Pigging Products & Services Association (PPSA)

Ardoe House Hotel
Aberdeen

15th November 2023

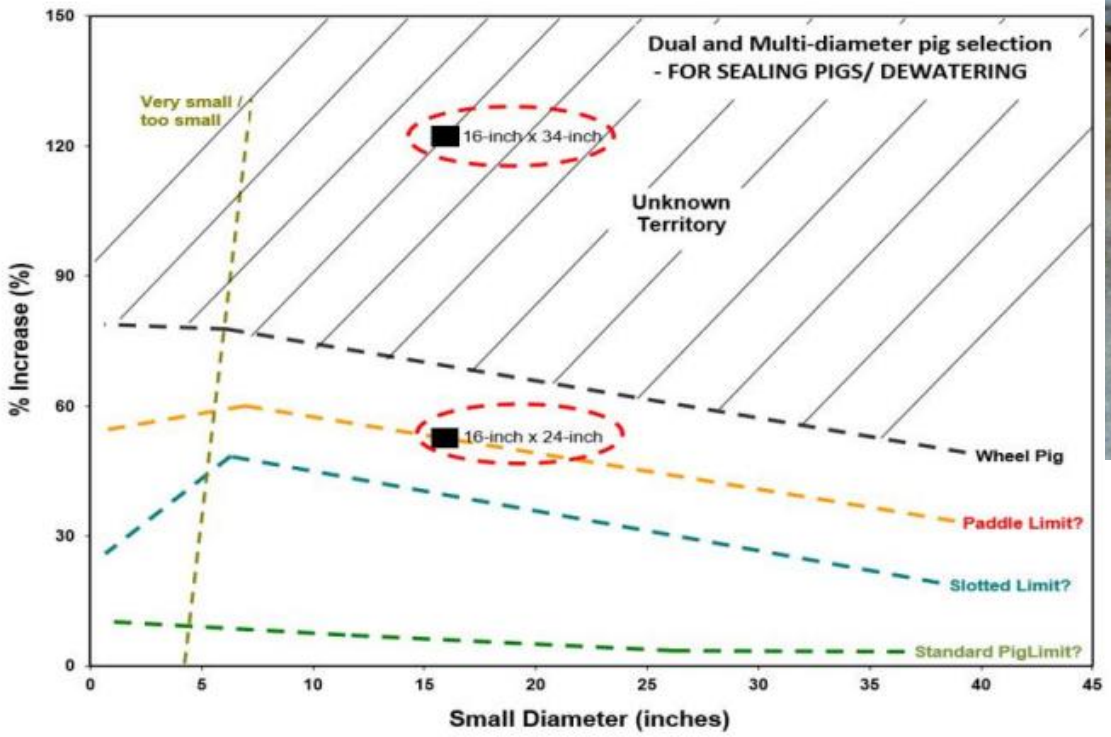
16” / 24” / 34” multi diameter operational pigging

