PIGGING IN THE ARCTIC CIRCLE

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Abstract

Often the main focus of inline inspection (ILI) is the inspection vehicle itself; however, the ultimate goal of any ILI operation is reliable and accurate data. This end goal can be challenged by the operational variables that many inspection companies are faced with, for example: line conditions; geographical complexities; changes in pipeline construction.

This paper explores the main factors that contribute to delivering the reliable and accurate inspection reports which pipeline operators demand whilst overcoming complex challenges and several coexisting, non-standard conditions.

A case study will be used in collaboration with IKM Testing (PPS Contractor/Client) and Var Energi (Operator/End Client) to focus on a unique project, running an inspection vehicle from a subsea pipeline launcher/receiver (PLR) to the Goliat Platform which is the Northern-most oil and gas production platform in the world.

This review is particularly valuable for operators of remote offshore pipelines with subsea launch and receive traps, where utilising ILI technology may not have previously been considered possible.

Introduction

In 2016 Baker Hughes were invited by IKM Testing to bid to undertake a baseline inspection of the 7km 10” gas injection flowline operated by Var Energi in the Goliat Field. The Goliat field is located in the Barents Sea, in production licenses PL229 and PL229B, in a water depth up to 430m. It is situated roughly halfway between Hammerfest and Snøhvit, approximately 50 nautical miles northwest of the city of Hammerfest, Norway. The Goliat FPSO is the Northernmost Oil and Gas installation in the world and was brought into the field in 2015.

The field is developed with eight templates, four of which are production templates, three are water injection templates and one is a gas injection template. Two production lines are installed with inline tees at the production templates. The two production lines form a loop in order to facilitate pigging operations. In addition, one gas injection flowline is installed, as well as a gas lift line and water injection lines in a daisy chain configuration.

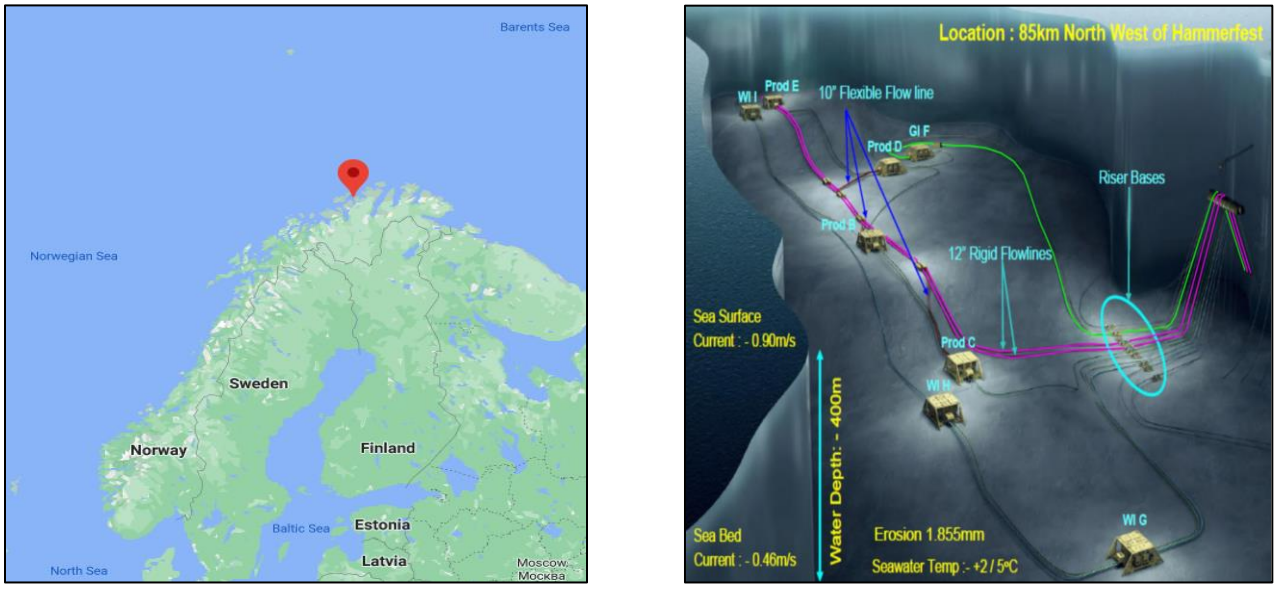

Figure 1 - Goliat Field indicating 10" Gas Injection Flowline

Baker Hughes submitted a bid to undertake the Intelligent pigging for the 10” 7km gas injection flow line (GI010). Baseline pigging operations were to be performed from a temporary subsea trap (PLR) to the Goliat FPSO to undertake the following:
• Assess the internal pipeline geometry
• Create a pipeline tally, identifying the location of all main pipeline appurtenances
• Detect metal loss defects
• Map the pipeline route (3D)

The inspection was applicable for the rigid parts of the system, e.g., inspection of flexible jumpers and risers was not part of the scope.

