DEEPWATER, HIGH-PRESSURE AND MULTIDIAMETER PIPELINES
A CHALLENGING IN-LINE INSPECTION PROJECT

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INTRODUCTION

In-line corrosion inspections with Magnetic Flux Leakage (MFL) or ultrasonic technology (UT) have become standard in pipeline integrity assessment worldwide. Lately, ultra-high resolution geometry inspection based on eddy current methods (EC) has been established to assess more accurately the internal geometry of pipelines.

Approximately 60 % of the world's gas, oil and product pipelines can be inspected with off-the-shelf inspection tools. In the past the remaining 40 % of pipelines have often been classified as 'unpiggable'. A large proportion of these unpiggable pipelines are offshore, multi-diameter lines, with low flow conditions and often with very challenging OD ratios.

Today, it is possible to develop individualized inspection solutions for multi-diameter pipeline systems. The development of such solutions can already be incorporated into the FEED process for these offshore structures. On the other hand, a great number of pipelines were constructed and laid in times when in-line inspection (ILI) was not available or not a requirement. Occasionally the passage of these offshore pipelines is restricted.

This paper presents the development of a series of 14"/18" ILI tools and their successful application survey in a 95 km long, high-pressure, heavy-wall, low-flow off-shore pipeline. In a team-effort between the pipeline operator ("Operator") and the inspection company (ROSEN) a solution was developed for a challenging pipeline, which would have been considered 'unpiggable' in the recent past.

THE PROJECT REQUIREMENTS

The project began with a request of the Operator to inspect a particular 14"/18" offshore pipeline to evaluate the integrity of the pipeline via an internal inspection.

In addition to its multi-diameter design, the pipeline posed several further challenges. The essential properties are as follows:
- Length: 163.9 km
- 14": 11.9 km (wall thickness: 20.6 mm – 22.2 mm)
- 18": 151.9 km (wall thickness: 22.2 mm – 28.6 mm)
- Bends 14": 5D
- Bends 18": 5D
- Maximum water depth: 1900 m
- Maximum pressure: 290 bar
- Known Minimum ID known: 300 mm
- Internally coated
- Medium: gas

Furthermore the pipeline has several subsea appurtenances (notably check valves, connectors, ball valves, tees and reducers) and two jumpers of the subsea connection segment and an adjacent wye-piece (Figure 1). The transition from 14" to 18" was directly incorporated in one leg of the wye-piece. This meant that a cleaning or inspection tool had to expand the driving unit and pass the cavity of the wye-piece while the rear parts were still in the 14" pipeline. Finally the tools have to pass and monitor potentially damaged sections of the 18" line.

