MULTIPLE PIG LAUNCHING SYSTEM

By: Rob Harrison, International Pipeline Products, UK

Abstract

Weekly pigging of a pipeline is a typical regime employed on many pipelines around the world. However this simple activity becomes costly when at one particular asset, every-time a pig is launched the emergency shutdown valve has to be activated resulting in a days lost production.

Development of a Multiple Pig Launching system that could be retrofitted to existing pig launchers with no / minimal invasive activities could reduce the number of times in a year that the ESD valve would need to be operated.

iNPIPE Products™ designed manufactured and tested a multiple pig launching system that allows a number of pigs to be launched individually without the need to open the closure door in-between launches.

This paper describes the key stages of development engineering and testing to create a successful conclusion to the original scope.

Nomenclature

CFD – Computational Fluid Dynamics
DP – Differential Pressure
ESD – Emergency Shutdown
FAT – Factory Acceptance Testing
MPLS – Multiple Pig Launching System
SCFM – Standard cubic feet per minute

Introduction

Pigging is part of routine pipeline operations to ensure flow assurance. In order to introduce a pig into a pipeline, typically a pig launcher is fitted to the pipeline. The launcher is isolated from the pipeline through a number of valves. With all the valves closed and the launcher de-pressurised, access to the launcher is through a closure door fitted to the end of the major barrel. The door is opened and a pig inserted into the major barrel, pushing the pig into the reducer to gain a seal. The closure door is then closed.

Should a problem exist with the mainline isolation valve, for example not fully closing then this presents a problem in access to the launcher by opening the closure door as hydrocarbons are passing the valve and entering the launcher. Opening the closure door allows these hydrocarbons to escape to atmosphere. A decision must then be made as to shut the system down to allow pig loading operations to commence. This has financial implications in lost revenue in the time taken to shut down and then re-pressurise the pipeline.

This example exists for one particular client who were pigging a 36” ns gas pipeline weekly. With an aging asset a fault developed on the mainline isolation valve and every time a pig was required to be launched the ESD valve had to be operated, resulting in a days lost production at approximately £750K. The client contacted iNPIPE Products™ in 2018 to request if they could help by providing a solution that would reduce the number of times in a year that the ESD valve had to be operated. In short could more pigs be installed in the launcher and still have the ability to launch them individually?

Existing MPLS designs currently or previously marketed, fall into two categories. Either relying on specifically designed launchers or complex valve arrangements built into the pigs.

1) Pig launcher fitted with fingers and valve arrangement. The pig launcher comprises of a number of nozzles fitted with a pig/sphere fingers and valve arrangement. The finger in front of the pig is retracted while the remaining fingers are in the extended position holding any subsequent pigs/spheres in the launcher. The valve arrangement is configured to launch the front pig.
2) Using a conventional launcher the pigs are fitted with a valve that is held open creating bypass through the pig. This is held open by the pig directly in front. As the lead pig is launched the valve on the trailing pig closes thus allowing it to be driven.

To cut down on costs could a solution be developed that utilised existing infrastructure and existing pigs.

iNPIPE Products™ Solution

The existing launcher has a number of nozzles fitted to the underside of the launcher originally intended as the drain system but currently only a couple of these are used. These could be utilised as launching points for the individual pigs. The centres between the nozzles did lend themselves to being used as launch points. A concept design was prepared and submitted to the client showing a cassette that would be preloaded with pigs onshore. The cassette would then arrive on the platform ready to be inserted into the launcher. It is anticipated that a number of cassettes would be in circulation to allow continuous pigging operations.

The concept behind this solution is that the first nozzle would be used to push the pig forward sufficiently passed the kicker line. At this point the kicker would take over to complete the pig launch. When the time for the second pig to be launched arrives, the nozzle behind the second pig would then be utilised to carry out the same operation as the first nozzle. This operation would be carried out for pigs three and four with all the nozzles being valved therefore each can be operated independently of each other. With four pigs fitted inside the launcher this would mean that the ESD valve would only need to be operated once a month rather than weekly with the current pigging operations.

A site survey was carried out to ensure an accurate set of measurements existing for the launcher and to interview personnel associated with pigging activities on the platform. Detailed measurements were taken of the launcher. Fig-1 and Fig-2 show the launcher and nozzles. One potential problem identified was that the nozzles underneath while on 3” flanges were in fact fitted to a 4” branch (See Fig-3). Data was also gathered on pigging pressures and flow rates required to launch the pigs. The survey also included how the pigs if loaded in a cassette would be moved from the laydown position on board to the pig launching facility, making note of potential obstacles, available handling space and crane facilities (Fig-4).

