FLEXIBLE RISER

EXTERNAL INSPECTION REPORT

Using MEC-FIT™

Prepared for

CLIENT

Final Report: Kxxx-xx

Rev	Document	Author		Checked		Approved By		Date
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	Director R&D
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1. Executive Summary

The inspection of the riser on the platform was carried out on ___. Three major defects have been detected. Two indications were found in the splash zone. The corresponding signals stem from the outer layer and represent surface corrosion. The metal loss amounts to some 30% of the thickness of the outer layer. At a slightly deeper position a cracked wire was detected.

2. Inspection Execution

2.1. Task

Innospection Ltd. has been asked by the client to inspect the riser of the platform using the MEC-FIT™ Technology.

The technology was built into the MEC-HUG™ tool (ref. 2.3) to allow for an inspection from top-side. The area to be inspected was from +7.5 m to -12.5 m. The particular attention was to be drawn to both layers of armoured wires. The splash zone was of particular interest.

2.2. Inspection Object

The inspected riser is an unbonded flexible riser pipe. It is located on the platform in a bundle of risers as shown in Figure 1.

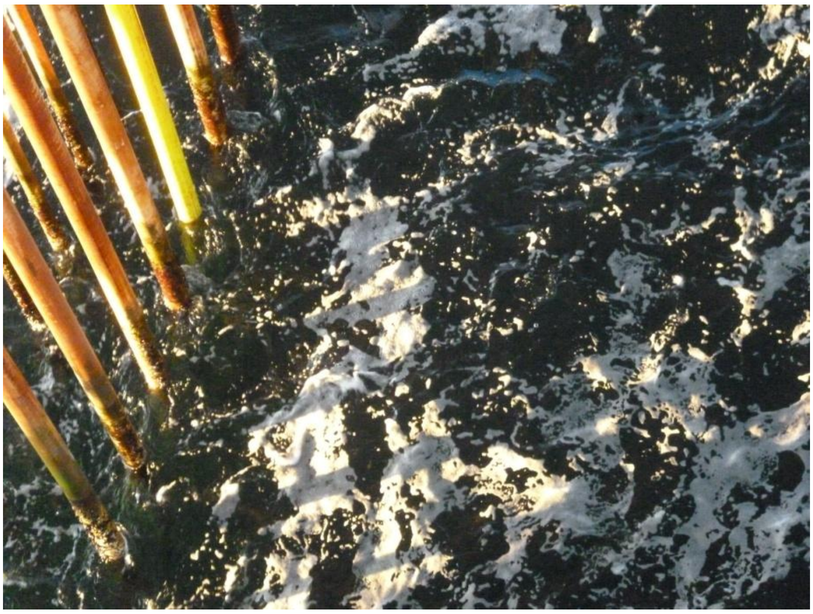

Figure 1: View on the bundle of flexible risers on the platform

The riser has an internal layer set-up as described in Table 1.

No	Item	Material	Layer Thickness [mm]	Outer Diameter [mm]
	Pipe inner diameter			101.6
1	Carcass	AISI316	5.0	111.6
2	Intermediate Layer	Polyester	0.5	112.5
3	Inner lining	PA11	5.0	122.5
4	Intermediate Layer	Polyester	0.3	123.0
5	Pressure armour	Carbon steel	6.0	135.0
6	Intermediate Layer	Polyester	0.4	135.8
7	Anti wear layer	PA	1.0	137.8
8	1.st tensile armour	Carbon steel	3.0	143.8
9	Intermediate Layer	Polyester	0.7	145.3
10	Anti wear layer	PA	1.0	147.3
11	2.nd tensile armour	Carbon steel	3.0	153.3
12	Intermediate Layer	Polyester	0.8	155.0
13	Outer sheath	PA11	5.0	165.0

Table 1: Layer set-up of the platform riser

For the inspection the relevant parameters are:

- Non-conductive thickness to first armoured layer: 5.8 mm
- Thickness of armoured layer: 3 mm
- Angle of wires towards axis: 35 deg

A determination of the lay angle of the armoured layers from the data is possible (ref. Section 3.8).

2.3. Equipment

The MEC-FIT™ inspection technology was used. For the top-side deployment a suitable tool (MEC-HUG™) was designed and built. The MEC-HUG™ tool has the following technical parameters:

MEC-HUG™ tool:	Hydraulically driven crawler to be clamped to a vertical pipe from the outside. The diameter is adjustable. The tool weight is 350 kg in air and 18 kg in water. It is 2 m high and has a diameter of 80 cm.
Sensors:	Eight Sensors of type FIT22. The unit covers a circumferential width of 180 mm. One Hall-Effect Sensor is used to control the strength of the magnet.
Scanning Speed:	up to 4.8 m/min or 0.08 m/s
Eddy Current Instrument:	MEC-IQ Data System
Software Version:	Innospectit Version 2.0

For more detailed information on the MEC-HUG™ -system refer to Section 4.

2.4. Mobilisation and Preparation

Inspection team

The inspection team was made up of the following people:

Team leader and project manager
Eddy Current PCN Level 2
Technician

Operational Dates

The equipment has been mobilised to the onshore base on ___. The cleaning was carried out in the time from ___ to ___. Upfront tests on site have been done on ___. All tracks have been recorded between the___ and the___. The crew has returned to the onshore base on ___. The equipment was retrieved back in the workshop on ___.

Cleaning

The cleaning was done by the contractor with high pressure water jetting. The cleaning was successful allowing for a smooth ride of the MEC-HUG™ tool over the surface. The riser was cleaned down to EL -15 m.

Procedure for Calibration and set-up

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

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- OperationalProcedure.xxxxxClient.Platform-FlexibleRisers

The general test set-up was done prior to mobilisation in the workshop. Flexible riser pipes with artificial defects have been tested to allow for classification and sizing of defects. On site the tool was checked by sliding bespoke reference pieces over the sensors. All sensors have shown appropriate signals. The settings were done accordingly before the tool was launched. In a first run data were acquired from the riser above the water level. This allowed for verifying the settings.

2.5. Execution and Performance

Scanner movement

The scanner moved smoothly on the riser. Above water the weight of the tool required it to be moved up and down by a winch. In water the movement was done by hydraulic drives as planned. In one case the aid of the steel rope was used to bring the tool back up. The circumferential movement allowed the device to be positioned on a defined circumferential position.

Figure 2 and Figure 3 depict the vertical speed profiles for a downwards track (No. 8) and for an upwards track (No.5). The scanning speed is calculated by the sampling rate and the corresponding encoder values. The sampling rate is given by the electronics and is constant at all times. In the first case the speed is at a very constant level of about 0.08 m/s. In the latter case there is a little more speed variation. There are no speed excursions that would compromise the quality of the inspection data.

