MEC (Extended SLOFEC) and UT Caisson Inspection Report

Client	**Client**
Facility	**Platform xx**
Items Inspected	**Open Drain Caisson x**
Inspection Method	**MEC (Extended SLOFEC and UT**
Date Commenced	**19th April 2014**
Date Completed	**20th April 2014**
Type of Report	**Final**
Report Number	**K xxxx**

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Unit 27/28
Webb Ellis Park
Rugby CV21 2NP
Warwickshire, UK
Phone: +44 (0) 1788 5472 94
Fax: +44 (0) 1788 5472 99

Howemoss Avenue - Unit 1
Kirkhill Industrial
Dyce AB21 0GP
Aberdeen, UK
Phone: +44 (0) 1224 724 744
Fax: +44 (0) 1224 774 087

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EXTERNAL CAISSON

INSPECTION REPORT

Using MEC (Extended SLOFEC)

Prepared for

Client

Final Report: Kxxx Rev 0

Rev	Document	Author		Checked		Approved By		Date
		Name	Signature	Name	Signature	Name	Signature	
0	Issue to client for comment	T. B.		K.R.		A.B.		07.05.2014

Name	Position
T.B.	Reporting Engineer
K.B.	Director R&D
A.B.	Group Managing Director

Disclaimer

Contents

1. Executive Summary

The inspection of caisson x at the Client's platform was carried out between April 10th and April 11th 2014. Several indications of severe internal corrosion were found during the inspection. In particular the elevation at -6 m is affected. In addition a severe circumferentially extended indication near the weld at -8 m has been detected. It corresponds to a through-hole observed in the video data.

2. Inspection Execution

2.1. Task

Innospection Ltd was invited by the Client to inspect caisson x at the Client's platform. The purpose of the inspection was to identify wall thickness reductions e.g. caused by general corrosion and pitting.

MEC (Magnetic Eddy Current) is the next generation of fast corrosion mapping technique based on the further development of the SLOFEC technique. The MEC technique utilises Eddy Current sensors and simultaneous magnetisation to detect corrosion on both sides of the wall. The MEC technology was built into the MEC-Combi crawler tool (ref. 2.3 and 4.4), this was integrated onto the HISS Triton XLX vehicle to facilitate subsea deployment and inspection. The areas to be inspected were defined within the workscope document "xx" which highlighted priorities as follows

- Priority 1 - The area between -4 m to -15 m
- Priority 2 - The area from -4 m upwards (through splash zone if possible)

2.2. Inspection Object

Caisson x is an open drain caisson with an outer diameter of 750 mm and a wall thickness of 20 mm. It is located on frame 2 at the platform as shown in Figure 2. On installation the caisson had a 4-layer external coating in the area between EL +8.9 m and EL -5.4 m and a 3-layer coating in the area between EL -5.4 m and EL -18.4 m. The composition of the original coating is given overleaf in Table 1.

An initial as found survey of the caisson identified that the majority of coating between -5.4m and -15m had been removed by the previously installed support rigging. The zinc based coating from -5.4m and above remained although showed signs of abrasion from the support rigging.

Figure 1: The Client's platform

EL [m]	Coating Nr.	Generic Type	Min thickness [µm]	Max thickness [µm]
+8.9 to -5.4	1	Inorganic Zinc	60	90
	2	Epoxy Polyamide	125	180
	3	Epoxy Polyamide	125	180
	4	Urethane Finish	40	60
		Total Thickness	350	510
-5.4 to -18.4	1	High Solids Epoxy	375	500
	2	High Solids Epoxy	375	500
	3	Urethane Finish	40	60
		Total Thickness	790	1060

Table 1: Coating layers of the xx open drain caisson at the respective EL ranges

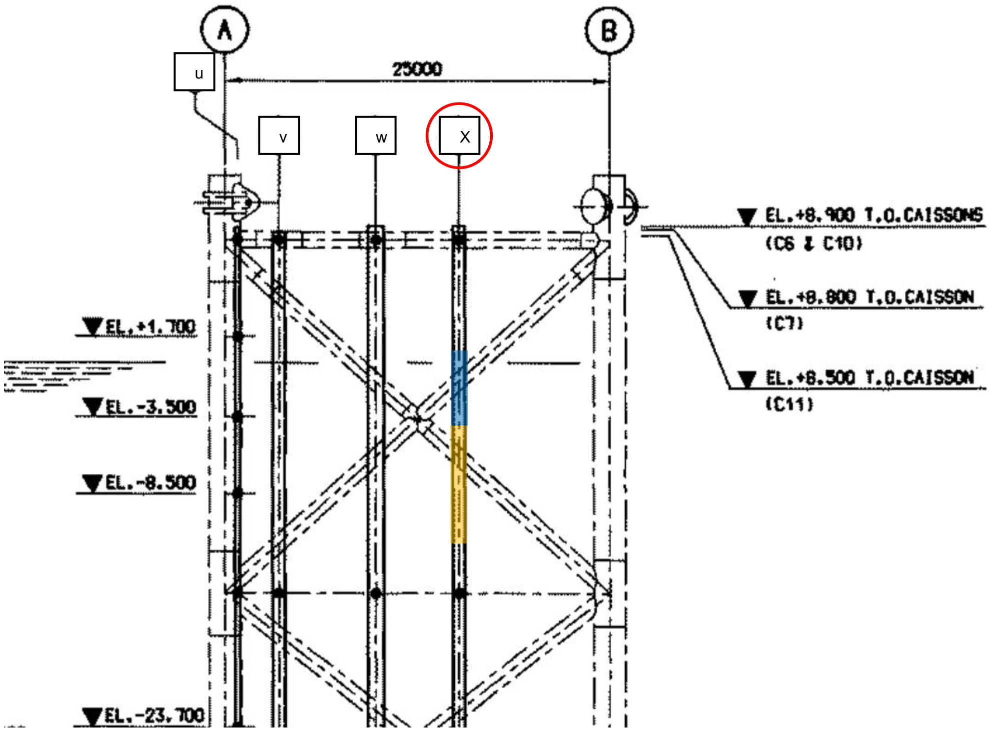


Figure 2: Location of caisson x on frame 2 and inspected area (Priority 1 scope marked in yellow, Priority 2 in blue)

2.3. Equipment

The Innospection MEC-Combi crawler carrying MEC inspection technology was utilised for the caisson inspection. The crawler was deployed to the caisson by the HISS XLX workclass ROV system. 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 160 kg in air and 20 kg in water (adjustable by modular buoyancy). It has a length of 110 cm, a width of 65 cm and a height of 60 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 2.2

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

2.4. Mobilisation and Preparation

Inspection Team

The inspection team was made up of the following personnel:

LS,	Shift Lead, Engineer (Eddy Current PCN Level 2 - x)
JJ,	Shift Lead, Engineer (Eddy Current PCN Level 2 – x, UT Level 2)
GN,	NDT Technician (Eddy Current PCN Level 2 - x)
SV,	NDT Technician (Eddy Current PCN Level 2 - x)

Mobilisation Dates

The equipment and inspection crew was mobilised on April 1st 2014. The additional cleaning was carried out two days prior to inspection. Upfront tests on site have been done on April 10th. All track runs have been done on April 10th and April 11th 2014.

Cleaning

The cleaning was done on April 8th by Subcontractors by ROV utilising a combination of grit blasting and cheese wiring technologies. It was successful, providing a smooth surface for the MEC-Combi crawler to traverse.