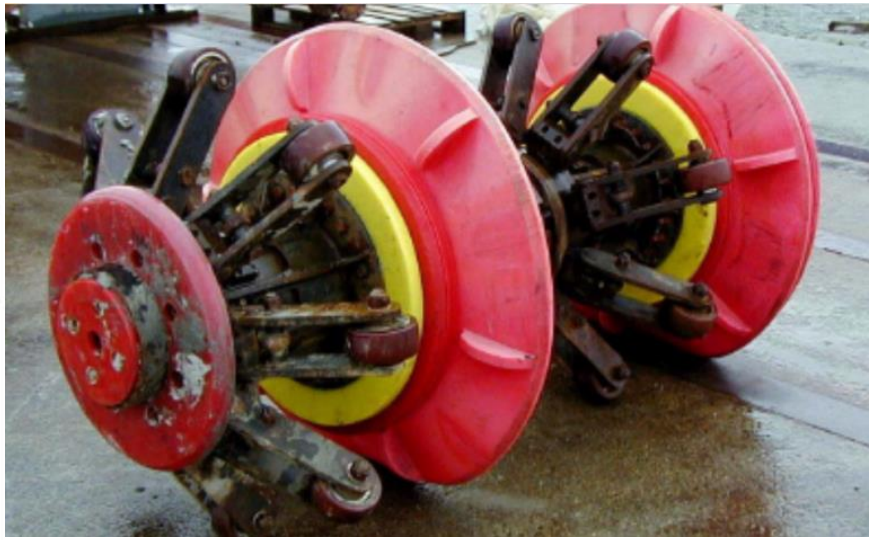
Multi Diameter Pigging

Pigtek Ltd
www.pigtek.com

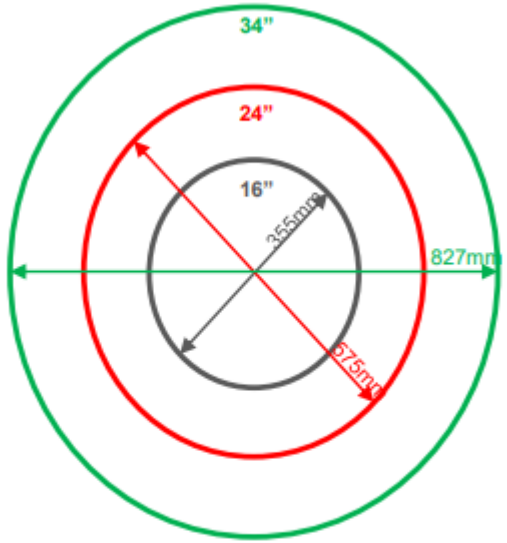
Over the last 20+ years the use of multi diameter long range pigs is nothing new in the pipeline industry. Pigs are regularly designed and ran in pipelines with diameter changes up to 60% of their original size.

The requirement for this project, exceeds this thresholds of what has been achieved to date and sets a record in what can be achieved in pigging in multiple diameter pipelines.