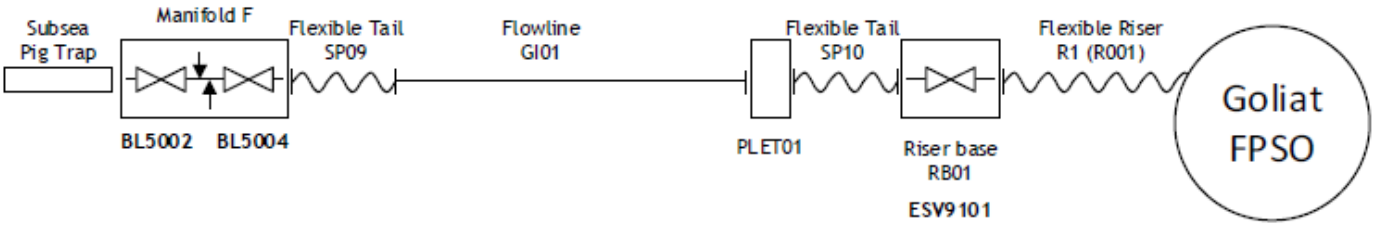

Figure 2 - Overview of the 10" Gas Injection System

2017 Inspection Campaign

Baker Hughes were awarded the contract in 2017 and were to undertake the inspection using the 10” MagneScan MFL inspection vehicle. The vehicle combines metal loss (MFL) and geometry inspection as standard, with the option of pipeline mapping (IMU). This allows the inspection to be completed within a single run with the added benefit of a fully aligned data set, which allows MFL, geometry and IMU data to be analysed in unison. In order to maximise flexibility, two specifications, ‘High Resolution’ and ‘Super High Resolution’, were offered for metal loss detection and sizing accuracy.

There were a number of logistical challenges posed in this project, requiring support vessels for the pipeline inspection and supporting operations in parallel. It was more cost effective for the project overall to provide two MFL vehicles: one vehicle to conduct the inspection operation and one vehicle to provide complete contingency should the first run not be successful. Each inspection vehicle is tailored to the pipeline details and operating parameters such as wall thickness variations, bend passing capability, pig detection or other modifications specific to the operation. The MFL inspection vehicles selected for the 2017 inspection campaign were to be fitted with a mapping kit (an additional mapping module and extra battery vehicle), an additional extra battery vehicle and a water service kit, given that the baseline inspection would be undertaken using treated water. The MFL inspection vehicles were also fitted with a bespoke isotope holder which would secure an isotope installed by the Operator’s vessel-based operations team prior to loading.