Procedure for Calibration and Set-up

The preparation and inspection of the caisson was done according to Innospection's procedure

- 34 - Inno-SLCASIoCBC -001-14 -Procedure for MEC & Ultrasonic Inspection Utilising Combi Crawler Equipment On Structural Leg, Caisson & Pipework Applications

Pre mobilisation tests were carried out in the Innospection workshop against test pieces #72 and #321. These have matching diameter and wall thickness to that of the test object; the test pieces contained artificial external and internal defects for classification and sizing of defects. On site and prior to launch the tool was calibrated utilising the same technique, all sensors showed appropriate signals. The lift-off of the sensor array to the inspected object was set to 6 mm.

2.5. Execution and Performance

ROV Operation and Scanner Deployment

The work class ROV operated by subcontractor positioned the scanner at the predetermined circumferential position on the caisson. Once on the caisson the hydraulically powered drive unit enabled the scanner to crawl up the caisson to carry out the inspection. The scanner moved smoothly on the test object with only little variation in velocity.

Tracks and Coverage

Due to the scan width of 180 mm, a total of 14 tracks would have been required for a full circumferential coverage of the 30'' caisson. Altogether, 15 track runs have been planned to ensure a good track overlap. A total of 11 track runs has been performed. The individual track parameters are given in Table 2. In the area -4m to -10m the tracks with ROV headings of 220°, 245°, 295°and 320° could not be done due to access restrictions for both the ROV and MEC Combi crawler, all other portions were completed in full.

Three tracks were completed from -4m to LAT, the remaining tracks were not completed due to lack of adhesion of the crawler to the zinc coated surface and swell at the time of inspection.

The tracks that were completed showed no significant wall thickness loss, these tracks were at 0deg, 300deg and 250deg.

For orientation purposes, 0° represents true north on all results contained within this document. Since an ROV heading of 0° means, that the scanner has been deployed on the area of caisson facing south, all orientations have been corrected by 180° (see Figure 3) The flat projections of the inspected object within this report are depicted looking from 0° (north) onto the outer surface of the caisson. Angles are increasing clock-wise when looking down the caisson.

All depth readings were taken from the depth sensor on the Triton XLX ROV system. Overviews of scan results for internal and external corrosion mapping are shown in sections 3.1 and 3.2. Additionally, enlarged images of the scan overviews are shown in the appendix to this document.

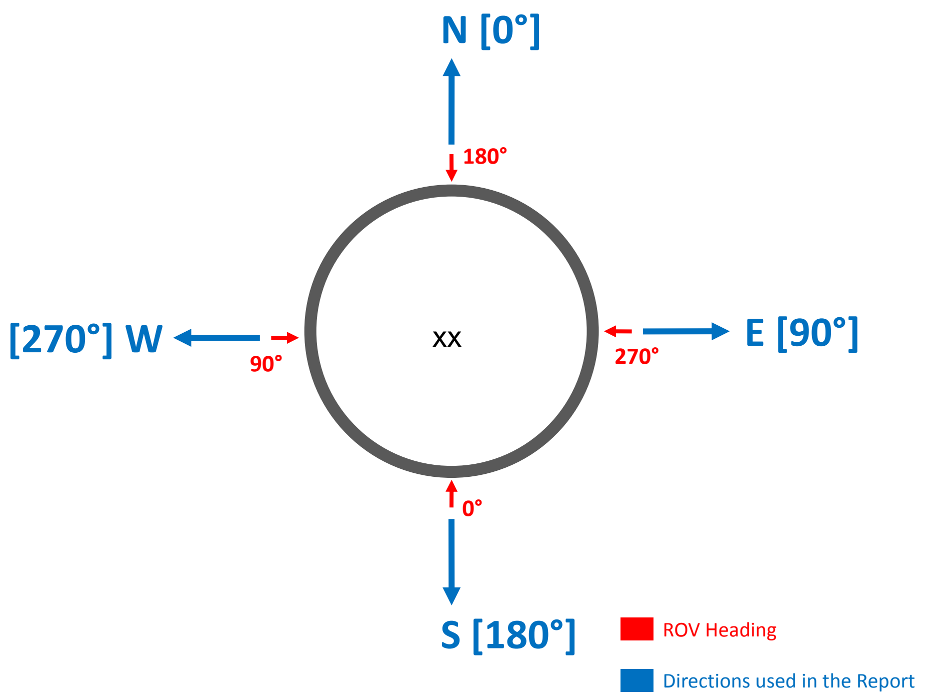


Figure 3: Definition of track orientation used in this report compared to ROV headings. The positive circumferential direction is clockwise when looking downwards

Speed Profiles

The scanning speed for all tracks was relatively constant and in the order of 0.2 m/s to 0.45 m/s. Speed profiles for two tracks are depicted exemplarily in Figure 4 and Figure 5. In general, the scanning speed increased slightly during the track run. The scan velocity slightly decreased when the scanner passed a circumferential weld, but the scanner did not stop at the weld.

