SUBSEA PIPELINE

EXTERNAL INSPECTION REPORT

Using MEC™ and UT

Prepared for

CLIENT

Final Report: K001-15INT-B

Rev	Document	Author		Checked		Approved By		Date
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Disclaimer

Contents

1. Executive Summary

The XXX pipeline was inspected with the MEC-Combi Crawler by means of Magnetic Eddy Current (MEC™) and ultrasonic wall thickness measurement (UT). The obtained inspection data is of very high quality.

The inspection of the subsea pipeline has revealed an early stage of internal pitting corrosion detected with the MEC technology. The depth of a few pits reaches 25% of the wall thickness. The affected areas run as axial bands along the pipeline. All inspected sections are affected with section B (Low Point) the most.

2. Inspection Execution

2.1. Task

Innospection Ltd. has been asked by Client to inspect several sections of subsea pipelines in the XXX field offshore Equatorial Guinea. The task was to scan the pipeline externally with the MEC-Combi Crawler on the full circumference to find internal corrosion. It was assumed that so-called channelling or 6 o'clock corrosion is present in the pipeline. As this type of corrosion can manifest itself as a chain of small pits as well as a smooth groove along the bottom of the line, a combination of MEC™ and UT corrosion mapping was chosen.

2.2. Inspection Object

The inspected API 8'' pipeline runs from the Manifold to the XXX FPSO in the XXX Oil field in West Africa. It has a length of 8128 m. The rigid steel pipe section is 7357 m with a nominal wall thickness of ½" (12.7 mm). It is externally coated with a three layer Polyethylene coating with a thickness of about 2 mm.

As a gathering line the XXX pipeline is non-piggable. It is accessible externally on the seabed at a water depth ranging from 205 m to 475 m. The schematics and the mapping of the pipeline are shown in Figure 1 and Figure 2.

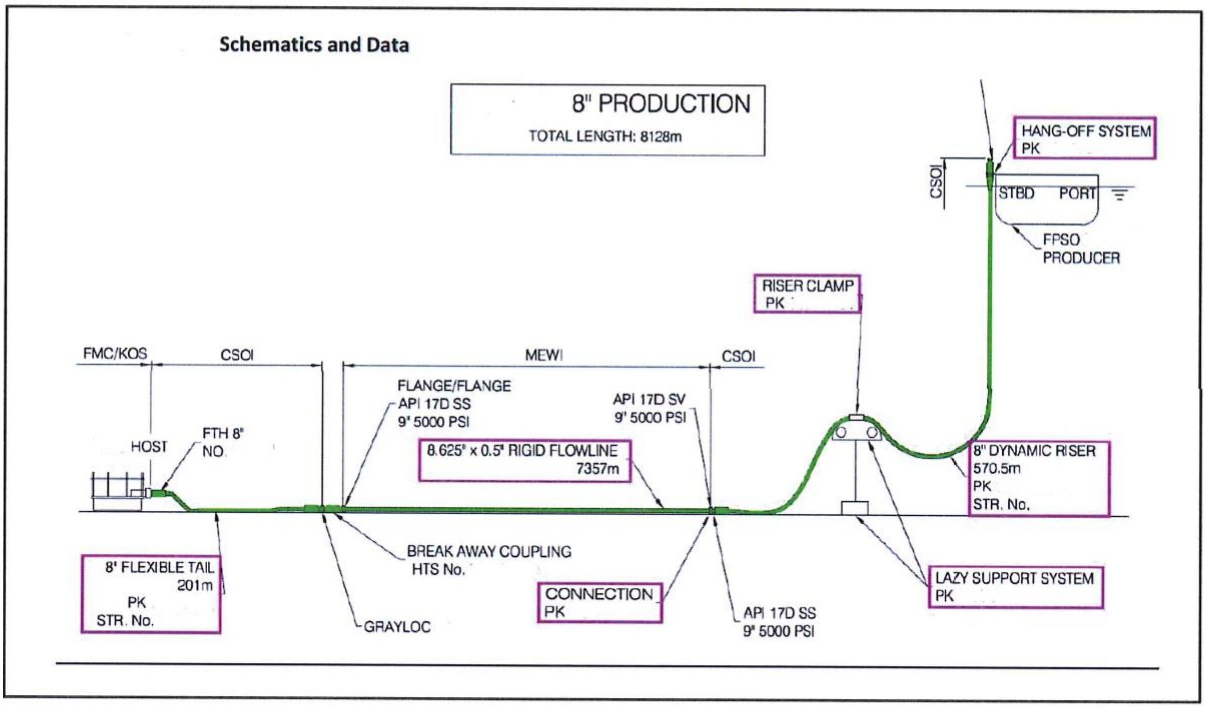


Figure 1: Schematics of the XXX pipeline

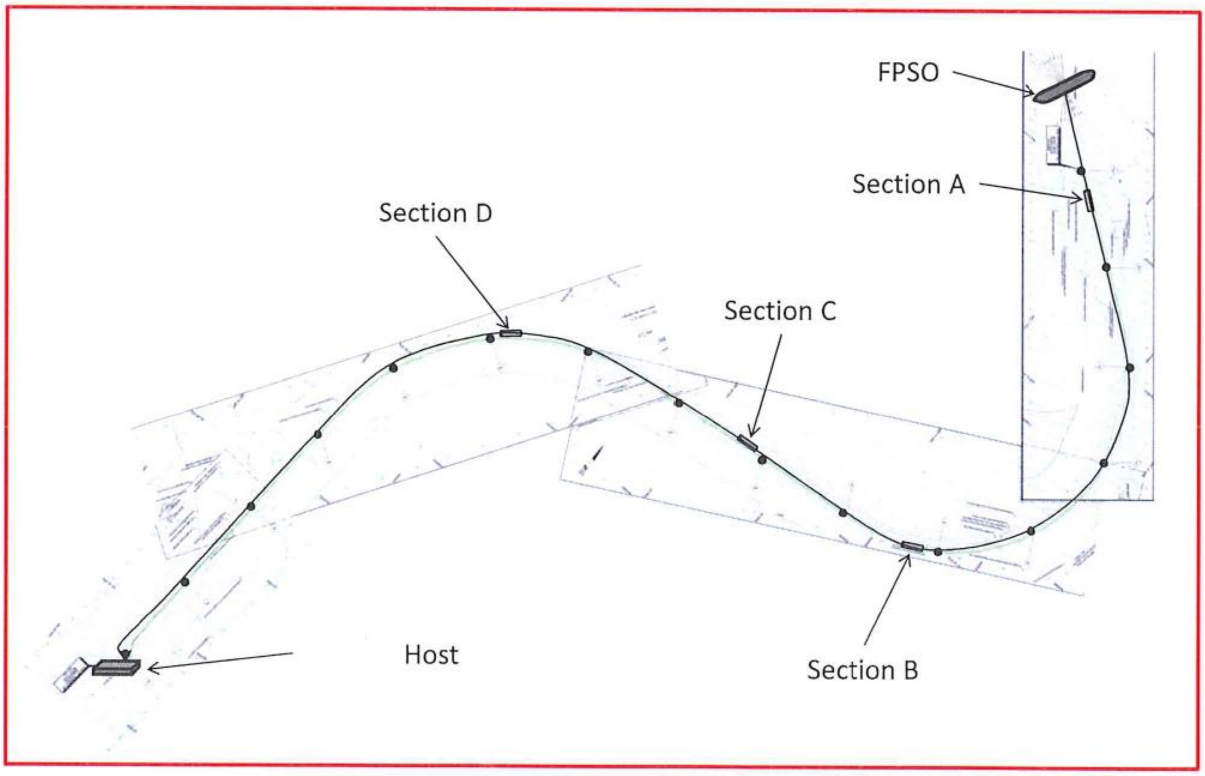


Figure 2: Map of the XXX pipeline.

2.3. MEC Equipment

The MEC™ inspection technology was used. For the subsea deployment a suitable tool (MEC Combi Crawler) was designed and built. The MEC Combi Crawler tool has the following technical parameters:

MEC Combi Crawler tool:	Hydraulically driven crawler to be attached to a horizontal or vertical pipe from the outside. The diameter is adjustable. The tool weight is 265 kg in air and 20 kg in water (adjustable by modular buoyancy). It has a length of 120 cm, a width of 60 cm and a height of 40.5 cm.
Sensors:	Eight Sensors of type FIT22. The unit covers a circumferential width of 180 mm.
Scanning Speed:	up to 30 m/min or 0.5 m/s
Eddy Current Instrument:	MEC-IQ Data System
Software Version:	Innospectit Version 2.6

For more detailed information on the MEC Combi Crawler system refer to Section 4.

2.4. Ultrasonic Equipment

To back the MEC technique up with absolute wall thickness and stand-off data, an ultrasonic sensor array system has been added to the scanner in combination with cameras.

Data Unit:	8x Sonotech S80
Probe:	10 mm Perpendicular Pulse-Echo Technique
Software:	Innospectit 2.61002

The sensor array was mounted onto the MEC-Combi Crawler tool and the data acquisition was performed in parallel to the MEC measurements. The width of the UT array is only half of the width of the MEC-Sensors.

2.5. Mobilisation and Preparation

Verification Test

The tool was tested in the Oceanlab in Newburgh near Aberdeen on the 28th and 29th of October 2015. The mechanical operation and the data acquisition were tested in a water pool. The operation was demonstrated to Client and ROV Supplier on the 29th of October 2015.

