PRE-INSPECTION CLEANING OF "UNPIGGABLE" SUBSEA OPERATIONAL PIPELINES

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Abstract

Subsequent to risk based inspection (RBI) and corrosion assessment, it was highlighted that several operator pipelines in the North Sea required internal inspection to verify line conditions and to ensure that the pipelines were fit for purpose. It was recognised that some of these pipelines were not readily equipped for pigging operations and challenges existed to enable inspection of the lines. The most feasible means of obtaining detailed inspection data was to perform intelligent pigging (IP) operations, requiring the installation of temporary subsea launch/receive facilities, which were also used to allow pipeline cleaning using a combination of chemical applications, progressive pigging, and pipeline gauging before the IP tools were run.

Introduction

Aging subsea infrastructure coupled with extended field life has led us to an era where in-line inspection (ILI) of pipelines has become a necessary requirement. Periodic checks on pipe wall quality give credence to continued use or highlight areas in need of remediation.

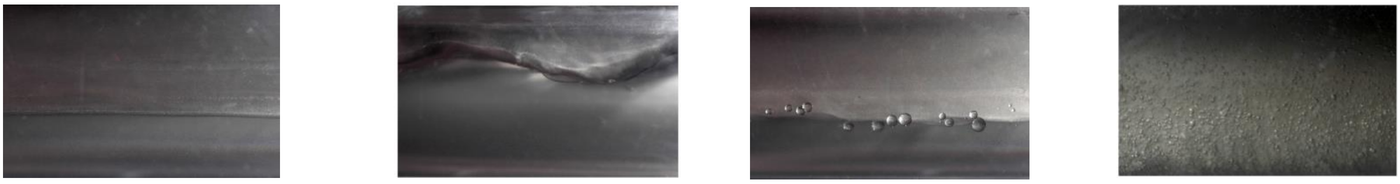
Installation of existing flowlines however have not always taken into account this requirement and, as such, the UK North Sea has many lines deemed "unpiggable" in their current configuration. To redress this balance on several infield flowlines, one North Sea operator embarked upon a campaign to make the un-piggable piggable. This required the cleaning of multiple lines over individual projects to allow pigging facilities to be incorporated and intelligent tools run.

A service company was chosen to provide cleaning and pigging services to these projects as well as pump support for the ILI runs themselves where necessary.

Early collaboration was a key component of project success and several methods for cleaning were considered and evaluated for each flowline dependent upon system conditions, such as:

- Type of deposit(s) expected in the line
- Volume of deposit(s) expected in the line
- Pipeline geometry
- Level of cleanliness required
- Technical difficulty
- Existing facilities and cost of refurbishing/replacing equipment to perform cleaning/inspection operations
- Cost of temporary equipment to perform cleaning/inspection operations
- Cost of consumables (pigs/chemicals) to perform cleaning/inspection operations

Physical constraints, such as platform based fluid handling capabilities and solids handling facilities, were also considered. These had an impact on the method and aggressiveness of the cleaning performed and influenced pumping/pigging speeds. In turn, pigging speed would define the flow regimens within each line, which in turn would impact the chosen cleaning methodology.



Stratified 0.25 m/s | Stratified wavy | Stratified mixing | Dispersion > 0.6 m/s

Fig. 1 Examples of Pipeline Flow Regimens

Operations were performed on three fields, as detailed below, each bringing their own challenges and tailored solutions.

	Field 1	Field 2	Field 3
Pipeline Length	22 km / 22 km Loop	14.5 km	3.5 km
	44 km Loop		65 km
	Note: One 10" line was common to both loops.		
Pipeline Duty and Nominal Diameter	8" Test to 10" Oil Production Dual Diameter	8" Oil Production	10" Oil Production
	10" Oil Production		16" Oil Production
PLR Setup	Subsea Launch – Subsea Receive	Subsea Launch – Susbea Receive	Subsea Launch – Subsea Receive
	Subsea Launch – Subsea Receive		Subsea Launch – Topside Receive
Disposal of Cleaning Fluid	Reused Via Pigging Loop	Pumped into Topside Process	Disposed to Platform Storage Cells

Figure 1 – Field Overview

Before construction activities for the addition of pig launchers and receivers, all pipelines were required to be de-oiled and cleaned to a level of less than 30 ppm oil in water. In addition, barrier checks were necessary to confirm satisfactory primary and secondary barrier from the wells before disconnecting subsea flanges.