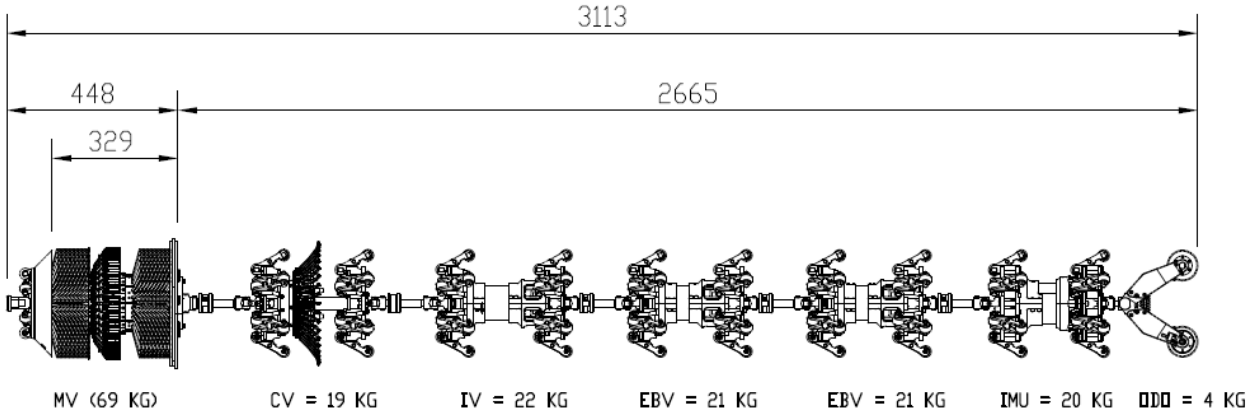

Figure 3 - 2017 MagneScan Inspection Vehicle, IKM Build

The infield operation would commence with delivery of all equipment to the IKM Testing onshore Base at Hammerfest, Norway. The two inspection vehicles and support equipment were then loaded onto the DeepOcean Vessel Edda Fauna and the receive equipment mobilised to the Goliat FPSO. The subsea PLR was to be pre-loaded with the MFL inspection vehicle on the vessel, the PLR was to be lowered and connected to the subsea manifold and the inspection vehicle launched into and driven through the pipeline using treated seawater until it was received on the Goliat FPSO.

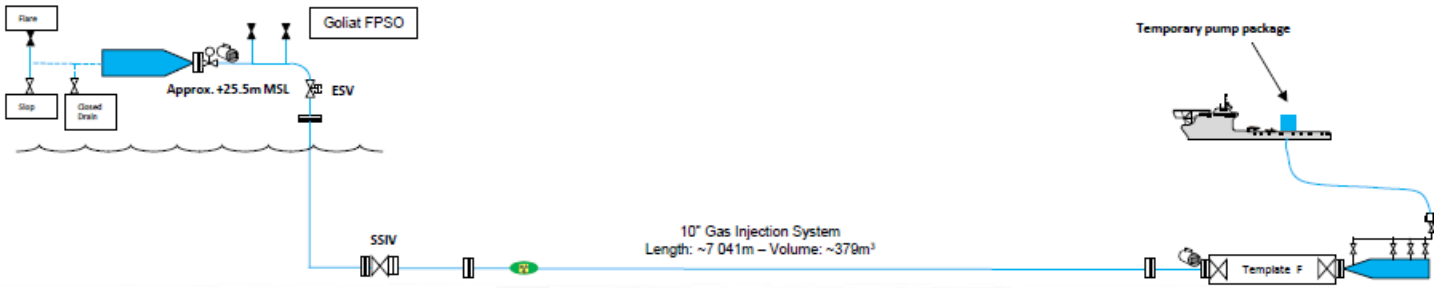

Figure 4 - Inspection Operation Overview

Prior to running the inspection vehicle, IKM Testing ran a gauge pig to ensure that the bore of the pipeline was within the minimum bore passing capability of the inspection vehicle. Baker Hughes provided the gauge plate requirements which was a 215mm diameter aluminium gauge plate ~4mm thick and segmented to allow a clear indication of any local deflection. Upon receipt of the gauge pig, the plate was removed, and the minimum diameter measured and photographed. The minimum diameter was measured at 211.18mm, which was below the minimum local bore passing capability of the inspection vehicle. The operation was suspended and a meeting convened to discuss the potential causes and next steps.

Figure 5 – 2017 Inspection Gauge Plate

2017 Operation Review

The first task undertaken was a review of the piggable items list provided by IKM Testing to consider the internal diameters of each pipeline segment to determine where the damage may have occurred. At the meeting, Baker Hughes advised on the potential risks of progressing with an unknown bore restriction in the pipeline and a decision was taken to demobilise and consider further options to assess what may have caused the damage to the gauge plate.

Collaboration

The results of the gauge run in 2017 presented Baker Hughes and IKM Testing with an opportunity to work collaboratively to develop a solution to undertake the baseline survey in the most efficient manner possible. The objective was to utilise the inspection vehicle to locate, identify and pass the known restriction whilst inspecting the remainder of the pipeline. Utilising the existing knowledge of the inspection vehicle's behaviour in several similar multi-diameter and reduced bore pipelines, Baker Hughes undertook a desktop feasibility study to challenge the limits of the specific inspection vehicle's performance. Such studies rely on testing to validate theories and as such the proposal was accepted and the scope revised to include detailed testing.

Baker Hughes commenced work alongside IKM Testing to develop a detailed plan to allow requisite time for testing prior to mobilisation of the tools and equipment. Due to the location of the Goliat field and the weather challenges it presented, an inline inspection operation was only viable between April and October; outside of this window the conditions could not be relied upon to support a vessel campaign and operations outside the module on the FPSO for a sustained period. As such, the Day 1 infield target date was set as 26th August 2019. Given the location of the field, the inspection vehicles and support equipment were required to mobilise from Baker Hughes' base in Cramlington, UK on 16th August 2020. Working back from these key dates was the starting point for the project teams to understand the timeline afforded to undertake detailed design, procurement of bespoke parts, assembly and testing. Baker Hughes managed this process by establishing a communication rhythm with the customer with bi-weekly calls and maintaining an action log and an MOC (Management of Change) procedure which was implemented after the first test runs.