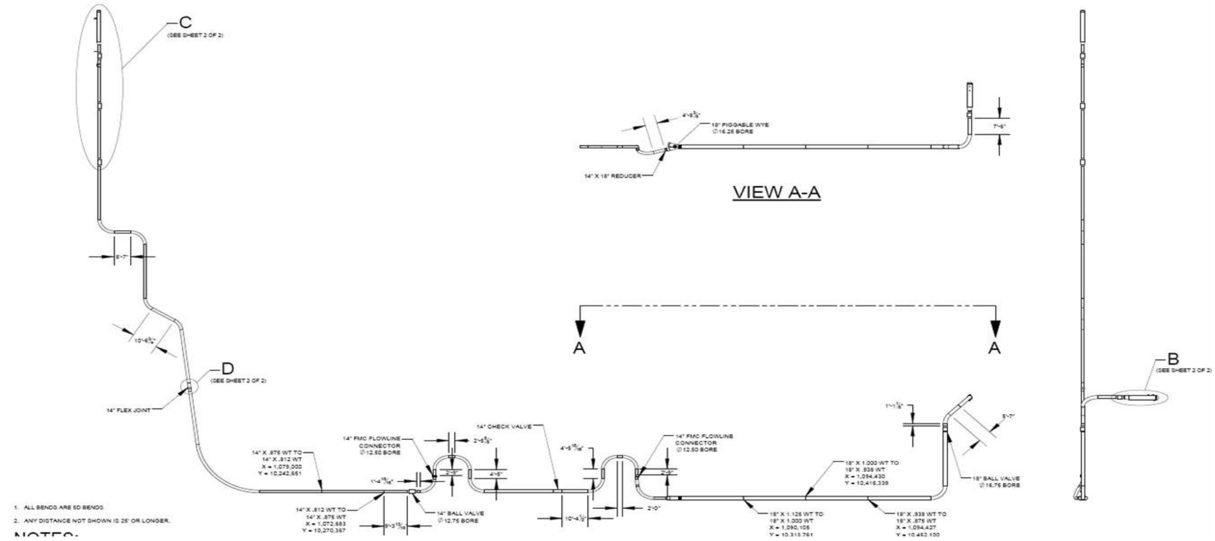

Figure 1: General view sketch of the 14"/18" pipeline

PROJECT PLANNING

The Operator's goal during project planning was to maintain its customers' product flow while ensuring the integrity and safety of its pipeline operations. With those aims in mind, the project team sought to inspect the pipeline during regular operation (no water filling or bi-directional inspection from the receiver side) through a program of high-resolution geometry (called RoGeo Xt) and MFL (CDP). Since the consequences of a possible failure of the pigging operation could have been enormous and because the particular challenges of the pipeline and operation, an extensive test program was incorporated.

The project plan had included following fields:

Tool Development

ROSEN had to develop, design and manufacture three multi diameter-tools (gauging, extended geometry, MFL) adapted to the pipeline and operational requirements.

Testing

An extensive test program was developed which included pull and pump tests of components and parts in the existing test facilities. This included pull tests through the existing 14"/16" and 18" test lines as well as pump tests in the 16" single size pump test loop simulating heavy external pipe damage.

For a full size test of the tools, the project included a test loop containing all crucial elements and features of the original pipeline (Figure 2) whereby all simulations of installations would be delivered by the Operator and the pipes, bends and additional elements would be supplied by ROSEN. The test loop was assembled and operated on the area of the Research & Technology Center (RTRC) in Lingen, Germany.

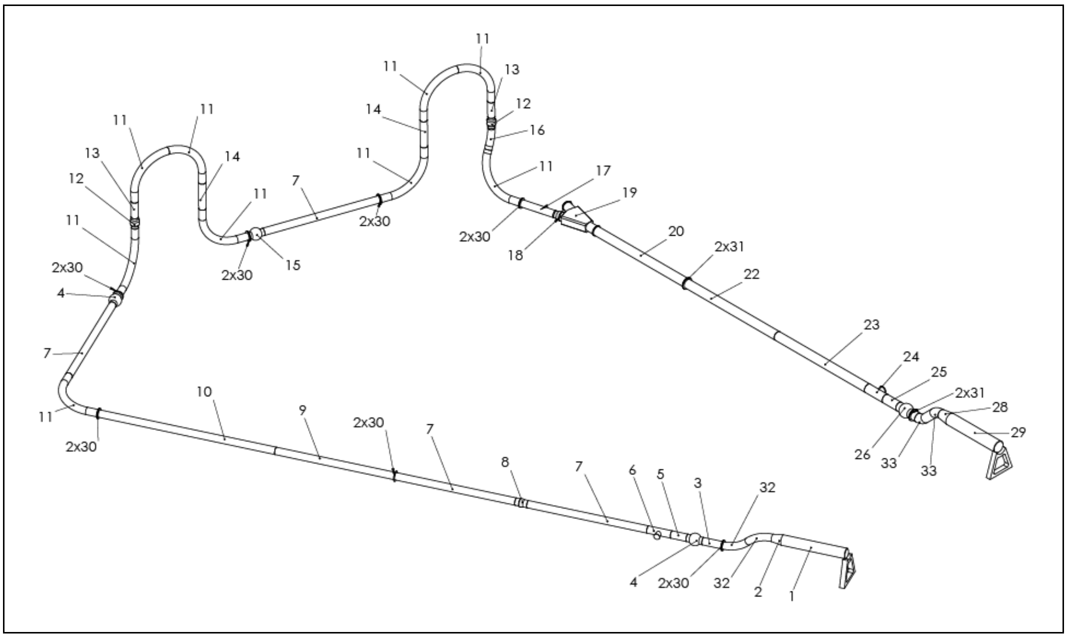

Figure 2: Final drawing of the test loop

Simulation of pipeline flow conditions

As the run conditions are very important for a reliable inspection run, the Operator provided data to simulate actual pipeline flow calculations. The combination of the planned flow conditions together with the effect of the pipeline topography and temperature turned to be out a critical issue with remarkable impact on the project schedule.