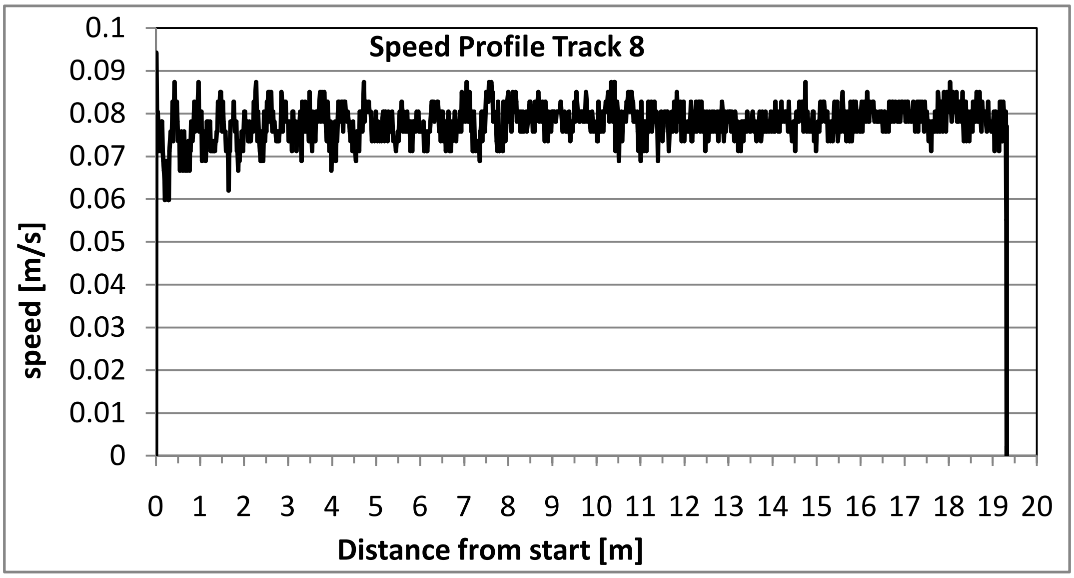


Figure 2: Speed profile for track 8 with an upwards movement

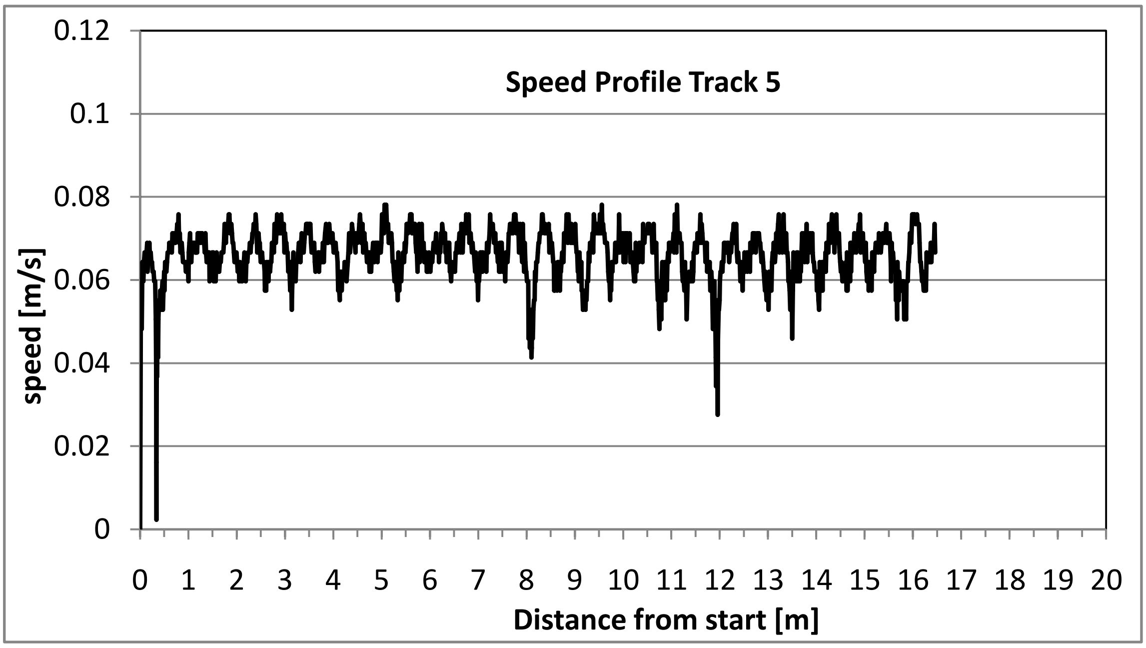


Figure 3: Speed profile for track 5 with a downwards movement

Tracks and coverage

A total of 8 track runs has been performed. This led to a full coverage of the riser in the respective elevation. Refer to Section 3.1 for an overview of coverage. Platform North (0°) has been chosen as reference for the inspection. The orientations of all tracks in this report are given relative to platform north. See Figure 4 for a definition of the tool positioning and the corresponding directions. The flat projections of the riser within this report are depicted looking from platform north onto the outer surface of the riser.

Track	Orientation [deg]	Start, [m]	End, [m]	Comments
1	150	-12.5	7.5	magnet off
2	45	7.5	-12.5	magnet off
3	300	-12.5	7.5	magnet off
4	210	7.5	-12.5	magnet off
5	150	-12.5	7.5	magnet on
6	45	7.5	-12.5	magnet on
7	300	-12.5	7.5	magnet on
8	210	7.5	-12.5	magnet on

Table 2: Overview of track parameters

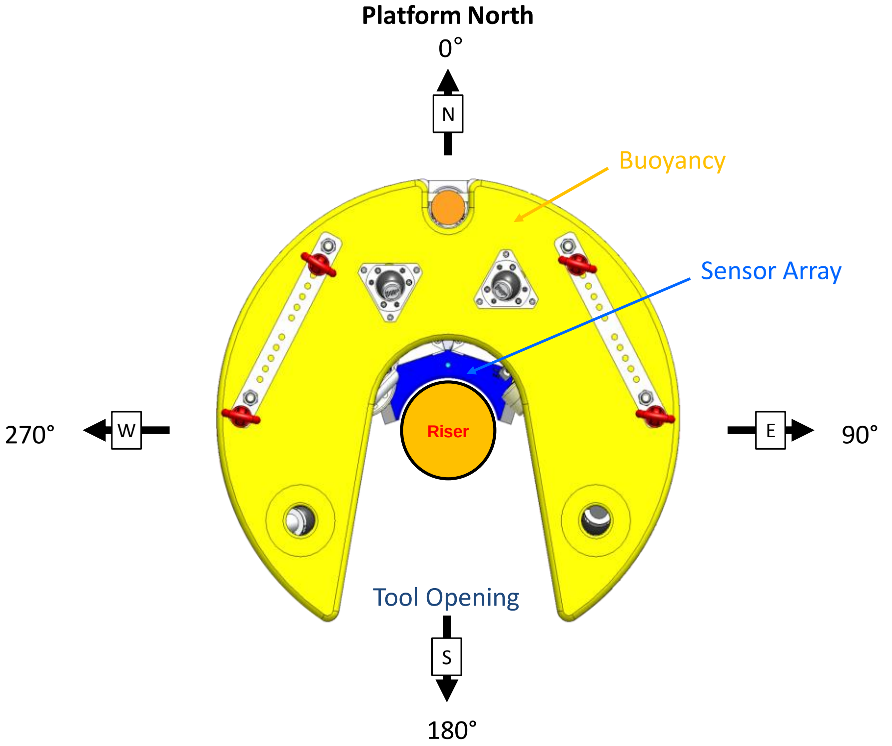


Figure 4: Definition of the tool orientation and the corresponding directions. All of the directions given in the report are relative to platform north.

Video Surveillance

The tool was equipped with three cameras, an upward facing camera, a side facing camera and a forward facing camera. The cameras worked fine at all times. The photos of Figure 5 were taken using the forward facing camera.

