

DEVELOPMENT OF THE PATHFINDER FOAM CALIPER PIG

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Background

The Pathfinder Foam Caliper Tool is a pipeline inspection device with a high level of mechanical compliance, which is capable of negotiating severe restrictions in a pipeline with minimal risk of blockage or damage. At the time of its development, the Pathfinder was a new concept, combining the flexibility of a foam cleaning pig with the capability of a full specification geometry measurement tool. The main use of Pathfinder is for the first stage assessment of operational pipelines prior to the use of metal-bodied pigs and the implementation of a pipeline pigging strategy including:

- New pipelines which have not previously been pigged
- Operational pipelines which have not previously been pigged
- Operational pipelines where production pigs are being received with unexplained damage
- Operational pipelines which have suffered damage due to external interference or 3rd party damage but are inaccessible for external inspection
- Operational pipelines with unknown levels and distributions of wax and/or scale deposits.

Information from the tool is used to locate and measure variations in internal diameter and identify any other geometric anomalies in the line, allowing informed decisions to be made on the appropriate types and configurations of pigs to be deployed to clean or gauge the line.

Development of the Pathfinder started in 2009 and in 2013 PIL presented a paper to the PPSA on the development process, from the initial concept through to the production of operational tools. At that time, PIL had a limited range of tools for pipe sizes from 6" to 12" with a maximum operating pressure of 20bar. We had carried out only six operational projects but already the tool was showing great promise. The very first line that we were asked to run (a 12" refined product terminal to tank farm line) had proven to be impossible to pig using hard bodied pigs due to the presence of deteriorating internal anodes that were detaching from the pipe wall causing the pigs to stick in the line.



Cleaning Pig Stuck In Bend



Pathfinder After Run

On the first attempt, a Pathfinder was successfully run through the line and despite significant damage to the front of the pig, the rear end containing the measurement system remained intact and good quality caliper data was obtained over the full length of the line. Using the bend detection system on the pig and correlating with strip maps provided by the client a total of 144 internal anode features were positively identified and locations pinpointed.

From these early beginnings we have seen year on year growth in Pathfinder business and to date Pathfinders have completed over 80 pipeline inspections. Development of the product has continued, improving the performance of the tool and allowing a greater range of applications to be undertaken.

Development

TECHNICAL DEVELOPMENTS

The essence of the Pathfinder design was intended to provide mechanical simplicity to ensure high levels of operational reliability and flexibility to minimise the risk of the pig getting stuck in difficult to pig or challenging pipelines. As development has proceeded these principles have been adhered to and in some cases exceeded. The principal areas of development have been:

- **Range of tools increased to cover pipe sizes 4" to 26".**
The extension of the size range up to 26" has been achieved using the same design principles for the measurement system but it has required the design of two additional sizes of datapack, one covering the range 14" TO 18" and the other 20" TO 26".
- **Maximum operating pressure increased from 20bar to 400bar**
Initial operating pressure capability was limited to 20bar by the use of plastic housings for the datapacks. Higher pressure requirements for operational pipelines demanded the use of stainless steel housings which have allowed the extension of the pressure range up to 400bar, primarily for use in deep water subsea pipelines
- **Maximum operating temperature increased from 40C to 70C**
Increased use of Pathfinder tools in oil pipelines demanded higher temperature capability. Incremental improvements have pushed the temperature capability up to 70C. It is unlikely that higher temperatures will be achieved in the foreseeable future
- **ATEX certification achieved for sizes 4" to 18"**
ATEX certification is rarely requested in most regions but is regarded as essential for North Sea operations.
- **Improved bend identification and Out-Of-Straightness measurement**
The addition of a gyro package to the system has provided full bend measurement capability including out of straightness over a distance of about 20m to 50m.
- **Bypass jetting version for lines with heavy deposits**
Increased demand for Pathfinder assessment of pipelines containing heavy levels of deposits has led to the development of a bypass jetting option to minimize the risk of a stuck pig. This option is available for all sizes from 8" upwards.
- **Bi-di version for single ended launch & receive**
A bi-di version of the Pathfinder was developed for a job where it was required to pump the pig through the topsides and into the riser and then reverse it out again using product flow. This worked well and opens up the opportunity for use in single ended lines.
- **Improved bore negotiation capabilities**
Development of a foam bodied tool (the Ranger) designed to increase minimum bore passing capability in 8" and 6" nominal sizes.