Field 1

Pre-Construction De-Oiling/Flushing

Flushing of the pigging loops proved to be relatively simplistic. Both loops were flushed and cleaned to the required cleanliness level using the existing FPSO water injection system. Oil in water was measured at 8 ppm at the end of the flushing operation. The flowlines were disconnected from their risers and temporary spools and subsea pig launchers and receivers were fitted in the system configuration as below. This allowed cleaning and ILI to be performed.

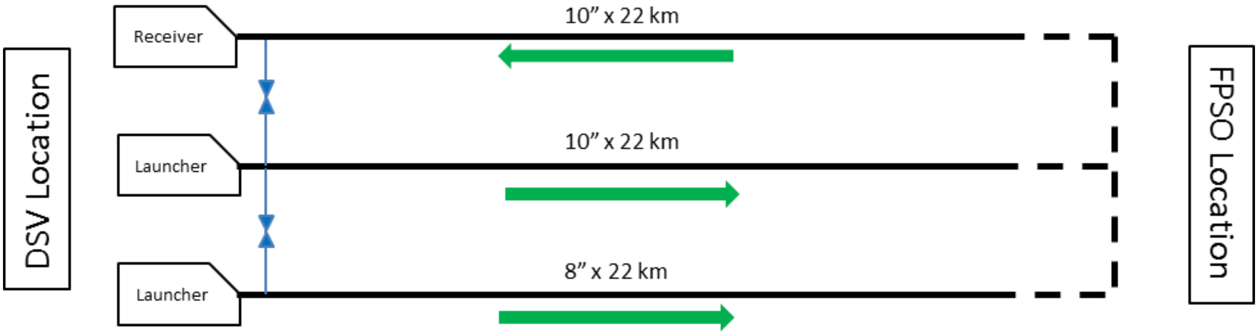


Fig. 2 Field 1 Pigging Configuration

Progressive Pigging

Mechanical Pigging of 10" to 10" Pipeline Loop

Although flushed to the required standard, it was essential that the pigging loop met an acceptable cleanliness criterion before running the in-line-inspection tool. As such, the following mechanical cleaning train was run.

Mechanical Pig Train:

The first mechanical pig train consisted of:

Pig 1:	Calliper foam pig	
Pig 2:	Low aggression pig	Launched and received as two pig train
Pig 3:	Medium aggression pig	Launched and received as single run
Pig 4:	High aggression pig	Launched and received as single run
Pig 5:	High aggression pig	
Pig 6:	High aggression gauge pig	Launched and received as two pig train

Pigs were propelled through the pipeline system at speed of 0.8 ms^{-1}.

ILI Tool

ILI tool was propelled through the pipeline at an average speed of 0.5ms^{-1}.
On recovery of the ILI tool, it was in good condition and very little debris was recovered in the bunded area.

Mechanical Pigging of 8" to 10" Pipeline Loop

Similar to the 10"/10" loop it was essential that the pigging loop meet an acceptable cleanness criterion prior to running In-Line-Inspection Tool. As such, the following mechanical cleaning pigs were run.

Mechanical Cleaning Pigs:

The first mechanical cleaning run consisted of:

Pig 1:	Low aggression pig	Launched and received as single run
Pig 2:	Low aggression gauge pig	Launched and received as single run
Pig 3:	Medium aggression pig	Launched and received as single run
Pig 4:	High aggression pig	Launched and received as single run

Pigs were propelled through the pipeline system at speed of 0.8 ms^{-1}.

ILI Tool
The ILI tool was propelled through the pipeline at an average speed of 0.5ms^{-1}. Upon recovery of the ILI tool, it was observed to be in good condition and very little debris was recovered in the bunded area.
Subsea temporary spools and pig traps were removed, risers were refitted, and the field was returned to operation.