Inspection Team

The inspection team was made up of the following people:

L.S, NDT Technician (Eddy Current PCN Level 2 - 302070)
M.M, Electronic Support Technician
A.S, Project Manager

Mobilisation Dates

The equipment was mobilised on the 9th of November 2015 to ROV Supplier who organised the shipment to Equatorial Guinea. The inspection crew was mobilised on the 10th of December 2015. The crew was mobilised to the vessel on the 11th of December. The XXX pipeline was inspected on the 16th and 17th of December. The equipment was received back to Innospection operations on January 20th 2016.

Preparation and Cleaning

Prior to inspection, the pipeline sea bed had to be removed and the pipeline had to be cleaned. The seabed intervention was done by water suction. The resulting free span of the pipeline was smaller than planned, but sufficiently long for the full circumference inspection on a few meters.

The cleaning was first done with water jetting by the ROV. The final cleaning was done with a wire ("Cheese Wire Method").

Procedure for Calibration and Set-up

The preparation and inspection of the riser was done according to Innospection's procedures

- Inno-PSloPIP-001-08 - SLOFEC™ Inspection Equipment on External Pipe Applications - Rev 5
- Ultrasonic Inspection Procedure No. InnoUT-001-10Rev-1
- OP.151127XXXField-SubseaPipelines

The tool was calibrated on site with suitable calibration coupons. The calibration data was saved and later used to adjust the settings of the inspection data.

2.6. Execution and Performance

ROV Operation and Scanner Movement

A work class ROV of type Centurion 21HD was used for placing the MEC-Combi Crawler onto the pipe. Once deployed on the pipe the crawler can run in axial and circumferential direction to find the optimum position for inspection. The inspection is done by running axially. In some cases the run was rough due to imperfect cleaning. The passing over field coated areas (girth welds) was avoided. Hence no girth weld signals are visible at any position in the data. The length of the scan depended on the accessible length of the pipeline.

The resulting speed of the scanner was in the range of 0.2-0.3 m/s (12-18 m/min). A sample speed profile is shown in Figure 3 which is taken from scan 13 of section B.

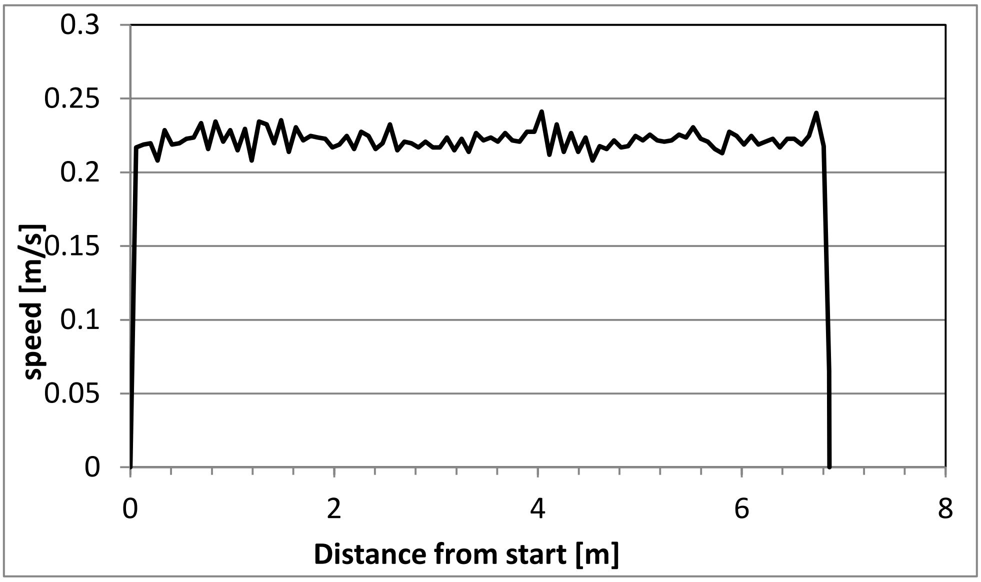


Figure 3: Speed profile of run B-13 (4 o' clock).

Sections and Tracks

Four sections have been selected for the inspection. From an integrity point of view they are most critical or most likely prone to internal corrosion. The location of the section is indicated in the pipeline route map in Figure 2. The direction of scanning has always been towards the FPSO, i.e. in the direction of flow.

Section	*Pipeline Position UTM Coordinates*	*Water depth and KP [m]*	*No. of tracks*	*Max. Distance covered [m]*	*Inspection Date/Time*	*Comment*
A	EXXXX NXXXX	217 m 0.2 km	13	4	17.12.2015 8:12 till 8:36	Riser (priority 2)
B	EXXXX NXXXX	390 m 2.6 km	19	8	16.12.2015 17:33 till 18:47	Low Point (priority 1)
C	EXXXX NXXXX	380 m 3.5 km	15	5	17.12.2015 13:19 till 13:44	Mid point (priority 4)
D	EXXXX NXXXX	362 m 5.2 km	15	6	17.12.2015 11:34 till 12:03	High Point (priority 3)

Table 1: Overview of Sections inspected on the XXXX Pipeline

Video Surveillance

The ROV as well as the MEC-Combi Crawler are equipped with video cameras. The video footage of the complete operation was saved and reviewed for the data analysis. The video yields information on cleanliness and smoothness of scanning motion.

Figure 4: Camera View on Section A of XXXX pipeline

Data Quality

The data quality is good for all three sets of data on all of the four sections. The video data is showing the tool deployment and scanning motion. In a few cases suspended dust impedes the view.

The Ultrasonic data shows only little echo and coupling loss. The UT stand-off data is sometimes affected by the coating. The detected entry echo may refer to the surface of the steel pipe or the polymer coating. Keeping this in mind, all values can be interpreted correctly. The unevenness of the coating is often visible in the stand-off data of the UT scan. The wall thickness data shows nominal wall thickness most of the time. The echo loss ratio is less than 5%.

The MEC data is of high quality. Due to the high overlap all positions on the pipe have been covered at least twice and in some cases four times.

3. Results

The following pages show the scan results. The distance starts at the datum point and runs in the positive directions towards the FPSO. The orientation increases clockwise when looking downstream. The conversion of o'clock position to degrees is shown in the upper left corner. Here 3 o'clock corresponds to an orientation of 90º. The MEC data and the UT data do not correspond exactly in the position for two reasons. First the Sensors are offset to each other. In addition the data recording is not started at exactly the same time. Tracks may thus differ slightly in length and position. There is one wall thickness legend for the MEC data in % of the wall thickness and one in mm for UT. The standard stand-off happens to be in the range of the nominal wall thickness; hence only one colour code is used for UT. In the UT colour code loss of echo is displayed as zero wall thickness in dark colour. Also there are a few echo misinterpretations due to the coating leading to some steps or unreasonably low values (in particular in Section B 11 o'clock). Refer to list of indications (3.5) for detected defects.