Wheeled pig

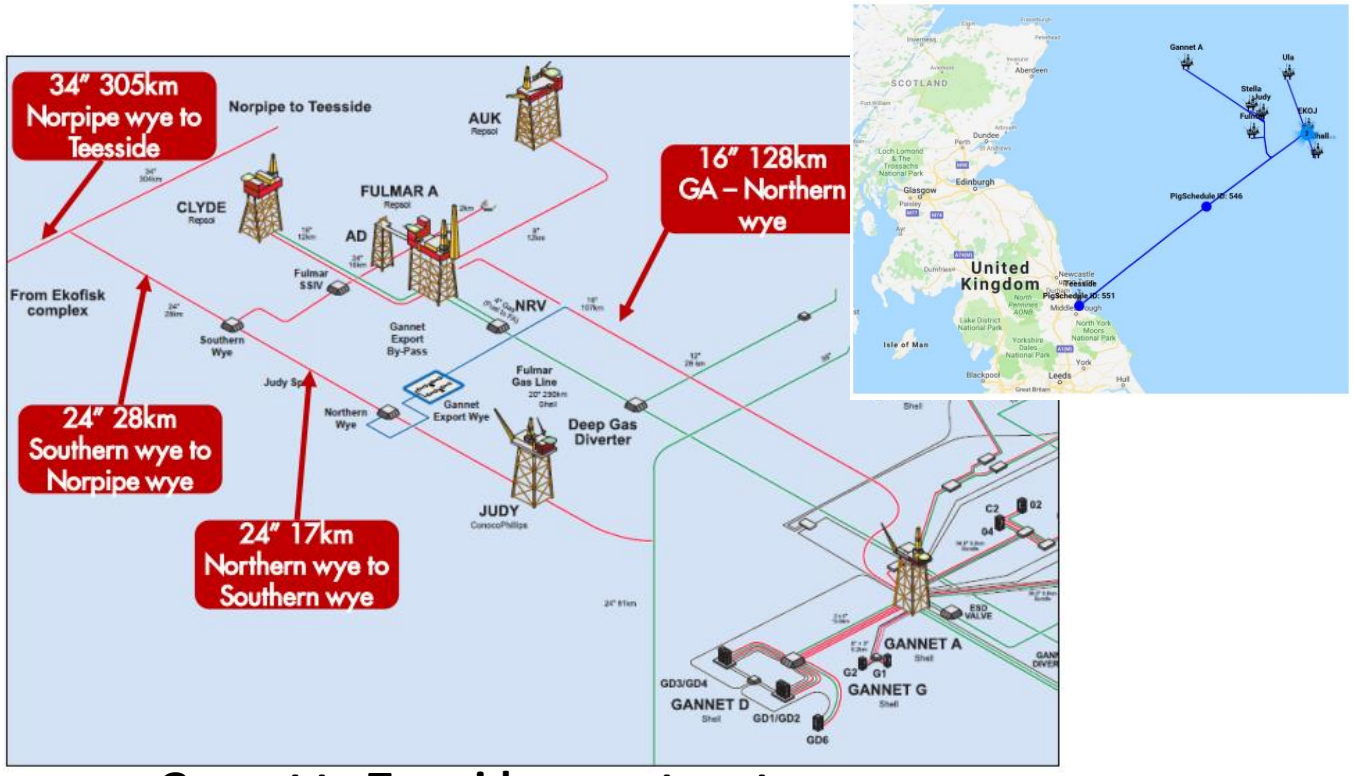


115% diameter change

Gannet Export Route

From 1993 and for 27 subsequent years there after the Gannet platform exported oil production via its 16” x 107km pipeline to the Fulmar platform. The pipeline was pigged on weekly basis to clear wax from the system using standard 16” diameter bi-directional pigs fitted with bypass ports. Wax collected from the 16” Gannet export pipeline was then disposed at the Fulmar platform. Oil received at Fulmar from Gannet was routed into the 24” / 34” pipeline Norpipe system which connected the Fulmar, Judy & Ekofisk platforms to the Teesside terminal.

16” standard bi-di pig



Gannet to Teesside export route

When the decision was made to decommission the Fulmar platform, this then required the Gannet export route to look for suitable alternatives for a new route to the Teesside terminal.

The route selected was to tie-in the 16” pipeline directly to the 24” Judy leg of the Norpipe system at the Northern wye location.

Once the pipeline bypassed the Fulmar platform this in turn removed the ability to pig the pipeline with standard 16” bi-directional pigs and the facility to remove wax at Fulmar. The new 16” pipeline system once constructed and tied in is 23km longer and tied directly into a new subsea 24” Gannet export wye.

The Challenge

Pigtek Ltd
www.pigtek.com

By removing the facility at Fulmar to recover wax and to receive 16” standard bi-directional pigs, the pipeline operator then had the following challenges to address to continue exporting oil through the new pipeline route to Teesside:

A new pig design shall be capable of performing the following:

1. The pigs design shall be capable of withstand the export oil temperature up to 60°C during launch, this will then gradually cool to approx. 6°C as the pig travels approx. 15km from the pig launcher.
2. The pig should also be capable of removing soft and hard wax deposits in the 16” x 128km pipeline section.
3. The pig shall be capable of sweeping water from the 24” x 46km pipeline sections.
4. The pig shall be capable of traversing through 3 x 24” wye and 1 x 34” wye structures without losing driving force
5. The pig shall then be capable of travelling in the 34” pipeline section for 305km until received in the Teesside pig receiver.
6. The pig shall have the capability to interact with other pigs in the system should they meet on route to Teesside.

The pigs design should also consider declining flowrates in later life of the Gannet field through to 2032, this is particularly important when transitioning from 16” to 24” at the 24” Gannet wye and from 24” to 34” at the Ekofisk wye.

Flowrates at the diameter transitions are particularly important as the ability of the pig to travel in the smaller diameter at a speed equal to 0.5 meters per second would be <0.2 meters per second in the larger diameter as the flow cannot be stepped up as the pig transitions the diameter change.

