CASE STUDY OF DEVELOPMENT OF DUAL DIAMETER TOOLS FOR REGULAR WAX REMOVAL AND INSPECTION OF DUAL DIAMETER PIPELINE

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Introduction

Making use of existing infrastructure has been a popular practice for 20 years in the North Sea. Gjøa is one of the platforms that are tied into the existing infrastructure, despite being so far from other platforms that the view from Gjøa is without any other platform.

Both gas and oil are exported via existing pipelines, the gas export being operated by Gassco and via the FLAGS pipeline to St. Fergus, and the oil via the Troll Oil 2 pipeline to Mongstad. This paper is about the oil export pipeline. Next year we will cover the gas export pipeline and how to pig it.

The tie-ins are to a vertical (or lateral) Wye installed at time of laying of the pipeline it ties into. At time of construction, the vertical Wye is typically selected, as it can be installed over the stinger of the lay barge, whereas alternative solutions can require a separate installation vessel.

The vertical Wye by itself would be piggable, but the challenge was created by introducing a dual diameter system together with a requirement for frequent wax scraping. Wax scraping in a dual diameter system had been done before, and passing vertical Wye was done before, but the combination was our challenge.

This paper describes how we solved the challenge and how we worked together.

Our plan is to use the Gjøa platform as a production hub for the area, again making use of existing infrastructure.

The Gjøa Field

The Gjøa field is located in block 35/9 and 36/7 in the Norwegian sector of the North Sea, and the estimated reserves are 82 million barrels oil and condensate, and 40 billion Sm3 gas.

The Gjøa production platform is a semisubmersible platform, and the first platform operated by GDF SUEZ E&P Norge AS. The platform, installed at a water depth of 365 meters, measures 85 x 110 meters and has a living quarter capacity of 100 single cabins.

The oil export capacity is 87,000 barrels/day, the gas export capacity is 17 MSm3/day.

Production started in November 2010.

Figure 1: The Gjøa Semi-Submersible.

The Statoil operated Vega fields are connected to the Gjøa Semi where processing and further export of gas and condensate takes place.

The Vega Unit comprising PL090 and PL248 consists of the gas and oil/condensate fields Vega North, Vega Central and Vega South.

The recoverable reserves are estimated at 26 million barrels of oil and condensate and 18 billion Sm3 of gas. Its top production rate will amount to 7 million Sm3 of gas and 25,000 barrels of oil and condensate per day.

The Gjøa oil export pipeline is dual diameter, transporting crude oil with a 5% wax content and a wax appearance temperature of 32ºC, merging into existing Statoil pipelines.

Pipeline Details

The 16” Gjøa oil export pipeline has a range of internal diameters from 375 mm to 385mm, the main internal diameter being 376.2mm for the 55km long sealine. The rough bore flexible riser has an internal diameter of 385mm. There are several connectors, of which some have a short length of oversize ID up to 406mm, and the minimum bend radius is 5D.

Where the pipeline joins the Statoil system, first the pipeline passes a vertical Wye for a future tie-in straight, then enters the 16” Kvitebjørn pipeline via the vertical Wye installed in 2002, and immediately downstream expands to 20”. Finally, the pipeline joins the 20” Troll Oil 2 pipeline via a 20” vertical Wye, to arrive another 50km downstream in the Statoil Mongstad 20” x 24” pig trap onshore.

Note that the pig launcher on Gjøa is 20” x 16” nominal size.

Design and Testing of Dewaxing Pigs

At an early stage, a study was made for the pig design, when commissioning pigging passing the Wye was considered. It was not confirmed that a similar challenge had been solved elsewhere in the world, and a variation of the 16” x 20” dual diameter pig regularly used in the Kvitebjørn pipeline was proposed.

When ROSEN was awarded the contract to design, test, supply and refurbish the wax scraping pigs for Gjøa, the study proposal was built up as a prototype tool for testing at Statoil’s K-Lab pig testing facility in Kårstø, with support from Statoil and their experts.

The 16” test loop comprised the different relevant components of the pipeline: a 16” x 20” launcher with cassette, straight pipe of different ID, 5D bends of 90 and 30 degrees, and last but not least, a vertical Wye. It was a spare, identical to the new future connection Wye installed in the Gjøa pipeline. With minor differences in internal design compared to the Wye previously installed in the Kvitebjørn pipeline, it was judged as conservative for the testing.