3.1. Section A

3.2. Section B

3.3. Section C

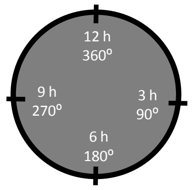
3.4. Section D

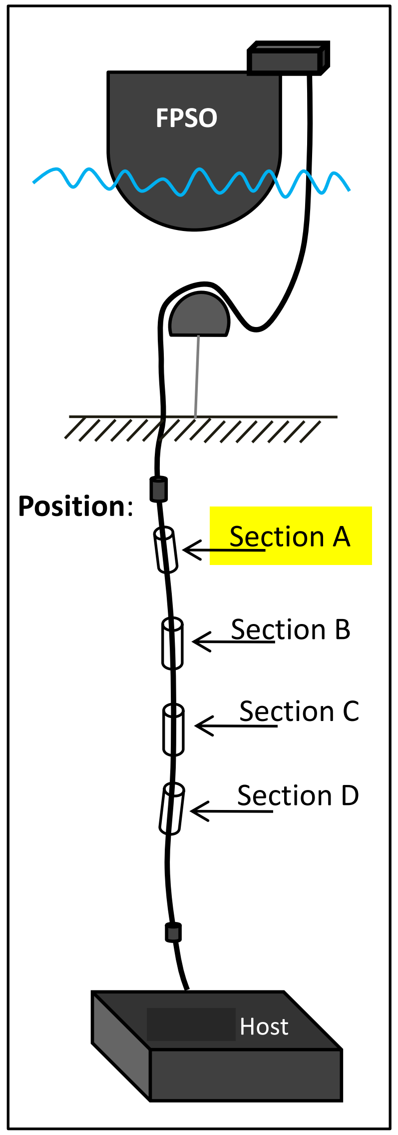
Client Field

MEC and UT subsea pipeline inspection report

Location (East) Section A

Direction of Scan: Towards FPSO/ in direction of flow

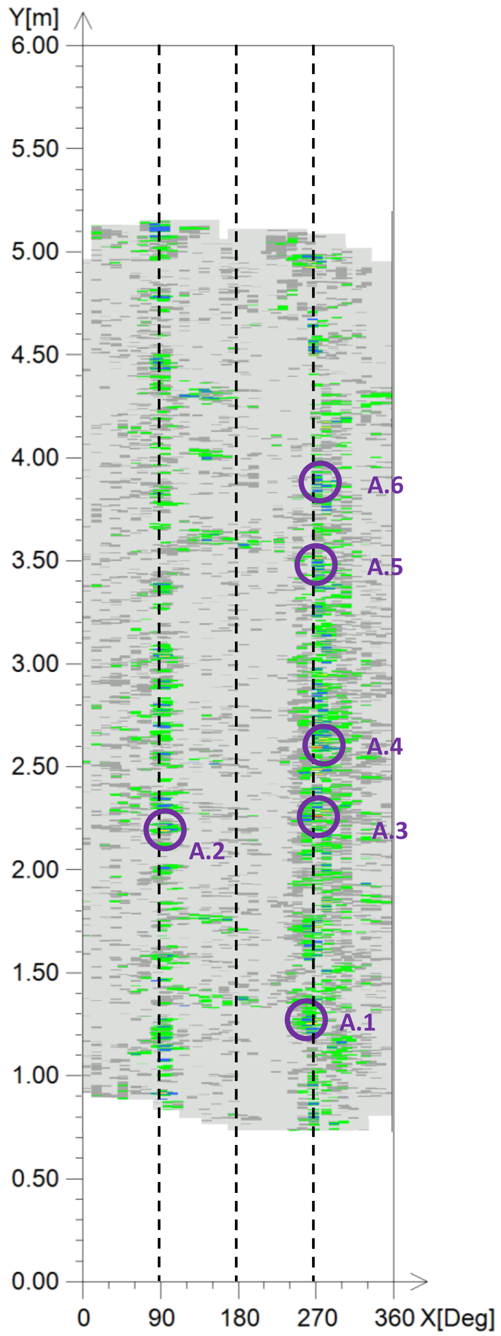




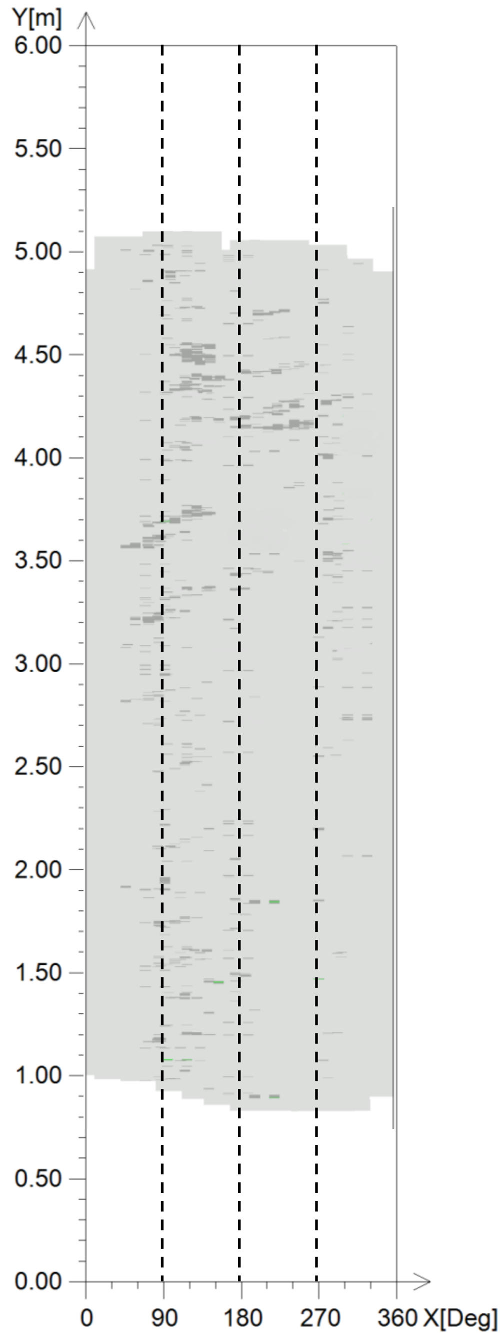
Results:

Two lines of pitting corrosion found at 3 and 9 o'clock. Deepest pitting about 25% loss of wall thickness (A.5).

