LONG DISTANCE PIGGING USING MULTIPLE INLINE ISOLATION TOOLS

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Abstract

Pigging multiple tools in a pipeline over long distances may be done regularly but presents its own challenges. Two or more pigs, inserted for different purposes, must travel the full distance of the pipeline and negotiate any features within it. At the same time, they must ensure the distance between them is not reduced to the point of contact, with the potential of obstructing their pigging performance.

Pigging of inline isolation tools meet the same requirements while its design with several modules being linked, overall length, weight, and its hard outside diameter close to the inner diameter of the pipeline, defying (or challenging the) basic pigging principles. Mid-line isolation typically requests the two isolation tools to be as close as possible to each other whilst the long-distance pigging of two tools requires the distance between them to be kept to a maximum.

This project details the isolation of a 40/42" gas export pipeline, using two inline isolation tools set 12km from the launch site on either side of a valve station to enable depressurization for replacement of the inline 42-in gate valve and isolation joint. On completion the two isolation tools were pigged further ~645 km through the subsea section to the receive site, as reversing the tools back to launch site was not an option. At the receiving end, further isolation activities were required and successfully completed. Finally, both isolation tools were safely recovered without any issues, damage or notable wear of any parts. Apparently, this sets an industry record in long-distance pigging of inline isolation tools.

The coming together of the tools was not an option, with meticulous engineering planning along the way. This presentation covers the up-front planning as well as the use of inline isolation systems to ensure all the challenges are met.

Introduction

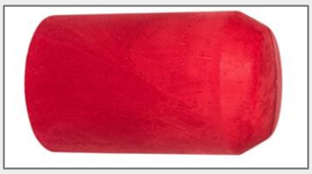
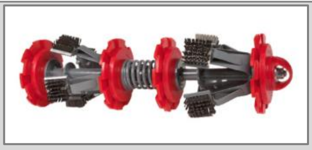
Carbon steel pipelines have been in use for over 100 years around the world. Pipelines are a means of transporting and storing specific products from a designated source to a designated destination.

They need to be inspected and maintained on a regular basis to preserve their integrity.
Maintaining the integrity of pipelines can take many forms:

- Design and installation of the pipeline with choice of parent material, internal coatings, external coatings/protection.
- Inhibitors and additives introduced into the product to protect the pipeline from any adverse effects.
- External protection of the pipeline, using cathodic protection typically for onshore pipelines and sacrificial anodes for subsea pipelines.
- Mechanical external protection – wrap, coatings, backfill.
- External inspections – above ground, ROV surveys.
- Internal inspections – coupon monitoring.
- Internal cleaning - Chemical cleaning, maintenance pigging.
- Integrity monitoring – Intelligent pigging, caliper pigs, Inline inspection pigs.

One of the activities involved in the maintenance and integrity assessment of pipelines is pigging. As a key part of integrity management, pigging is performed as a standard, regular operational activity throughout the pipeline network's lifecycle. Typical examples of pigging applications include pre-commissioning, line-proving, cleaning, liquid removal, inline inspection, inline isolation, and decommissioning. Pipeline products and transportation conditions, including pressure and temperature, will often dictate the type and frequency of pigging.

Pigging of any pipeline is typically very progressive. If a pipeline has never been pigged (new pipelines or existing ones), the sequence of pigging must reflect this. Typical pig sequences would be:

Type	Illustration
Foam pig. This is a non-solid pig which will prove the ability to travel the length of the pipeline. **Foam pig with gauge plate.** This will prove that the bore of the pipeline maintains a circular cross section for the duration of the line.	 **Figure 1 Typical Foam pig**
Cupped pig. This is a more solid pig once the confidence is there that the line is piggable. The body of the pig is small in diameter allowing for bore passing capability.	 **Figure 2 Typical Cupped multi-purpose pig**
Brush cleaning pigs. Starting the cleaning process	 **Figure 3 Typical Brush multi-purpose pig**
Aggressive cleaning pigs. Removal of more stubborn pipeline debris, either on the wall or lying in the pipeline.	 **Figure 4 Brush multi-purpose pig**
Bidi pig with gauge plate. This progresses the line to prove its diameter throughout.	 **Figure 5 Bidi Gauge Pig**
Caliper pigs. This is the first phase of intelligent pigging where actual pipeline data is recorded to allow assessment of the pipeline.	 **Figure 6 Typical Caliper Pig**
Intelligent pigging. This is typically based on technology like magnetic flux leakage (MFL) or Ultrasonics (UT)	 **Figure 7 MFL ILI tool**

Pigging Principles

The basic principle of pigging is that product is introduced into a pipeline at a controlled rate and removed from the pipeline at the other end at a similar controlled rate. This will maintain a certain pressure in the pipeline and the product will flow in the line according to the input and export rate.