Preparation of On-Site Activities

During the preparation period the aspects of on-site activities were also widely considered. Based on the launcher and receiver documentation as well as on-site visit information, the launching (vertical) and receiving procedures were defined by ROSEN USA. The necessary equipment (transport frame, launching tube) was then designed and manufactured. All these procedures, parts and actions were finalized in an on-site tool handling and launching/receiving procedure document.
Further the project addressed a contingency plan for the unwanted case that a tool exceeded the calculated traveling time or became stationary.

Preparation of Data Evaluation

The fact that the investigation's goal was to discover the unknown condition of the pipeline required a coordinated and quick evaluation of the inspection data as well as other possible indications (gauge plate, tool condition), before progression to the next phase. Therefore the ROSEN on-site personnel were chosen to be experienced in both tool behavior and data evaluation. For a detailed analysis of the inspection data, capacity at ROSEN USA and the RTRC in Lingen was scheduled.

Project Communication

For the entire duration of the project a policy of very close communication between the Operator and ROSEN (RTRC and Houston branch) was realized. This included several meetings and occasionally weekly telephone conferences. This policy allowed close co-operation and well-coordinated procedures throughout.

TOOL DESIGN

The main challenges for the tool designs was the wide multi-diameter working range from about 300 mm to 415 mm, the high pressure (295 bar) and the wye-piece passage. The direct consequences were small tool bodies and long sealing lengths. Since it was known that the pipeline was internally coated and that other cleaning tools had already passed the pipeline without heavy wear, it was decided to use conservative design for the gauging tool. However, it became clear after the first pump test in the 14"/18" test loop that the setup had to be adjusted. The tool consisted of two bodies connected by a flexible joint. A four guiding petal disc design was chosen (Figure 3). The tool was also equipped with a Pipeline Data Logger (PDL) and a transmitter.

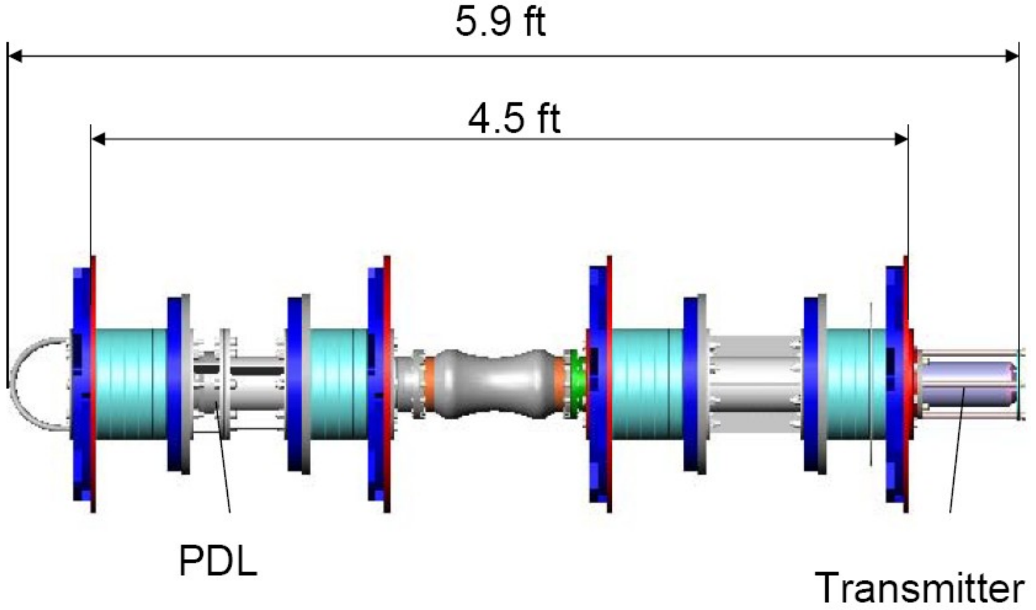

Figure 3: 14"/18" Gauging tool

Figure 3 shows the sealing length to accommodate the wye-piece passage (1.4 m), which had to be the same for the intelligent tools. For those latter tools (essentially for the MFL tool) however, the pull unit had to provide much more stability and driving force than the petal setup could provide. Therefore a particular segmented multi-diameter driving unit had to be developed. Although it was designed for the MFL unit, it could also be used for the geometry tool (Figure 4). The staggered sensor arrays of this tool provided full circumferential coverage in pipelines of both sizes (i.e. 14"/18").