Further CAD modelling indicated that, with modifications to the MFL inspection vehicle, it would be possible to inspect in a 5D bend of 210mm and 205mm in straight pipe.

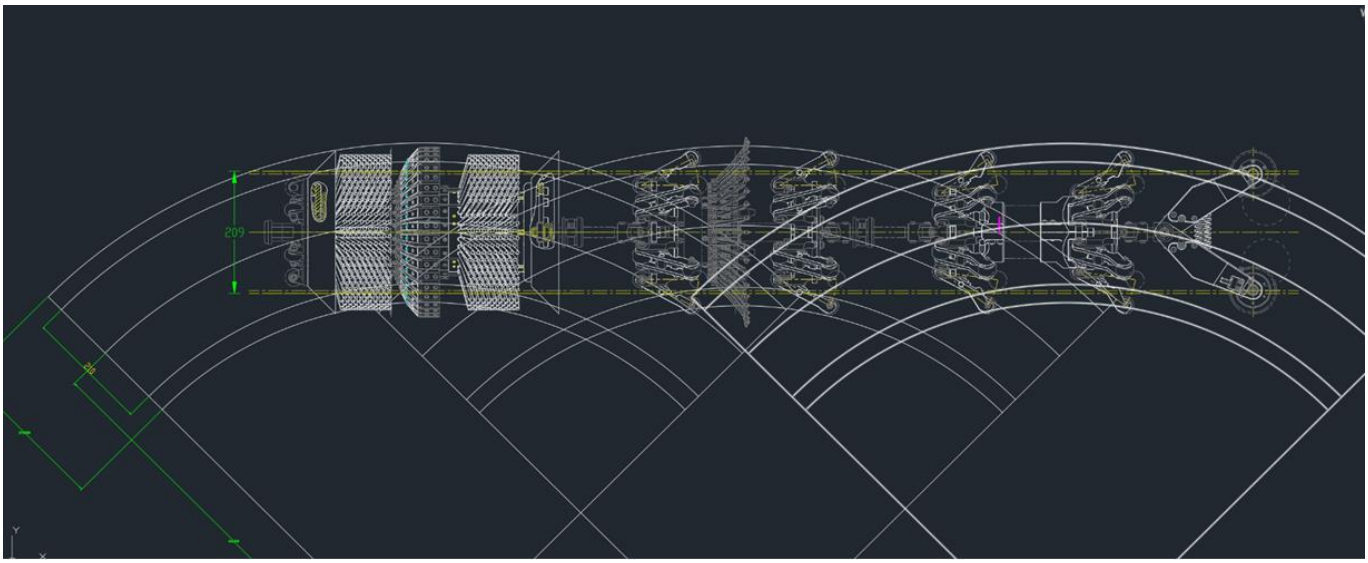

Figure 6 – MagneScan MFL Inspection Vehicle modelled in a 3D 210mm ID pipe

The MFL inspection vehicle required for the inspection consisted of six inter-connected modules and an odometer assembly: a Magnetic Vehicle (MV), a Caliper Vehicle (CV), an Instrument Vehicle (IV), two Extra Battery Vehicles (EBV) and an Inertial Mapping Unit Vehicle (IMV), all connected by carbon steel tow bars mounted to universal joints on each module.

Revisiting the pipeline listing information provided by IKM Testing, Baker Hughes assessed the passing capability of each element of the modified MFL inspection vehicle and its suitability for passing the identified restriction from 2017. The restrictive elements of the MFL inspection vehicle are the drive cups, bristles, the sensor ring assembly on the MV, the trailing module suspension wheel assemblies and the velocity wheel assembly. The suspension wheel assemblies and velocity wheel assembly were redesigned to ensure they would pass through a 200mm ID bore.

Testing

Baker Hughes' initial proposal offered testing of the inspection vehicle configuration and verification via pull-through in a test rig including a pipe spool at the 211mm ID minimum bore at Baker Hughes' Cramlington site. IKM Testing, and their end client Var Energi, were to witness the vehicle configuration and verification of minimum bore passing capabilities of the derived geometry inspection vehicle. The trial was to be conducted with one inspection vehicle only, with the second inspection vehicle being prepared in the same configuration prior to mobilisation.