Figure-1 Launcher and Closure Door

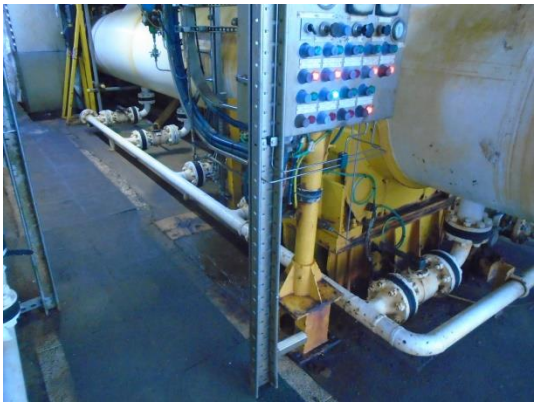


Figure-2 Nozzle Positions

Figure-3 Nozzle In Detail

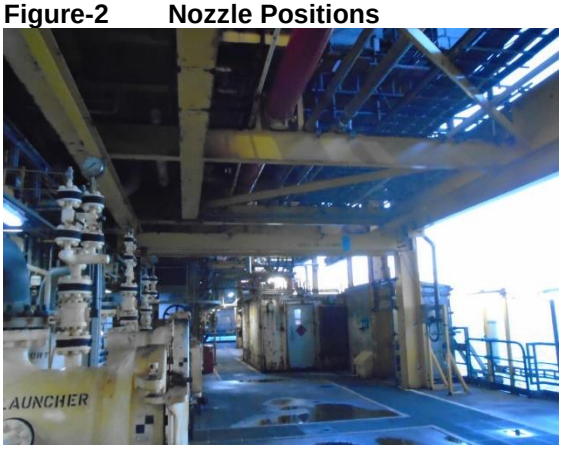


Figure-4 Space & Handling Facilities

The site survey concluded that the existing launcher could be used. The challenge now was developing a seal that could close off the nozzle on the inside curvature of the major barrel.

Design Development

A seal was required that would self-energise when the pressure entered the seal from the nozzle. This would be similar in concept to a closure door lip seal, but making this work in three dimensions. The seal would be suspended from the underside of the cassette so would also require protection as the cassette would be removable from the launcher.
A concept was created for the seal and would be tested independently of the cassette to find out if the concept would create an adequate seal.
The test rig mirrored the findings offshore. The seal was moulded and installed in the test rig shown in Fig-5. Testing required the seal to hold a 1 Barg differential pressure. The requirement in the field would be holding pressure for no more than 10 minutes. Testing was conducted over night with no loss of pressure. Fig-6 shows the test rig set up.

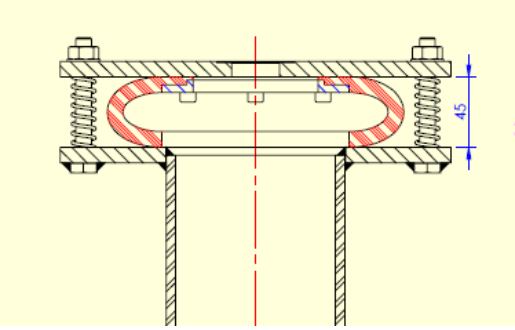


Figure-5 Seal & Test Rig set-up

Figure-6 Testing

Run in parallel with the seal development was a CFD project to understand if a pig could be launched using a nozzle. The benefit of these calculations would save costs in having to build a prototype if the results stated that the pig could not be launched. The data gathered from the offshore survey along with the existing pig design, proposed cassette design and how the pig would be launched was presented to an outsourced analysis company. An additional question raised by the client "on launching the first pig would a vacuum or turbulence be created which would in turn cause the second pig inadvertently launching the second pig"
The conclusion of the analysis stated that the first pig successfully launched with negligible movement of the second pig. This gave confidence that full prototype testing could be conducted. Fig-7 & Fig-8 detail some of the work carried out by CFD.