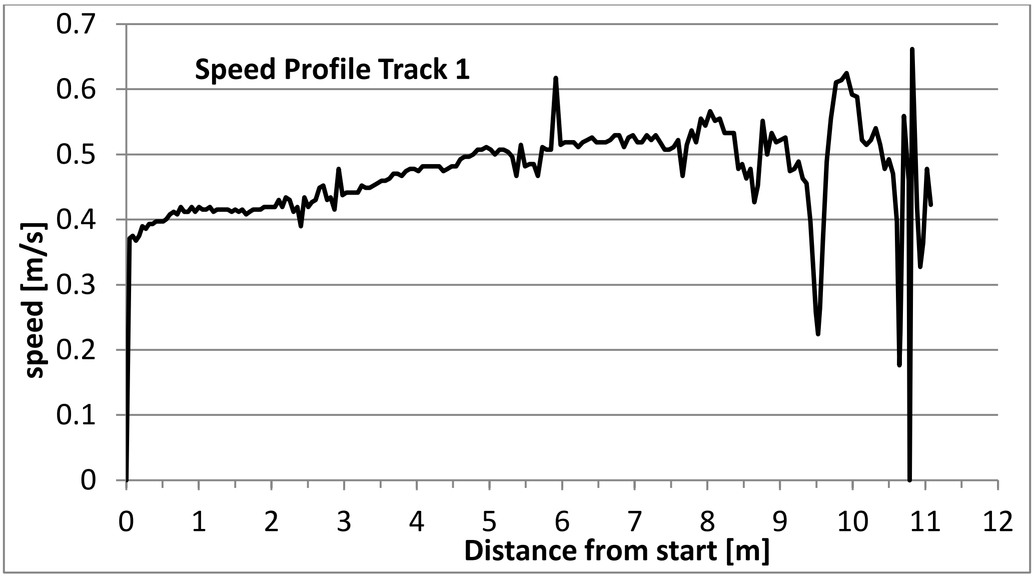


Figure 4: Speed profile for Track 1 with upwards movement

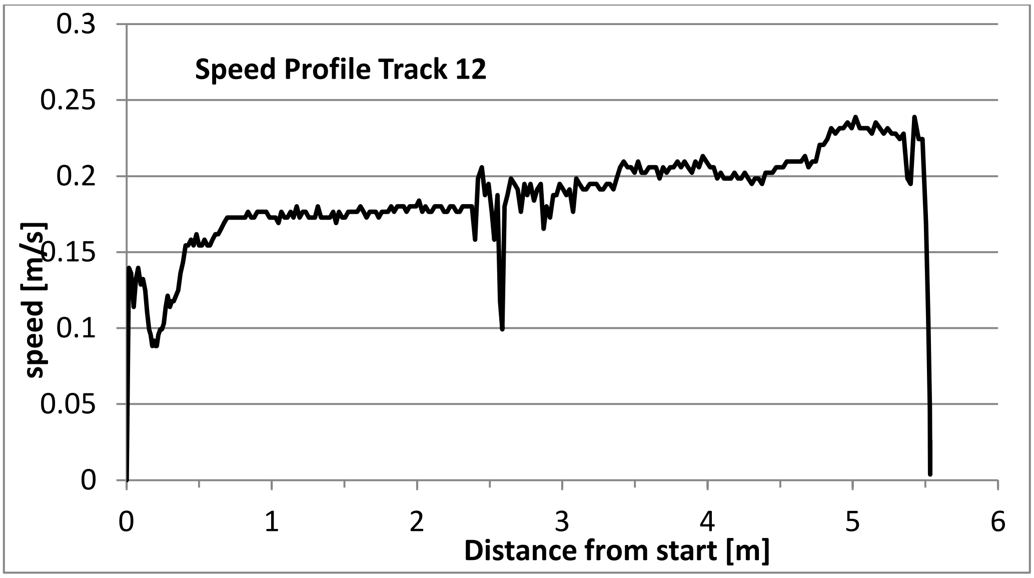


Figure 5: Speed profile for Track 12 with upwards movement

Track	ROV Heading [deg]	Corrected Heading [deg]	Start, [EL]	End, [EL]	Length [m]	Scan Direction	Comments
1	75	255	-10.5	+0.5	11.0	up	
2	105	285	-10.5	-1.61	8.9	up	
3	105	285	-10.5	-2.8	7.7	up	
4	145	325	-10.2	+0.4	10.6	up	
5	170	350	-10.1	-0.2	9.9	up	
6	195	15	-10.5	-3.5	7.0	up	
7	220						Not Possible for ROV access
8	245						Not Possible for ROV access
9	270	90	-3.7	-13.6	9.9	up	
10	295						Not possible for crawler to pass adjacent structure
11	320						Not possible for crawler to pass adjacent structure
12	345	165	-10.5	-4.3	6.2	up	
13	360	180	-10.5	-4.2	6.3	up	
14	25	205	-10.5	-4.0	6.5	up	
15	50	230	-10.4	-3.1	7.3	up	

Table 2: Overview of track parameters

Video Surveillance

The MEC-Combi crawler tool has been equipped with a forward facing camera which worked at all times and has been used for orientation and documentation purposes. Screenshots of the different camera views are shown in Figure 6.

Figure 6: Video screenshots of MEC-Combi crawler inspecting caisson xx (left) and view from the front camera of the tool (right)

Data Quality

The switching of the magnet worked without any problems and the distance encoder and video surveillance worked at all times. The starting EL values for the tracks were given by the ROV crew.

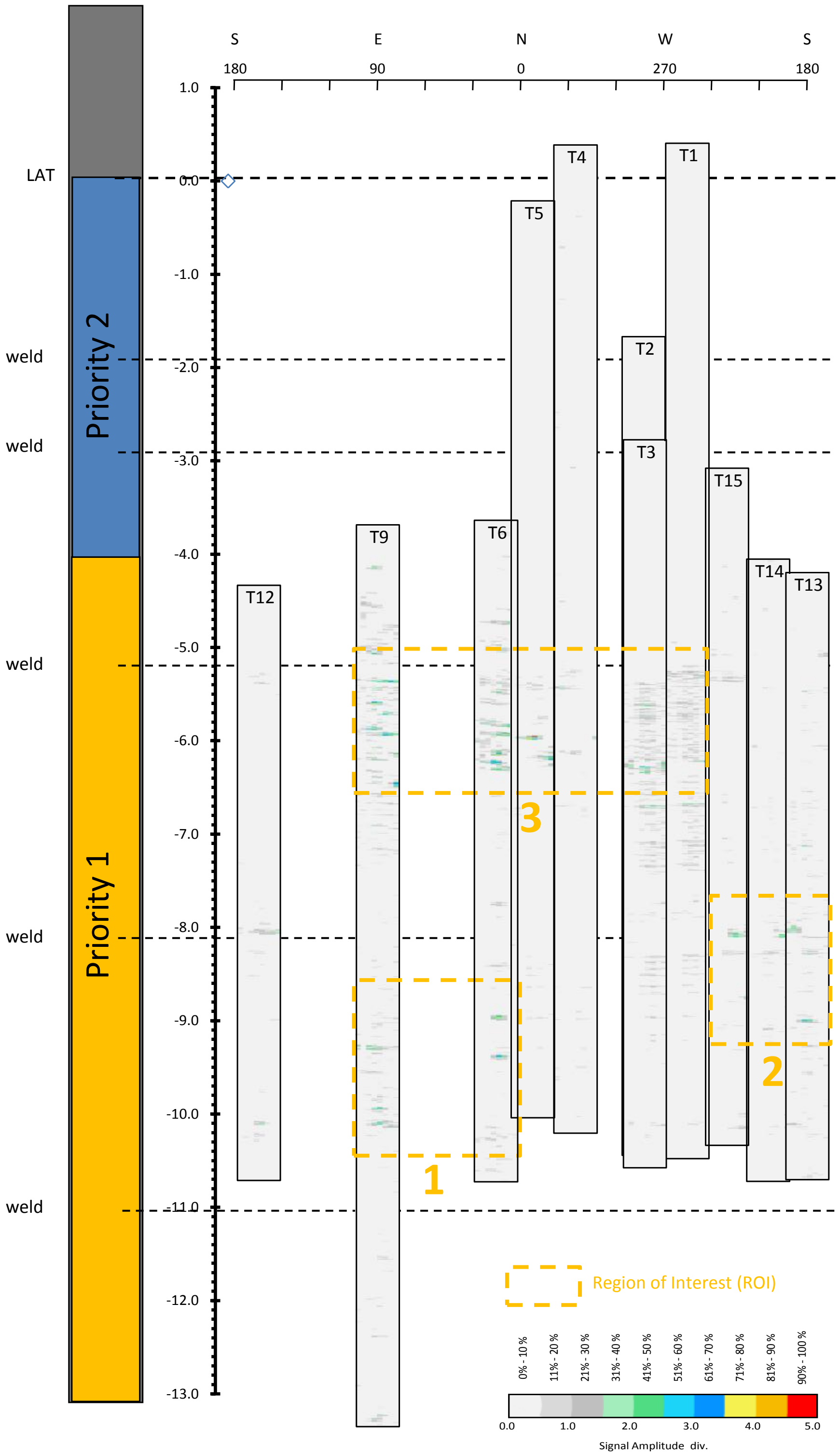
Following interface to the HISS Triton XLX ROV and subsequent pre-deployment calibrations the MEC-Combi crawler had no significant issues during the campaign.