After discussion internally with Senior Applications Engineers and the Testing Manager, it was decided that pump-through testing would better replicate the conditions the inspection vehicle would face in the pipeline and thus give more reliable findings Therefore, a third-party specialist was considered to support this phase of the project. A pump-through rig design was discussed and agreed with IKM Testing and was placed in production for the testing of the MFL inspection vehicle scheduled to take place in March 2019.

The testing rig below incorporated restrictions replicating the limits of the MFL inspection vehicle's passing capability, namely 205mm ID in straight pipe and 210mm ID in a 5D bend. Baker Hughes tested below the known feature in the line to provide an additional level of contingency in the operation and also requested a 263mm to 205mm ID taper transition to be included in the rig. However, to determine if the MFL inspection vehicle could pass the 'worst case' transition, Baker Hughes agreed to a final test to determine if the MFL inspection vehicle could pass a fully circumferential step of 29mm. This had never been tested previously.

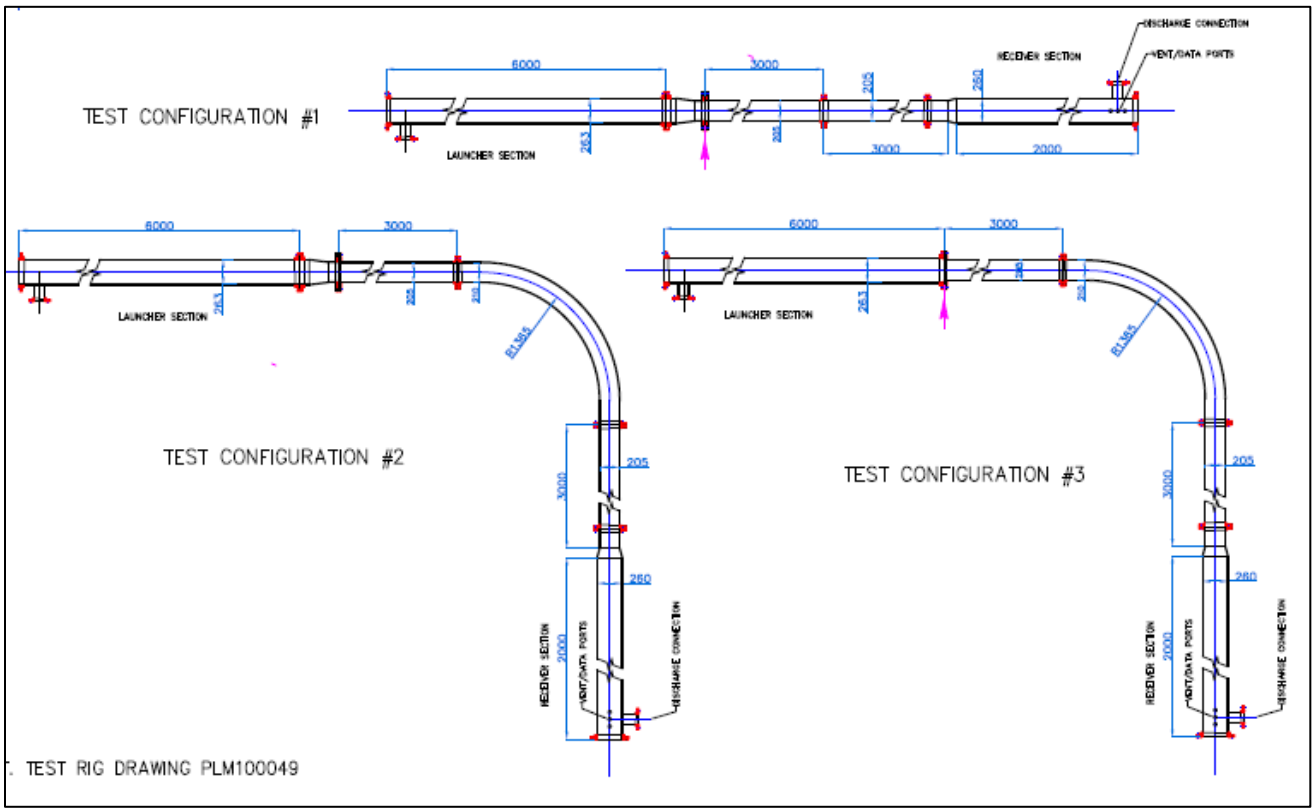

Figure 7 - Test Rig Configurations

The objectives of the testing phase were two-fold:

1. To utilise the pull-in equipment mobilised with the MFL inspection vehicle to replicate the loading of the PLR (Pig Launcher / Receiver) onboard the dive support vessel
2. To demonstrate the passing capability of the MFL inspection vehicle in a variety of bore restrictions.