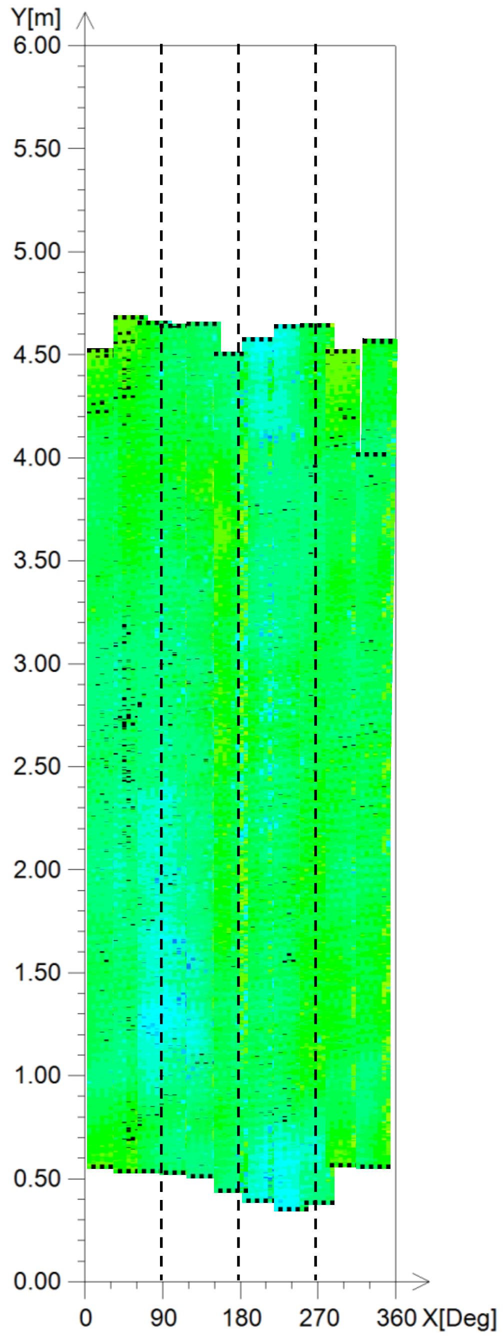
MEC-Data: Internal View



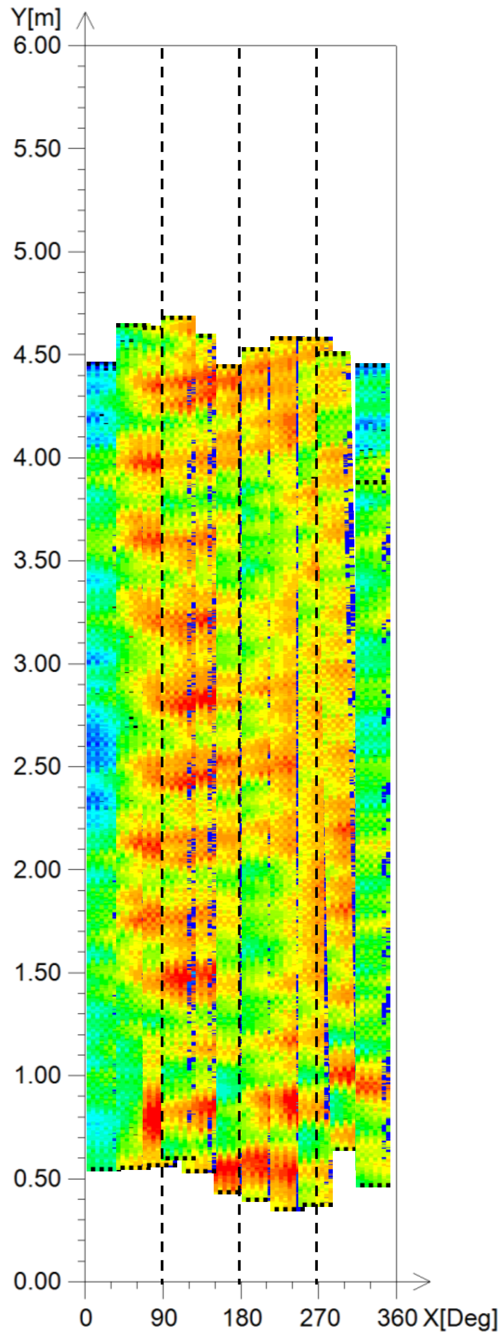
MEC-Data: External View



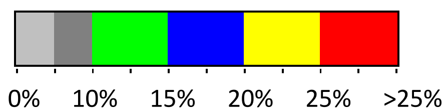
UT Data: Wall Thickness



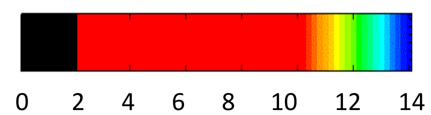
UT Data: Stand-off



MEC Legend
% Wall Thickness Loss



UT Legend
mm Wall Thickness and Stand-off

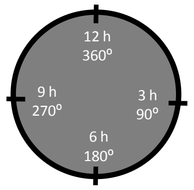


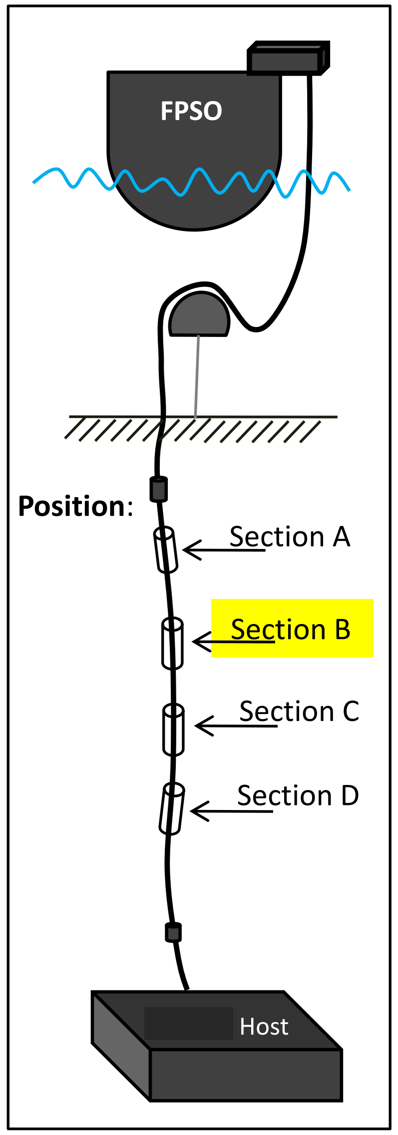
Client Field

MEC and UT subsea pipeline inspection report

Location (East) Section B

Direction of Scan: Towards FPSO/ in direction of flow

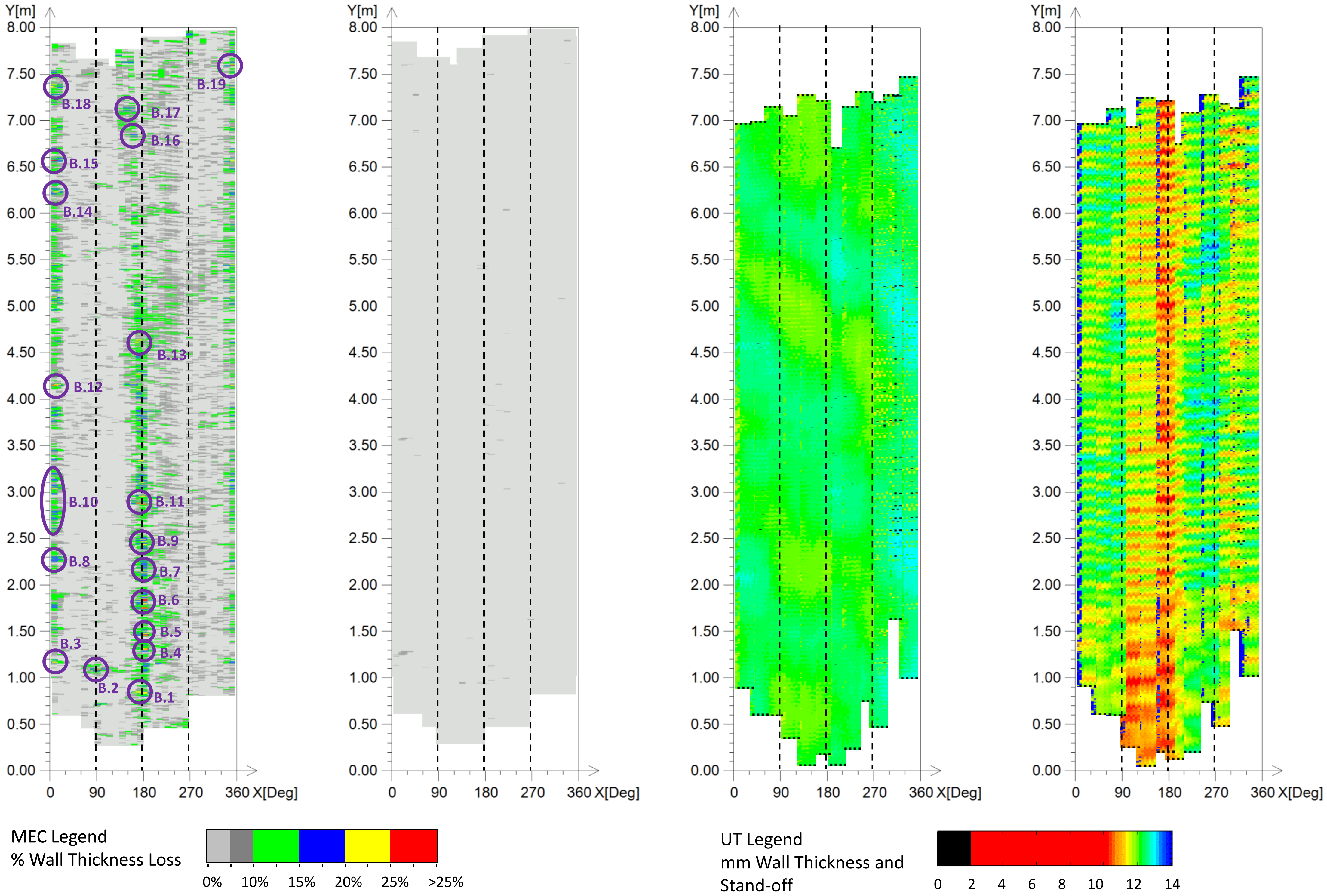




Results:

One line of intense pitting corrosion found at 6 o'clock with deepest pits above 25% wall loss. Another line found at 12 o'clock.

MEC-Data: Internal View | MEC-Data: External View | UT Data: Wall Thickness | UT Data: Stand-off