Field 2

Pre-Construction De-Oiling/Flushing

A chemical cleaning/de-oiling train was injected into the pipeline by means of a temporary pumping spread located on a dive support vessel (DSV) and propelled through the pipeline at a speed of 0.5m/s. This allowed a contact time between the wax dissolver and wax deposit of 48 minutes.

Following the chemical cleaning train, the pipeline was high velocity flushed with inhibited filtered seawater.
Based on the debris assessment supplied by the operator, the following chemical/de-oiling trail was designed:

Slug 1:	40m^3 of Wax dissolver
Slug 2:	3.2m^3 of X-linked gel
Slug 3:	14m^3 of Debris pick-up gel
Slug 4:	3.2m^3 of X-linked gel
Slug 5:	120% of Pipeline line volume of seawater c/w corrosion inhibitor and chemical cocktail

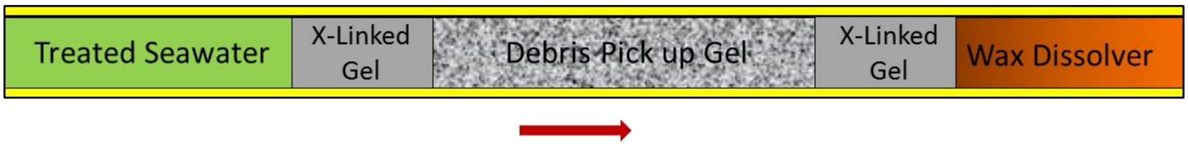


Fig 3. Field 2 De-Oiling and Flushing Train

After the chemical train was run, a total of 3.55 tonnes of sand was recovered from the separator on the operator platform as a result of the chemical cleaning.

Progressive Pigging
Upon completion of the chemical cleaning, the 8" production pipeline had temporary subsea pig traps fitted to facilitate mechanical cleaning before being intelligently pigged.

Mechanical Pig Train 1

The first mechanical cleaning pig train was to consist of the following:

Pig 1:	Calliper foam pig	
Pig 2:	Calliper foam pig	Launched and received as two pig train
Pig 3:	Low aggression bi-directional pig	
Pig 4:	Medium aggression b-directional pig	
Pig 5:	Low aggression bi-directional pig	
Pig 6:	Medium aggression bi-directional pig	Launched and received as four pig train
	120% Line volume flush	

The calliper foam pigs were launched and recovered before the remaining pigs being launched. Upon recovery of the calliper foam pigs to the bunded area on the DSV, both appeared to be in a good state giving an early suggestion that the pipeline was in good condition. Data was received and downloaded from the dataloggers, allowing it to be sent to Aberdeen office for detailed analysis.

During the first pig train runs, high ppm oil in water was measured. To overcome this problem, a total of 120% pipeline line volume of untreated seawater was flushed through the pipeline to try and reduce the volume of hydrocarbons in water. On completion of this pumping operation a decision was made by the operator representative that chemical injection was no longer necessary and the remaining pigs would be run through the pipeline using untreated seawater.

The remaining pigs were then launched in turn; however, it was decided not to run the final pig because of positive results received on board the platform, indicating that the pipeline was relatively clean and ready for the second mechanical pig train.

Mechanical Pig Train 2

The second mechanical pig train consisted of:

Pig 1:	High aggression bi-directional pig
Pig 2:	High aggression bi-directional pig
Pig 3:	High aggression bi-directional pig
Pig 4:	Gauge pig
Pig 5:	Gauge pig
Pig 6:	High aggression bi-directional pig

On the basis of the data received from the calliper foam pig and the results of the first mechanical pig train, the second cleaning train was loaded as discussed previously. On recovery in the bunded area on the DSV, the pigs were found to be in good condition. Additionally, very little debris was recovered. As such, a decision was made to run the ILI tool.

ILI Tool

The ILI tool was propelled through the pipeline at an average speed of $0.3ms^{-1}$. On recovery, the ILI tool was in good condition and very little debris was recovered in the bunded area. Data was captured and sent off for analysis.