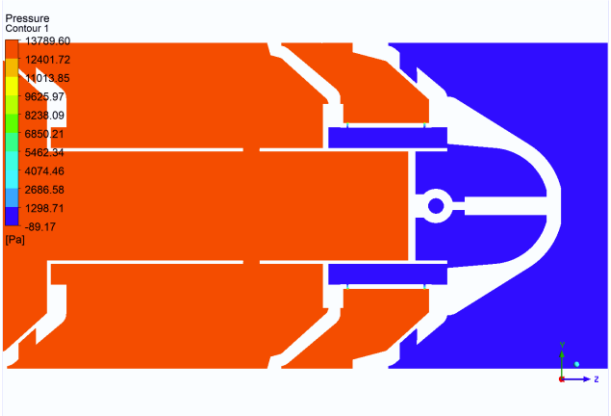


Figure-7 Pressure Contours

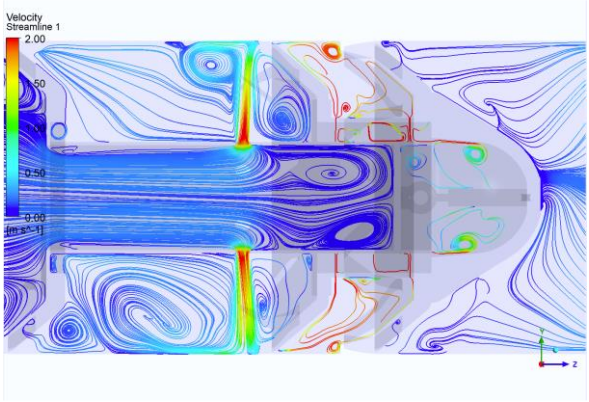


Figure-8 Velocity Streams

Prototype build

With the successful seal testing and the positive results of the CFD analysis the next stage was a full size prototype. A launcher suitable for the internal diameter already existed from previous testing conducted for this client but would need to be modified to mimic the actual launcher on the platform, adding the kicker line, and nozzles as positioned. This modification work was carried out internally.
A cassette to hold two pigs was again fabricated in-house and throughout the build measurements checked along with trial fits to the launcher conducted.
The test rig was then assembled to enable testing to be conducted firstly with water then switched over to allow testing with gaseous medium (compressed air).

The FAT procedure and Risk Assessment was developed with the client to allow a safe testing method to be conducted.

Figure-9 Cassette Fabrication

Figure-10 Test Rig

FAT Testing

From the safety aspect testing would initially be conducted using water, however the pipeline transports gas so a true comparison would be to conduct a test using compressed air. Prior to testing the test rig was hydro-tested to 15 Barg pressure tested to ensure pressure containment.

Tests to be carried out:

- Loading of Pigs into Cassette
- Loading of Cassette into Launcher
- Validation of Launching Pig #1 – With Water
- Validation of Launching Pig #2 – With Water
- Validation of Launching Pig #1 – With Air
- Validation of Launching Pig #2 – With Air

Figure 11: Water Testing Set Up

Figure 12: Air Testing Set Up

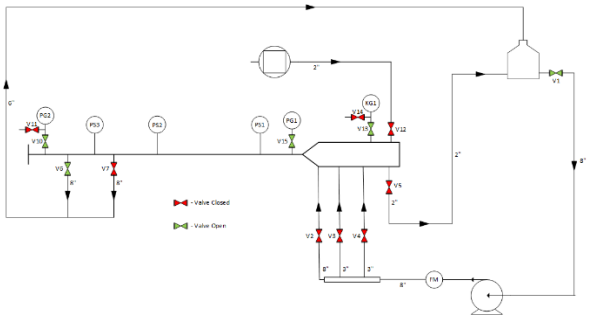


Figure 13: Water Test Schematic

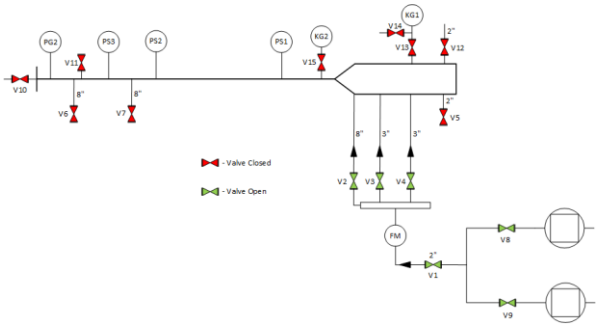


Figure 14: Air Test Schematic

2 of the clients' Operational pigs were loaded into the cassette ensuring that they were in the correct position with the mushroom seals located, see figures 15 & 16 below.