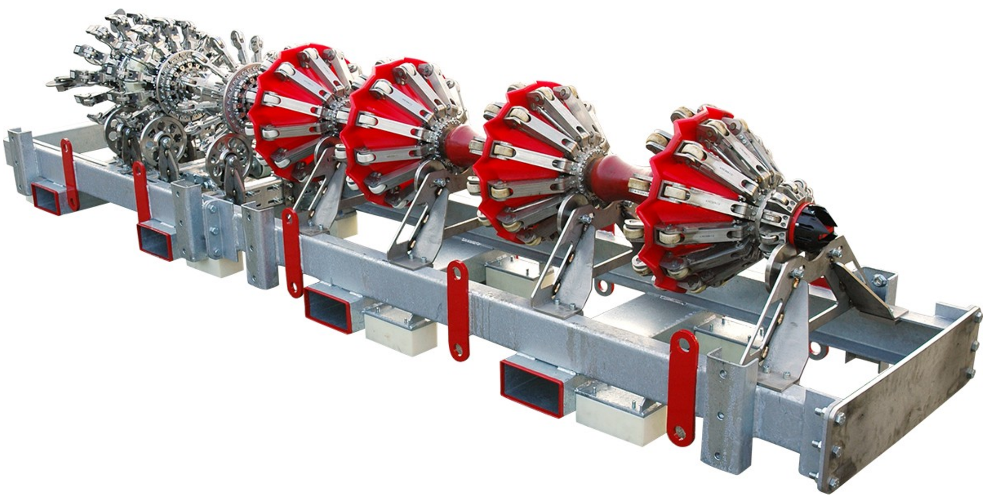

Figure 4: The 14"/18" Extended Geometry tool (RoGeo Xt)

In the case of the MFL tool, the driving unit has to pull two heavy-wall (25 mm), multi-diameter MFL units and a trailer for batteries and electronics (Figure 5). All components of these three tools were designed to withstand a pressure of 300 bar.

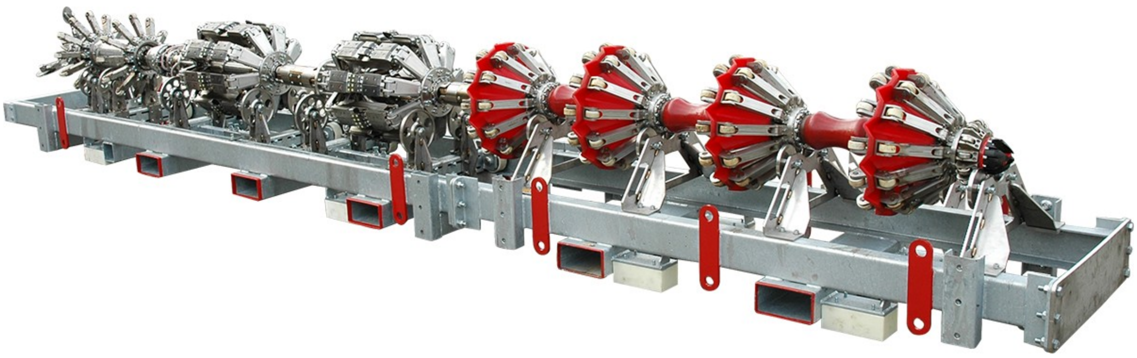

Figure 5: The 14"/18" Metal Loss tool (CDP)

TESTING
This phase was divided into three parts:

a. Pressure test of standard components and vessels (300 bar)
b. Tool component tests (pulling force, flip over test)
c. Test for the complete tools

Out of these, the tests for the complete tools were by far the most laborious. All tools were pulled through the 14", 16" and 18" pull test lines. During these runs, the intelligent tools already collected information and the pulling forces were recorded.

Figure 6: The 14"/18" test loop

The most important tests were, of course, the pump tests in the special 14"/18" test loop (Figure 6). During these runs both tool and pipeline flow and pressure data were measured to evaluate tool performance and optimize the behavior.

The test loop was put into operation at the end of October 2007. In the time until the tools were delivered in February 2008, the following runs were conducted:
Gauging tool: 4 runs (one change in discs setup)

RoGeo Xt tool: 6 runs (one change l to the design of the driving unit due to damage)
CDP tool: 12 runs (one change to the design of the driving unit for enhanced function)

Differential pressure and flow measurements were taken. The flow speed was the only operational parameter which could be varied during the tests. Due to the fact, that the real pipeline is operated with gas and the pump test loop with water, some runs were conducted at a very low flow speed (0.25 m/s) to approximate as closely as possible the effect of bypass in a gas line.