Post analysis of the data gathered during the campaign confirmed high quality data had been gathered giving confidence in the published results

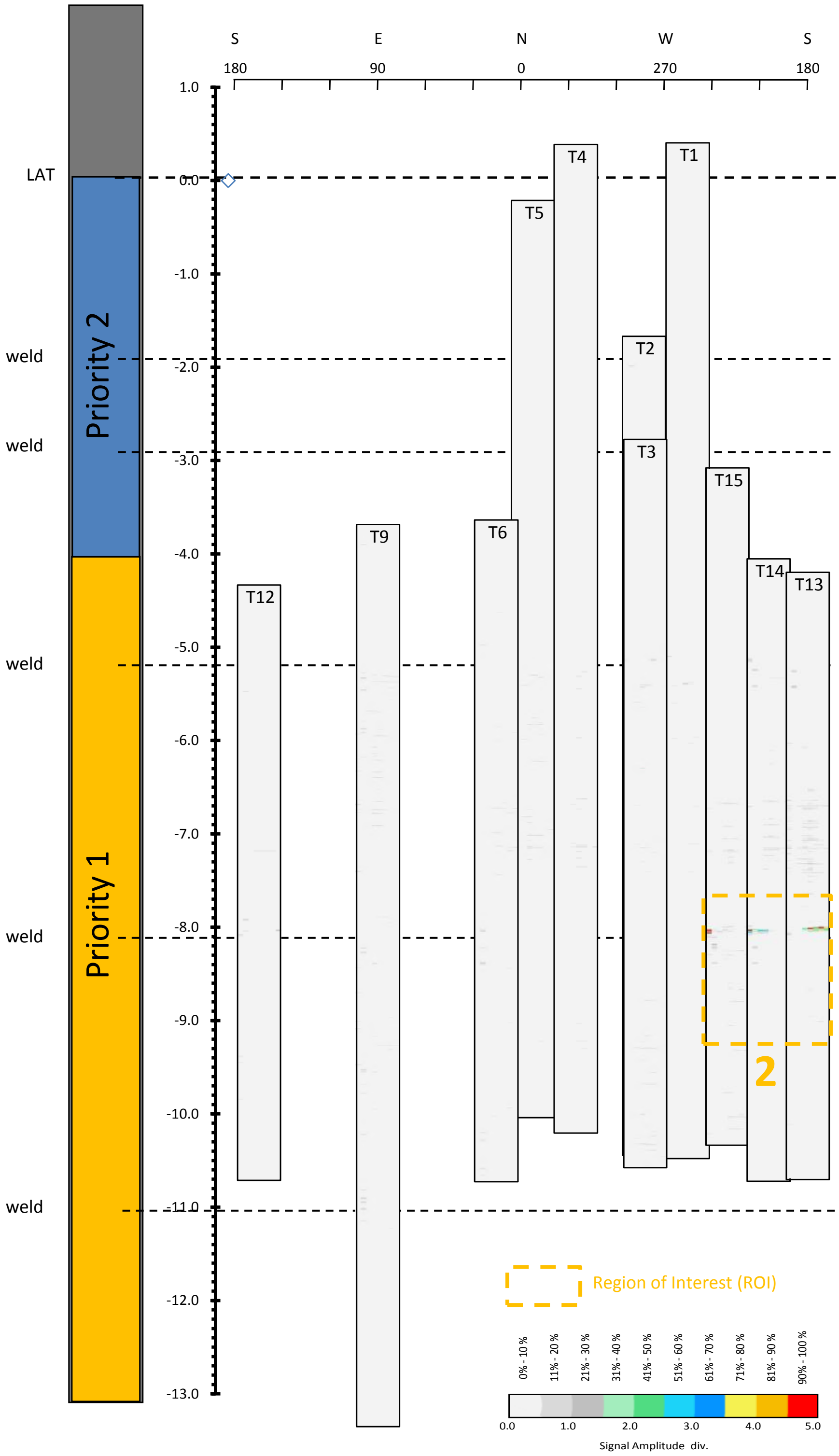
The overall signal quality is more than adequate for the specified probability of detection for defects and complete data analysis.

3. Results

3.1. Scan Results and Track Position Overview (internal corrosion)



3.2. Scan Results and Track Position Overview (external corrosion)



3.3. List of Indications

For the sake of clarity, indication locations have been split into three regions of interest (ROI), see Table 3, which will separately been discussed in section 3.4. Nomenclature of the indications is (ROI).(Indication Nr.). Therefore, indication 1.1 would be the first indication in ROI 1. A list of indications is given in Table 4. Expanded views of these areas showing the extent of wall loss are shown in Figure 7 to Figure 10.)

ROI	EL Range [m]	Angular Range [deg]
1	-10.5 to -8.5	0 to 105
2	-9.3 to -7.6	170 to 240
3	-5.0 to -6.5	105 to 240