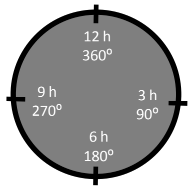


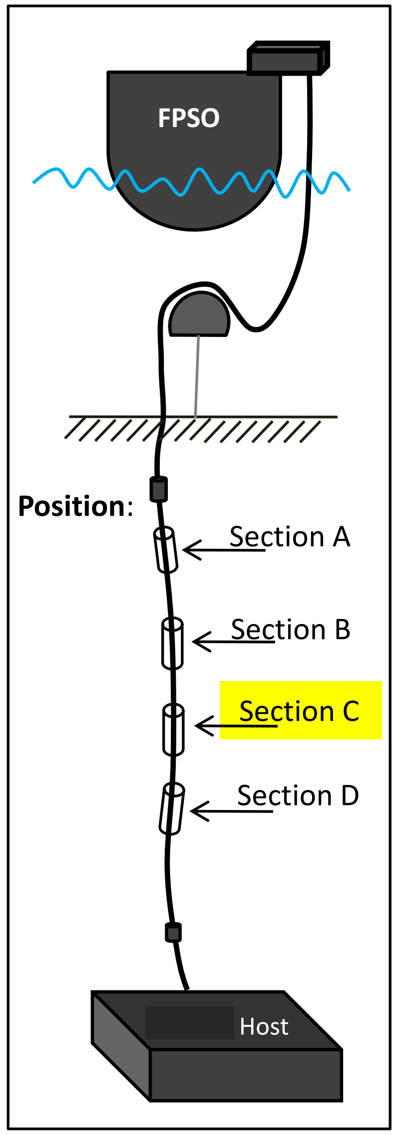
Client Field

MEC and UT subsea pipeline inspection report

Location (East) Section C

Direction of Scan: Towards FPSO/ in direction of flow

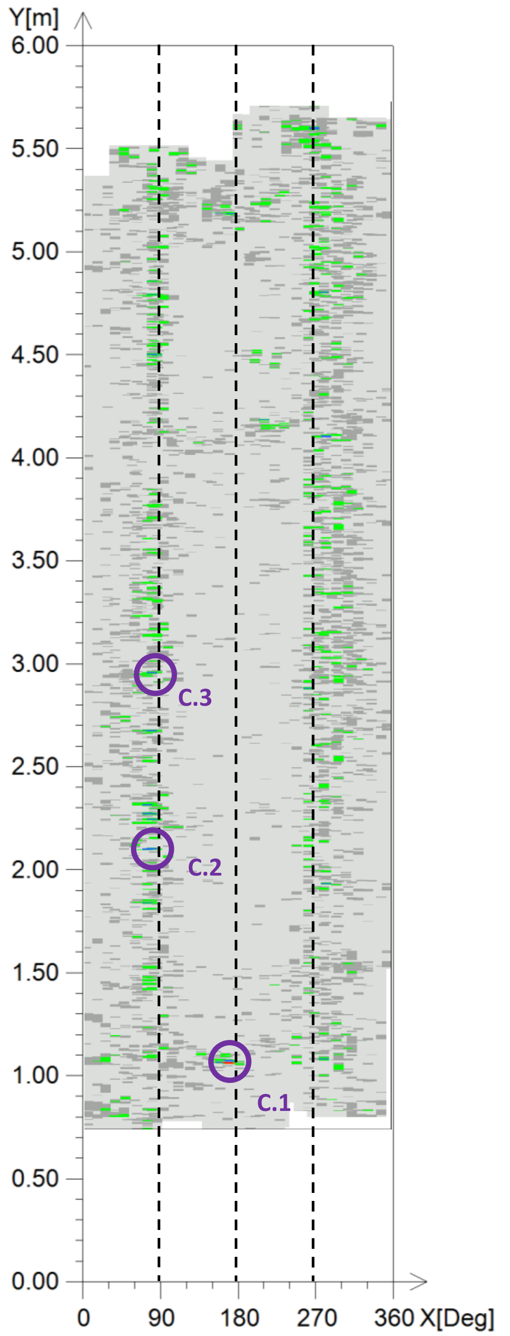




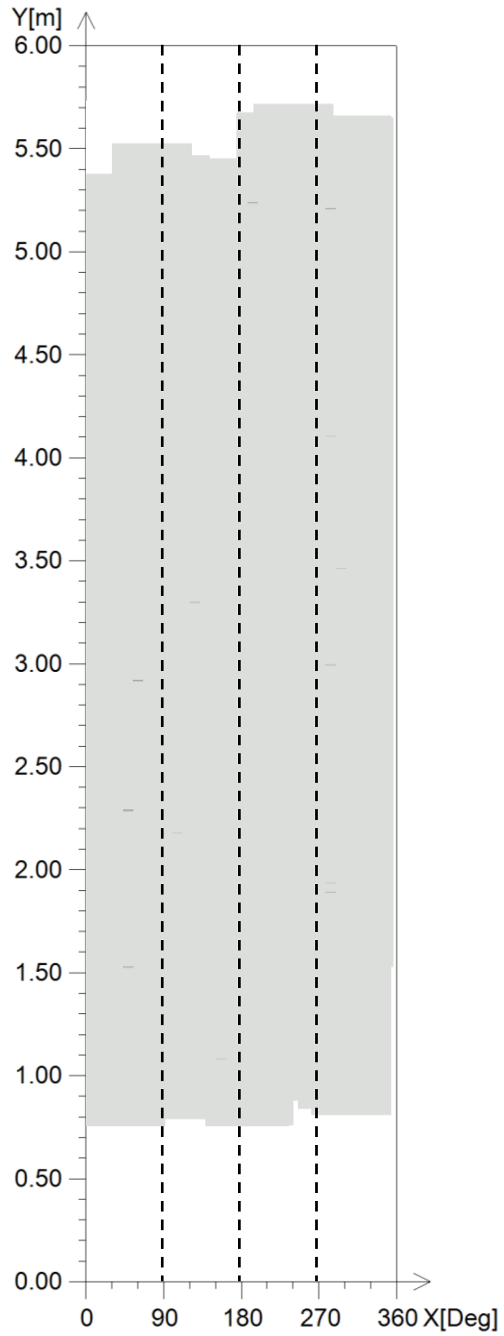
Results:

Two lines of minor pitting corrosion found at 3 and 9 o'clock. One isolated deeper pit found in 6 o'clock orientation (C.1).