OPERATIONAL/SERVICE DEVELOPMENT

- **Continued development to simplify operation** of the tool allows most clients to use the tool without the need for a caliper technician to attend site – this provides significant cost savings for the client and also avoids the need to allocate beds on offshore platforms where availability is often limited.
- **Fast response remote data analysis** – all analysis is carried out at the PIL UK facility – data transferred by internet using file sharing software – first pass analysis to identify any significant restrictions and confirm acceptability of data - Preliminary report issued within 24hrs of data recovery. Full analysis and final report issued within 7 days.
- **Ultra-fast response remote data analysis** – A data analyst can be provided on 24hr/7day standby allowing first pass analysis to identify any significant restrictions and Preliminary report issued within 6 to 12 hours of receipt of data.

APPLICATIONS

PRE-ILI ASSESSMENT

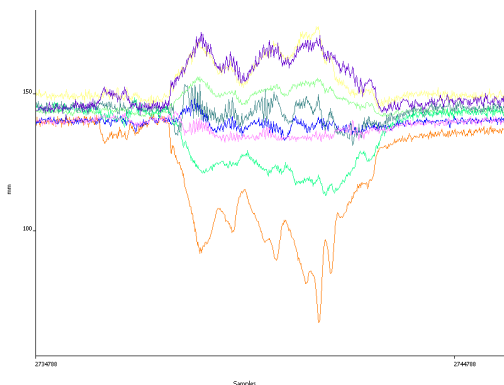
By far the most common application for the Pathfinder is in support of cleaning and gauging operations prior to running ILI tools. Typically Pathfinder tools are run prior to running hard bodied cleaning or gauging pigs which have a much greater risk of becoming stuck in a line. The Pathfinder has the capability of identifying and measuring:

- bore restrictions caused by third party damage
- restrictions due to deposits such as wax or sand
- thick wall sections of pipeline or thick wall bends which may not be recorded in pipeline construction records
- tight radius bends (in liquid pipelines only)
- partially closed/misaligned valves

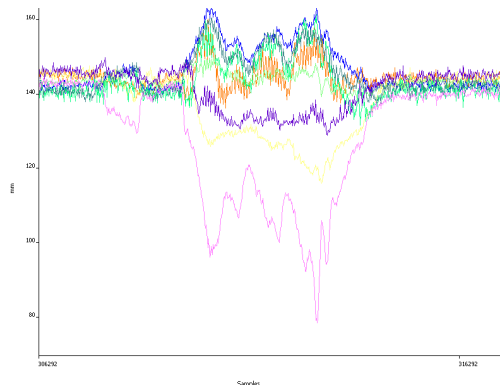
By providing a full geometry check on the pipe bore, the pipeline operator can proceed in confidence with cleaning and gauging operations. In the event that restrictions are present the operator can make a decision whether to intervene to remove the restriction or select pig designs which can accommodate the bore reduction.

12" Crude Oil Pipeline Offshore Sicily

A bore proving run by the Pathfinder on a Subsea pipeline offshore Sicily, prior to running an MFL tool identified an unexpected and severe restriction in the line. This occurred on a 12" crude oil pipeline offshore Sicily. The pipeline was a relatively short run of 3km from an offshore platform to an onshore terminal. The Pathfinder run was completed uneventfully and the Pathfinder was received in good condition and undamaged. However, when the data was downloaded, a large anomaly was identified in the data about 12 minutes into the run.