Table 3: EL and angular ranges of the different regions of interest

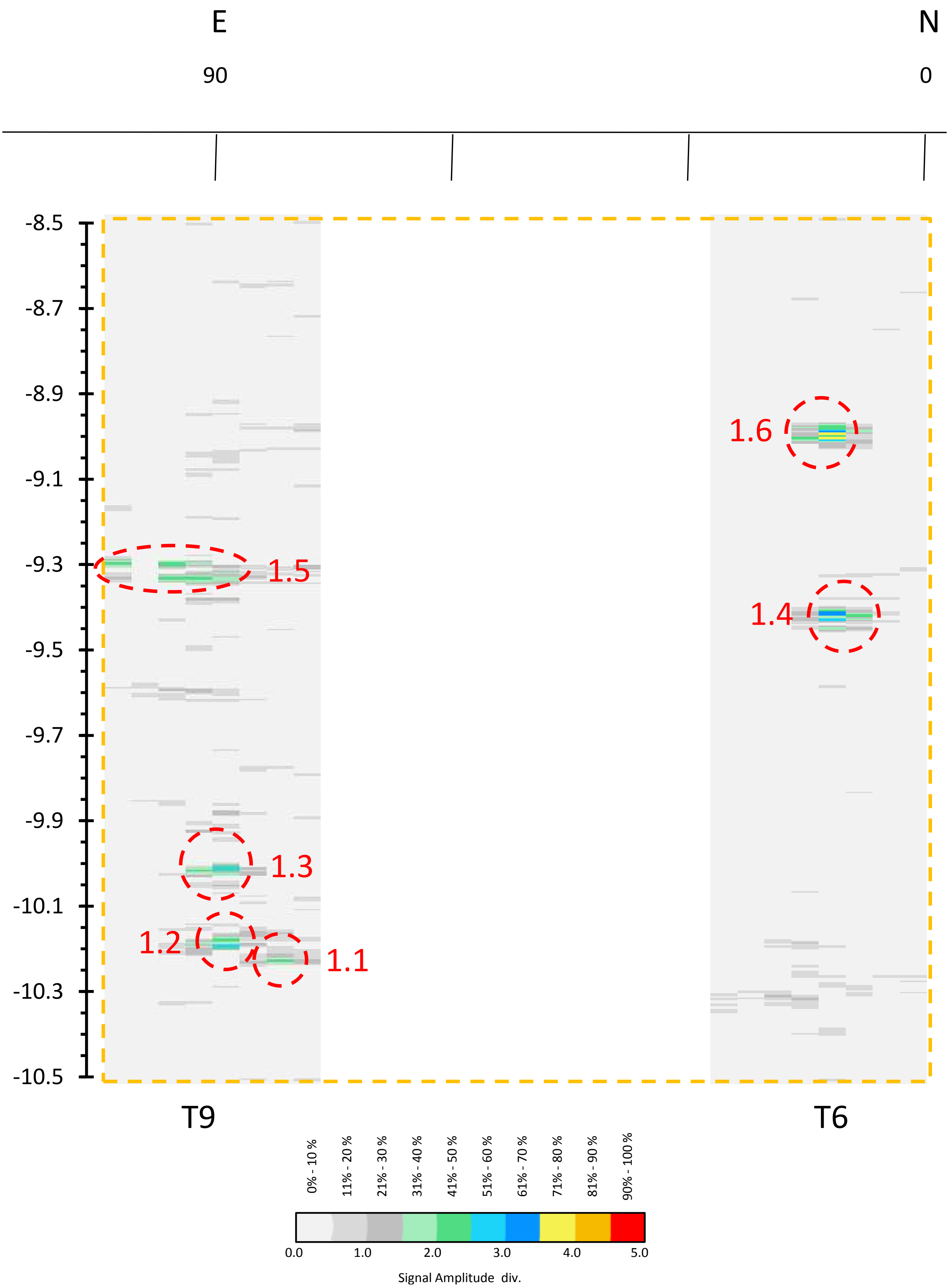


Figure 7: Region of interest Nr. 1 and contained indications

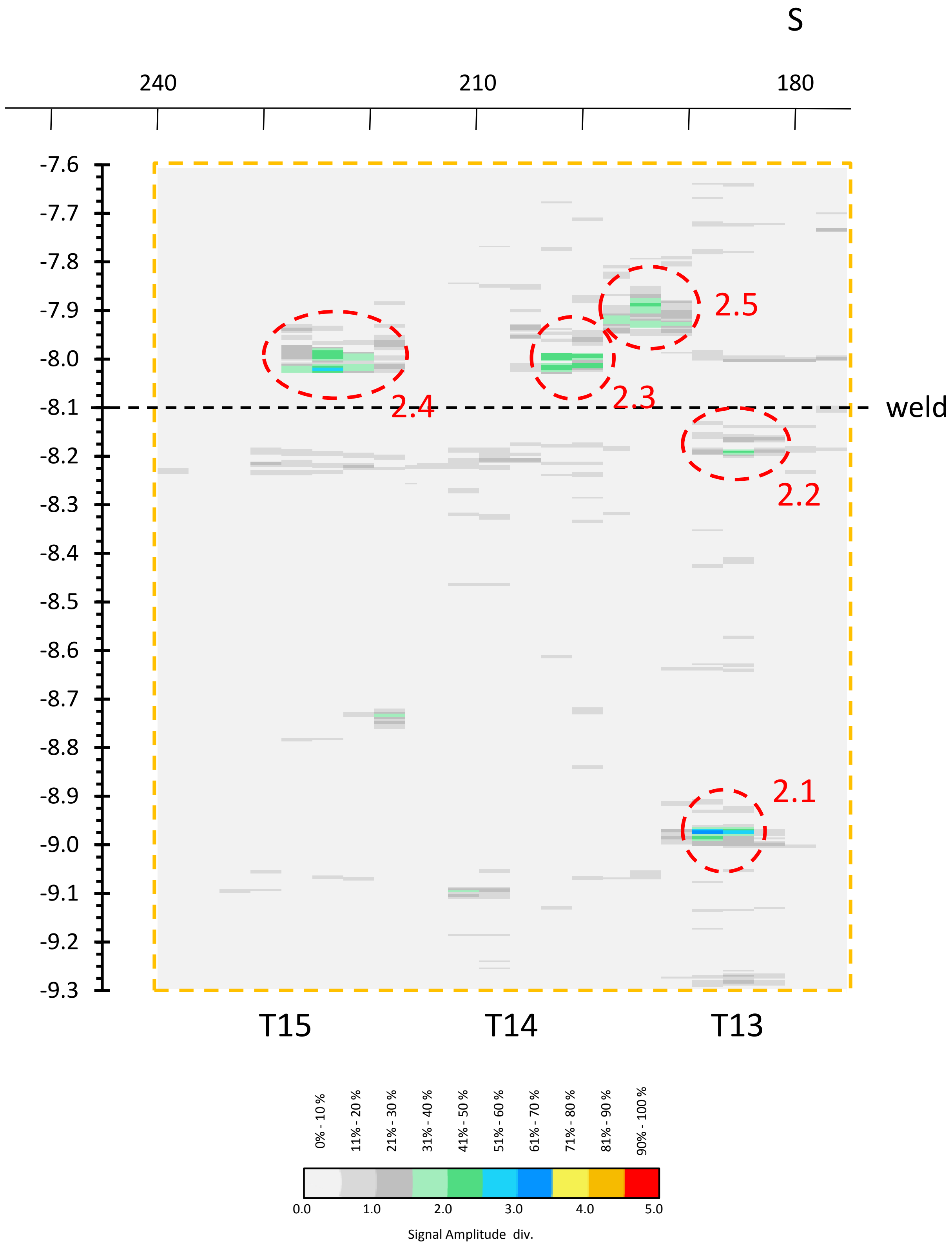


Figure 8: Region of interest Nr. 2 and contained indications of internal corrosion

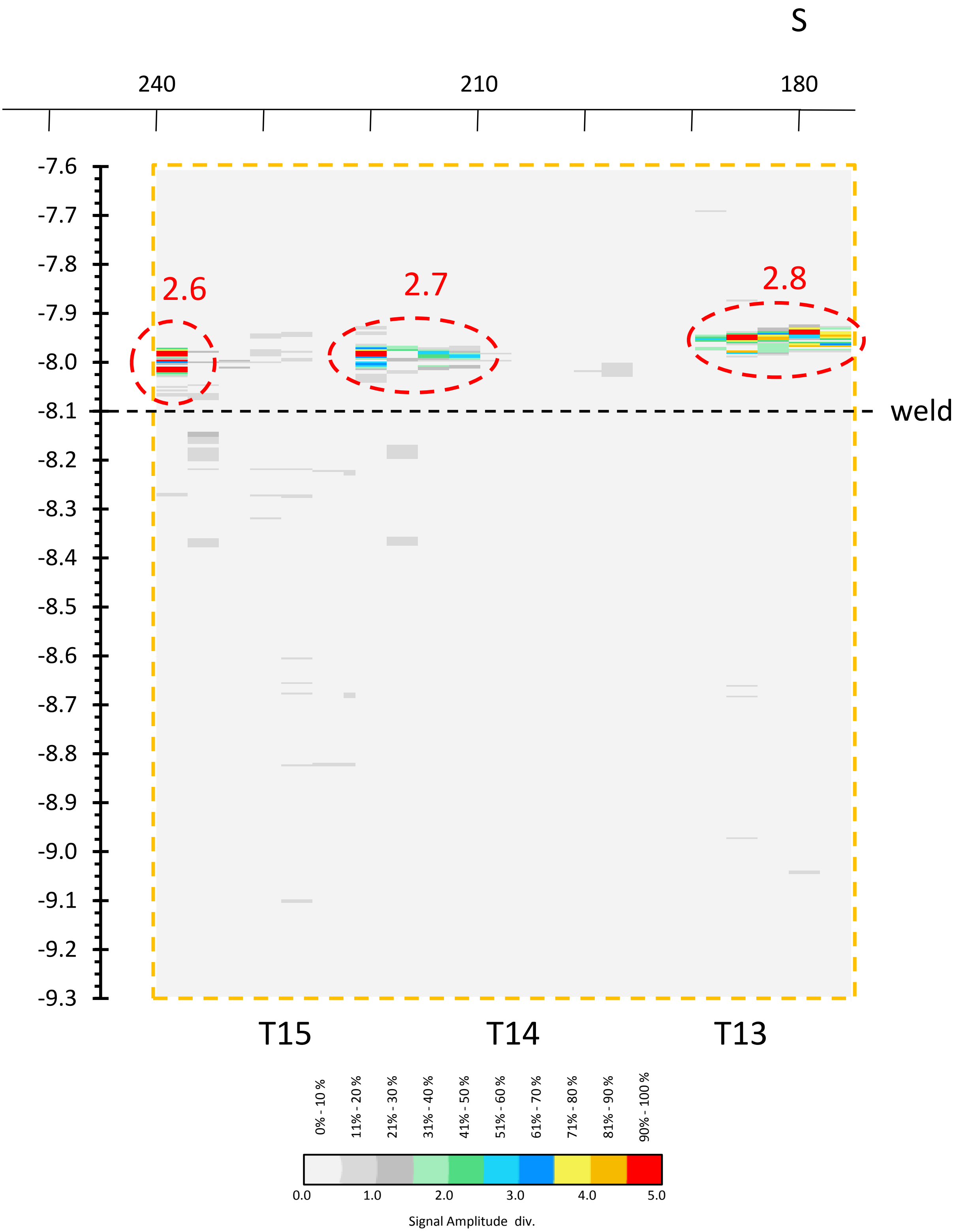


Figure 9: Region of interest Nr. 2 and contained indications of external corrosion