The test provided a flanged lead in spool (see figure 7) as part of the test rig arrangement with an ID of 263mm. This closely replicated the PLR (actual ID 260.3mm) into which the MFL inspection vehicle would be loaded before being lowered subsea and connected to the pipeline during the infield operation.

Once the inspection vehicle was fully pulled into the spool, it was noted that the MV nose was downward. This is primarily due to the direction of pull from the pull-in chain and lack of support from the reduced length bristles that form part of the 10” reduced bore passing kit. This concern was noted, and consideration given to review the front support of the inspection vehicle. To progress with the secondary testing, the nose was lifted and centred using a soft sling.

There was some concern that, once the lead in spool was fitted to the pump-through rig during start-up of the pump, water would bypass the front drive cup and the vehicle would fail to drive and/or engage in the first section of the reduced bore pipe spool (205mm ID). Baker Hughes therefore fitted secondary drive elements (highlighted in red below) to ensure that the given flow equated to ~0.3m/s and the vehicle would drive into the reduced bore section.

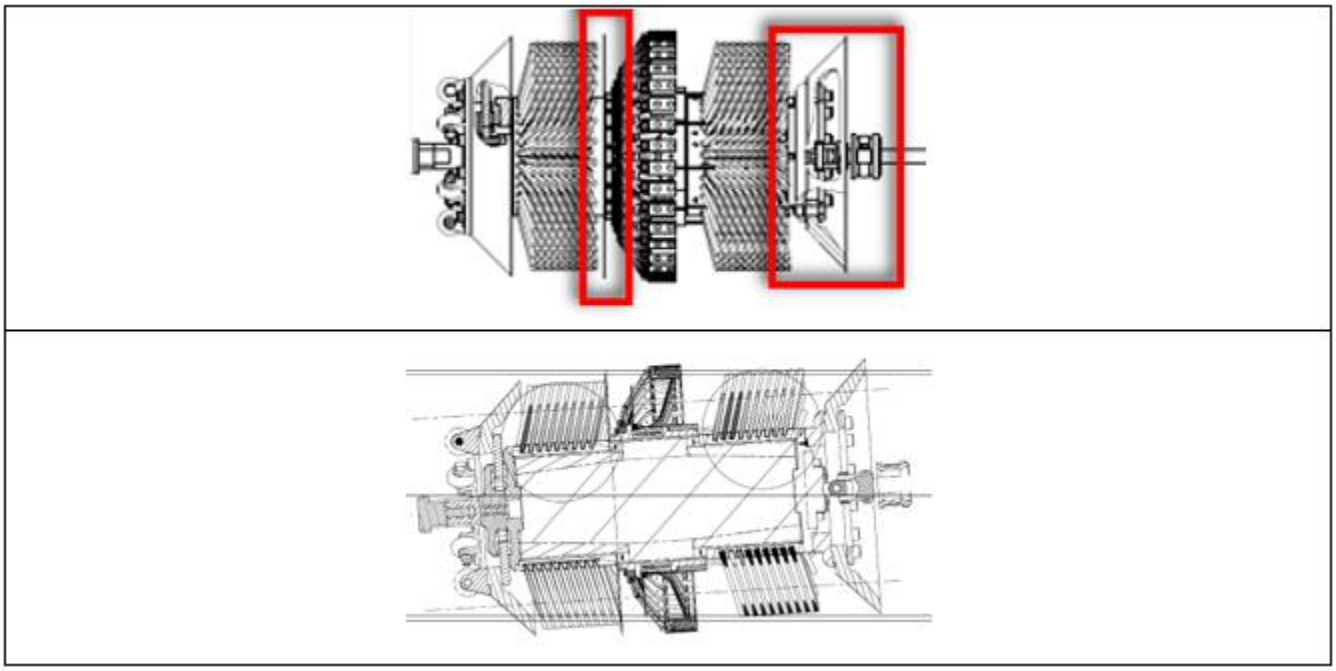

Figure 8 - MFL secondary drive elements and position of MV in 263mm lead-in spool

This testing proved essential given the findings and resulting actions. In the process of improving the passing capability of the MagneScan inspection vehicle, the support to the MV was compromised to the effect that in 263mm NB pipe the front cup was not sealing. If run in the pipeline in this build, the vehicle would have driven and passed the reduced bore sections albeit in a nose-down orientation in the nominal bore with reduced magnetisation from the lack of bristle contact and downward attitude. This would have affected the metal loss detection and sizing capability and also affected the mapping units' recorded data. As a result of these findings, the test was suspended.

