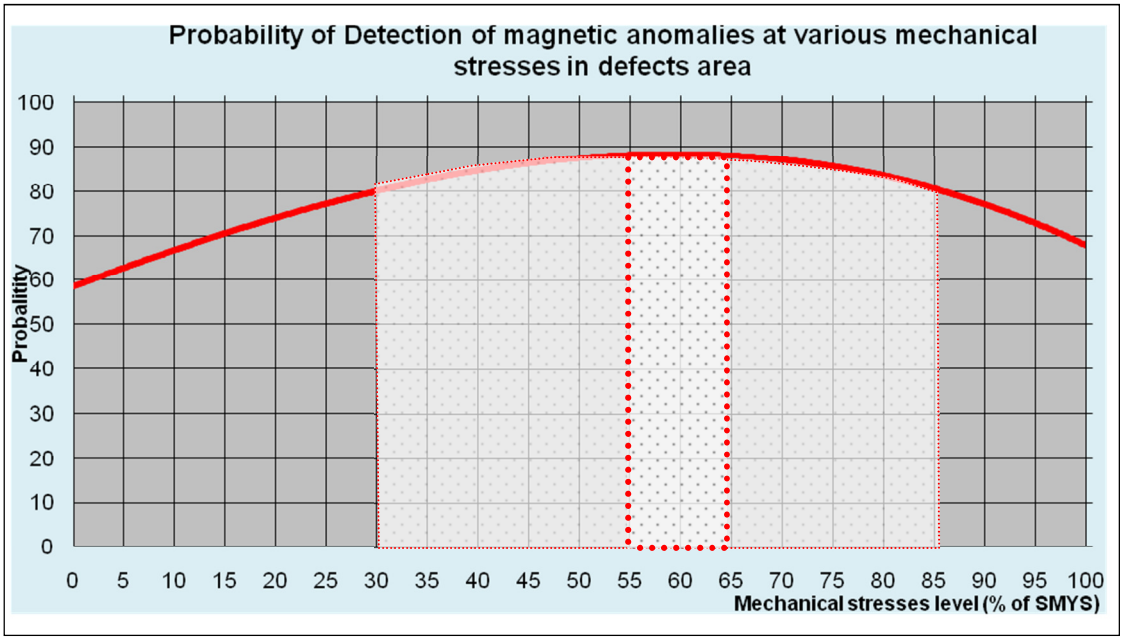


Table 1 :MTM probability of Detection (POD) versus stresses

5.0 AQUA MTM ® ASME – CORRELATION (Burst Strength Prediction)

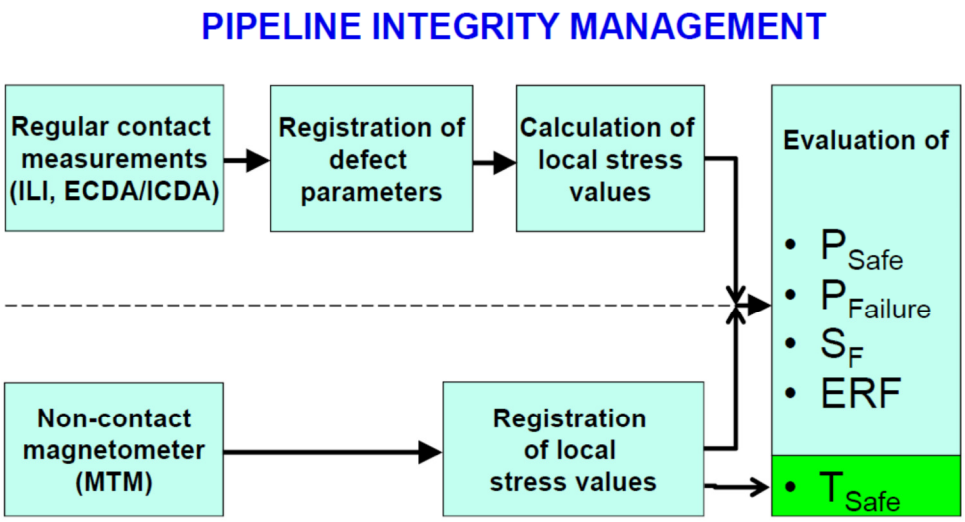
5.1 General

5.1.1 A pipeline has been chosen to interpret the AQUA MTM ® inspection results and derive maximum values for hoop stress, longitudinal stress and shear stress in the stress estimation document. On the basis of the stress estimation document, stresses have been linked with the burst strength theory to derive a set of equations that may be used to assess the burst strength of corroded pipe using the AQUA MTM ® inspection results.