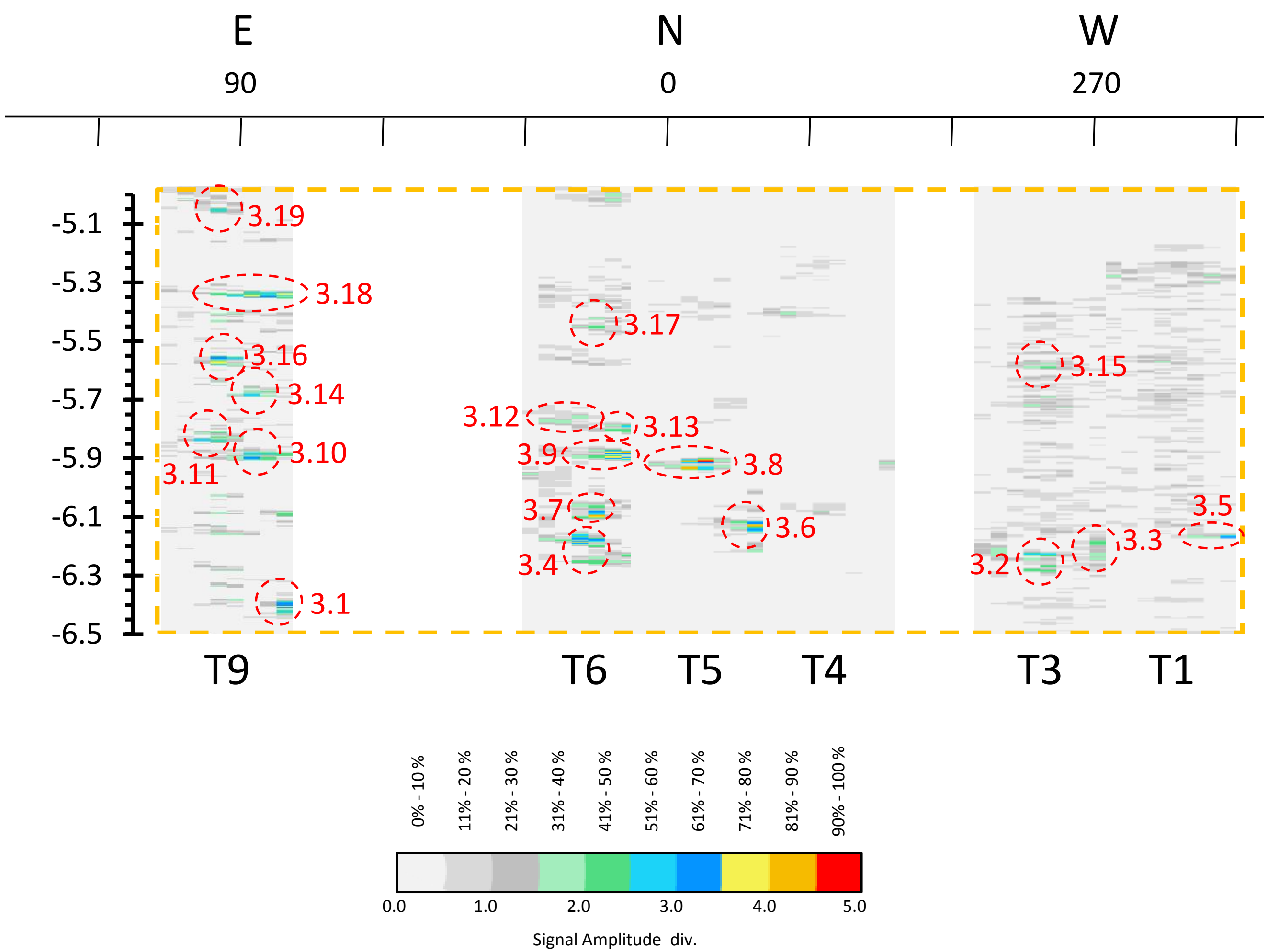


Figure 10: Region of interest Nr. 3 and contained indications of internal corrosion

Indication	EL [m]	Orientation [deg]	Length [mm]	Width [mm]	Depth Range [%]	Surface Location	Description
1.1	-10.25	70	20	20	41-50	INT	Metal Loss / Corrosion
1.2	-10.2	80	30	20	51-60	INT	Metal Loss / Corrosion
1.3	-10.0	80	20	20	51-60	INT	Metal Loss / Corrosion
1.4	-9.4	270	30	20	61-70	INT	Metal Loss / Corrosion
1.5	-9.3	90	30	50	41-50	INT	Metal Loss / Corrosion
1.6	-9.0	275	30	30	71-80	INT	Metal Loss / Corrosion
2.1	-8.17	185	20	20	61-70	INT	Metal Loss / Corrosion
2.2	-7.9	185	20	20	31-40	INT	Metal Loss / Corrosion
2.3	-7.78	205	30	30	41-50	INT	Metal Loss / Corrosion
2.4	-7.78	225	30	30	51-60	INT	Metal Loss / Corrosion
2.5	-7.83	195	40	20	41-50	INT	Metal Loss / Corrosion
2.6	-8.0	240	20	20	91-100	EXT	Metal Loss / Corrosion
2.7	-8.0	215	20	20	91-100	EXT	Metal Loss / Corrosion
2.8	-8.05	185	30	70	91-100	EXT	Metal Loss / Corrosion

Indication	EL [m]	Orientation [deg]	Length [mm]	Width [mm]	Depth Range [%]	Surface Location	Description
3.1	-6.4	80	20	20	61-70	INT	Metal Loss / Corrosion
3.2	-6.25	280	30	20	51-60	INT	Metal Loss / Corrosion
3.3	-6.2	270	30	20	41-50	INT	Metal Loss / Corrosion
3.4	-6.2	20	50	20	61-70	INT	Metal Loss / Corrosion
3.5	-6.15	240	10	30	61-70	INT	Metal Loss / Corrosion
3.6	-6.1	345	20	20	81-90	INT	Metal Loss / Corrosion
3.7	-6.05	15	20	20	81-90	INT	Metal Loss / Corrosion
3.8	-5.9	350	20	50	91-100	INT	Metal Loss / Corrosion
3.9	-5.9	15	20	30	71-80	INT	Metal Loss / Corrosion
3.10	-5.9	90	20	30	61-70	INT	Metal Loss / Corrosion
3.11	-5.8	100	20	20	51-60	INT	Metal Loss / Corrosion
3.12	-5.75	15	20	30	31-40	INT	Metal Loss / Corrosion
3.13	-5.75	10	20	20	51-60	INT	Metal Loss / Corrosion
3.14	-5.7	90	20	20	51-60	INT	Metal Loss / Corrosion

Indication	EL [m]	Orientation [deg]	Length [mm]	Width [mm]	Depth Range [%]	Surface Location	Description
3.15	-5.6	280	20	20	41-50	INT	Metal Loss / Corrosion
3.16	-5.55	90	20	20	71-80	INT	Metal Loss / Corrosion
3.17	-5.45	15	30	50	41-50	INT	Metal Loss / Corrosion
3.18	-5.35	85	20	45	71-80	INT	Metal Loss / Corrosion
3.19	-5.05	95	20	20	51-60	INT	Metal Loss / Corrosion

Table 4: Features of the individual indications

3.4. Discussion

Several severe indications of internal metal loss have been found. They are isolated pitting type indications. The wall thickness in between these indications seems to be unaffected. The typical size of these indications is in the region of 20-30 mm with wall loss readings in the order of 60% - 90%. None of them seems to have grown through the surface. However, the depth of the deepest of these indications seems to be close to a through hole.