When introducing any pig into a pipeline the discs or cups on the pig will form a seal in the pipeline and product is introduced at the launch end. At the same time product is extracted at the receive end, and this will naturally create a differential pressure (DP) across the discs or cups. Once sufficient differential pressure is achieved the forces pushing on the pig will overcome the static friction between discs and pipe wall and start the movement of the pig. Once moving, the dynamic friction will be slightly lower and require slightly less DP to keep the pig moving. Typical DP for pigs will be from 0,2-2 bar depending on design and purpose.

Figure 8 Foam Pigs moving through pipeline

In liquid lines the non-compressibility of the product allows for a stable movement of the pig during product flow. In gas pipelines, in particular at lower pressure, it is more challenging to keep stable movement of the pig during product flow. Changes in internal diameter, internal surface conditions, pigging through bends or other components may change the friction between the pig and pipe wall, resulting in temporary stalling and speed excursions of the pig. In addition, topography may cause changes in pig velocity due to gravity. The gas density will increase with pressure and at high pressures give more stable pig velocity. However, stalling and speed excursions due to changes in friction will still occur.

Figure 9 Pigs used to remove debris and content

Pigging with multiple devices in line

Pigging of pipelines may require running multiple pigs or products designed for different purposes at the same time through the line. Typical examples of this are pre-commissioning of pipelines, commissioning of pipelines, and operational pigging with partially decommissioning and commission related to pipeline repair or construction work. In the industry this will typically be called sending pig trains.

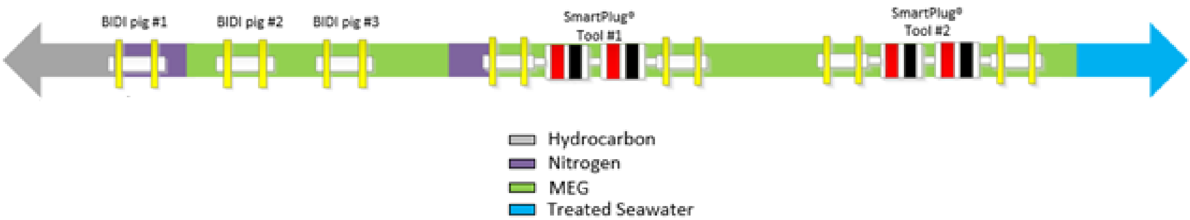


Figure 10 Pig Train for pipeline repair/ construction work

Each of the pigs in the pig train could have a dedicated or combined purpose. A dedicated purpose could be separation of media, and a combined purpose could in addition be gauging, cleaning, or isolation purposes.

A correct pig design is critical for performance. Testing of pig design robustness may be mandatory in some scenarios and performed in purpose build test pipes before launching into the operational pipe. Common for the type of operations that requires use of multiple pigs in the pipeline is that the correct outcome of plan is obtained with the correct tooling and robust procedures. Risk reviews must contain the mitigations for undesired operation scenario, like one tool stalling while the next tool catches up. This could lead to unsuccessful operation, damage to tools, and in worst case damage to the pipeline.

Pigging Isolation Plugs

Isolation tools are pigged through pipeline to locations where they are activated to isolate the pipeline pressure, providing a verified and monitored double barrier isolation. A local isolation enables a pressure-free and inert environment for effective and safe interventions to pipeline systems, while the remainder of the system is pressurized and even operational. While an isolation tool may look very similar to other multi-module tools that are regularly deployed through pipelines, like intelligent inspection (ILI) tools, there are key differences that affect the way these tools are pigged and what the risks may be.