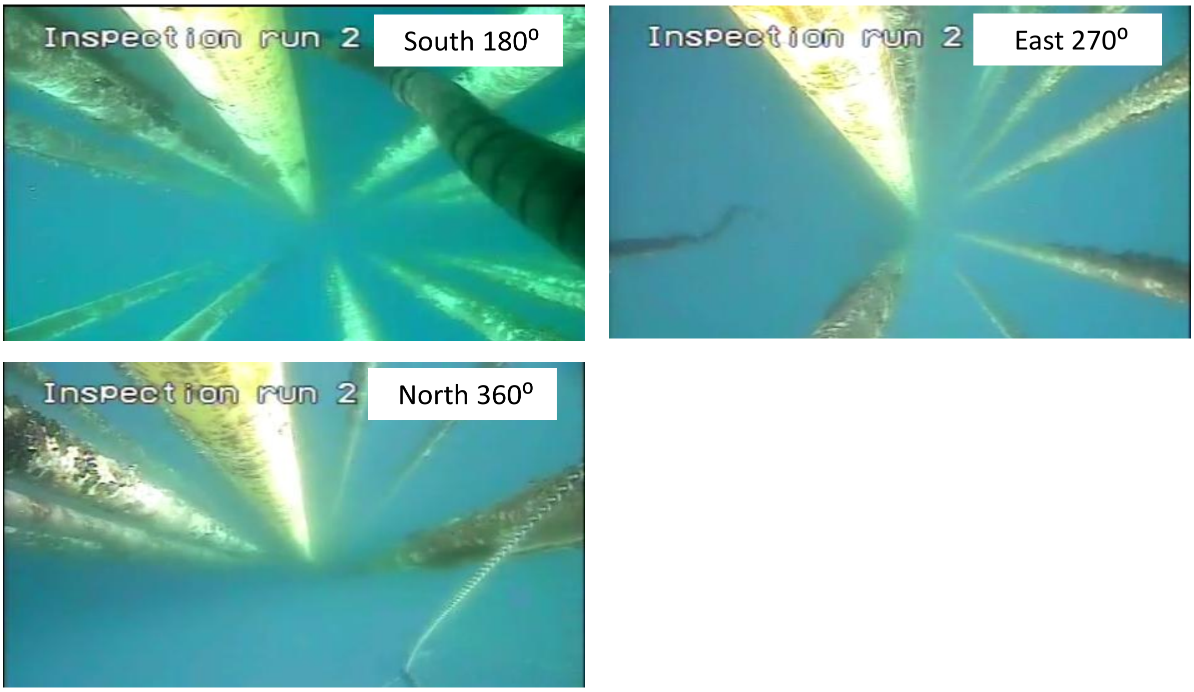


Figure 5: Views of the forward camera at different circumferential positions

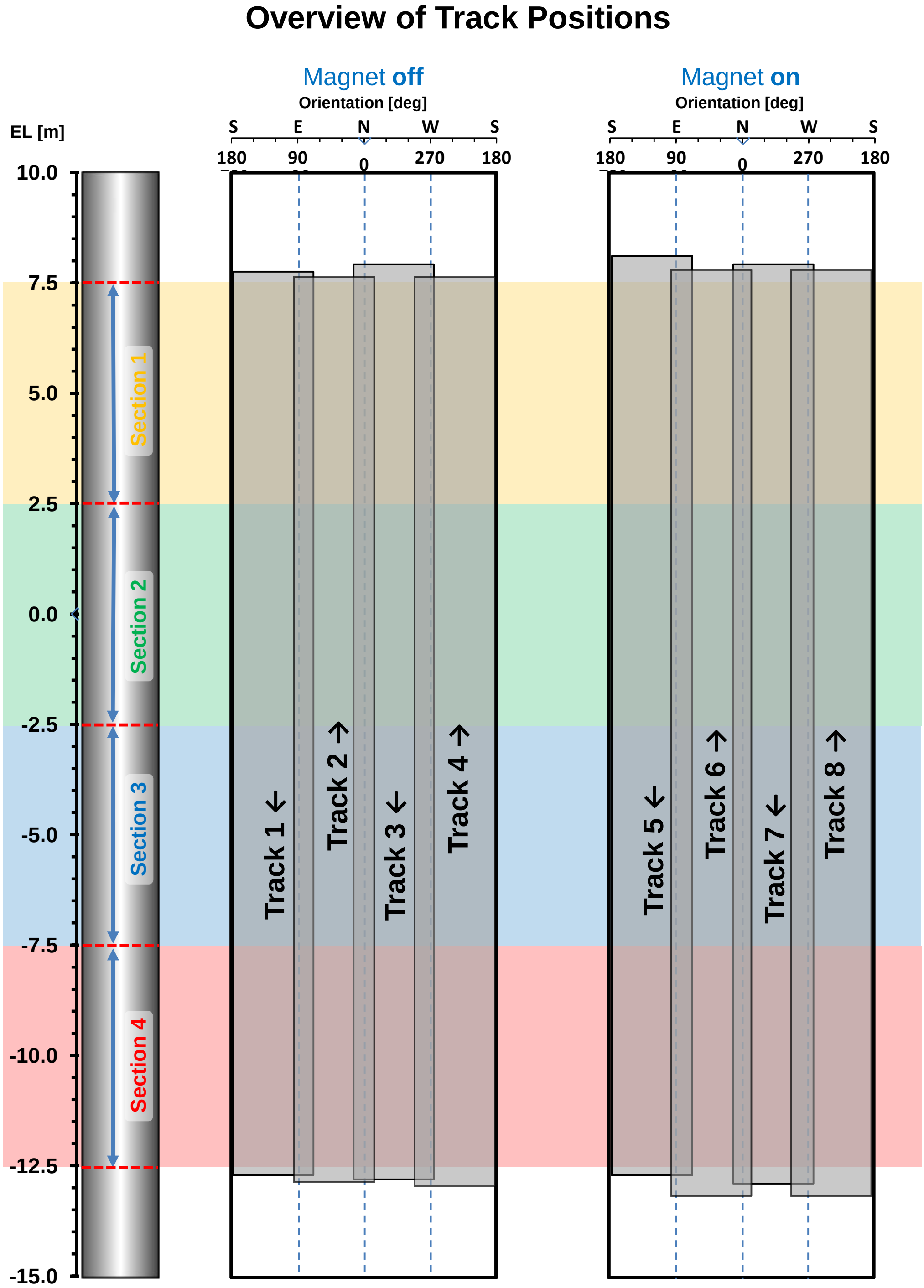
Data Quality

The switching of the magnets worked without any problems and the status of the magnet was monitored by the Hall Effect sensor. The distance encoder worked at all times. The typical start position was with the MEC-HUG™ tool at +8.6m. The sensors are at EL 7.5 m in this position. A marking allowed for reproducible starting conditions. The encoder was used to ensure stopping at the correct position in the submersed range.

The signal quality has been definitively good for a proper probability of detection for defects and complete data analysis.

3. Results

3.1. Track Position Overview



The separate sections are depicted vertically with the elevation scale on the left. The orientation is given on the top. The view is onto the north side of the riser. Altogether four views of the same riser section are shown. The data originates from two different scans, one with magnet on, one with magnet off. For both scans the data is shown at different phase selections. For the meaning of different phase selections refer to section 4.

In case of indications a red circle is drawn around the area of interest. This circle is shown on all respective spots, even if the signal is only visible in one of the views. A reference number is put next to the circle.