In addition a severe indication was found immediately above the weld at -8 m (see Figure 11). The components are marked 2.6 to 2.8 in the table. In the MEC-Data it appears internal and external. In some areas the depth of the indication is rated to 100% meaning that it has grown to the outside. It can clearly be assigned to an area observed in the video data. The section is shown in Figure 11. The area is marked in red and also shows a through hole since water in- and outflow has been observed in the corresponding video footage. The axial extend of the indication is in the order of 50 mm. It runs in the circumference for some 50 cm.

Figure 11: View of the south-western weld region of xx at EL -8.1 m (screenshot from video file of Track 14). The area marked in red corresponds to the external indications shown in Figure 9.

4. Technical Details of the Instrumentation

4.1. Description of the MEC (Extended SLOFEC) 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 pipe structures. However, modifications of the standard eddy current technologies allow for the inspection of deeper structures. At Innospection magnetically biased eddy current 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. MEC (Magnetic Eddy Current) is the next generation of fast corrosion mapping technique based on the further development of the SLOFEC technique.

Specifically developed Eddy Current sensors are able to generate a higher density Eddy Current field for increase defect detection sensitivity are used on the 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 in Figure 12.

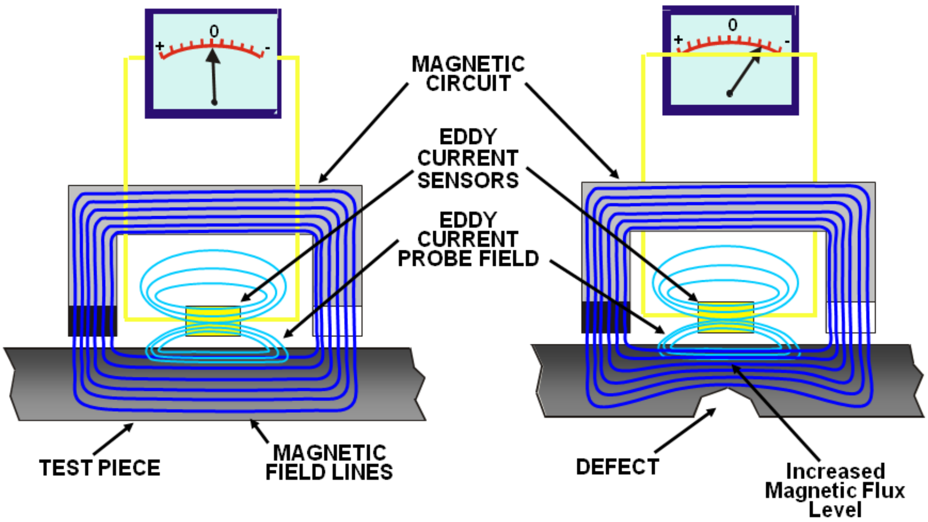


Figure 12: Principle of Eddy current measurement

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

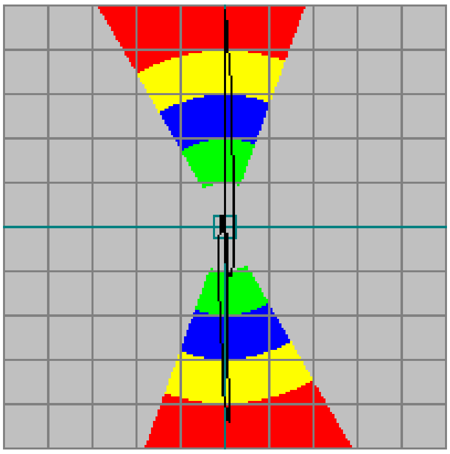
For external corrosion detection, the differential mode was used.

The amplitude of the signals was set so that the artificial reference defect (Ø 10mm, 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.

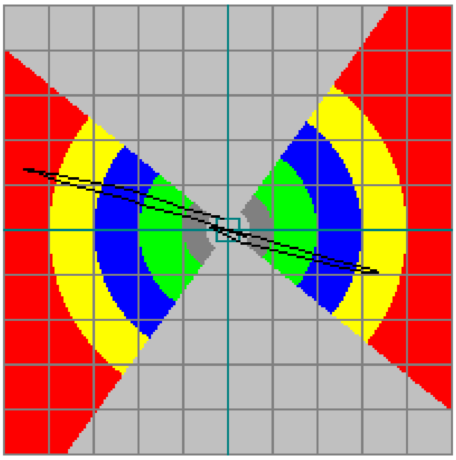
The differential channels of all the sensors were set so that internal defects were indicated in the vertical signal phase direction as shown in the diagram below. By moving the scanner in the reverse direction, the internal defect signal would show the first peak down, followed by the second peak up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

Sample signal display of internal defect

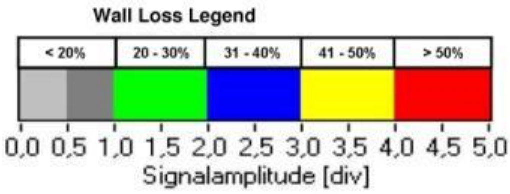


Subsequently external defects are indicated in the horizontal signal phase direction as shown below. Moving the scanner in the reverse direction, the external defect signals have the first peak left followed by a right movement with the second peak right.

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 standard colour scheme is shown below which can differ from the actual colour scheme used in the report. The applied colour code is shown on the report sheets.



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

Below 20%	Wall Loss	- Grey
20-30%	Wall Loss	- Green
31-40%	Wall Loss	- Blue
41-50%	Wall Loss	- Yellow
Above 50%	Wall Loss	- Red

Eddy Current inspection is an evaluation method of NDT; hence all results obtained are based upon the test piece used. Material and wall thickness 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.

For the analysis the data is exported as bitmaps. These bitmaps are used for an exact arrangement of the tracks. The arrangement can be refined using circumferential weld signals. Once the exact arrangement is established, a track overview is generated, showing the exact coverage of the inspected object.

The inspected object usually is split up into sections. Even if the object is scanned in one run, it is advisable to split the data up into shorter sections. The data displayed in bitmaps will not reveal anything if too long distances are shown. A typical section length is 10 m. For these sections bitmaps 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. The bitmap with horizontal phase displays the outer layer of the object, whereas the bitmap with vertical phase displays the inner surface. Different types of defects may appear in different shape and size.

4.4. Description of the MEC-Combi Crawler Tool

The MEC-Combi Crawler pipe scanner is designed and built for high performance inspection applications. Using the **M**agnetic **E**ddy **C**urrent technique (MEC), the pipe scanners allow the detection of internal and external corrosion in thin and thick walled piping/vessel components. This dynamic inspection technique utilises eddy currents in combination with a magnetic field. With the superimposed DC-magnetisation, the depth of penetration is increased to such an extent that the internal corrosion attack (metal loss) can be detected from the external surface. It also allows the detection of small volumetric internal and external defects. Additionally, the tool is equipped with a UT sensor allowing scattered measurements of the wall thickness.

The scanner head with a multiple 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. A view of the tool is shown in Figure 13.