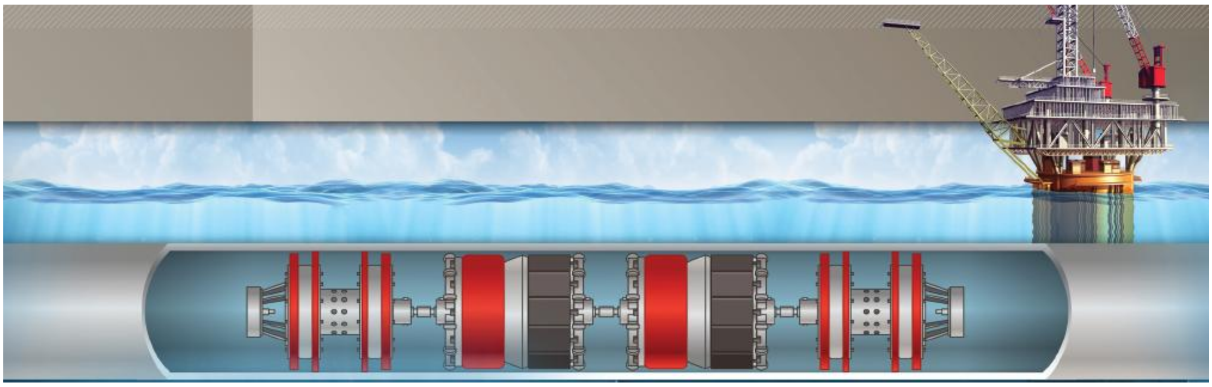


Figure 11 Pipeline pressure isolation, double barrier tool

As marked up in Figure 12 below, the key differences may be: (1) the overall mass and inertia when an isolation tool is pigged, (2) lower dynamic friction than other pigged products, due to the majority of the mass being supported by wheels, some also with ball bearings for long distance travel, (3) no magnetic drag (vs ILI tools), (4) larger outer diameter “hard OD” than other typically pigged products, etc.

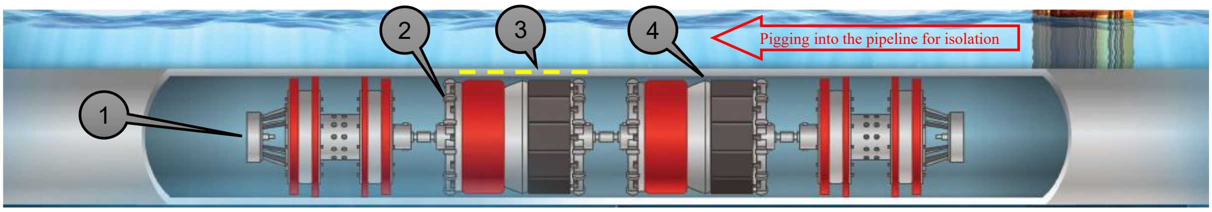


Figure 12 Aspects pigging an isolation tool

In some cases, more than one isolation tool is involved to provide a mid-line isolation. Typically, two isolation tools can be deployed and set on either side of a pipe section to allow maintenance or repair work to be performed in the depressurised section. Two tools bring additional aspects to the pigging and installation operation, like (5) a defined (and minimum) distance between the tools at the set locations, access to monitor both isolations. For long pigging distances, the pipeline length and configuration can affect the distance between the tools, where the tools’ pigging performance, selected pigging medium and any changes to the pipeline pressure plays a role.

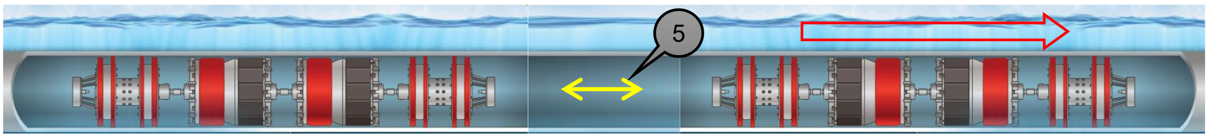


Figure 13 Pigging two isolation tools

Multiple isolations and long-distance pigging project

In a recent achievement an impressive distance of ~660km pigging was successfully completed using two 40in/42in SmartPlug® isolation tools. These tools were successfully deployed for the purpose of isolating on either side of a valve station along the coast of Norway where a gate valve and isolation joint had to be replaced.

This paper focusses on the key factors when planning and executing this project, including typical challenges and solutions the pigging of (such large) isolation tools represent. The paper also highlights that successful outcome is also dependent on good collaboration, planning and coordination between client, pumping contractor, TDW and other interested parties. The project consisted of several parties, with personnel located at the different physical locations involved, at both pipeline end terminals and the valve station.