Figure 15: Operational Pigs Loaded into Cassette

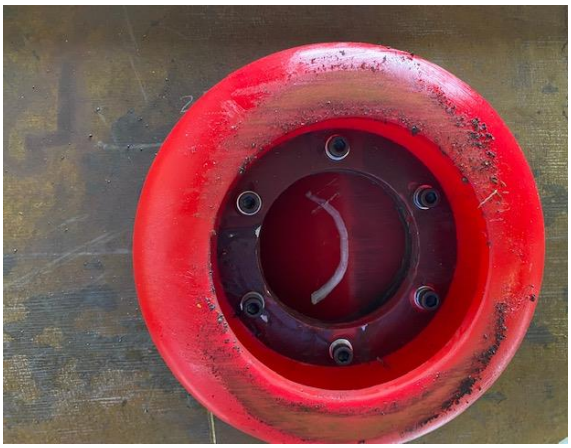


Figure 16: View Through Mushroom Seal

Once the pigs were loaded into the cassette the cassette was loaded into the test rig, see figure 17 below.

Figure 17: Cassette loaded into Test Rig

WATER PIGGING

Water was pumped into the test rig to launch the 1st pig. However, after running the pump for a few minutes it was clear that the pig #1 had not launched. It was agreed to stop the test and investigate into why pig #1 had not launched.

The cassette was removed and it was found that pig #1 had initially launched but had stalled due to bypass, through the bypass slots in the cassette and over the front cup, as the front cup had straddled the slots in the cassette, see figure 18, below.

Figure 18: Stalled Pig across Cassette Slots

Once the cassette had been removed and the cause of the stalling pig could be clearly seen. It was agreed that the pig should be reconfigured with an additional sealing disc behind cup #2, see figure 19 below, which would maintain drive as the front cup passed over the slots.

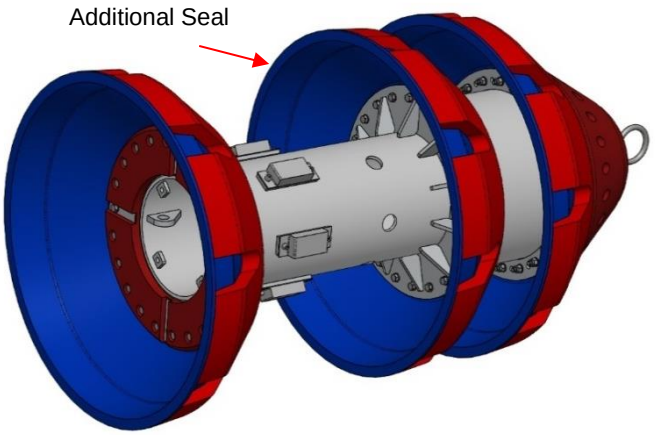
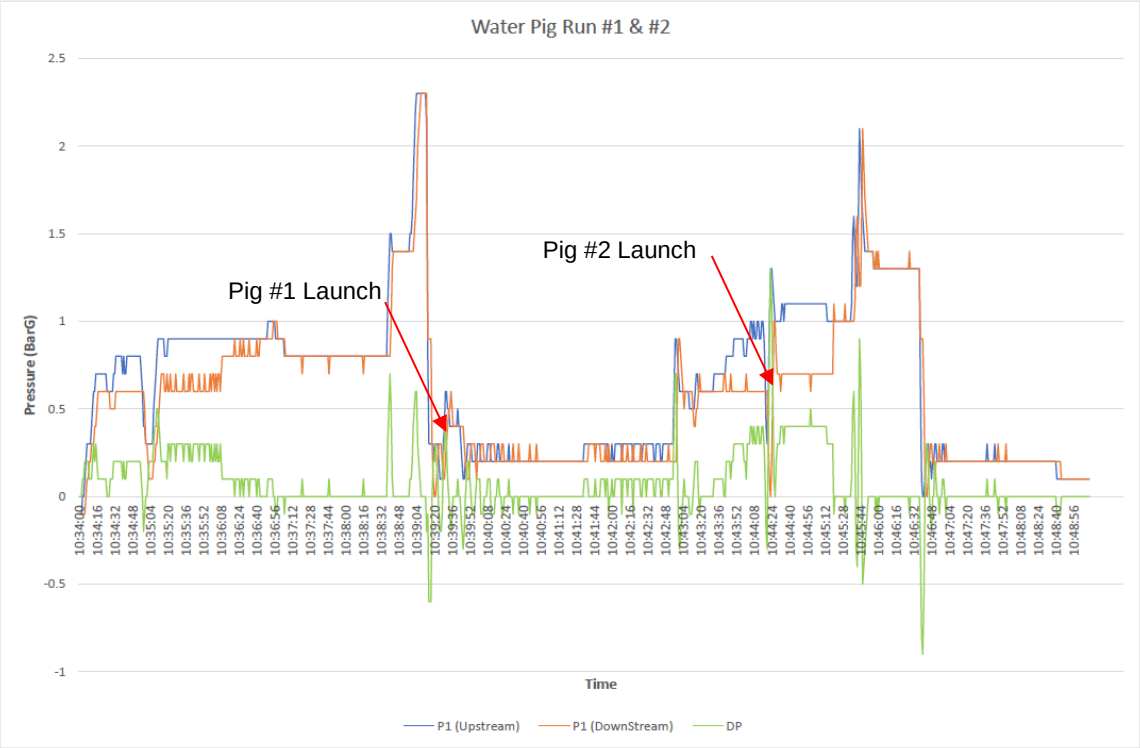