During the test phase all tools passed the entire flow loop at all times. Occasionally high differential pressure values were observed and analyzed and important findings were gained. These were for example an improved performance of the disc setup of the CLP, and modifications of the driving unit.

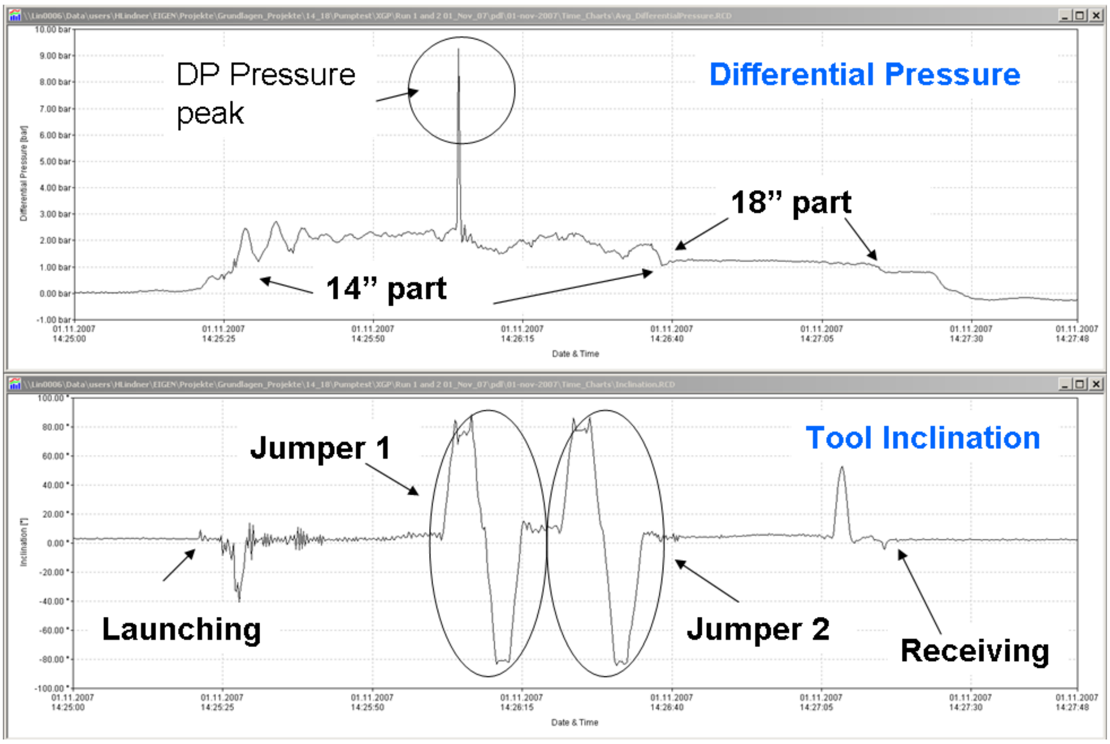

Figure 7: Results of pump test with RoGeo Xt (Top: dp, Bottom: tool inclination)

Figure 7 illustrates the differential pressure (dp) along the RoGeo Xt tool as measured by an on-board PDL during a pump test. The dp is about 2 bar in the 14" and 1 bar in the 18" section. The bottom diagram shows the inclination of the tool during the run. The inclination is a good indicator for the tool position resulting from the two jumpers as shown very clearly in Figure 7. The swan necks of launcher and receiver too are plainly visible. The pressure diagram also shows a distinct peak of nearly 10 bar. This peak reflects damage to the pull unit including missing wheel support. In combination with the synchronized display of the inclination it was possible to identify the reason for the peak and corrective design actions could be made. The subsequent tests did not show any similar effect.