New Pig Basis of Design

With such a larger diameter change to manage, the Pigtek team were conscious of the following when proposing a new pig design for this system.

Pig length and configuration

- As the pig was required to pass through 16” 5D bends and seal in 24” wye pieces this drove the need for a dual module pig.

Loading & launching

- As the pig ran through the 16” section first and then required to form a seal in the 24” system, the pig would need to be in a compressed state for the 16” portion of the run and therefore launched from a cassette.

Wax management

- The pig's ability to clear wax in the 16” system is also key and therefore bypass across the pig had to be available to control the pigs speed and to manage wax ahead of the pig.

Centralisation

- Centralising the pig is key along with supporting the pig's weight in the larger diameter, as more steel and urethane is needed in the larger diameter to create a seal in the pipe. Large heavy pigs tend to sit in the base of the pipe and therefore bypass in low flow situations quite easily.

Neutral Buoyancy

- The pig’s weight is key to the success of the pigging operation in all 3 diameters. To achieve neutral buoyancy in crude the pig is required to weigh 89 kg. All pig trials are to be performed in water therefore the pig would be fitted with weights to increase it to 93kg making it neutrally buoyant in water.

Compression set

- The effects of compression set in the compressed urethane components of the pig, to later enable the pig to reform into the larger diameter is also a contribute to the pig's success. This is particularly important when the propelling medium is heated.

24” / 34” dual diameter pig

Production Pig Speeds

Pigtek Ltd
www.pigtek.com

Flowrates across the field are planned to reduce significantly over the period 2019 to 2030. Please see the table below for expected pig speeds in the 16”, 24” & 34” pipeline sections.

Pig speed meter per second based on oil production rates	16” Gannet	16” Gannet & 24” Judy	16” Gannet, 24” Judy & Fulmar*	16” Gannet, 24” Judy, Fulmar & 34” Ekofisk
2019	0.23	0.25	0.33	0.97
2023 (* Fulmar offline)	0.16	0.17	0.17	0.95
2030	0.09	0.08	0.08	0.38

As production continues beyond 2023 and as Fulmar is taken out of production, pig speeds in the 16” & 24” are very low.

Pig Trials Setup

Pigtek Ltd
www.pigtek.com

Pig trial rig used over a 4-year period from 2017 to 2020 in varies configurations.

Trial setup incorporating all pipeline features that exist in the Norpipe system from the Gannet platform pig launcher to Teesside terminal pig receiver.

1. 16” Pig launcher
2. 16” 5D bend
3. 16” pipe with dent feature
4. 16” pipe internal coated with wax
5. 16” to 24” reducer
6. 24” 30° equal wye
7. 24” acrylic spool
8. 24” 5D bend
9. 34” 30° equal wye
10. 34” acrylic spool
11. 34” hydro coupler replica
12. 24” & 34” pig receivers

All trials performed in water/ water environment with the ability to deliver flow to the launcher and wye piece opposing legs as required.

Phase 1 – Pig Designs

In 2018 two pig designs were selected for trial based on the evaluating the pipeline system

16/24A discs in compressed state

16/24A “sun pig”

Each of the pig module comprises of a polyurethane tubular pig body onto which are fitted with 16” guide discs, spacers and 24” overlapping segmented cups. The modules are connected by a flexible polyurethane coupling incorporating a chain welded to a flange at each end of the coupling.

16/24B

Each module comprises of a tubular steel pig body onto which are fitted with guide discs, seal discs, spacers, moulded cups and star support discs. The modules are connected by a flexible polyurethane coupling incorporating a chain welded to a flange at each end of the coupling.

Phase 1 – Pig Trials

Pigtek Ltd
www.pigtek.com

Pig trials performed to see how the pigs would travel in 2 pipe diameters (16” & 24”) and their ability to remove wax in the 16” diameter.

16/24A “Sun Pig”

This prototype pig performed well in the 16” diameter, however, did not remove the wax from the 16” as efficiently as a standard bi-di pigs. 16/24A traversed the system however it was noted that the discs did not recover in the 24” section as well as expected.