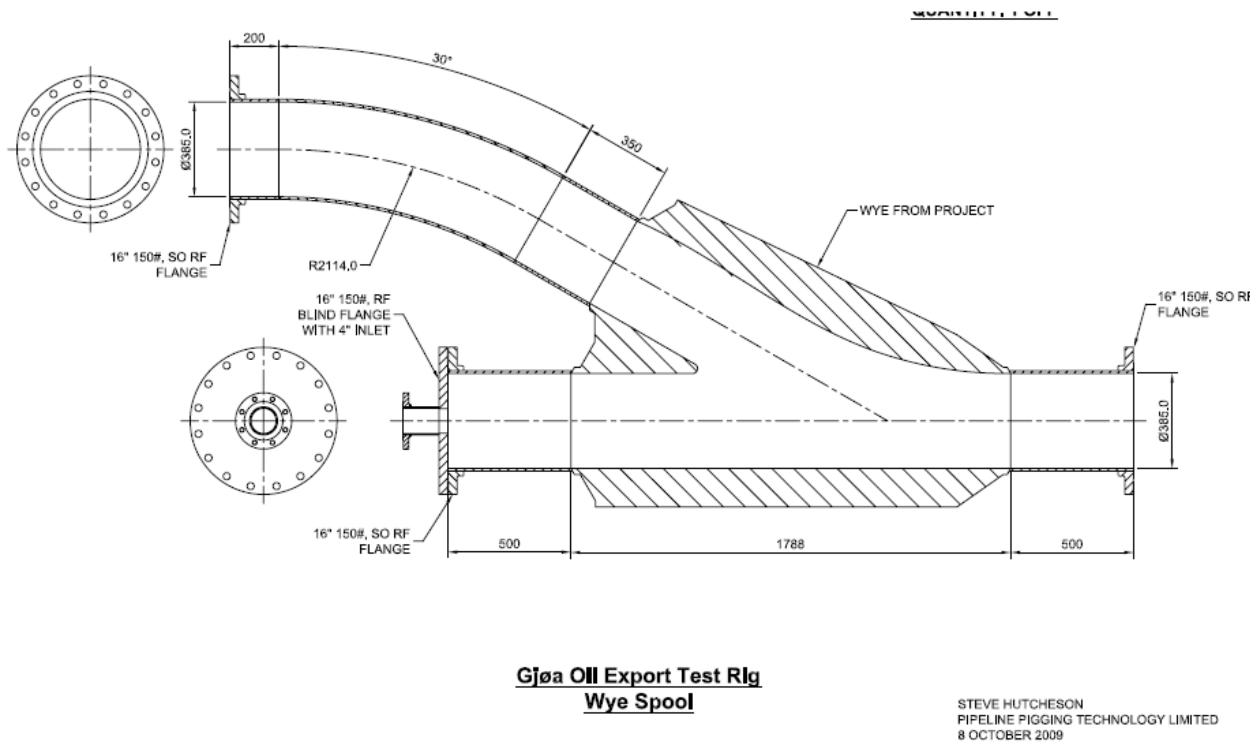

Figure 2: Drawing of the vertical 16" Wye prepared for testing

The K-Lab test loop is equipped with full instrumentation to continuously measure and log pressure, water flow rate and pig speed with high accuracy. Flow rate can be varied from 0.7 m/s down to 0.1 m/s or lower (in 16").

Passage of the pig in the 20" Wye and 5D bends were tested separately.

Unfortunately, the initial testing of the proposed configuration (based on the study and the Kvitebjørn pig configuration) proved the pig could not pass the Wye reliably, despite various modifications.

An alternative prototype design, this time by ROSEN, suitable to carry both an ELF transmitter for tracking purposes and a PDL pipeline data logger, was built and passed the Wye reliably in testing. The key element making the typical design of a dual diameter dual module disc pig successful is the proprietary reinforced polyurethane coupling originally developed for the demanding application in multi-sectional MFL ILI tools.

Figure 3: ROSEN pig configuration at test facility

Further testing was performed to optimize disc setup for wax removal and tool behavior in bends. The testing also confirmed the requirement to use a launching cassette to properly launch the tool.

For wax removal, the pig allows for an adjustable bypass, including around the connecting PU coupling. The test data correlated very well with the calculated velocity reduction at the actual differential pressure required to drive the pig. Balanced bypass settings were determined for the complete velocity range in order to ensure the front module is pulling the rear unit, with just enough drive from the rear unit to pass the Wyes where the front module loses its seal.

A total of 17 pump tests were performed at this stage.

At the lowest speed tested of 0.1 m/s, the pig could run with over 50% velocity reduction. Although it stopped at the Wye, it could be easily re-started by a slight increase in flow rate. In order to confirm the reliable operation at higher speeds than were tested originally, later the trial in the critical 16” Wye was repeated at the RTRC test facility in Lingen, Germany with speeds exceeding 1.5 m/s. Again, the pig performed reliably and did not suffer damage from repeated test runs.