5.1.2 The purpose of this work is to estimate the pipeline stress with defects under certain internal pressures and derive a theory/method that links AQUA MTM ® inspection results with ASME B31G stress estimation or equivalent ASME/API/DNV approach. Finite element analysis method (FEM) using an ABAQUS analysis approach was conducted to further verify the stress values registered by AQUA MTM ® and calculated by the above mentioned methods

5.1.3 **PETRONAS and TRANSKOR-K** had proposed to ASME committee during its presentation in Norfolk, Virginia, USA in September 2012 to make updates to **B31G** Code in the part of determining the Remaining Strength of Pipelines (Part 2. Evaluation method) in order to correlate the stress results from both inspection techniques.

This is because the remaining strength is determined by stress values (not a geometrical parameters of defects) as shows below.



5.2 **Experiment**

- A 350 feet pipe with artificial flaws of various types was tested.
- Internal pressure was manually changed from 1 MPa to 32 MPa in 9 steps.
- Mechanical stress in defective areas was controlled by means of strain gauges and as well measured by means of AQUA MTM ®.
- Integrity parameters were calculated at each defective area at each pressure value.
- The integrity parameters were compared to those calculated by other codes (since the flaw geometry was perfectly known)

Photo 1 : Strain gauge was placed at each defect

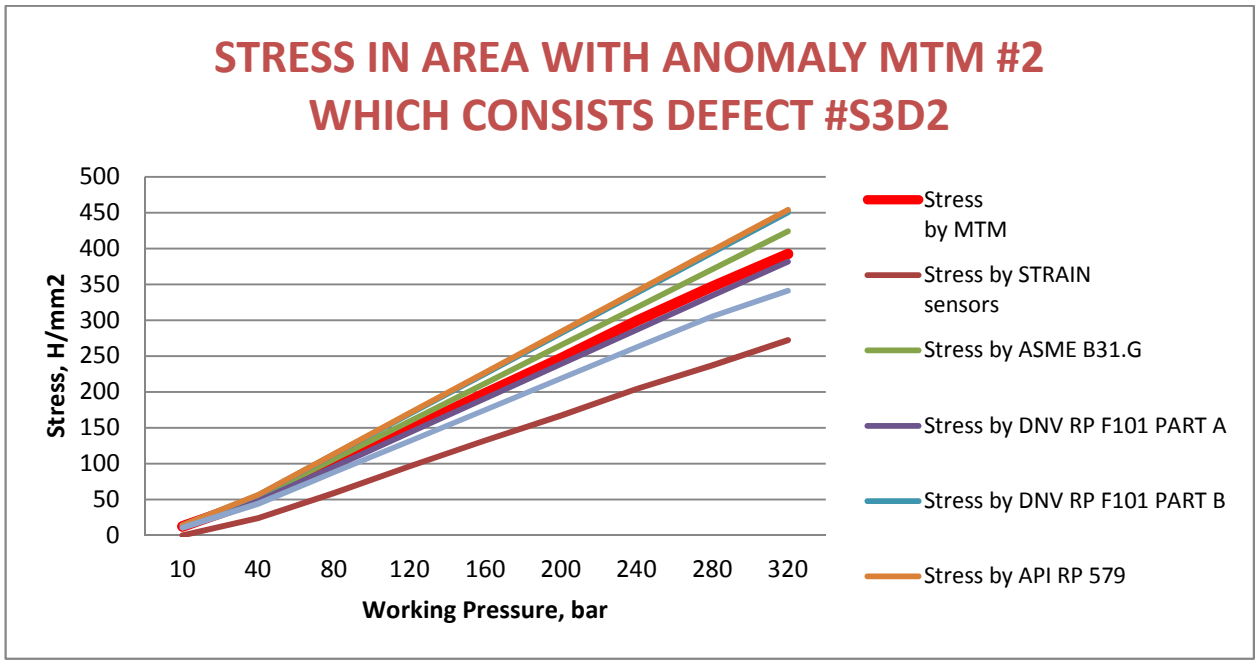
Photo 2 :The defect dimension was verified by a third party inspector