16/24B

This pig was very difficult to load in the 16” pig launcher due to the friction from the larger discs.

This prototype pig performed well in the 16” diameter and removed the wax from the 16” as per the standard bi-di pigs. 16/24B traversed the whole system and the larger discs recovered in the 24” section as expected.

Conclusion: 16/24A failed to remove wax and discs recovery in the 24”, decision taken to move forward with 16/24B design.

Phase 2 – Pig Design

16/24 D

In Phase 1 it was shown that the 16” & 24” pipeline features can be traversed with this pig design, focus was now to ensure the pig can pass through 34” diameter unaided and without intervention from another pig in the system.

The update from 16/24 B to 16/24 D was all about weight saving and to increase the pig's buoyancy.

By increasing the pig’s buoyancy allows the pig to better centralise in the 24” diameter with an aim to seal effectively and also to travel through the 34” x 305km section by using the flow of oil to push the neutrally buoyant pig all the way to Teesside unaided.

The pig was changed to a dual module titanium body c/w internal cavities and external collars fitted with syntactic foam elements to save weight and increase buoyancy. The 24” discs were replaced with a 24” spider arms to give support and reduced thickness 24” sealing discs.

Calculations showed that to enable the pig to be neutrally buoyant in water the pig would need to weigh approx. 89 kg in air and with all the changes made to the pig and the exchange of components the complete dual diameter pig achieved a weight of 8kg in water. Buoyancy was further verified by submersing the pigging in a water tank to check the pig’s buoyancy and trim.

Phase 2 – Pig Trials

Pigtek Ltd
www.pigtek.com

Pig trials were performed with the 16/24D pig to review its ability in the 34” section and its interaction with the other pigs in the system if they were to meet at key locations across the system.

The trials were performed at very low flow rates to give an understanding of how the pig behaves when also trying to transition a diameter change (16” to 24” and 24” to 34”)

A target flow rate of 60m3/hr (pig speed 0.15 m/sec) was set as a benchmark for the pig to be able to travel through the 16” & 24” section. This was achieved in part during this trial, but the pig did tend to stall at points in the 24” section and required the flowrates to be increased to approx. 150m3/hr to complete the journey.

The pig’s ability to travel through the 34” system was adversely impacted by its 8kg weight in water where the pig tended to travel at the bottom of the pipe, requiring flowrates up to 550m3/hr to make the passage to the 34” pig receiver.

Interaction with other pigs in the system, revealed no issues.

16/24D during interaction trials with 34” Ekofisk pig

Conclusion

The pig design is certainly the correct vehicle to progress to next stage, however the 8kg weight in water is impacting its ability to travel in the larger diameters. Weight losses at a component level needs to be investigated further to make the pig neutrally buoyant in water and subsequently crude oil.

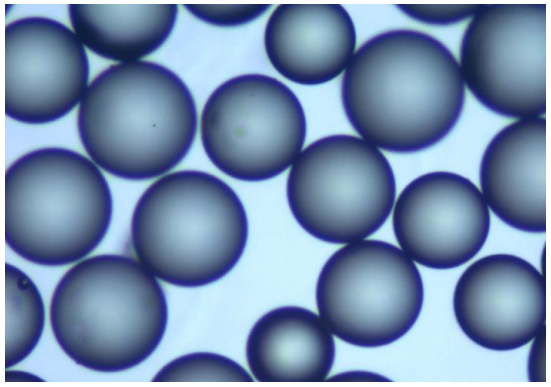
Weight loss and Increased Buoyancy

Pigtek Ltd
www.pigtek.com

With approx. 8kg of weight to lose and the requirement to make the 16”/24” pig neutrally buoyant in water, new exotic materials generally not considered for standard pig manufacturer were incorporated.

- Microsphere bead encapsulation into PU components
- Improved syntactic foam for increased buoyancy internal and external mounted on the pig
- Reduced thickness of 24” sealing discs
- Titanium body “pepper potted” to reduce mass of titanium from the body, whilst ensuring the pigs strength.