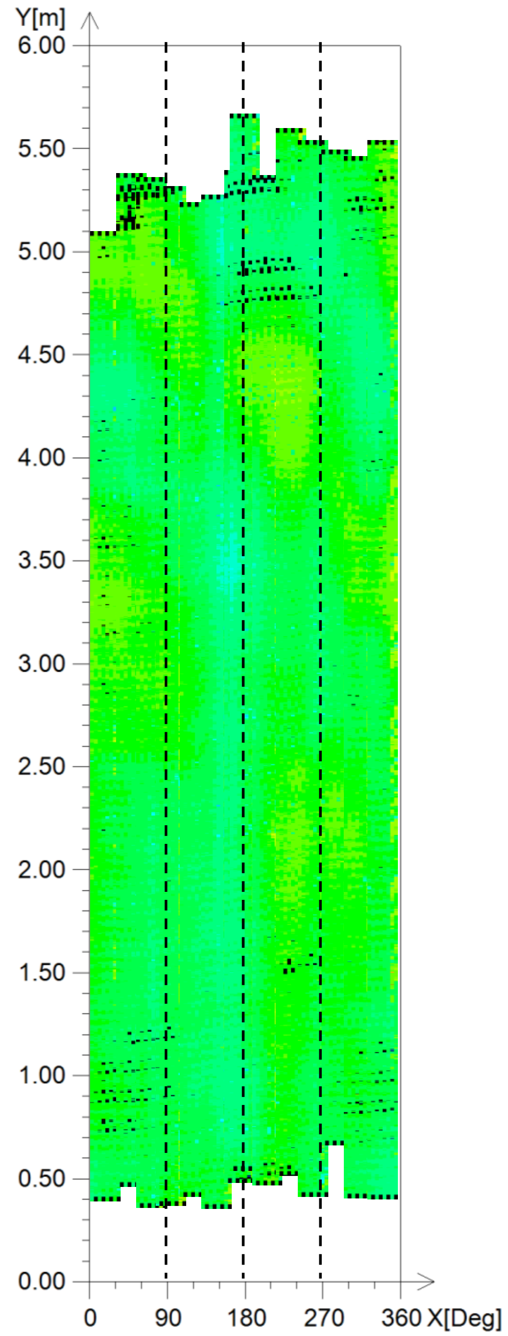
MEC-Data: Internal View



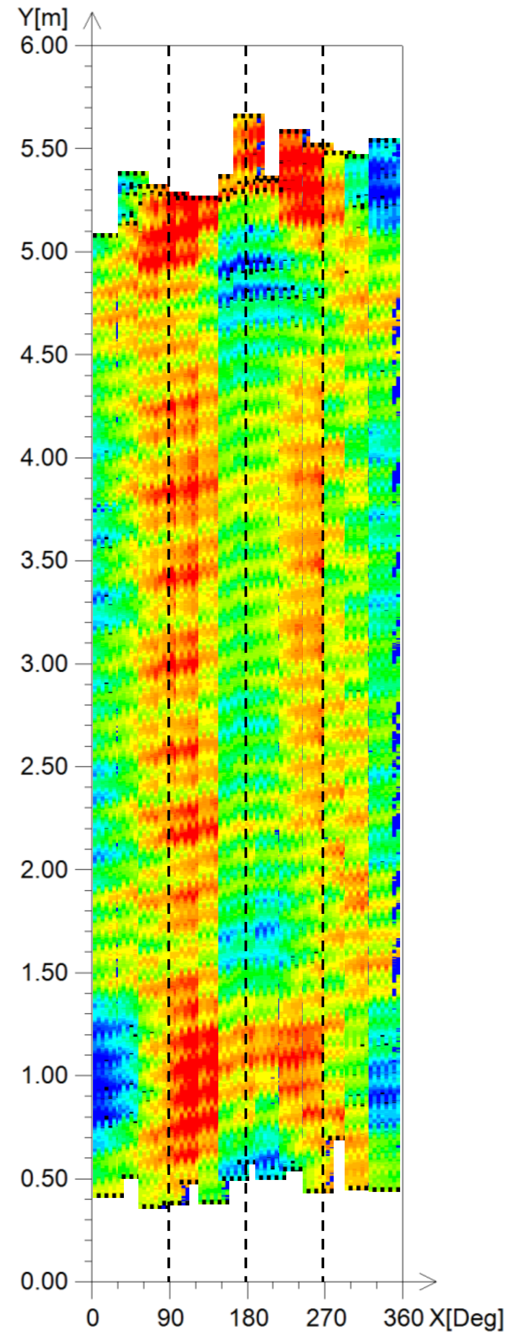
MEC-Data: External View



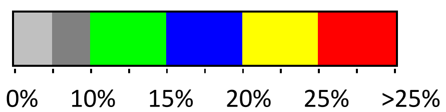
UT Data: Wall Thickness



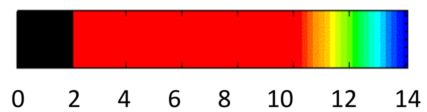
UT Data: Stand-off



MEC Legend
% Wall Thickness Loss



UT Legend
mm Wall Thickness and Stand-off

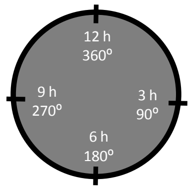


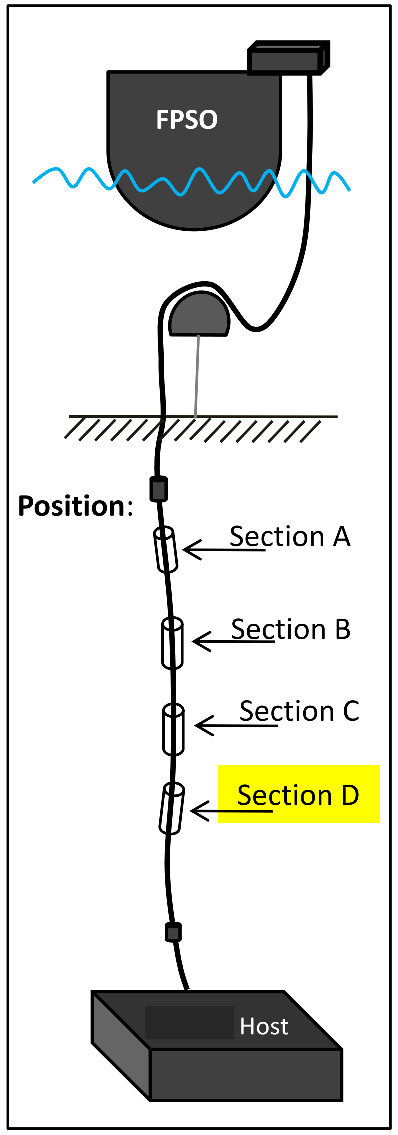
Client Field

MEC and UT subsea pipeline inspection report

Location (East) Section D

Direction of Scan: Towards FPSO/ in direction of flow

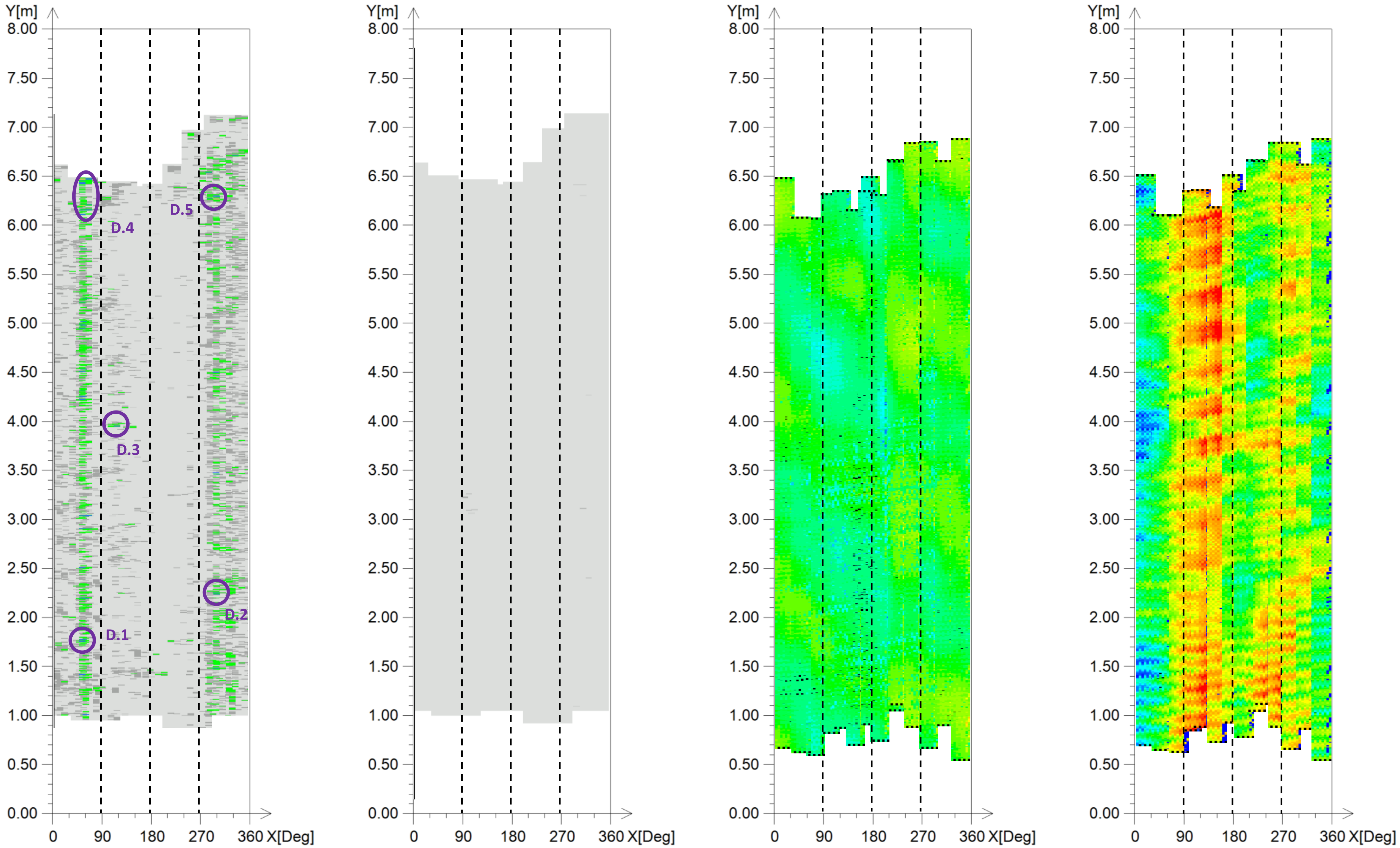




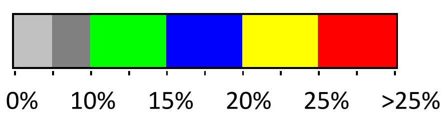
Results:

Two lines of pitting corrosion found at 10 and 2 o'clock orientation.

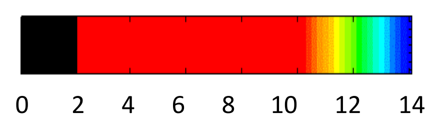
MEC-Data: Internal View | **MEC-Data: External View** | **UT Data: Wall Thickness** | **UT Data: Stand-off**



MEC Legend
% Wall Thickness Loss



UT Legend
mm Wall Thickness and Stand-off



3.5. List of MEC™ and UT Indications

Indications have been identified in the MEC-data as isolated entities. The UT data shows a rather gradual change in wall thickness. The following table shows indications from the MEC-data. All significant indications exceeding 20% of the wall thickness as well as the three deepest indications for every section are included. The naming is according to the scheme <Section>.<Defect-Number>. So indication A.1 represents the first indication in Section A. The numbering increases with axial distance on the pipe.

Item	*Position from datum [m]*	*Orientation [o' clock]*	*Depth [%] (±10%)*	*Approx. Length [mm]*	*Approx. Width [mm]*	*Description*
A.1	1.25	09:00	21	25	25	pit
A.2	2.20	03:30	17	30	30	pit
A.3	2.25	09:00	15	20	20	pit
A.4	2.6	09:30	24	40	20	pit
A.5	3.5	09:15	22	120	30	chain of pits
A.6	3.85	09:15	21	180	30	chain of pits
B.1	0.8	06:00	20	30	30	pit
B.2	1.1	03:00	25	40	40	pit
B.3	1.15	00:30	18	20	20	pit
B.4	1.20	06:00	23	20	30	pit
B.5	1.45	06:00	24	25	25	pit
B.6	1.75	06:00	23	300	30	chain of pits
B.7	2.10	06:00	19	220	30	chain of pits
B.8	2.25	12:00	18	40	40	pit
B.9	2.45	06:00	20	250	30	chain of pits
B.10	2.50	12:00	21	900	30	chain of pits
B.11	2.80	06:00	25	100	30	slot

Item	*Position from datum [m]*	*Orientation [o' clock]*	*Depth [%] (±10%)*	*Approx. Length [mm]*	*Approx. Width [mm]*	*Description*
B.12	4.10	00:15	18	30	30	pit
B.13	4.60	05:45	22	30	30	pit
B.14	6.20	00:15	17	30	40	pit
B.15	6.55	12:00	24	40	40	pit
B.16	6.80	05:00	17	25	25	pit
B.17	7.05	04:45	19	50	30	pit
B.18	7.45	12:00	18	150	30	chain of pits
B.19	7.60	11:30	19	200	30	chain of pits
C.1	1.05	05:45	25	15	15	pit
C.2	2.10	02:30	15	100	20	chain of pits
C.3	2.90	02:45	16	30	30	pit
D.1	1.75	01:45	17	30	25	pit
D.2	2.20	10:00	12	20	30	pit
D.3	3.95	04:15	15	30	30	pit
D.4	6.20	02:00	17	40	20	pit
D.5	6.50	10:00	15	40	30	pit

Table 2: Features of the individual indications

Many more smaller features are visible in the range from 10 to 20 % wall loss. Also features smaller in size are visible that do not exceed 15% wall thickness and which are of a diameter in the range of 10 mm. The overall appearance of the features corresponds to what is called channelling corrosion or 6 o'clock corrosion albeit that the channels are not always at the 6 o'clock position.

A significant indication is found in Section C with item C.1. It is not embedded in the channelling but rather isolated. It is scanned in five different scans.

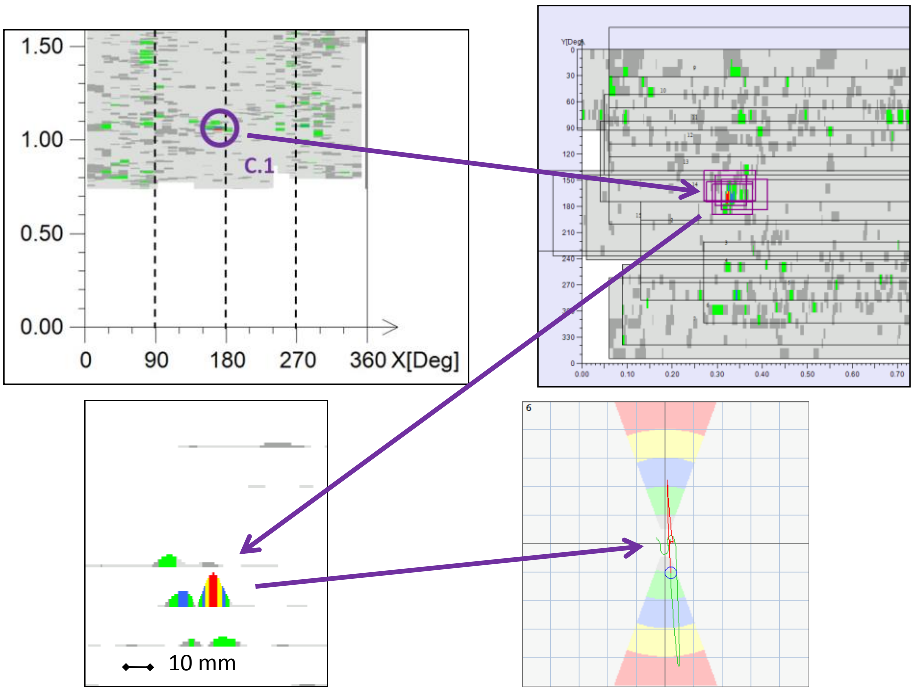


Figure 5: Detailed view of the indication C.1

The UT wall thickness mapping does not show any degradation of the wall thickness. Instead manufacturing related gradual variations of the wall thickness are visible. Even certain patterns are visible in particular in Section B. They show a typical pattern of seamless pipe. Figure 6 shows such a fine pattern with near horizontal stripes and a larger helical pattern.