Figure 4: Bypass of water through open nozzles during testing in 20'' bend.

Launching and Receiving

As mentioned above, the launching trap is of 16" x 20" nominal size, with an eccentric flat bottom reducer, requiring the use of a launching cassette, as determined during testing.

Unfortunately, the launching table, a complex system designed and built by a company that had since gone in administration, did not allow the use of a cassette without modifications. A cassette matching the internal diameter of the trap, with plastic seals to protect the duplex pig launcher complete with insertion and retraction tubes, was designed by ROSEN.

A lot of last minute work from different parties went into finding a solution to first pull the pig into the cassette onboard Gjøa, and then to maneuver the cassette in the trap, and this bottleneck was resolved just in time, prior to the start-up of production.

The pigs are received in the Statoil Mongstad pig trap, which serves the three pipelines from Troll, Kvitebjørn and Gjøa, each pigged on a regular basis for wax control. As a standard practice, the pigs are cleaned in the receiver by circulating oil at 75ºC, melting the wax recovered without affecting the PU of the pigs.

Refurbishment

The wax control strategy for the Gjøa oil export pipeline calls for target of a pig run every 5 days. Up to September 2012, 86 pig runs were performed. 6 pigs are in operation, and on a contract with a qualified subcontractor in Mongstad, pigs are inspected and refurbished after each run.

A spreadsheet developed by ROSEN allows the measurements and observations to be recorded, at the same time providing guidance on wear limits and record of the batch number of each disc replaced. In general, the wear of even the 20" guiding and sealing discs that travel over 55 km in the 16" section of the oil pipeline, is less than anticipated, based on the testing running with water as transportation liquid. In addition, the polyurethane couplings are replaced for each pig after 10 runs, purely as a precautionary measure.

Pipeline Data Logging

To date, 3 runs with the PDL pipeline data logger were performed. Despite some initial problems with the pressure hose feeding the downstream pressure to the instrument that is installed at the rear of the dual module pig, this has allowed the conditions in the pipeline to be monitored:

An actual temperature profile has been recorded in each run, for comparison with the theoretical profile used for the wax control strategy.

The pressure in the system has a cyclic variation, and the girth weld pattern confirms that the resulting speed variations are maintained over the complete length of the 16" pipeline.

The actual velocity reduction achieved by the bypass can be calculated based on the known production volume and the recorded passage time at the subsea Wyes, where no detection system to monitor pig passage is presently installed.

In general, the differential pressure observed is considerably lower compared to the pump testing performed using water. As expected based on earlier observations in other waxy crude oil pipelines, the friction of the pig increases when the temperature of the crude drops below the wax appearance temperature. Interestingly, in a section of seamless pipe of higher wall thickness but identical internal diameter downstream of the flexible riser, a considerably higher differential pressure was observed than in the downstream sealine.