Run 1 Data

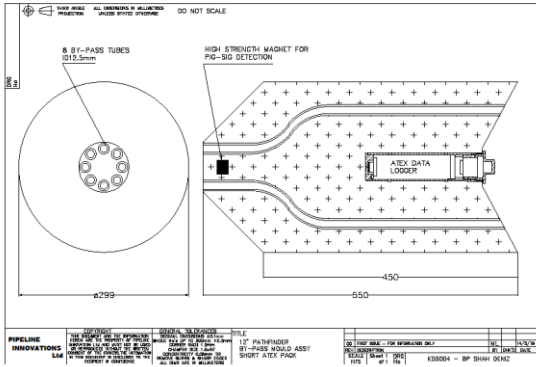


Run 2 Data

In order to confirm the findings two more Pathfinder runs were carried out with similar results obtained. The caliper data indicated that the anomaly extended over a pipe length of 13m to 15m with a maximum bore reduction of 86mm to 100mm. The pipe section containing the anomaly was excavated and it was confirmed that the damage matched the Pathfinder findings. The damaged section of pipe was cut out and replaced with new pipe spools allowing the cleaning and inspection of the line to be completed.

SUPPORT PIPELINE CLEANING PROGRAMS

A growing application area for Pathfinder is to assist with pipeline cleaning programs by providing information on the thickness and distribution of deposits along the pipeline at an early stage in the cleaning process before hard bodied cleaning pigs are introduced. If it is suspected that significant quantities of wax or sand may be present then the rate of removal of the deposits could be significant, even with foam pigs, leading to the risk of blockage of the line due to buildup of debris in front of the pig. This has led to the development of the Pathfinder high bypass Jetting pig which has an array of bypass tubes passing through the pig body to produce high velocity jets issuing from the nose of the pig creating turbulence and flushing debris away from the pig.

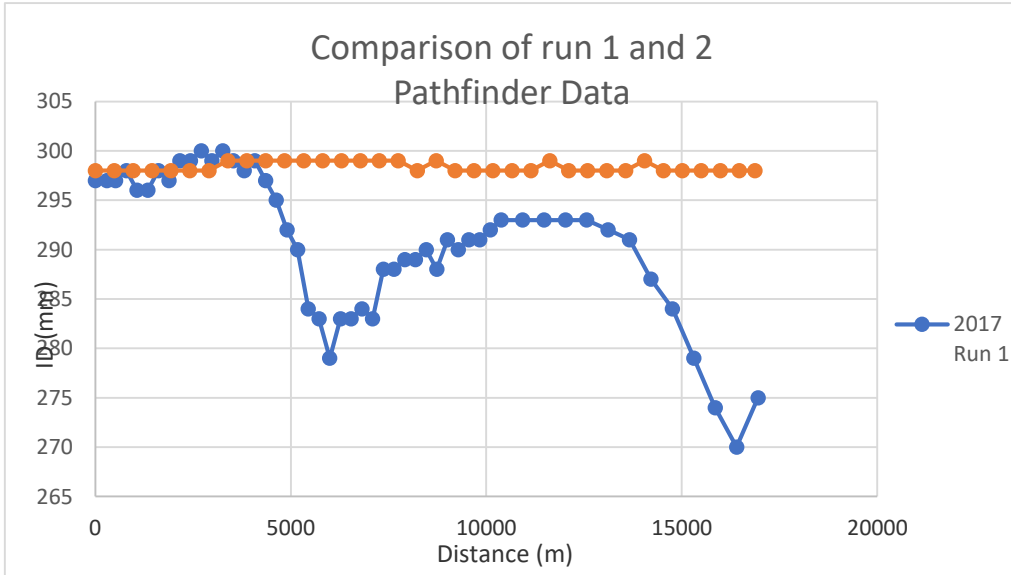


Jetting Pathfinder

As part of a cleaning program the Pathfinder can be used to assess the levels of debris and or extent of pipewall deposits at intervals during the cleaning program to provide an indication on the performance of the selected pigs or cleaning technology used to measure the progress of the cleaning program. Typically the Pathfinder can be used at the start to provide information on the amount of debris present at the beginning, during the program to monitor cleaning progress and at the end to confirm that the required level of internal cleanliness has been achieved.