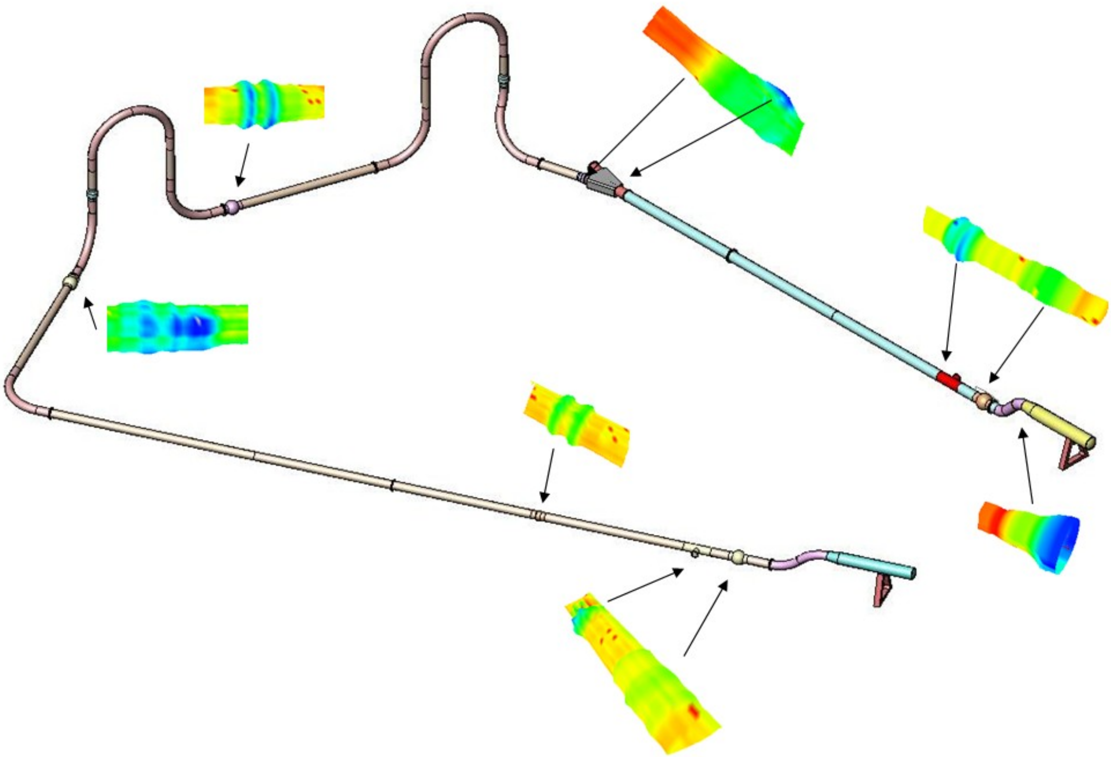

Figure 8: Data of selected features collected by the RoGeo Xt tool (raw data, not to be scaled)

Some of the measured pipeline installations are represented in Figure 8. The raw data furnished by the caliper arms clearly indicate the valves, connectors, tees and of course the wye-piece.

PDL measurements of a MFL test run can be seen in Figure 9. Again the lower diagram shows the tool inclination in support of the information provided by the upper graph. The MFL tool needs a higher dp than expected: it is between 3.8 bar in an 18" and 5.5 bar in a 14" straight pipeline segment. For the passage of the jumper bend combination, a slightly greater differential pressure is required (up to 7.5 bar). The passage of the wye-piece was performed without stop and shows only little effect on the measurement.