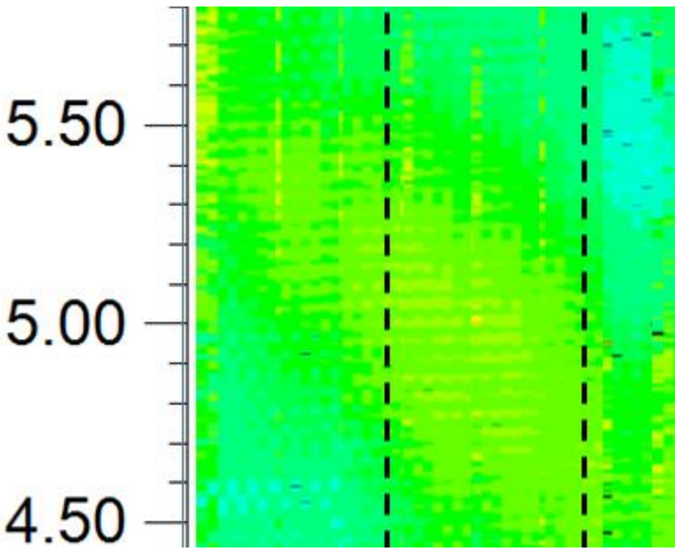


Figure 6: Manufacturing related wall thickness variations visible in the UT data in section B.

Single pits are not visible in the UT data. It is known that UT wall thickness measurement often misses small pits, if an echo from the sound rear wall is still captured.

3.6. Conclusion

The indications found in the MEC and the UT data show that the pipeline is affected by an early stage of internal corrosion at all sections. The corrosion runs along grooves that extend along the axis of the pipe. All grooves are always symmetric with respect to the 6 o'clock orientation.

For section A, two lines of pitting corrosion found at the 3 o'clock (90º) and 9 o'clock (270º) orientation. The deepest pitting is about 24% loss of wall thickness (A.4).

In Section B, one line of intense pitting corrosion found at 6 o'clock with deepest pits about 25% deep (B.11). Another line found at 12 o'clock. The number and density is the highest in this section compared to other sections.

Section C shows two lines of minor pitting corrosion found at 3 and 9 o'clock. One isolated deeper pit found in 6 o'clock orientation (C.1).

Section D shows two lines of pitting corrosion found at 10 and 2 o'clock orientation.

4. Technical Details of the Instrumentation

4.1. Description of the MEC™ Technology

Standard eddy current instrumentation is only sensitive to the surface of a metallic material. Even this can be quite a benefit for the inspection of flexible riser pipe. However, modifications of the standard eddy current technologies allow for the inspection of deeper structures. At Innospection magnetically biased eddy current MEC™ has been found to be a versatile method for the inspection of ferritic steel structures. The technology is also known under the trade name of SLOFEC™.

The idea of MEC™ is to use an eddy current coil on ferromagnetic material and to magnetise the section of ferritic steel components at the same time. The magnetisation has several effects. It changes the permeability of the material. Hence, the penetration depth increases. At the same time changes in permeability due to different flux distribution become visible. With these effects also defects embedded in the material can be picked-up with eddy current sensors. The principle is shown below.

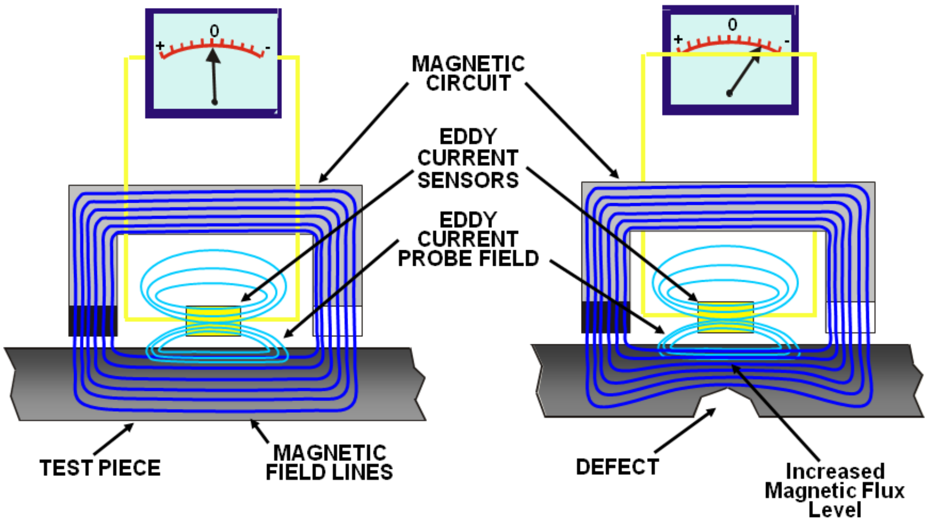


Figure 7: Principle of Eddy current measurement

The principle of measurement is related to MFL-measurement, but the set-up works at lower magnetisation levels. Since only moderate levels of magnetisation are required, the method works to higher wall thickness pipe, or through several millimetres of coating thickness.

Obviously one difference to MFL is that the level of magnetisation should be adjusted. In contrast in MFL the magnetisation level should always be as high as possible.

4.2. Equipment Calibration

For corrosion detection, the differential mode was used. The frequency setting used for channel 1-8 (differential mode) was 75 kHz.

The amplitude of the signals was set so that the artificial reference defect (Ø 25mm 60% depth) was set to 5 screen divisions. This is only classed as the initial pre-calibration setup and may then be further adjusted when the first true indication is detected and evaluated for depth, this by utilising the ultrasonic pulse echo technique.

Optimum signal/noise ratio and signal phase separation between the internal defect indications and other indications were considered when selecting a suitable test frequency.

The differential channels of all the sensors were set so that internal defects were indicated in the vertical signal phase direction as shown in the diagram below. By moving the scanner in the reverse direction, the internal defect signal would show the first peak down, followed by the second peak up with an upward movement.

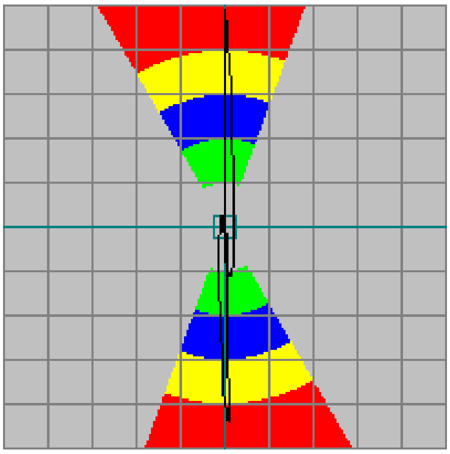


Figure 8: Sample signal display of internal defect

Subsequently external defects are indicated in the horizontal signal phase direction as shown below. Moving the scanner in the reverse direction, the external defect signals have the first peak left followed by a right movement with the second peak right.

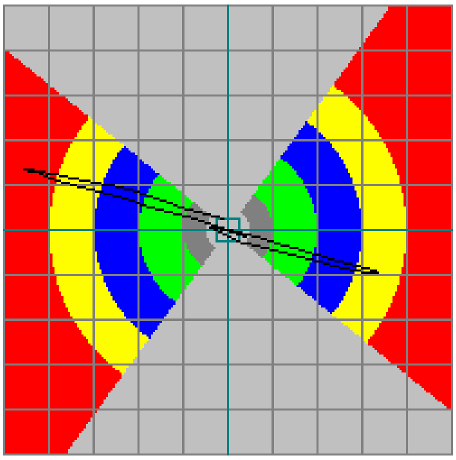


Figure 9: Sample signal display of external defect

The general overview of the inspected areas with its results is presented in the attached colour scan reports with wall loss represented in colour classes as below. The applied colour code is shown on the report sheets.

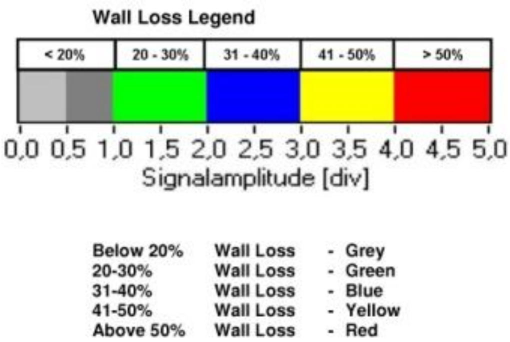


Figure 10 Signal Y-component /angle analysis window set for indication of internal defects with approx. depth information

Eddy Current inspection is an evaluation method of NDT; hence all results obtained are based upon the test piece used. Material, wall thickness and coating thickness and type of the test piece should be as near as reasonably practicable to the item under inspection. Artificial defects should be as near in size and shape as to the type sought.

Because MEC™ signal amplitudes are an indication of defect depth and volume, the defect depth analysis by signal amplitude can only be done in comparison with varying depth artificial reference defects.

4.3. Analysis Procedure

Once the data of an inspection job is received all sensitivities and phase angles are adjusted to the correct calibration.

The bespoke analysis software Innospectit allows arranging the tracks according to the scanning of the sections. For the report the data is exported as bitmaps. The inspected object usually is split up into sections. The data is displayed and saved into bitmaps for every scanned section.