PU disc mixed with microsphere content, showing the disc has neutral buoyance in water versus a standard disc which is not able to float.



Microspheres are small spherical particles, with diameters in the micrometre range (typically 1 µm to 1000 µm (1 mm). Glass microspheres are primarily used as a filler and volumizer for weight reduction.

16/24E pig neutral buoyancy check in test tank

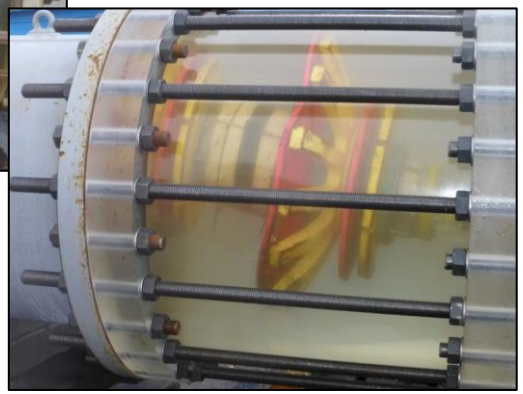
Phase 3 - Pig Trials

Following the weight loss and increased buoyancy modifications made to the pig, 16/24E was then made ready for pig trials once again in 2019.

The pig was put through a full suite of trials:

- 16” Wax removal trial – Passed, with wax removal better than standard 16” pig
- 16” 5-day compression trial – mixed results signs of deformation, but pig still recovered to 24” diameter
- 16” to 24” transition at low speed – Pig able to travel at 30m3/hr in 16” (0.07 m/sec) and 100m3/hr in 24”(0.1 m/sec)
- 24” to 34” transition at low speed – Pig able to travel at 100m3/hr in 24” (0.1m/sec) and 150m3/hr in 34” (0.08 m/sec)

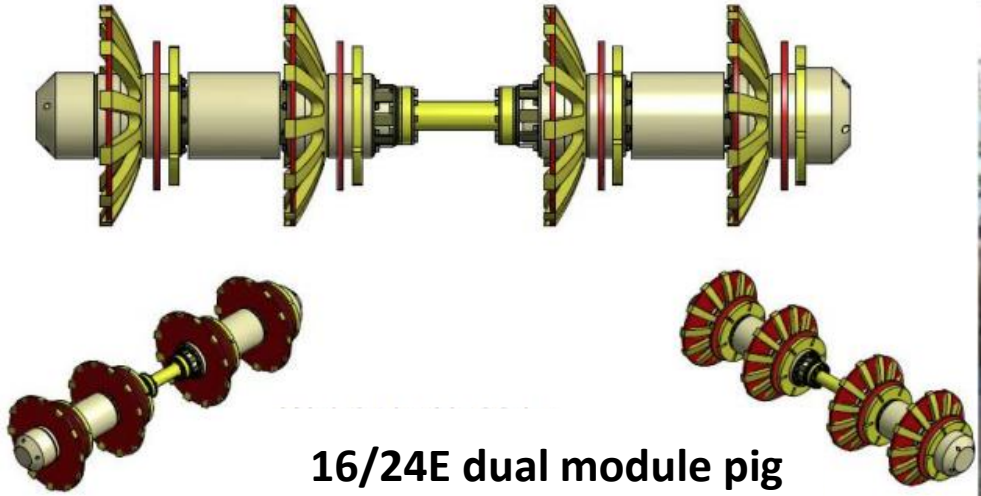
16/24E being recovered from 16” pipe follow wax and compression trial



16/24E passing through 24” & 34” acrylic spools

Conclusion: Pig put forward for operational service in the pipeline system.

1624E Pig - Operational Service



16/24E dual module pig

The pig was first run in an operational environment from the Gannet platform to Fulmar platform (16” x 108km) prior to the Fulmar platform being bypassed. It was evident that heat effect from oil at >60° with compression set of the discs being partially present on the 24” sealing discs as this point. However, the pig was received at Fulmar without issue.