12” x 17km Crude Oil Pipeline

An example of how Pathfinder can be used to assist with implementing a cleaning programme was a 12” x 17km crude oil pipeline offshore Italy which was being cleaned using Reinhart Hydrocleaning SA (RHC) specialist cleaning tools. The line was known to have fairly heavy wax deposits so a Pathfinder was passed through the line at the start of the programme to get an estimate of the thickness and distribution prior to introduction of the hard bodied hydrocleaning tools.



A mean bore plot of the pipe bore showed that the wax thickness peaked at a distance of about 15km from the launch creating a bore restriction of about 30mm. Using this information, RHC were able to optimise their tool configurations and cleaning program for this operation to maximise cleaning performance over a reduced number of runs.



Wax During Cleaning



Significant quantities of wax were removed and the Pathfinder was re-run at the end of the programme confirming that the line was clean.

PRE-COM GAUGING OF NEW PIPELINES

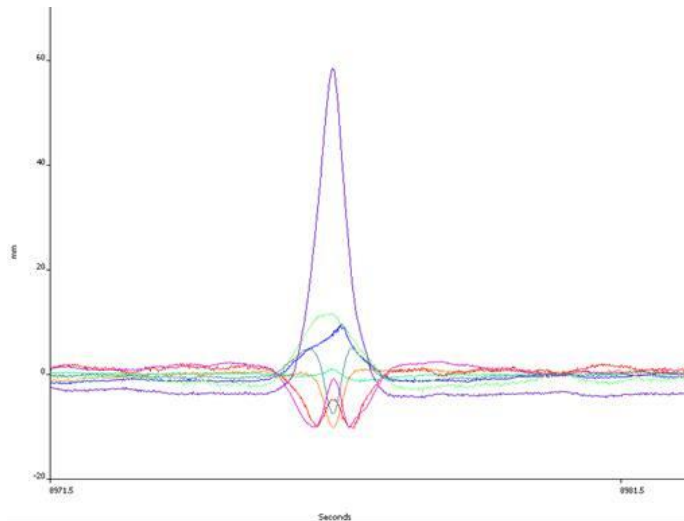
Pre-commissioning specifications for new pipelines commonly include a requirement to gauge the line to confirm that the line is clean and free from defects. Increasingly pipeline operators also require a baseline geometry survey as a reference for future ILI piping programmes. This is an area that PIL specialises in particularly for deep water subsea pipelines where operating pressures during inspection may be up to 300bar. On occasions PIL have been asked to supply Pathfinder to gauge/caliper a pipeline during pre-commissioning operations. Projects have been carried out in the North Sea, Offshore Egypt, in the Gulf of Mexico and offshore Trinidad. In the event of pipeline damage during the construction phase the risk of Pathfinder becoming stuck is considerably less (depending on the extent of pipeline damage) when compared to a metal bodied gauge pig. It will also provide accurate information on the location and extent of any such damage eliminating the additional cost and extended duration of running a caliper tool after a damaged gauge pig has been received.

14"/12" Offshore Pipeline

One interesting example is a dual diameter 14"/12" offshore pipeline where the dual diameter nature of the line did not allow gauging to be carried out. When the Pathfinder run was carried out the pig came out in good condition but the data revealed a large anomaly about 1.8km into the run.



Pathfinder After Run



Pathfinder Caliper Response

The response of the caliper sensors in the anomaly suggested an outward bulge in the pipe at the 1 o'clock position with a maximum outward displacement from the normal pipe profile of 60 mm. The anomaly also appears to have ovality components in the 3 to 9 o'clock position with a maximum bore reduction of 20mm. At the 3 o'clock and 9 o'clock positions, smaller responses were observed either side of the central bulge response. The axial length of the anomaly was approximately 0.8m. In addition, the gyro sensors, which measure changes in the heading angle of the pig, show a change in angle across the anomaly of approximately 6 degrees for run 1 and 8 degrees for run 2.