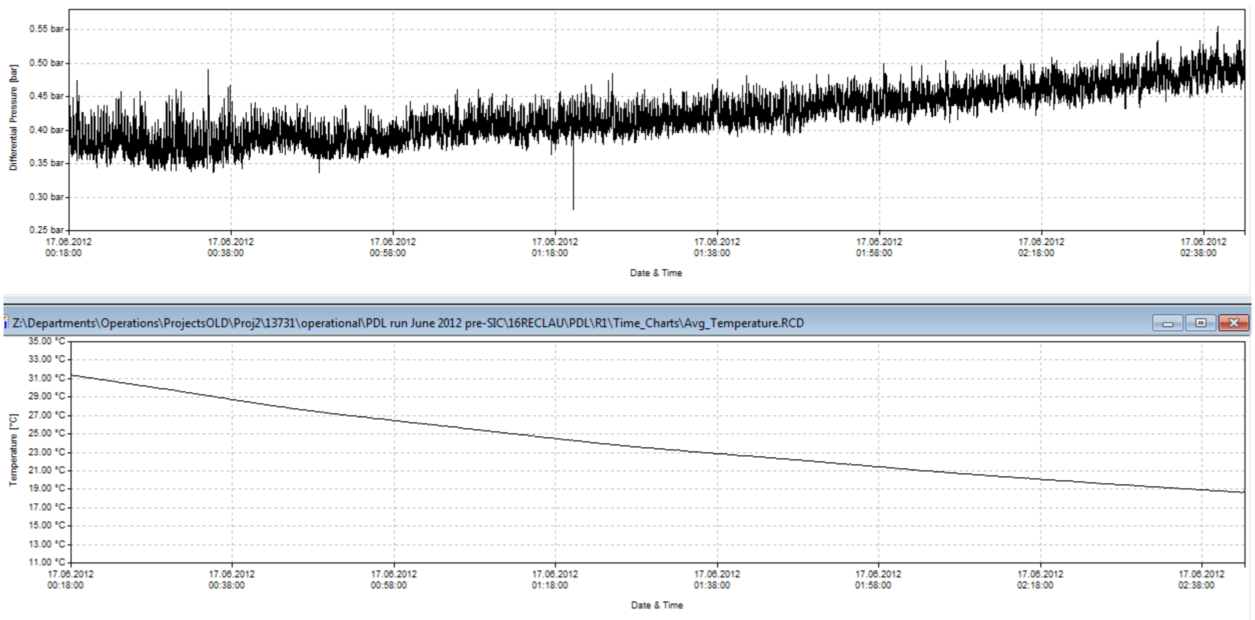

Figure 5: Gradual rise of differential pressure (top) due to wax deposition at decreasing temperature (bottom).

There are no indications in the data of geometric anomalies or difficulties passing the Wyes, and the data confirm the temperature of cleaning with hot oil in the Mongstad receiver.

Inspection Pigging

A mandatory baseline inspection survey for geometric anomalies and internal metal loss in the 16” pipeline was awarded under a separate contract.

ROSEN proposed its unique RoCorr-SIC (shallow internal corrosion) technology, which provides both a high accuracy geometric survey, and internal metal loss detection. At the same time, the technology detects and measures sensor lift-off, actually acting as a deposit measurement tool in the case of hard deposits. Also, the technology compensates for sensor liftoff in detection of geometrical and internal metal loss features.

A single diameter 16” ILI tool would be towed using a dual diameter towing unit. This would be the technique deemed to present the minimum complications passing a vertical Wye (compared to MFL) in a heavy wax pipeline (compared to UT). This proposal was accepted.

Interestingly, the single diameter 16” inspection tool has 37mm better capacity to pass reductions than the towing module, for which an identical setup was used as the proven regular de-waxing pig.

Consequently, as an extremely rare exception, is was not deemed of any use to perform any pre-inspection gauging. A program with reduced interval between 3 de-waxing pig runs immediately preceding the ILI tool run was performed to minimize the wax deposits in the pipeline.

As before with the de-waxing pigs, a pump test at various speeds was conducted at the RTRC pump test facility, to confirm the reliable operation of the ILI tool.

The tool was installed in a lengthened launching cassette prior to mobilization. Scheduling the running of 3 cleaning tools and the ILI tool, all within a single week in the three-pipeline system, was probably the most complex undertaking during site operations.

Complete data in the 16” pipeline were recorded in a single run. Despite the high bypass over the inspection tool, some slippage of the odometer wheels occurred in certain areas. However, data recording was time-based and the preliminary results indicate there is no corrosion detected. Some minor findings of the survey are currently under investigation.

Figure 6: The RoCorr-SIC ILI tool during testing at the ROSEN Technology and Research Centre.

Lessons Learned

The design of pipeline pigs for the Gjøa oil export pipeline system presented a particular challenge due to combination of features built into the system, and it is essential that such conditions are routinely identified at an early stage.

During all stages of planning, engineering and construction, an integral system analysis and monitoring of pipeline design and operating conditions is required, from trapdoor to trapdoor, even extending to handling equipment at launcher and receiver sides.

Testing of proposed pig designs has shown to be absolutely necessary for complex pipeline systems, taking the operational conditions at startup and later life of the pipeline into consideration. In this example, the systematic testing approach with the support of pigging experts was not only decisive for a reliable solution, but also allowed optimization of the ultimate performance.

Despite regular and intensified cleaning, data collection by ILI tools in wax rich crude oil pipelines remains critical.

Conclusions

The requirement is to scrape wax to avoid thickness of 2 mm, set as a standard requirement by the operator in the design phase. Over a length of 25 kilometers even only 2mm of wax accumulates to a substantial amount. Wax deposition studies were carried out as part of early design, estimating 5% wax (by weight). It is difficult to measure actual wax thickness, which we can see by using the data logger is a good correlation between estimated wax formation and measured pressure differential over the scraping pig. The wax formation is as expected and the assumptions from design are confirmed. The pigging operation is therefore continued as planned.

The challenge was solved! The open communication, in Gjøa language called "collaborative community" solved the wax scraping pigging requirements for the oil export pipeline. We scrape the wax every week, the pigs are maintained and returned to the platform, exporting high wax oil is achieved, and it is well monitored and safe!

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