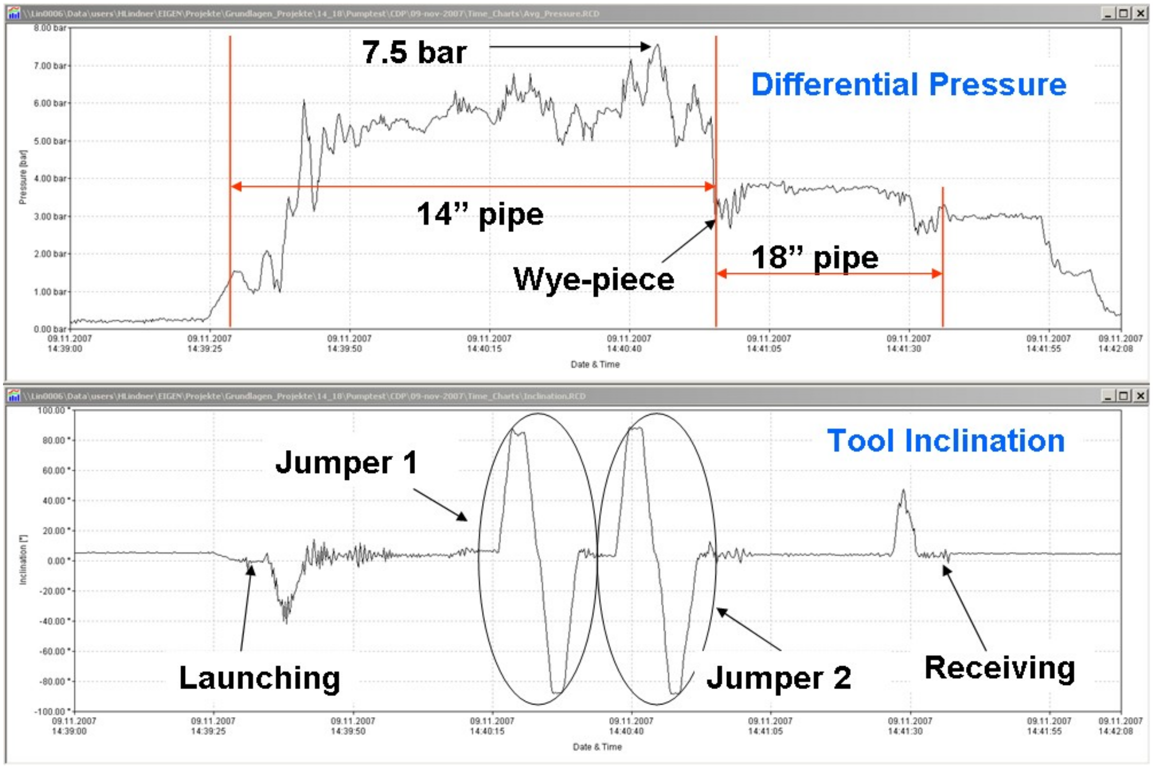

Figure 9: Results of the pump test with the CDP tool (top: differential pressure, bottom: tool inclination)

Finally, a full-scale replica of the vertical launcher was built and the launching procedure performed as documented.

After all these tests, calculations and planning, the tools and procedures were ready for the job and mobilized. Meanwhile the operational data (90 bar, 65.000 sm^3/h) provided good conditions for the run. As the actual pipeline was internally coated and had certain contend of fluids, a lower dp was expected compared to the pump test in the non-coated test loop.

GAUGING AND INSPECTION RUNS

For the preparation of the actual pigging project, a lot of supporting actions had to be prepared and conducted. For example a special vessel with a remotely operated vehicle (ROV) was hired for subsea operations, subsea markers were placed and the required equipment was supplied to the platform.

Actual pigging operations started at the end of June 2008 with the gauging tool. This initial run was successful: neither the tool nor the gauge plate showed damage, and wear on the PUR was low. Therefore the decision was made to run the geometry tool.

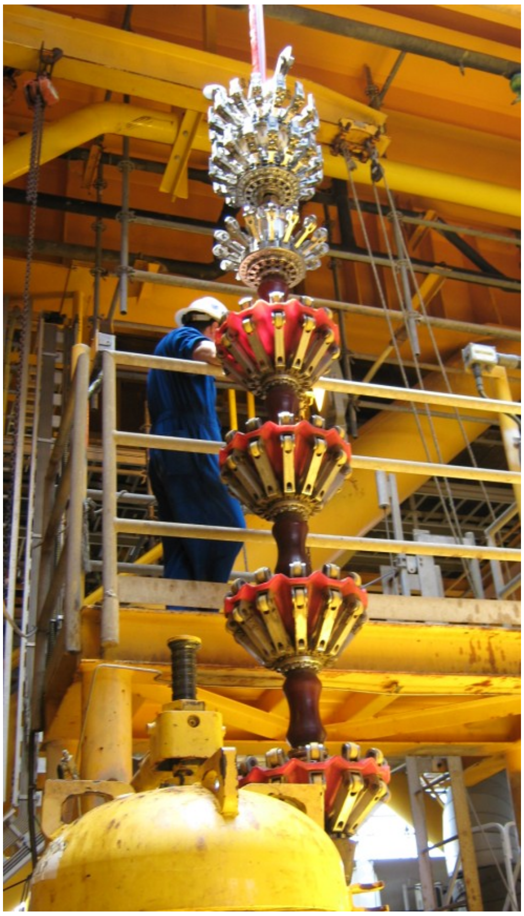

Figure 10: Vertical launching of the geometry and MFL tool

The geometry tool (Figure 10: left) was launched without any problem and arrived within the calculated time. The data collected during the geometry run was complete and of very high quality. The same evening initial data analysis was performed by the on-site team and data was transferred to the ROSEN Data Evaluation Department. One extreme measurement was observed and isolated for detailed evaluation. Because of the known pipeline layout, it was clear that the signal was recorded in the check valve between the jumpers. The evaluation of the data revealed the internal geometry of the check valve (Figure 12). In the RTRC, this information was carefully compared to the tool design and decided that it is just as expected and therefore no critical installation, though the MFL tool could be launched.