Figure 19: Reconfigured Pig with additional seal disc

The reconfigured pigs were loaded into the cassette which was then then loaded into the test rig. The test was repeated with Pump set to 1800 RPM, max output, with the return fully open. The test resulted in successful independent launches of pig #1 & pig #2.

Graph below shows the pigging pressure and Differential Pressure.



Graph 1: Water Pig Run #1 & #2

From the recorded data, shown in Graph 1, it can be seen that pig #1 launched with a DP of 0.7Bar & pig #2 launched with a DP of 0.7Bar.
Test was concluded as a success and stopped. Test rig was then reconfigured for Air Pigging.

AIR PIGGING

The testing spread was reconfigured with 2 off 10bar (restricted to 7Bar) 750scfm compressors delivering a combined flow of 1500scfm, see figure 20. The pigs, as configured for the previous water test, were loaded into the cassette which was then loaded into the launcher.
The test was started with both compressors delivering max air flow of ~1500scfm, see figure 20 below.

Figure 20: Flow Meter

The test rig pressure was increased and equalised to 4Bar and then locked in. Once locked in the delivery valve was opened to inject the air flow and increase to 5Bar. Once the downstream pressure had reached 5Bar then air was vented downstream to 4Bar, creating a DP to launch Pig #1. This was competed a number of times, but without a successful launch. Test was stopped to review.

After a Toolbox Talk it was agreed that once the test rig had equalised to 4Bar the delivery hoses would be charged to 6bar and then open up the delivery valves to the test rig to deliver a larger charged volume to launch the pig. Test was restarted and revised procedure followed; but this did not result in a successful launch.

Testing was stopped to review and understand why the pigs failed to launch. Cassette was removed and confirmed that the Pig #1 had not launched. It was the view that there was bypass across the pigs and that when loading the pigs into the cassette the Blue Seal discs had buckled not creating a good seal and resulting in failure to launch the Pig #1.

It was then agreed that the front 2 cups & seals on each pig would be replaced with solid cups, creating a better seal, see figure 21 below.

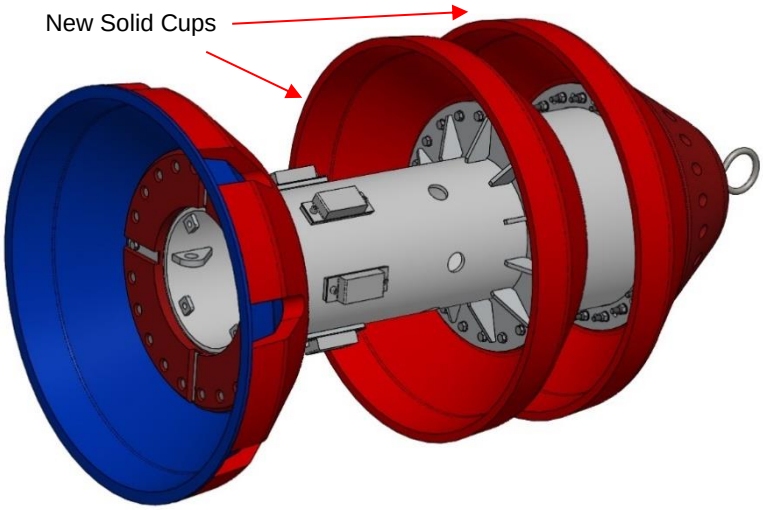


Figure 21: Reconfigured Pig with Front 2 Solid Cups

Pigs were reconfigured, as per figure 21, installed into the cassette and then loaded into the launcher.