3.2. Section 1: above LAT

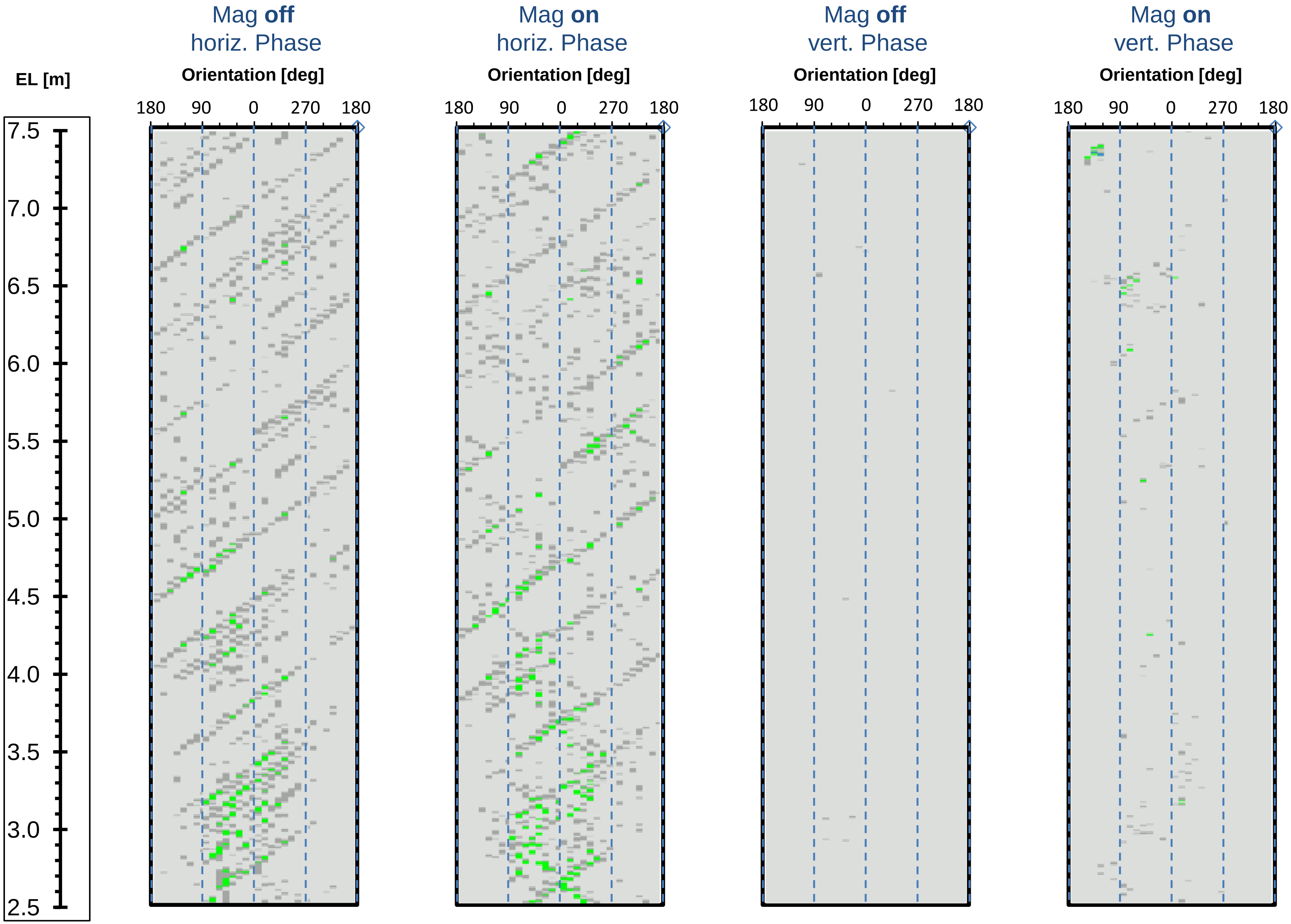
3.3. Section 2: 7.5 to -2.5 m

3.4. Section 3: -2.5 m to 2.5 m

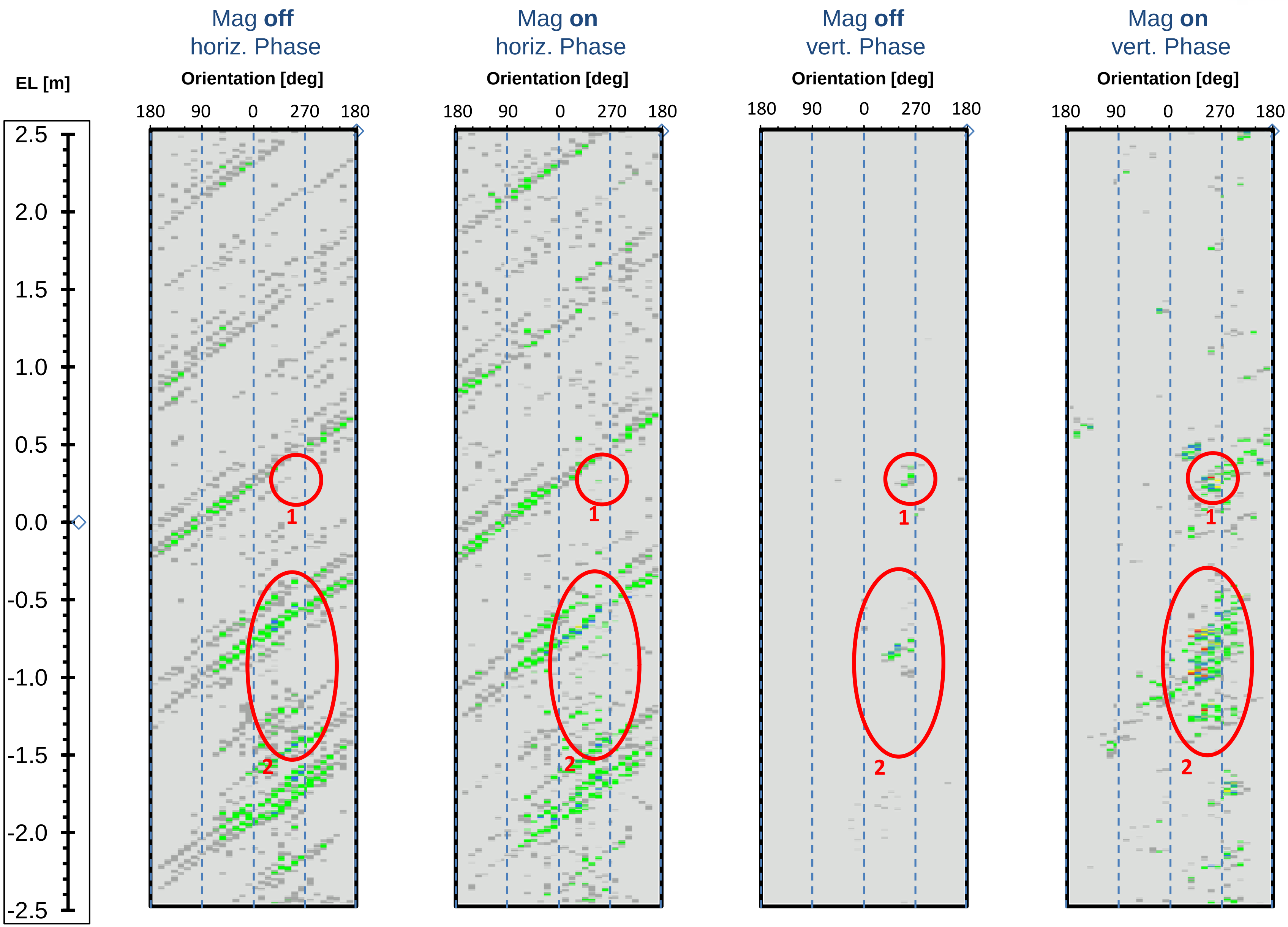
3.5. Section 4: -7.5 m to -2.5 m