16/24E pig received at Teesside 34” pig receiver

In mid 2020 the 2nd operational pigging run from Gannet platform to Teesside took place in the new pipeline configuration. Based on flowrates it should take approx. 11 days to travel from Gannet to Teesside, however 5 days into the run it became evident that the pig was suffering from Compression set of the 24” discs once again as it failed to trigger pig detection equipment at the newly installed subsea 24” Gannet wye location and beyond.

Using a combination of ullage from each of the platforms the pig was eventually recovered to Teesside a number of weeks later, showing the 24” spider arms and discs had badly deformed to circa 18”.

Conclusion: No further operational pig runs and back to the drawing board on the 24” elements.

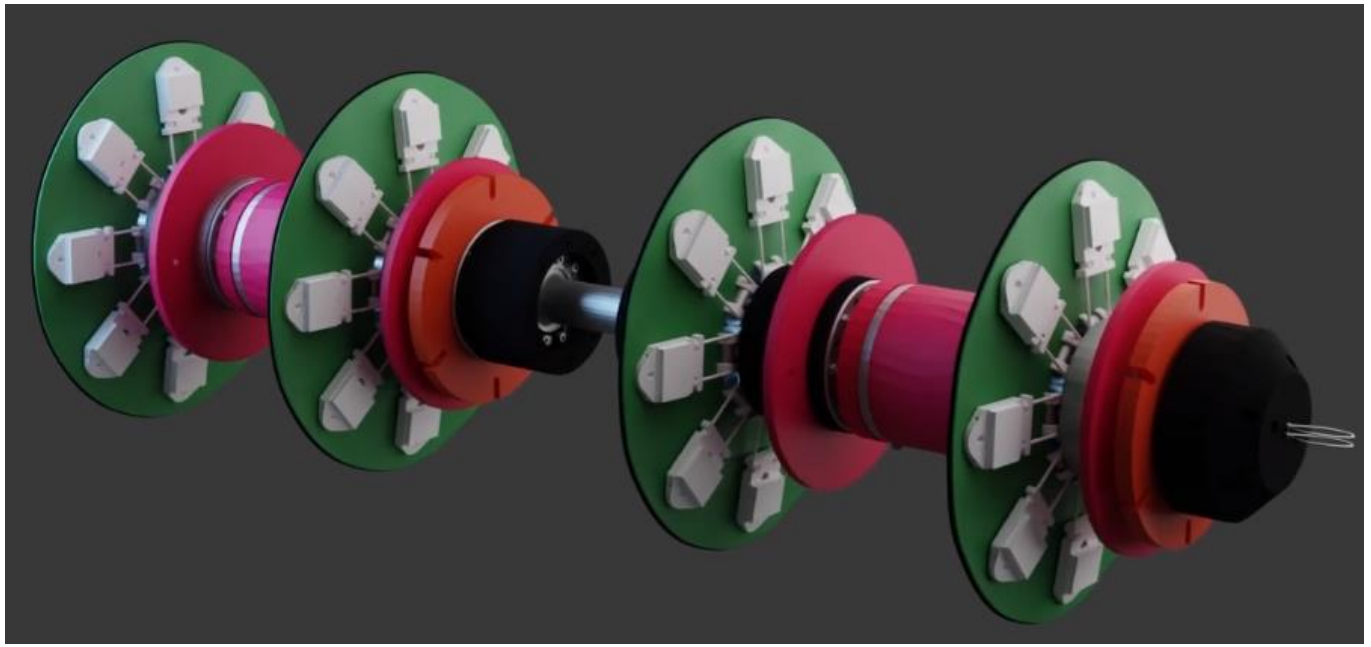
1624F Pig - Redesign

Pigtek Ltd
www.pigtek.com

Given the failure of the 24” PU spider arms and the 24” sealing discs due to heat and resulting in compression set of these components.