Test was started with a single compressor delivering ~750scfm. Air was injected, test rig pressure increased and equalised to 4Bar and then locked in. Delivery valve was opened and test conducted, but resulted in a failed launch. 2nd compressor was started to inject air at 1500scfm. Process was repeated a number of times but pig failed to launch each time.
It was agreed to stop the test and remove the cassette to observe any pig movement.

Upon removal of the cassette it could be seen that pig #1 had indeed initially launched but had stalled as it exited the cassette, see figure 22 below.

Figure 22: Cassette removed from Launcher

Once removed it was clear that pig #1 had initially launched but had stalled as the 2nd cup was passing the slots in the cassette. The front cup had not created a seal in the reducer section of the launcher as the 2nd cup was passing across the cassette slots. This had resulted in creating a bypass path for the air from behind the 2nd cup, across the slots, down the front of the 2nd cup and out of the cassette behind the 1st cup.

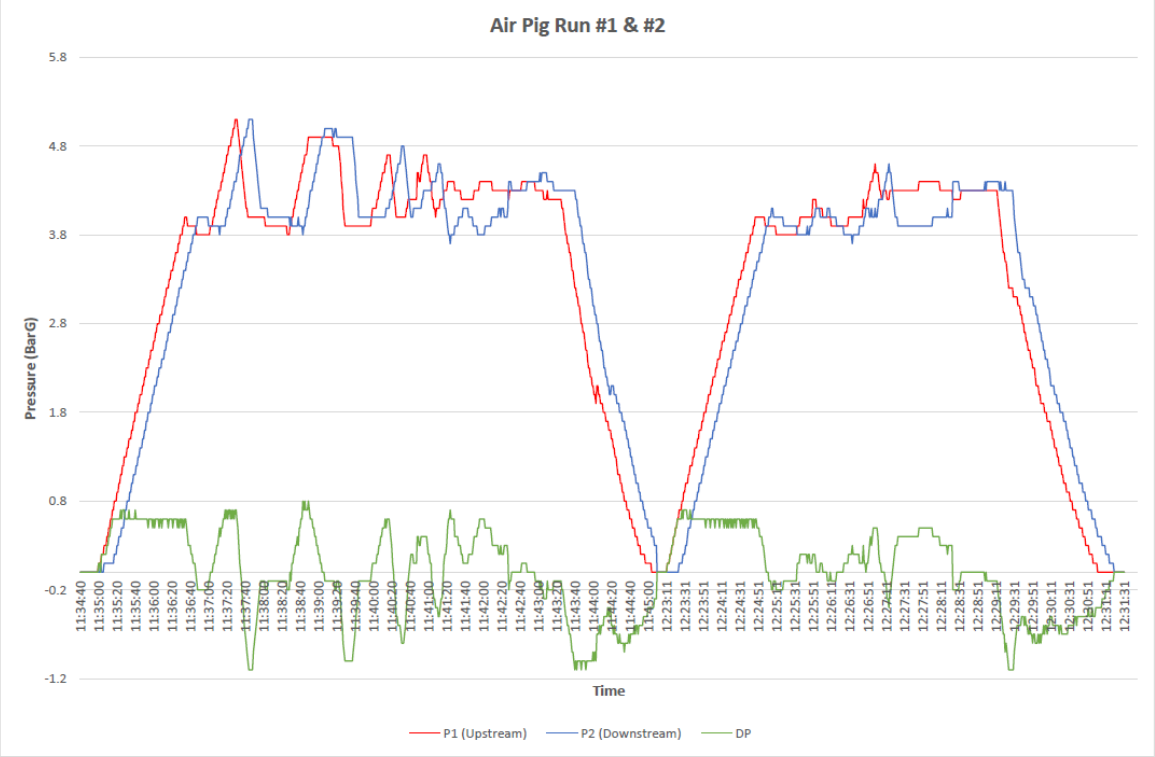
Figure 23: Close Up of Bypass Path

After further review it was agreed that the slots in the cassette should be reduced in size by 50% but additional slots created to maintain the same area volume for the air flow.