3.6. Section 5: -12.5 m to -7.5 m

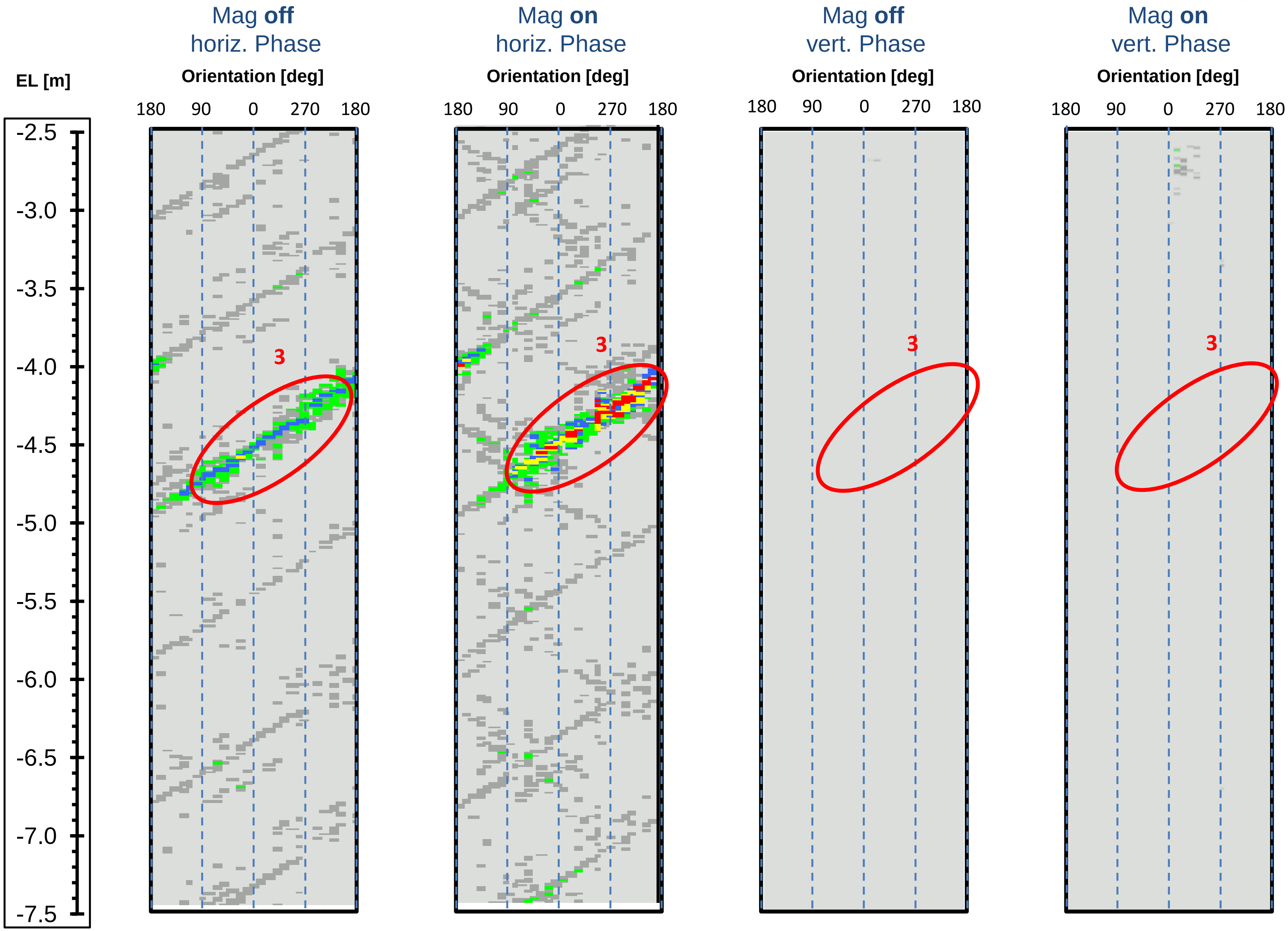
Riser Section 1 (EL 2.5 m to EL 7.5 m)



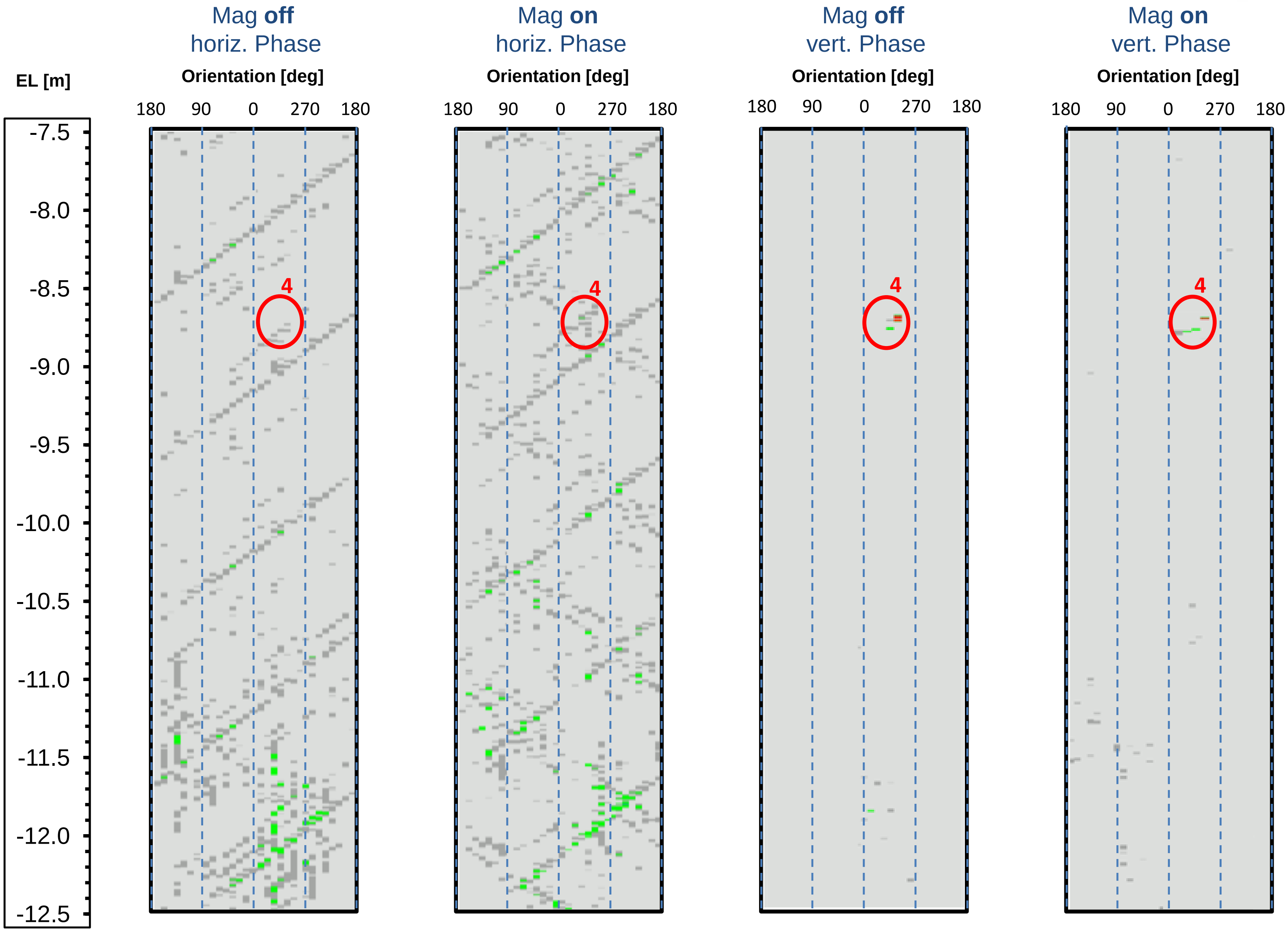
Riser Section 2 (EL -2.5 m to EL 2.5 m)