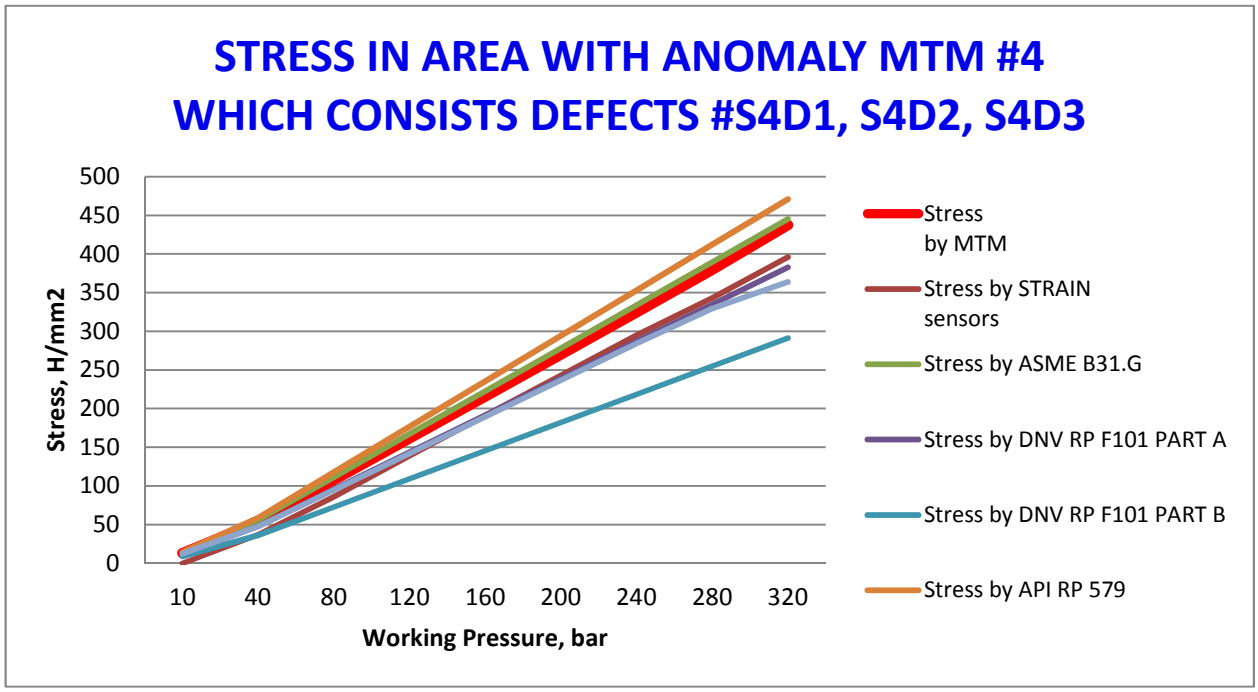
Photo 4 : Measuring background magnetic interference

Photo 3 : The test spool is ready for actual test

5.3 **Results**

5.3.1 The correlation results are shows as below :-





5.3.2 Pipeline mechanical stress values and integrity parameters obtained by means of MTM were consistently correlating well with corresponding values calculated by conventional international codes.