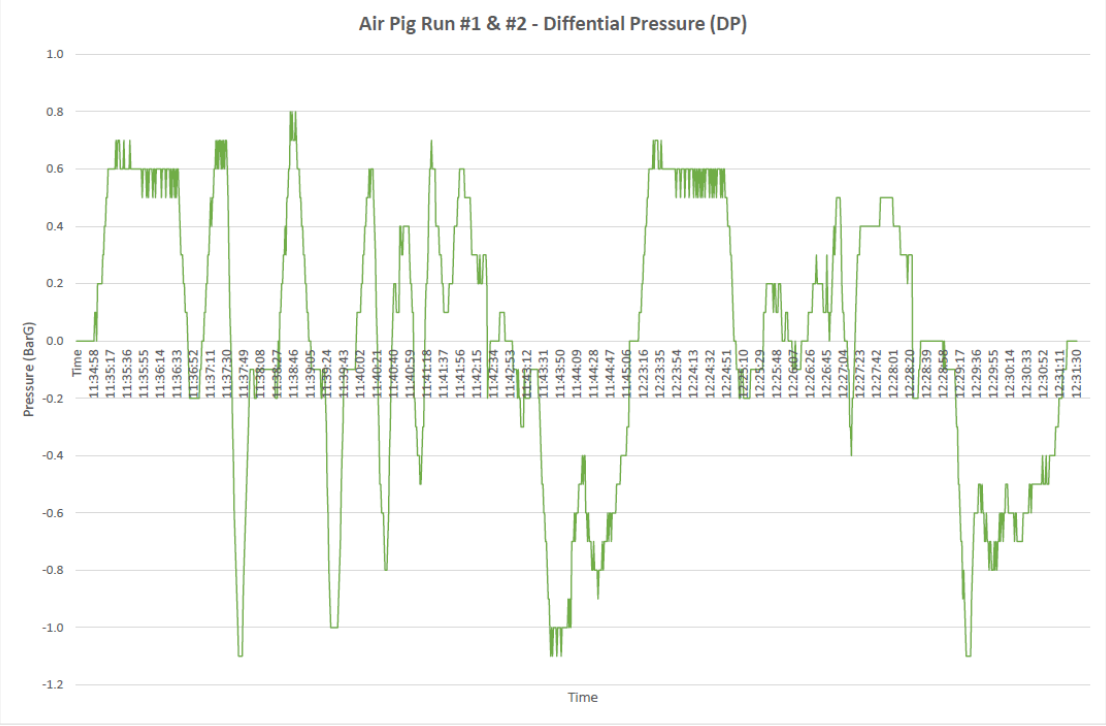
Figure 24: Modified Cassette Slots

Cassette modifications were completed, pigs were loaded into the cassette, which was then loaded into the launcher and the test repeated.

Test was carried out with a successful independent launch of pig#1 & pig #2.



Graph 2: Air Pig Run #1 & #2



Graph 3: Air Pig Run #1 & #2 (Differential Pressure)

Pig #1 was launched and once traversed through the test rig the test was stopped, test rig depressurised and pig #1 removed. Upon removal of pig #1, the test rig was sealed and the test repeated to launch pig #2, as per the procedure. Pig #2 was launched and once traversed through the test rig the test was stopped and the test rig depressurised and pig #2 removed. Depressurisation of the test rig simulated the offshore trap isolation and depressurisation activity between pig launches.

From the data shown in Graph 2 & 3 it can be seen that pig #1 launched with a DP 0.7Bar increasing to a max DP of 0.8Bar and then pig #2 launched independently with a DP of 0.7Bar.

This completed the testing.

CONCLUSION

From the testing results it can be concluded that the design and functionality of the Mushroom Seal and the cassette have been verified and confirmed that independent launches of the Pig #1 & Pig #2 can be achieved. The important actions to take away from the testing are as follows:

- Pig configuration to be confirmed – Final testing was conducted on a reconfigured Operational Pig with 2 off front solid cups.
- Design of the Cassette – The position of the slots in relation to the pig exiting the cassette and maintaining a seal needs to be engineered correctly for the operational cassettes.
- Pigs launch confirmed with a flow rate of ~750scfm through the 3” Injection line, flow needs to be introduced via the 8” Kicker Line to maintain pig movement through the pipeline.

ACKNOWLEDGEMENTS

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