Prior to the second test, the inspection vehicle build was to be assessed to determine options to provide adequate support to the front of the MV to better centralise it in 263mm bore without impacting on the ability to pass the reduced bore sections. Baker Hughes then completed additional desktop studies and modelling prior to a design review in advance of procuring the requisite components and completing the build prior to remobilising to repeat the testing stages. A more detailed representative test was also agreed by activating the inspection vehicle prior to loading to collect data during mechanical testing to prove that no electrical damage had occurred.

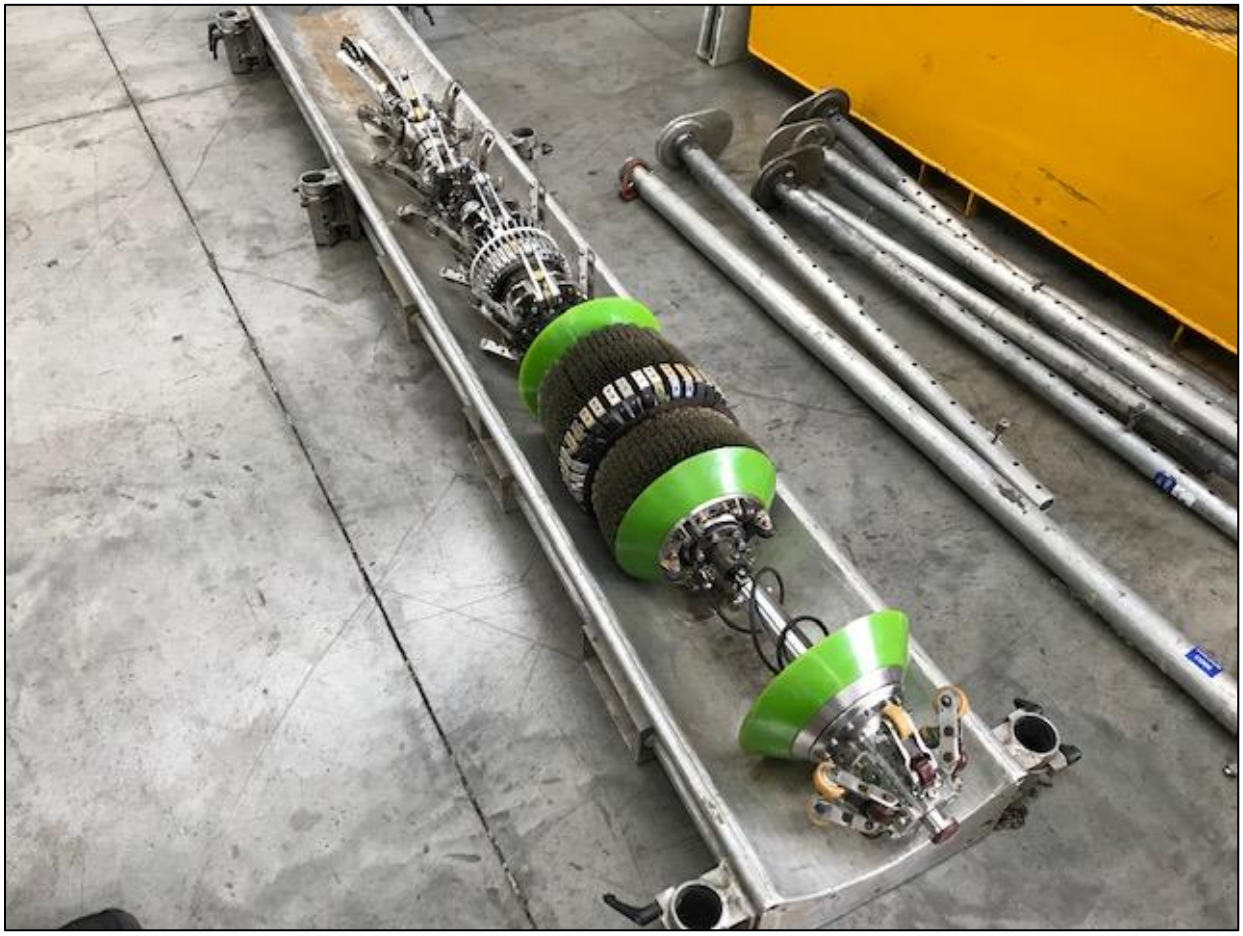

Figure 9 - Modified MagneScan MFL Inspection Vehicle with Extra Drive Unit

This testing proved successful resulting in various modifications, not least the addition of the Extra Drive Unit. It was modified to increase to 25mm spacers, ensuring the sealing of the cup and centralisation of the MV in the 263mm ID pipe, allowing for full magnetisation.

The modified bristle rings allowed for magnetisation and saturation of the test spool with machined defects which were witnessed in the data recorded. All modifications also successfully negotiated the reduced bore sections of the test rig. Analysis of the data recorded determined that the inspection vehicle functioned correctly, with detection and sizing specification confirmed when compared with the defect test spool.

Figure 10 - Test rig for second 'live' test

2019 Inspection

Two inspection vehicles and associated support equipment were mobilised to Hammerfest, Norway on 26th August 2019 as per the agreed schedule. All equipment was loaded onto the DeepOcean Vessel Edda Fauna, which mobilised to position above the subsea template on 2nd September 2019 to run a series of cleaning pigs and a gauge pig. The reason for running an additional gauge pig was to check that the pipeline had not been subject to third party damage in the two years since the last gauge run, which could impact the minimum internal diameter. In order to allow for contingency during this operation, a process flowchart was agreed whereby Baker Hughes could modify the MagneScan inspection vehicle to run as a standalone caliper vehicle by removing the front MV module and fitting a towing vehicle that had been subject to the same testing as the inspection vehicle. This would allow Baker Hughes to provide IKM Testing with a known location of the minimum internal diameter, so that further action could be taken if required.

Preparations were made to complete fast-track infield analysis of caliper data if necessary. Baker Hughes committed to an agreed response time to mitigate the number of hours the Edda Fauna vessel and support teams were required on site.