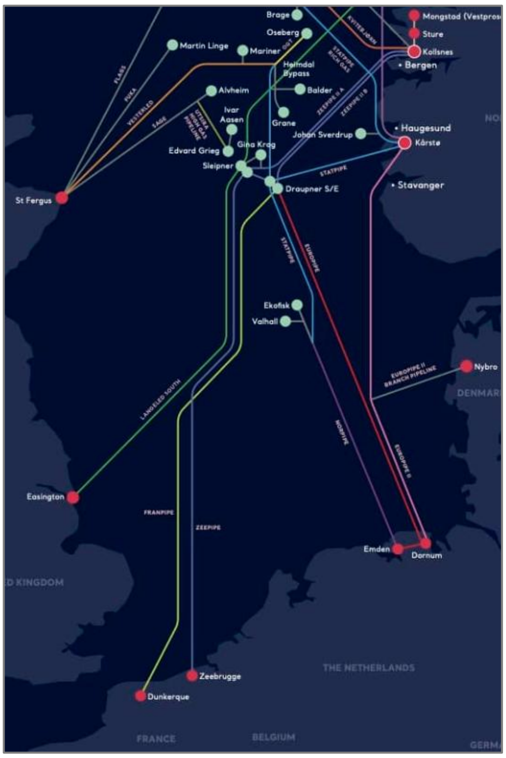


Figure 14 Pipeline System Overview (Source: Gassco)

Project background

The pipeline runs between the gas terminal receiving facility terminal. The pipeline was designed to transport dry natural gas between the North Sea and Europe and has two nominal external diameters: 42-in and 40-in.

TDW was requested by the Client to perform necessary engineering required for two 42-in SmartPlug® isolation tools to allow for in-line gate valve and isolation joint change out at a valve station located 12km from the launch site. This included the design and manufacturing of new plug modules. The plan included launching and pigging two double barrier isolation tools with suitable distance, position and set these on either side of the valve to allow the pipeline intervention work to start. When the repair work was completed, the tools would be unset and pigged further ~645km to the other end of the pipeline for retrieval, traversing also a midline tee and traversing the last 20km through a 40-in section.

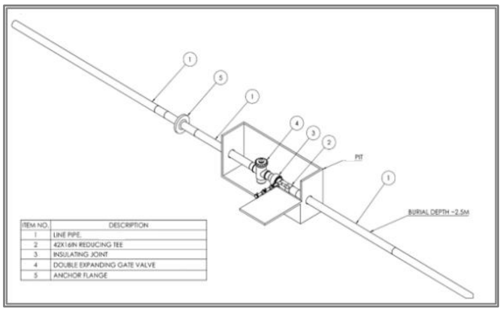


Figure 15 Pipeline Isometric View,

Challenges

A project like this typically includes review and planning of both the pigging and isolation operations, each with their own challenges. When the pipeline is long and consists of different sections, several key aspects need to be covered in particular:

- Verifying that the internal diameter of the bends in the 40-in section allows traversing with the 42in Isolation Tool.
- Launching two 42-in Isolation Tools with correct spacing, keeping distance and stop at correct position with large volumes of gas present on each side of the tools.
- Keeping distance between the two Tools during retrieval pigging with a midline branch present.
- Negotiation of the 40-in section onshore at the receiving end.
- Safe retrieval of the Tools with minimal disruption of the gas import.

Preparations

Prior to periodic inspection of the pipeline a gauge pig run had been performed. The report showed damages on the gauge plate. The diameter was reduced from 950m to 941mm. This result was sufficient for running the inspection tool but raised a risk for the isolation tool.
TDW designed a gauge pig with a dual purpose. Primarily for proving sufficient bore through the 40-in bends, but also for proving the proposed pigging set-up for the isolation tool with regards to centralization and disc wear.
The gauge run was successfully executed with minimum disc wear, and the 950mm gauge plate had no damages or reduced diameter. The risk of insufficient bore through the 40-in bends was removed.

Figure 16 Gauge Pig

Together with the client and other parties involved in the operation, detailed plans and procedures for the operation were made. Flow simulations were made to ensure predictable pigging and a stable settle-out pressure to allow for the tools to be stable in the pipeline once parked at the intended set locations on each side of the valve station. These simulations had to consider pigging of two isolation tools together weighing almost 20T in a challenging topography with large elevation differences. Risks were managed systematically.