Riser Section 3 (EL -7.5 m to EL -2.5 m)



Riser Section 4 (EL -12.5 m to EL -7.5 m)



3.7. List of indications

Ind.	EL [m]	Orientation [deg]	Length [mm]	Width [mm]	Depth % of one wire thickness	Affected wires	Description
1	+0.2	300	20	20	0-25	1-2	Surface corrosion
2	-1.1	315	500	100	0-25	>10	Surface corrosion
3	-4.5	270	400	300		1-2	Surface wire misalignment
4	-8.7	300	<5	20	25-50	1	Crack-like indication

Table 3: Features of the individual indications

3.8. Discussion

For the lay angle of the armoured layers, the data yields a value of approx. 36º ± 2º. This would be consistent with the given value of 35º, which is quite common.

Three indications have been found within the scanned area of the riser. Two of them are in the splash zone and represent some surface corrosion. The latter is found at deeper elevation and stems from a cracked wire.

Indication 1:

Indication is found at +0.2 m slightly above LAT. The signal corresponds to a surface corrosion. The depth of the deepest point is in the range of 30% wall loss of the thickness of a wire. The signals were captured by tracks 3 and 7. The screenshots depicted in Figure 6 are taken from Track 7 with magnet on. It is close to indication 2 and of the same kind.

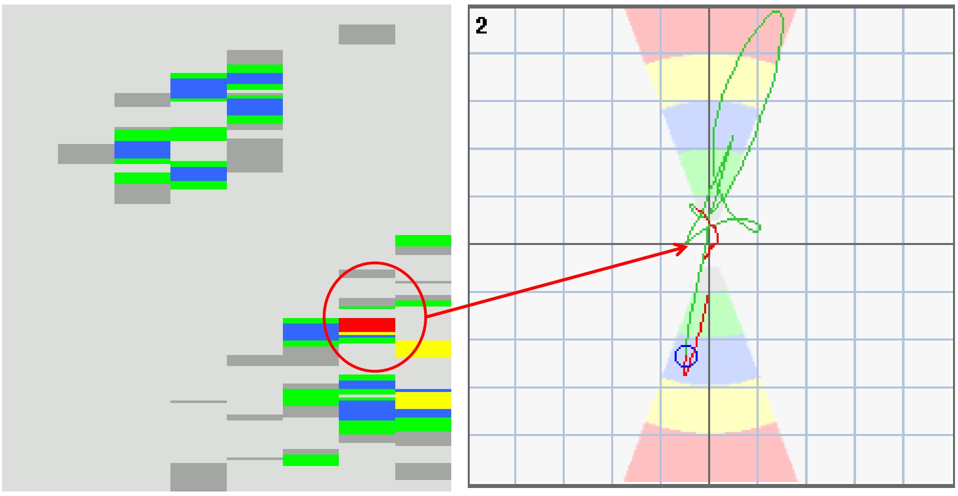


Figure 6: Signal of indication 1

Indication 2:

The second indication is shown in Figure 7. It consists of a larger area of surface corrosion. The loop-signal is shown for a deeper part of the area. The deeper spots should be in a range of 30% wall loss of the outer armoured wire (2^{nd} tensile armour).

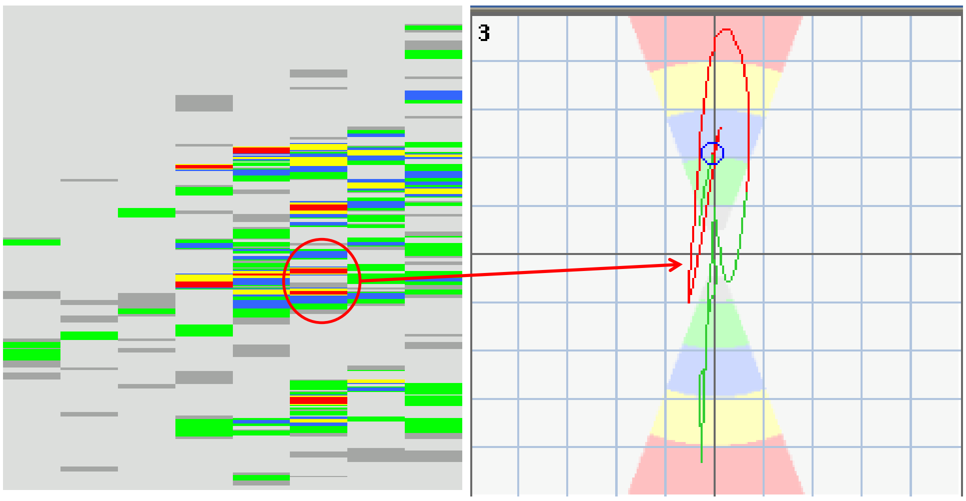


Figure 7: Indication 2; a larger area of surface corrosion

Indication 3:

Indication 3 runs parallel to the outer wire structure. The signal is shown in Figure 8. The width indicates that one wire is affected. The signal shows that this one wire is not in the regular position, but is running on top of the neighbouring wire for a length of about one meter. The signal stems from the edge of the wire and the corresponding void in the remaining structure.

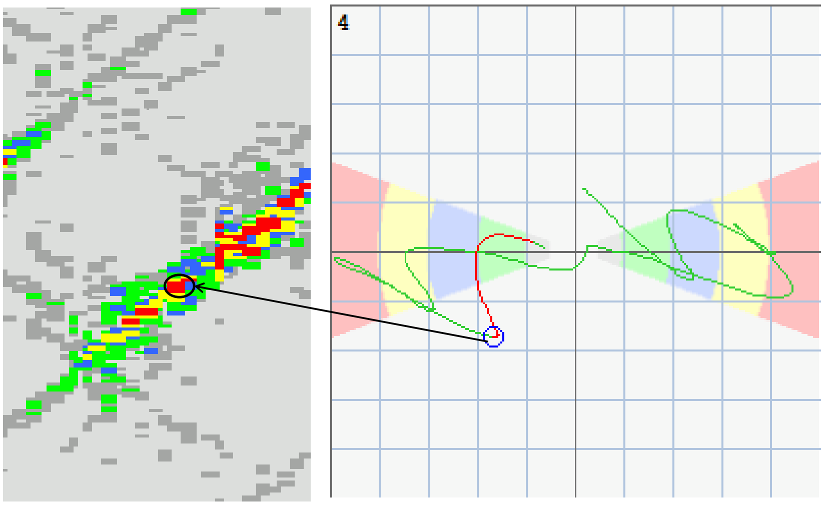


Figure 8: Signal of Indication 3

Indication 4:

The signal of indication 3 is shown in Figure 9. It is a very localised indication. The appearance indicates a crack in a single wire. The signal is only seen on a single sensor. The crack is likely to be at least 50% through the thickness of the outer armour layer. The signal remains with the magnet off. Hence it grows from the outside. A completely snapped wire would produce a larger signal.