On completion of subsea barrier testing, and prior to the subsequent ILI pigging, the 10" GI line was decommissioned/FW filled by use of pigs separated by MEG slugs, propelled by a freshwater spread located onboard the Vessel, from the subsea PLR at Template F to topside PLR at Goliat .

The cleaning and gauge pigs were launched into the pipeline on 8th September 2019 and recovered the following day. As in the 2017 Inspection Campaign, the gauge plate was removed, measured and photographed.

Figure 11 - 2019 Inspection Gauge Plate

As only a single segment on the gauge plate was deflected, it was determined with advice provided by Baker Hughes' Application Engineering department that this may have been as a result of impact in a bend or offtake and Baker Hughes could proceed with the MFL Inspection run.

On 11th September 2019 the MFL inspection vehicle was launched into the pipeline. It was removed from the receive trap on Goliat FPSO the following day. Swift infield reply of the inspection data confirmed that a full survey had been obtained from this successful run

Subsequent data analysis was undertaken to detect and size any metal loss or geometry features present in the pipeline and the results passed to IKM Testing, with a report presentation held with Var Energi in attendance to discuss the findings. The minimum ID within the pipeline was recorded as 207.044mm. This was located in the receive area of the pipeline, at absolute distance 6988m.

Upon completion of the ILI Pigging and acceptance of the data the 10" GI line was Recommissioned/Dewatered by use of pigs separated with MEG slugs driven by Nitrogen from a Nitrogen spread on the vessel from subsea PLR at Template F to topside PLR at Goliat.

Post Operation Review

The location of the Goliat field was the least challenging of the factors associated with this unique inspection operation. The collective effort of the project team, who were invested in the inspection operation throughout, was required to prevail when unforeseen challenges occurred, not least the unknown restriction that was detected during the 2017 gauge run. Stakeholder engagement throughout demonstrated the commitment to quality in order to achieve the overall objective of collecting reliable and accurate data from the customer's pipeline.

The ability to take a reliable pipeline inspection vehicle such as MagneScan and challenge its capabilities proved a rewarding step into the unknown, not only for Baker Hughes but hopefully the wider industry. The versatility and resilience of the technology was showcased to reliable effect and proved a successful method of determining the pipeline condition. By utilising testing to validate theories and pushing proven technology to the limits of mechanical bore passing, a solution was found and proven in the pipeline.