Early in the project a major risk was discovered related to passing of a branch approx. midline through the retrieval pigging. Losing the volume of the batch into the branch could lead to the first tool stalling, while the second tool would catch up and potentially collide with the first tool at high velocity. The batch volume was established based on flow simulations and was set to approx. 150m.

Pigging details

The two 40in isolation tools were first pigged from the launcher to the isolation location. This is a total travel distance of 12km. Since this is an onshore section of the line the configuration presents some challenges due to the topography along the route. In principle: Higher pigging pressure is required as the two tools, having a total weight of 15-20ton, traverse uphill to higher points along the route, and the same higher pressure is a potential undesired factor causing higher pigging speeds when the tools descend to lower points along the route. Here, tracking the tools and calculating the pigging speed, gives key input in verifying that the planned pigging procedure is followed and implementing necessary adjustments to achieve correct speed and positioning control. When the tools were successfully positioned and set the pipeline intervention and valve replacement work started. These steps were also performed as per plan. When the tools were released, they were pigged with the pipeline flow to the pipeline receiving facility , instead of returning them the shortest route back to the launch site. Reversing the flow and returning the tools to the launcher, where they were inserted would require system to receive the volumes involved in bringing the tools to set location. This pigging to the pipeline's end receiving facility was adding 645km to a total pigging distance of ~660km. During this pigging the tools traversed through two different pipe sections, where the pipeline size changes from 42in to 40in. This caused a reduction of the pipe's ID, which potentially could alter the pigging performance. Good performance of the pigging discs is essential in achieving a stable and predictable tool pigging, and when combining high tool weight and long distance of travel. Still, the tools performed very well during this part, and there was almost no wear to discs or wheels, considering the high number of

Figure 17 Tracking tools – Onshore section

Figure 18 Recorded pigging pressure

km and wheel revolutions required to arrive at the retrieval location.

During the preparation for this project, it was also decided to run a gauge pig through the line, as a separate project. This was done to prove the line had full bore before the isolation tools were pigged and verify no damages are found along the entire pigging route. Also, this pigging was performed with the same good results as for the isolation tools, where the pigging performance was high, and disc wear was minimal. Contributing to the minimal wear of the discs are the internal pipeline flow coating. When the tools were received the distance between the tools was still intact and with minimal chance, indicating that the flow simulations and predicted behaviour of the tools had been correct.

Figure 17 Gauge Pig

Summary

This project is a remarkable achievement and proves that pigging long distances with several isolation tools simultaneously, are possible. This is documented using one of the largest isolation tools in the TDW fleet of SmartPlug® tools. As such, TDW considers this a reference project that provides proof and experience also to future projects where such options can be required.

This project requested engineering and planning to set up robust procedures for the pigging between launcher and set location, the positioning and setting at correct locations, and the pigging after the isolation work was complete. The engineering contained evaluation of many different aspects related to the total pigging distance, the pigging route including dimension changes between sections of 42in and 40in pipelines, which in turn was reflected both in the tool design and procedures.

Figure 18 40in SmartPlug isolation tool before insertion

Long distance pigging of one tool presents its own challenges, where the pigging performance of the tool are key to secure a desired outcome. The weight of the 40/42in isolation tool with all relevant parts and fluids onboard is ~8.5-9tonnes. Ensuring safe travel and arrival is key. Adding a second isolation tool requests for a review of the additional challenges and risks. There were constraints in terms of spacing to position the tools at the planned set locations defined at each side of the valve station 12km away from the launcher. Thanks to good experience with pigging tools, and the great collaboration between the client's representatives, the pumping operator and the TDW crew at the different locations, this task was achieved with high precision and successful outcome.

Establishing the initially requested and planned 2x double barrier isolation was successful with minimal deviations to plan. Also, the additional isolation scope at the receiving facility was performed without any issues. This was found required to facilitate additional and unplanned intervention work needed on the receiving facility, that would not have been possible using only the valves on the pipeline itself. Instead, it was done using one of the newly arrived isolation tools to provide a verified double barrier near the pig trap. This proves the reliability of the SmartPlug isolation tool, long pigging duration and multiple isolations in the same line is indeed possible.

Figure 19 40in SmartPlug tool after 670km pigging

Figure 20 Isolation tool being loaded (left), both tools packed, ready for return shipment (right)