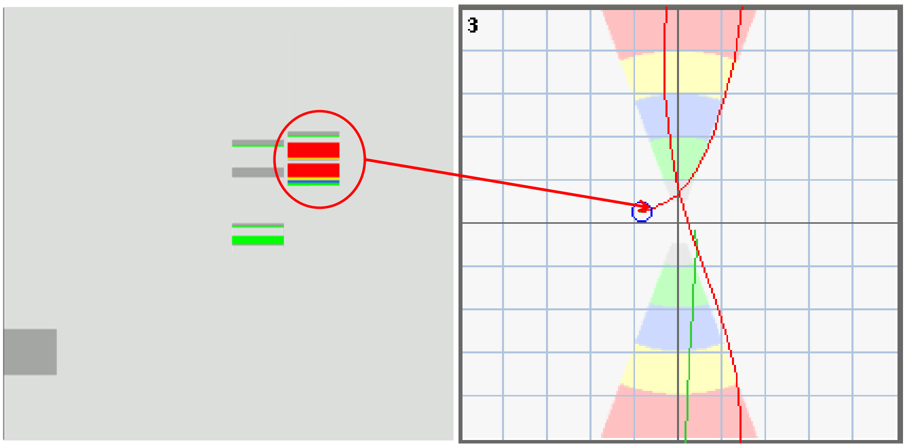


Figure 9: Signal of Indication 4

4. Technical Details of the instrumentation

4.1. Description of the MEC-FIT™ 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 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™. For the modification and adaptation to flexible riser inspection it is now known as MEC-FIT™.

The idea of MEC-FIT™ 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.

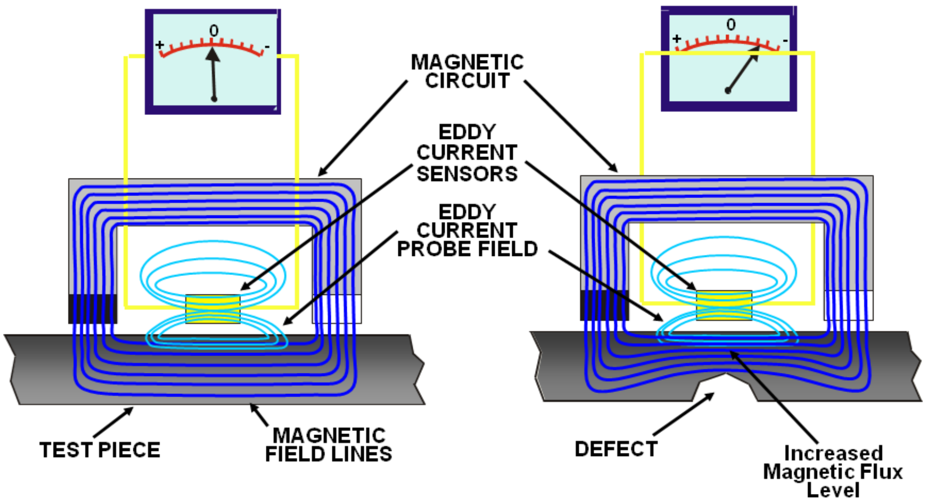


Figure 10: Principle of Eddy current measurement

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.

One of the most defining aspects of flexible riser pipe is the presence of wires or strings running helically around the pipe. This has a fundamental impact on electromagnetic NDE methods. The question of the scanning and magnetisation direction needs to be considered. Several configurations can be conceived. A certain level of magnetisation needs to be achieved; hence the magnetisation cannot deviate too much from the direction of the wires. There are at least two wiring directions. For mechanical reasons only axial and circumferential scanning are reasonable.

In addition the employed probes usually yield a strong signal for the gaps between the wires. Refer to Figure 11 for a sample measurement of 4 mm thick armour wires, 12 mm in width and a gap of app. 2 mm.

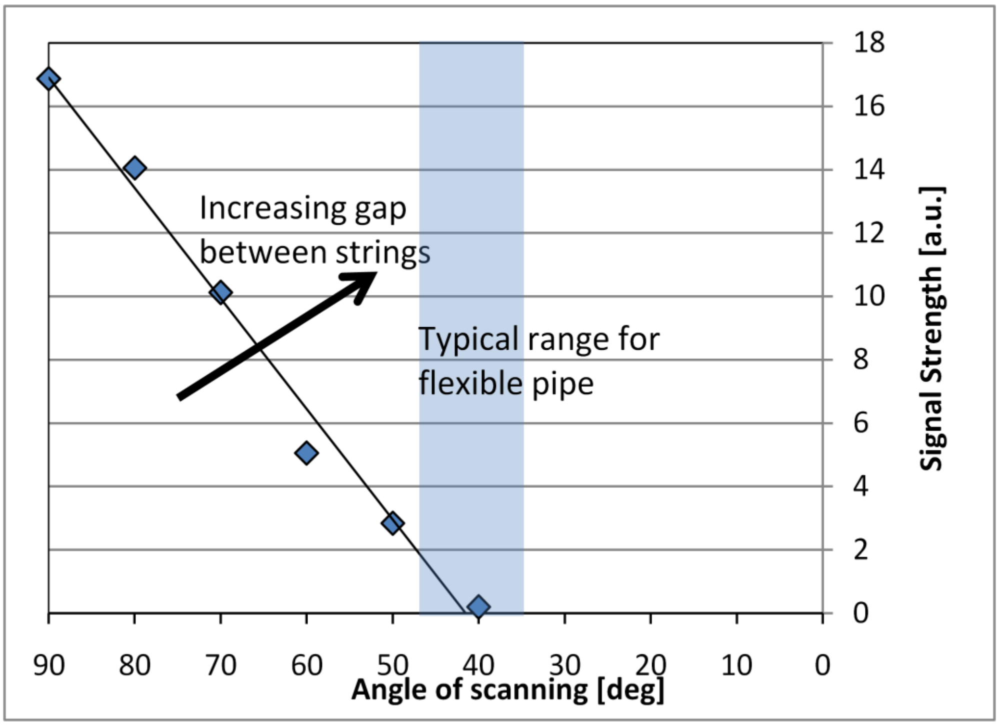


Figure 11: Signal of gaps between wires as a function of scanning direction measured versus the pipe axis.

Typical flexible riser pipes have angles between 35º and 45º. With the two layers wound in opposite directions an angle of 45º would be a crossing of the layers at right angles. As can be seen in Figure 11 the probes are designed such that the signal of a gap becomes irrelevant at the typical angle. It is known that the gaps are not at all uniform in flexible riser pipes. It may be interesting to be able to detect larger gaps in the armour layer. Larger gaps do not necessarily constitute a defect, but it may be used as a reference location in a structure that may appear very homogeneous otherwise.

Another question is the implication of the magnetisation direction. In general this will be parallel to the scanning direction. The wire structure has a fundamental impact on the magnetizability of the structure. A finite element study has been carried out to determine this impact. A typical configuration is shown in Figure 12.