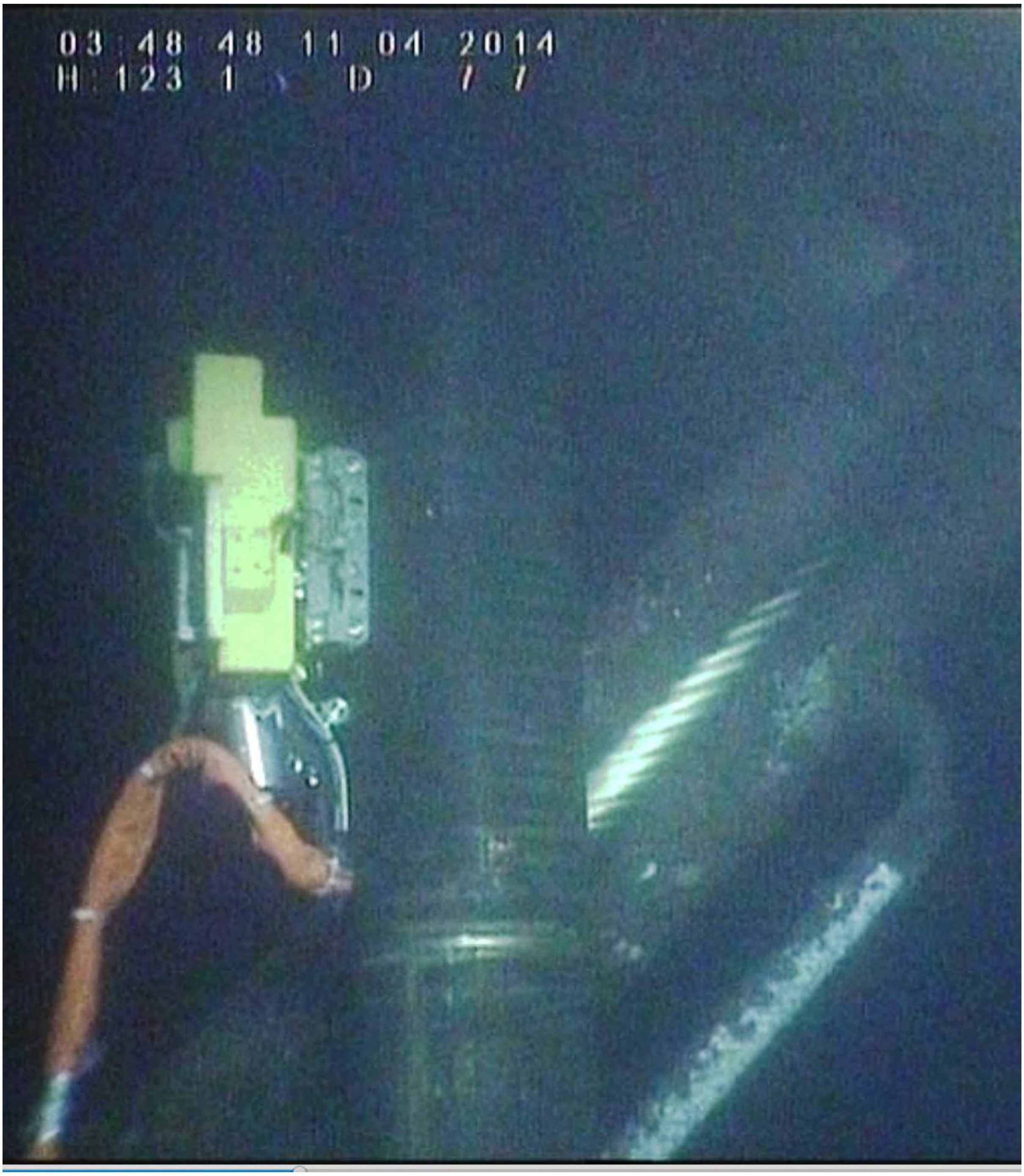
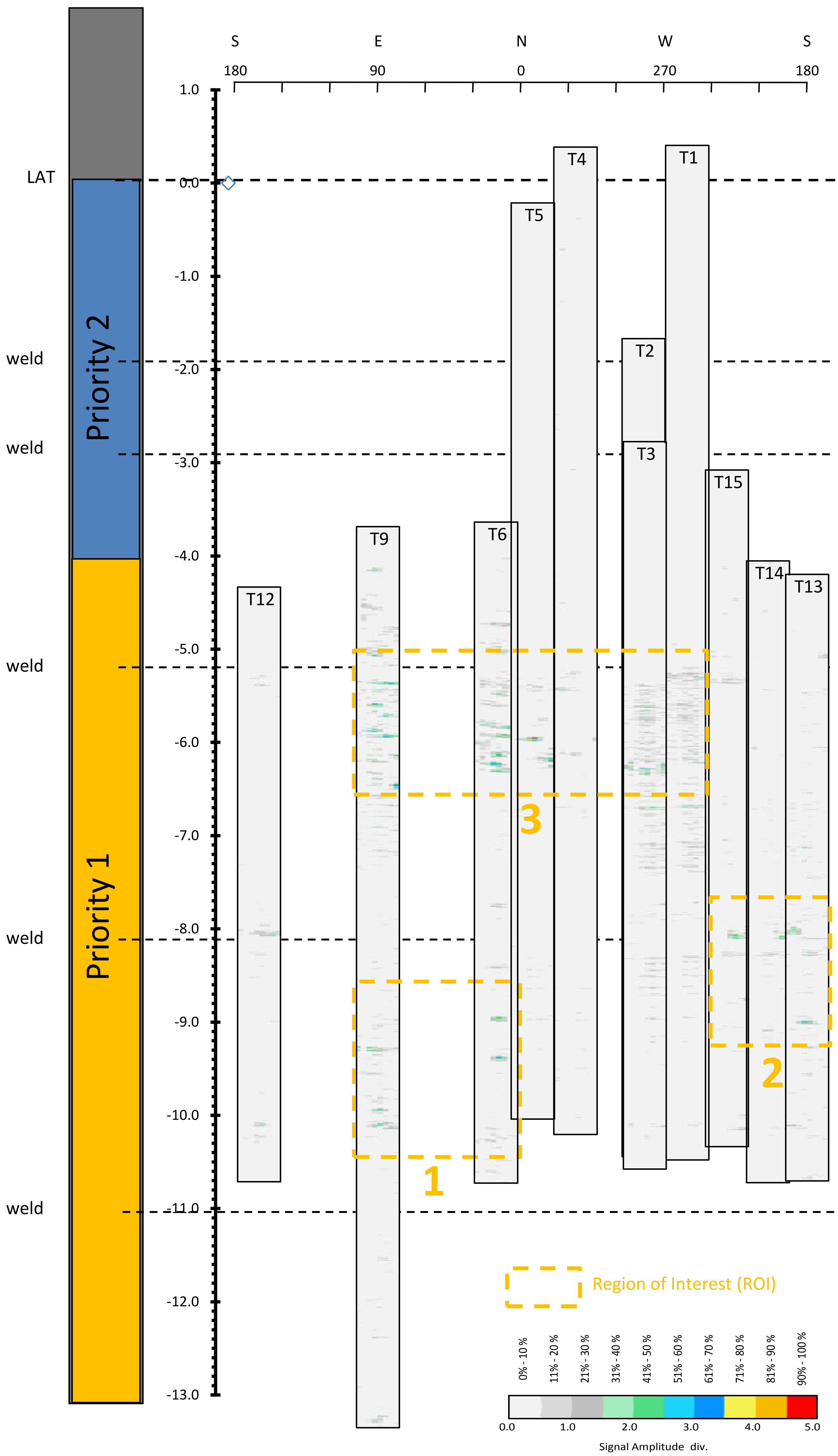


Figure 13: The MEC-Combi crawler tool for the inspection of pipes with top-side deployment

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.

APPENDIX

Scan Results and Track Position Overview (internal corrosion)



Scan Results and Track Position Overview (external corrosion)