Defect No	Defect ID	POD	POI			
			Correlation, Average +- Standard Deviation (%)			
			ASME B 31.G	DNV RP F101 Part A	DNV RP F101 Part B	API RP 579
1	S3D1	100 %	99.7 ± 0.3	81.9 ± 7.0	97.6 ± 0.5	95.4 ± 12.7
2	S3D2	100 %	93.3 ± 0.4	96.4 ± 0.5	87.8 ± 0.4	87.1 ± 0.4
3	S3D3	100 %	98.4 ± 0.5	82.5 ± 2.1	47.5 ± 4.1	98.3 ± 0.5
4	S4D1; S4D2; S4D3	100 %	96.8 ± 0.8	87.4 ± 1.0	52.0 ± 1.3	91.5 ± 0.8
5	S4D4	100 %	95.0 ± 1.4	79.9 ± 1.6	98.8 ± 1.3	94.8 ± 1.5
6	S5D1; S5D2; S5D3	100 %	98.7 ± 0.8	83.7 ± 0.9	47.8 ± 1.2	90.6 ± 16.9
7	S5D4	100 %	93.0 ± 0.9	94.9 ± 1.0	60.0 ± 1.3	82.5 ± 0.8
8	S6D1; S6D2; S6D3	100 %	97.2 ± 0.8	85.9 ± 0.9	50.4 ± 1.2	93.9 ± 0.8
9	S6D4; S6D5	100 %	99.2 ± 0.6	87.9 ± 0.9	95.1 ± 0.8	93.1 ± 0.8
10	S7D1	100 %	90.4 ± 2.9	98.0 ± 1.5	65.5 ± 2.1	75.8 ± 1.2
11	S8D1; S8D2; S8D3	100 %	90.0 ± 0.6	96.9 ± 1.1	63.7 ± 1.3	82.3 ± 1.2
12	S8D4; S8D5; S8D6	100 %	96.6 ± 0.9	79.9 ± 1.0	98.6 ± 0.7	97.2 ± 0.9
Total on all anomalies		**100 %**	**96.0 ± 0.92**	**88.0 ± 1.64**	**72.0 ± 1.35**	**90.0 ± 3.19**

6.0 AQUA MTM ® PROJECT REFERENCES

Item	Client	Project	Length (km)	Year
1	PETRONAS CARIGALI – SABAH OPERATION (SBO)	Provision of AQUA MTM ® Inspection Work for Subsea pipelines in Sabah offshore, **MALAYSIA**	2.46	Sept 2011
2	PETRONAS CARIGALI – PENINSULAR OPERATION (PMO)	Provision of AQUA MTM ® Inspection Work for Subsea pipelines in Terengganu offshore, **MALAYSIA**	1.40	Dec 2012
3	PETRONAS CARIGALI – SARAWAK OPERATION (SKO)	Provision of AQUA MTM ® Inspection Work for Subsea pipelines in Sarawak offshore, **MALAYSIA**	99.00	Jan 2013
4	PETRONAS CARIGALI – PENINSULAR OPERATION (PMO)	Provision of AQUA MTM ® Inspection Work for Subsea pipelines in Terengganu offshore, **MALAYSIA**	98.80	April 2013
5	PETRONAS CARIGALI – PENINSULAR OPERATION (PMO)	Provision of AQUA MTM ® Inspection Work for Subsea pipelines in Terengganu offshore, **MALAYSIA**	32.00	April 2013
6	CHEVRON INDONESIA COMPANY	Provision of AQUA MTM ® Inspection Work for Subsea pipelines for CHEVRON in Balik Papan, Santan offshore, Kalimantan, **INDONESIA**	7.00	July 2013
7	PETRONAS CARIGALI – SABAH OPERATION (SBO)	Provision of AQUA MTM ® Inspection Work for Subsea pipelines in Sabah offshore, **MALAYSIA**	8.86	Oct 2013
8	PETRONAS CARIGALI – SARAWAK OPERATION (SKO)	Provision of AQUA MTM ® Inspection Work for Subsea pipelines in Sarawak offshore, **MALAYSIA**	11.81	Oct 2013
9	ADMA (UAE)	Provision of AQUA MTM ® Inspection Work for Subsea pipelines in Zakum field offshore, **UAE.**	3.5	Nov 2013
10	PETRONAS CARIGALI – SARAWAK OPERATION (SKO)	Provision of AQUA MTM ® Inspection Work for Subsea pipelines in Sarawak offshore, **MALAYSIA**	11.81	Oct 2014

THANK YOU