The data displayed in bitmaps will not reveal anything if too long distances are shown. A typical section length is less than 10 m. The bitmap-images are arranged to show the mapping of data in a position versus orientation coordinate system. This is done for the two phase directions and, if available, for the UT sensor data. It yields four mappings of the object. The bitmap with horizontal phase displays the outer layer of the object, whereas the bitmap with vertical phase displays the inner surface. The UT data is shown as wall thickness maps and a map of the sensor stand-off. Different types of defects may appear on different mappings.

4.4. Accuracy of the measurement

Resolution

The lateral spacing of the UT Sensors is 9 mm. The pulse repetition frequency is 625 Hz for both the UT and the MEC-Sensors. With a typical scanning speed of 0.25 m/s this leads to a sampling distance of 0.4 mm. The MEC-Sensors have a width of 18 mm.

Probability of Detection

The detection of localised corrosion is mainly through the MEC technique. A POD of 95% is reached for a single isolated pit with a diameter of 4 mm and a minimum depth of 10% of the wall thickness. POD will increase with higher diameter and depth.

Accuracy

The sizing accuracy for the MEC sensors is ±10% of the wall thickness. The sizing accuracy of the UT wall thickness measurement is ±0.2 mm.

Location Accuracy

The location is given with respect to the datum point. Here the datum point is the start of the scan, which is given by Easting and Northing coordinates from the ROV. With respect to this datum point the location accuracy is ±10cm in the axial direction and ±15º for the circumferential positioning.

4.5. Description of the MEC Combi Crawler Tool

The MEC Combi-Crawler pipe scanner is designed and built for high performance inspection applications. Based on the **M**agnetic **E**ddy **C**urrent technique (MEC), the pipe scanner allows for the detection of internal and external metal loss defects at a rather high scanning speed. Additionally, the tool is equipped with a UT sensor array allowing corrosion mapping of the covered area.

The scanner head with a MEC sensor array covers 180 mm circumferentially, meaning that a number of axial runs are to be taken with overlap to have 360° coverage of the full pipe. For a 6” pipe with ~200 mm diameter this would require four scans to complete the full 360° coverage. Several views of the tool are shown in Figure 11, Figure 12 and Figure 13.

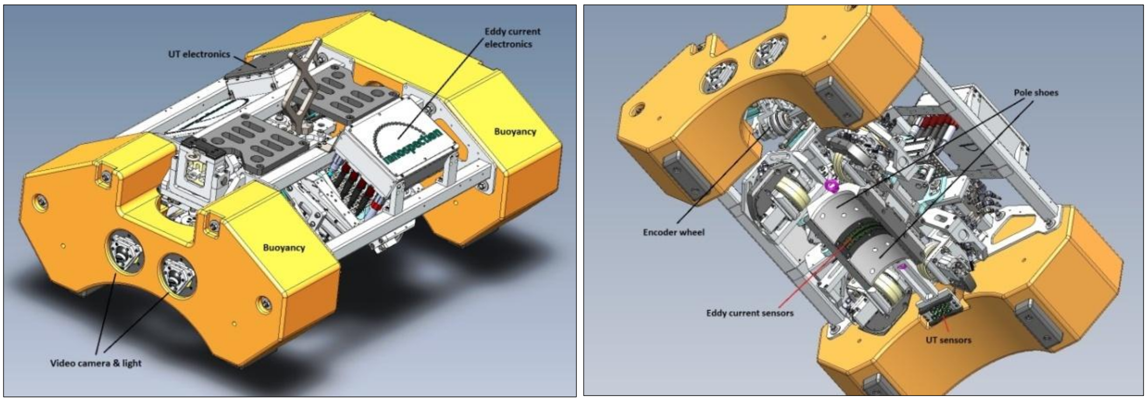


Figure 11: The MEC Combi Crawler tool for the inspection of subsea pipelines

The UT sensor array also consists of eight sensors. The sensors are staggered to allow for a closer circumferential sensor pitch. The UT sensors and the MEC sensors are separated by 395 mm axially.

The distances driven are measured with an encoder-wheel. An umbilical is connected to the tool for supply of electrical and hydraulic power by the ROV. In addition the eddy current and UT signals are routed to a top-side data-acquisition system via the ROV umbilical.

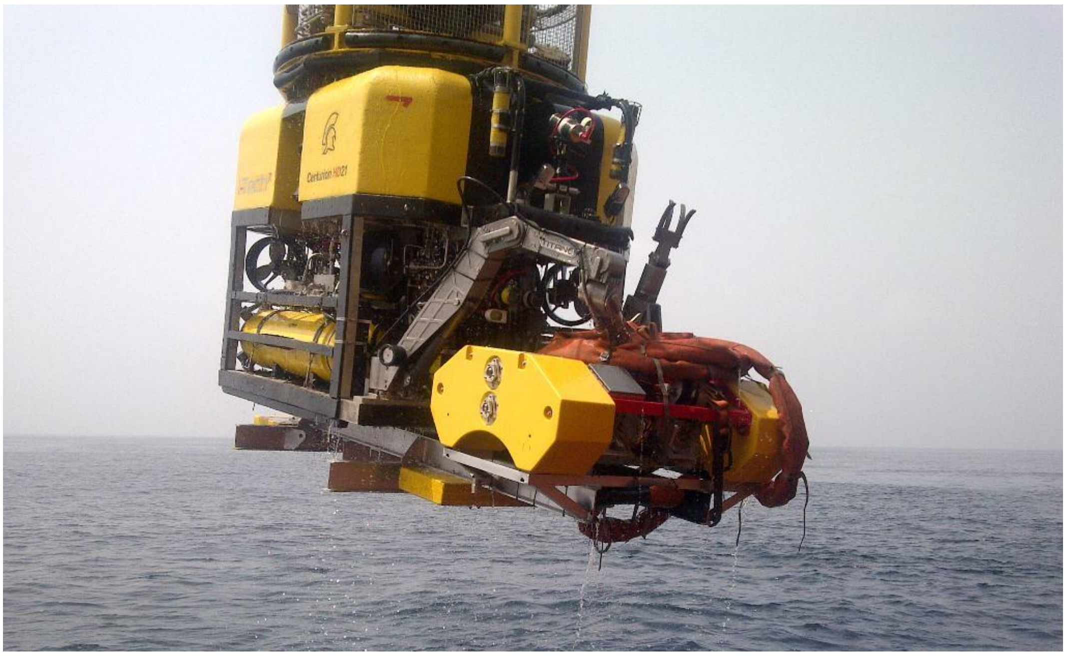


Figure 12: The MEC Combi Crawler on site

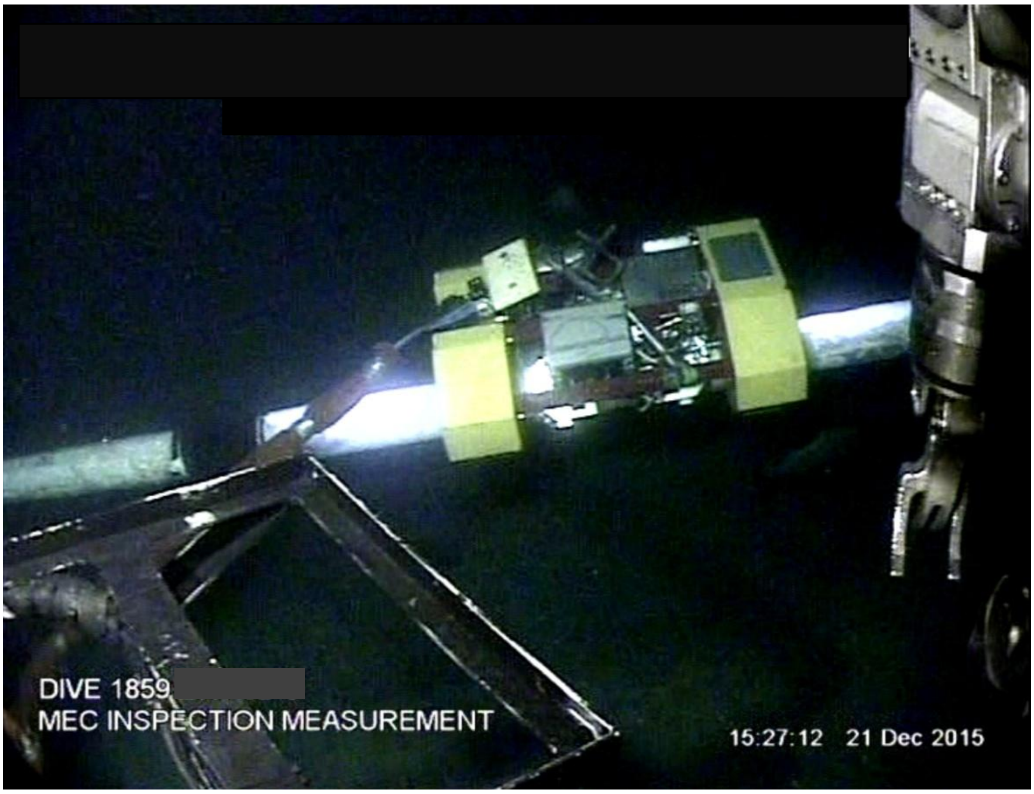


Figure 13: The MEC Combi Crawler in operation scanning part of XXX Field Pipeline (Here XXX Section C)