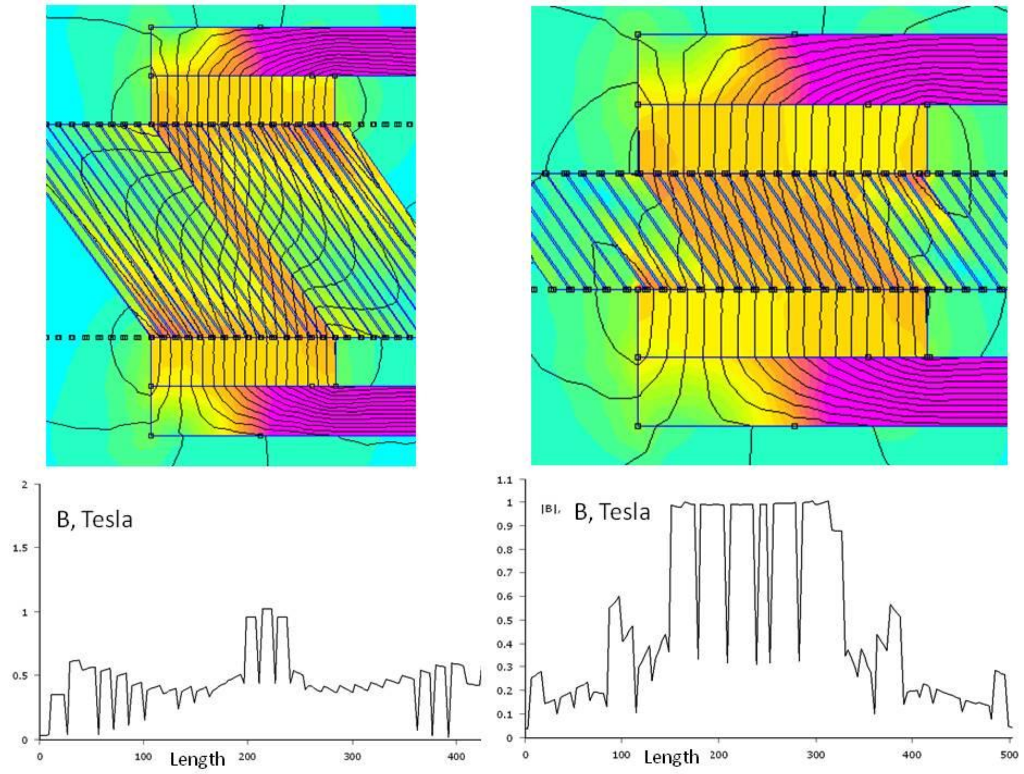


Figure 12: Comparison of different magnetization devices on the wire magnetization

The upper part of the picture shows different configurations of the magnetisation device. In particular the width to length ratio has been altered. The lower diagrams show the respective magnetisation level. The area of homogeneous magnetisation is too small in the configuration on the left.

4.2. Analysis Procedure

Once the data of a flexible riser is received all sensitivities and phase angles are adjusted. The adjustment is done such that the underlying wire structure becomes visible. This is the lowest level signal. The signal of the wire structure is put into a horizontal phase angle. The wires appear in a “left then right” sequence. These settings are put into the “topside” layer of the Innospectit Software. The wire gap signals are amplified to yield approx. ¼ of the full screen height. A colour code is selected that makes wider gaps appear in green and smaller ones in gray. The layer topside shows colours in perpendicular orientation. An example is shown in Figure 13.

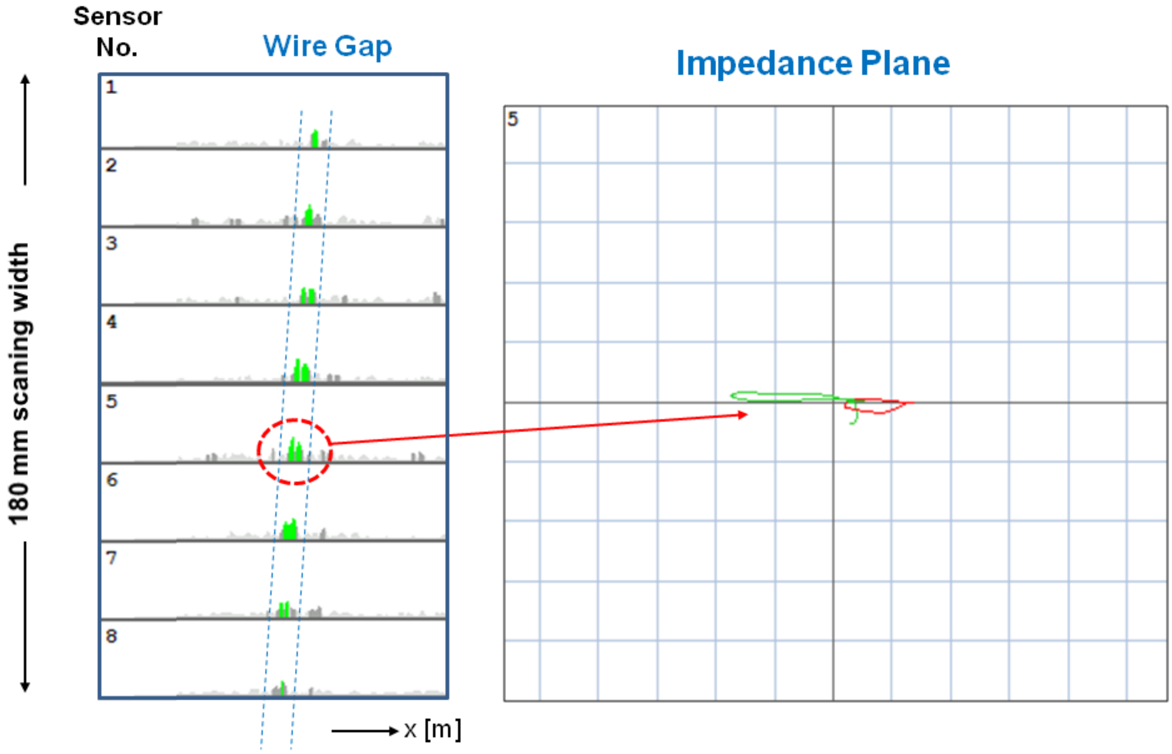


Figure 13: Typical signal of a wire gap. This signal is used as a reference.

For the analysis the data is exported as bitmaps. These bitmaps are used for an exact arrangement of the tracks. The arrangement can be made rather fine using the background gap signals. Once the exact arrangement is established, a track overview is generated, showing the exact coverage of the riser.

The complete riser is split up into sections. Even if the riser 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 5 m. For these sections bitmaps are arranged to show the mapping of data in an elevation versus orientation coordinate system. This is done for the two phase directions and for magnets on and off. It yields four mappings of the riser. The number of mappings can be higher, if intermediate magnetisation levels and other phase angles are used as well. The bitmap with horizontal phase and magnet off displays the outer wire structure. The bitmap with horizontal phase and magnet on usually displays the same wire structure. In the latter sometimes the inner wire structure also becomes visible. The vertical phase bitmaps do not show any signal at all for an intact flexible riser. Different types of defects may appear in different shape and size.

4.3. Description of MEC-HUG™

The MEC-HUG™ tool employs the proven MEC-FIT™ inspection technology in a tool for top-side deployment. It allows for scanning in the axial direction of the riser and can be positioned at any circumferential orientation.

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. It is the “smart drive system” which carries wheel devices turning hydraulically in axial or circumferential orientation. The MEC-HUG™ tool is equipped with six of these wheels. This allows driving the tool in the different directions. The tool is shown in Figure 14.

Figure 14: The MEC-HUG™ tool for the inspection of flexible riser for top-side deployment.

The distances driven are measured with an encoder-wheel. It also turns when the tool changes orientation to allow for a proper positioning. An umbilical is connected to the tool for supply of electrical and hydraulic power. In addition the signal is routed to a top-side eddy current data-acquisition system via the umbilical.

Figure 15: The two pictures show the umbilical on the left and the control-box on the right.

The magnetisation level is controlled by the use of an integrated Hall sensor. The Hall sensor is positioned in between the poles and thus the voltage is related to the level of magnetisation.