Because of the length of the launcher barrel, the two segments of the driving unit had to be pushed into the reduction for a certain distance. Additionally, a launching tube was used to keep the magnet units away from the wall to reduce the required pushing forces. As this was also tested on a dummy launcher with original measures, the launching procedure worked perfectly. Again, the tool was received within the allocated time and with complete data of high quality.

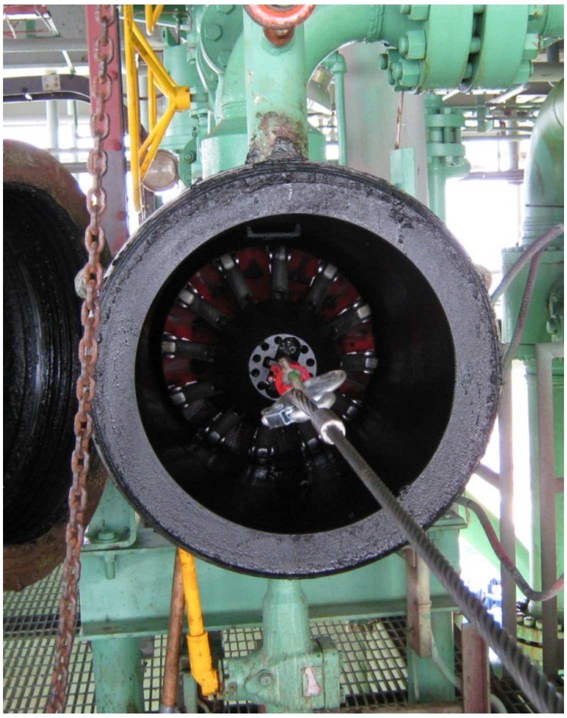

Figure 11: The tool in the receiver

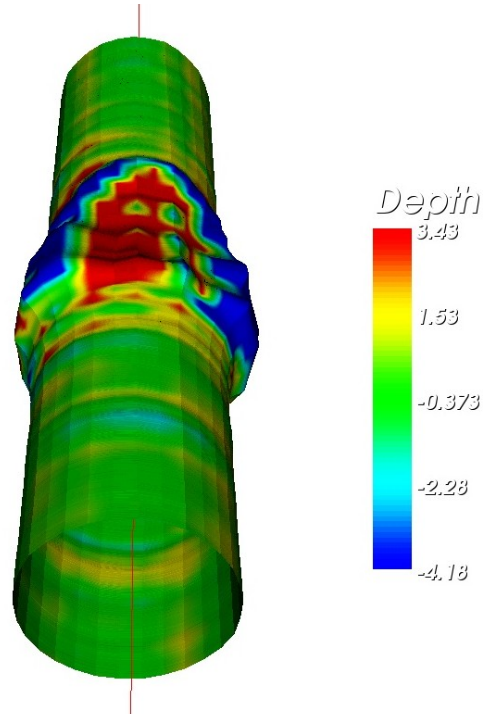

Figure 12: Evaluation of geometry tool: Check Valve

SUMMARY

The Operator desired to perform an in-line inspection to gather data to determine pipeline integrity. Because of the particular properties of the pipeline (high pressure, multi-diameter 14"/18", high wall thicknesses and subsea installations) and the high risk of the deep water operation, a unique development project was necessary. Therefore ROSEN developed and produced two in-line inspection tools (geometry and MFL). In close co-operation with the Operator, a large test program was performed at the ROSEN facility in Lingen ending with full scale tests in a 130 m test loop including all crucial installation simulations.

During the test phase some deciding improvements of the design were identified and made due to pump test results. All tests, results and changes were communicated among the project team, leading to a demonstrated solution and confidence for the inspection project.

Parallel to the tool development, manufacturing and testing, the Operator and ROSEN evaluated the operational conditions and the on-site procedures. Furthermore, a contingency plan was compiled regarding the definition of possible incidences and the following actions.

Due to the detailed and comprehensive preparation of the inspection and the professional and uncomplicated cooperation of the project teams all tool runs (gauging, geometry and MFL) were launched and received without incident. The tools arrived in time with complete data of high quality.