Temporary pigging equipment was removed subsea and the system reconfigured to restart production.

Field 3

Pre-Construction De-Oiling/Flushing

De-Oiling of 10" Pipeline

The 10" pipeline was initially de-oiled using two off calliper foam pigs separated with a 100 linear metre MEG slug. The flushing medium was filtered and chemically treated seawater with 110% of line volume being pumped behind the last calliper foam pig.

All of the products were diverted into the 16" pipeline by way of a temporary jumper hose connecting the 10" Receiver to the 16" flushing flange.

On completion of de-oiling/flushing operations, the subsea pig launcher and receiver were fitted to facilitate cleaning and ILI operations.

De-Oiling of 16" Pipeline
Based on the debris assessment supplied by the operator, the following de-oiling train was designed:

- **Slug 1:** 50 Linear metres of wax dissolver
- **Slug 2:** Gel pig
- **Slug 3:** 100 Linear metres of 100% MEG
- **Slug 4:** Gel pig
- **Slug 5:** 105% of Pipeline line volume of seawater c/w corrosion inhibitor and chemical cocktail

Fig 4. Field 3 16" De-Oiling Train

An initial slug of 50 linear metres of wax dissolver was injected into the 16" pipeline to reduce potential wax buildup in front of the pig. An additional flush of downline volume plus 20% was necessary to clear downline of wax dissolver before change out of the flushing flange. Treated seawater was used as the flushing medium to fully displace the wax dissolver.

Gel pigs were separated with 100 linear metres of MEG, which acted as an interface between treated seawater and hydrocarbon.

Chemical Cleaning of 16" Pipeline
During this stage all returns were being routed through a temporary debris handling spread located on the operator platform to platform storage cells. The seawater behind the chemical train was intended to aid the pick-up of solid debris based on liquid velocity and expected particle size and specific gravity.

Based on the debris assessment supplied by the operator, the following chemical cleaning trail was designed:

- **Slug 1:** 6m^3 of X-linked gel
- **Slug 2:** 36m^3 of Debris pick-up gel
- **Slug 3:** 6m^3 of X-linked gel
- **Slug 4:** 105% of Pipeline line volume of seawater c/w corrosion inhibitor and chemical cocktail

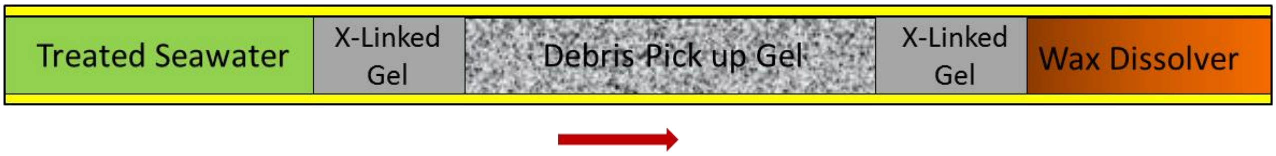


Fig 5. Field 3 16" Chemical Cleaning Train

Note: The crosslinker was broken topside on the operator platform by injecting a suitable gel breaker into the topside pipework in front of the pig receiver.

Chemical Soak of 16” Pipeline
Following the positive receipt of the chemical cleaning train, a chemical soak train was injected into the 16” pipeline. A total of 40 m^3 of wax dissolver was injected and pumped until the train was located over the expected area of wax buildup in the 16” pipeline.

The wax dissolver in the 16” pipeline had the transit velocity between 0.21 and 0.42 m/s. The wax dissolver was left in place whilst the 10” mechanical pigging was performed.

To make every effort to allow the wax dissolver to work effectively during the extended period of the 10” mechanical pigging operations, two supporting gel plugs (one each end of the chemical slug) were used.