PU spider arms were moved to a steel torsion spring design to counter the effects of heat at the launch end of the pipeline. Giving the ability for the 24” sealing elements to spring into position once the 16” to 24” transition is reached.

The 24” sealing discs are now thinner and backed with a Kevlar sheet for further heat protection, both sealing disc and Kevlar sheet are both attached to each if the 8 x torsion springs.

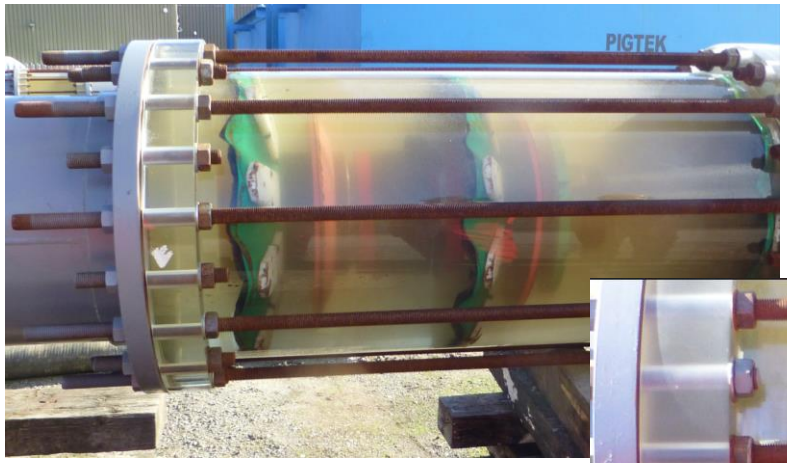


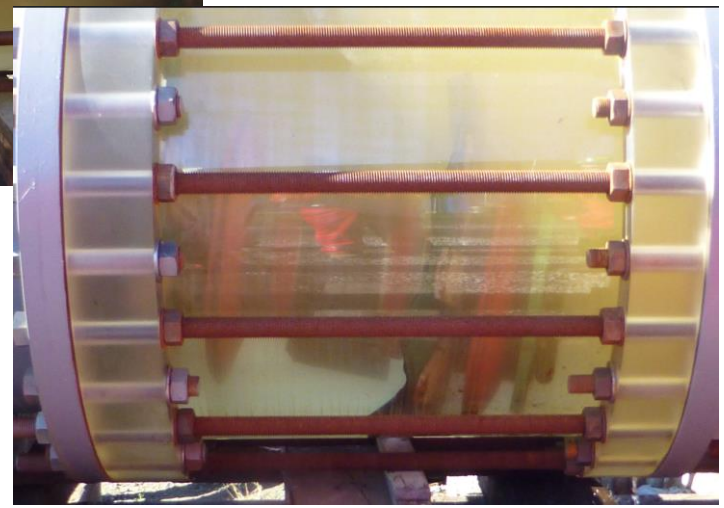
16/24F c/w torsion spring components

1624F Pig – Pig Trials

To understand if the changes made to the pig could withstand the >60° when held in a compressed state, the pig was subjected to heat trials where the pig was pulled into a 16” cassette and then submerged in diesel at 60° for 5 days. This would replicate the pig’s condition whilst being held and launched from the Gannet platform

Following successful completion of the heat trial, the pig showed very little effects of compression set and the torsion springs returned back to the 24” diameter with ease. At this point the same pig was then pumped through the test rig to confirm that the pig can indeed pass through the 16”, 24” & 34” diameter changes and all associated pipeline features as per the flow set out in the phase 3 pig trials.





The Solution

The dual diameter 16/24F has routinely cleaned the 16”, sweep water 24” & transited the 34” x 477km pipeline from the Gannet platform to the Teesside terminal for more than 2 years (2021 to 2023) and will continue to whilst the Gannet platform is exporting oil to Teesside.

The pig travels the complete system in approx. 11 days from launch to receipt at a frequency of every 30 to 60 days.

The 1624F pig is designed, built, tested, and refurbished for each operational pigging run by Pigtek Ltd.

16/24F ready for deployment