Based on the debris assessment supplied by the operator, the following chemical soak train was used:

Slug 1: 6m^3 of X-linked gel
Slug 2: 40m^3 of Wax dissolver
Slug 3: 6m^3 of X-linked gel
Slug 4: 110% of Pipeline line volume of seawater c/w corrosion inhibitor and chemical cocktail

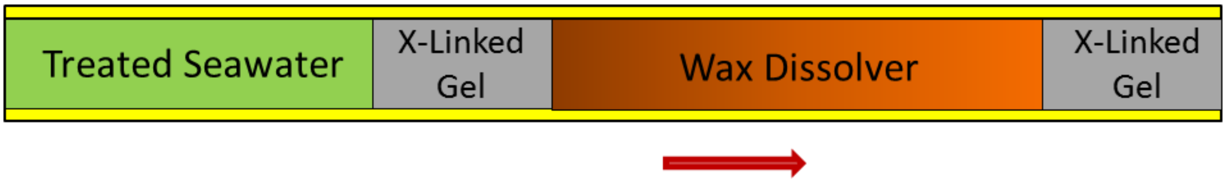


Fig 6. Field 3: 16” Chemical Soak Train

Note: The crosslinked gel was broken on reaching the operator platform by injecting a suitable gel breaker into the topside pipework in front of the pig receiver.

During this stage, a subsea pig launcher was fitted. Receipt of pigs/tools was handled on the receiving platform into an existing pig trap.

Field 3 – Progressive Pigging
All pig loading and pig unloading took place on the back deck of a DSV using a hydraulic pig loading and handling tool with the pig launcher being deployed and recovered as necessary.

Mechanical Pigging of 10” Pipeline

The following pigs were propelled through the 10” line to prepare the system for ILI.

Mechanical Pig Train:

The first mechanical pig train consisted of:

Pig 1:	Low aggression pig	Launched and received as single run
Pig 2:	Medium aggression pig	Launched and received as single run
Pig 3:	High aggression pig	Launched and received as single run
Pig 4:	High aggression pig	
Pig 5:	High aggression gauge pig	Launched and received as two pig train
Pig 6:	High aggression gauge pig	Launched and received as single run

All pigs were propelled through the pipeline system at an average speed of 0.5 m/s.

ILI Tool:

The ILI tool was propelled through the 10” pipeline at an average speed of 0.5m/s and was recovered to the DSV for data download and analysis.

Mechanical Pigging of 16” Pipeline

The following pigs were propelled through the 10” line to prepare the system for ILI.

Calliper Foam Pig Train:

The first pig train consisted of:

Pig 1:	Calliper Foam Pig 1
Pig 2:	Calliper Foam Pig 2

The pig train was propelled through the pipeline system at an average speed of 0.6ms^{-1}. Pigs were recovered and data downloaded. During calliper data analysis, no significant bore restrictions were identified in the line, which allowed the cleaning to progress to the next stage.

Mechanical Pig Train:

The second pig train consisted of:

Pig 3:	Low aggression pig	Launched and received as single run
Pig 4:	Low aggression gauge pig	
Pig 2:	Medium aggression pig	
Pig 6:	Medium aggression pig	Launched and received as three pig train
Pig 7:	High aggression gauge pig	
Pig 8:	High aggression pig	Launched and received as two pig train

The pig train was propelled through the pipeline system at an average speed of 0.6m/s with minimal debris received.

ILI Tool:

The ILI tool was launched subsea and propelled through the 16” pipeline at an average speed of 0.5m/s. The tool and was received topside on the platform and data retrieved for analysis.

Summary and Conclusions

As cited, the three projects described demonstrate how currently unpiggable systems can be adapted to allow pigging operations to be performed. The use of chemical cleaning in conjunction with gels has been validated as viable to allow subsea intervention for the retrofitting of temporary (or indeed permanent) pigging facilities. These, in-turn, allow more aggressive cleaning to be performed with a view to carrying out full in-line inspection operations. The data received can then be used to justify extension of useable life of existing infrastructure.

Early collaboration between operators, construction companies, and pigging/cleaning specialists allows the best fit for purpose methodologies to be devised. Up front preparedness is only half the battle, however, and an ability to react to operational findings is key to timely delivery of project objectives.