The pipeline constructor was finding it difficult to believe that there could be a defect in the line as a full ROV video survey of the line had been carried out after the pipeline had been laid and nothing had shown up. A second Pathfinder run was therefore carried out and the result obtained confirmed the findings of the first run.

An outward bulge of this magnitude is something that had not either been tested for or previously experienced by the Pathfinder in operational pipelines but our interpretation was that it was a complex type of buckle with an outward bulge on the top of the pipe and indentations on both sides of the pipe. After receiving our report the constructor carried out a more detailed ROV video survey at the location indicated by the Pathfinder.



Location Of Buckle

The video survey located the anomaly at the positions predicted by the Pathfinder. The outward bulge on the top of the pipe was not easily visible due to the viewing angle but the indentations at the 3 o'clock position were clearly visible.

UNKNOWN RESTRICTIONS CAUSING PIG DAMAGE

One of the more challenging applications for the Pathfinder is on pipelines where proving or operational pigs have been badly damaged or even become stuck and the cause is unknown. There have been a number of occasions where we have been presented with evidence of significant damage to pigs and asked whether Pathfinder can be used to locate and identify the source of the problem.

20" x 1km New Construction Gas Pipeline, UK

A new 20" pipeline in a UK gas storage facility was being cleaned and gauged as part of the pre-commissioning operations. Cleaning pigs were being pumped through on air and all pigs were being severely damaged.



Damaged Cleaning Pigs



Pathfinder Being Loaded

A Pathfinder run was successfully carried out without damage to the pig. Analysis of the data revealed a number of thick wall bends in the line which were causing pigs to stall and then overspeed on exit of the bend. The damage to the Bi-Di pigs was being caused by the pigs crashing at high speed into the next downstream bend. Whilst the Pathfinder data showed that the pig was suffering the same high speed excursions, the foam pig body was acting as a shock absorber, protecting the pig and the datapack from damage.

16" x 40km New Construction Offshore Malaysia

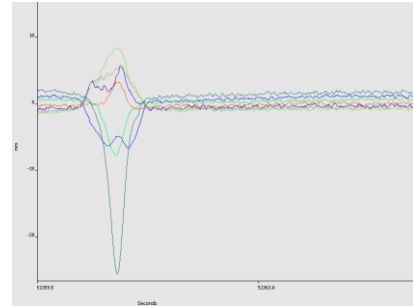
Cleaning and gauging pigs running as part of the pre-commissioning operations were being received in a badly damaged condition. A Pathfinder run was carried out to locate and identify the cause of the blockage.



Cleaning Pig Damage



Pathfinder After Run



Pathfinder Dent Response

The run was completed with no damage to the pig. Data analysis showed a significant dent approximately 33km from launch. By matching the girth weld count from the caliper data with the pipe tally in the as-laid pipe book, it was possible to identify the exact GPS coordinate location of the dent. Using this information the pipe was excavated and the damage pipe spool located.

10" x 22km Crude Oil Line China

The pipeline operator had been carrying out a pigging campaign to clean the line using a variety of foam pig configurations. A total of 17 foam pigs had been run through the line and all had emerged badly damaged. As a result the operator had been unable to progress to the next stage of the cleaning program, using hard bodied pigs, for fear of the pigs getting stuck in the line.



Foam Cleaning Pigs



Because of the high risks of running an intelligent pig in the line , PIL requested that a run be carried out using a dummy Pathfinder to determine whether it was feasible to run the full Pathfinder tool. The dummy Pathfinder is a pig made from the same material and to the same dimensions as the Pathfinder but without the datapack or measurement system. The dummy came out badly damaged but the rear of the pig was intact indicating that there was a good chance that the datapack and measurement system would survive. A decision was taken therefore to run the Pathfinder.



Dummy Pathfinder



Pathfinder



Hot Taps

The Pathfinder completed the run in the expected time but when the pig emerged it was also badly damaged, with large pieces of the foam body missing, even towards the rear of the pig. However, the datapack and measurement system had survived the run and a full set of data covering the full run length was downloaded.

A total of fifty anomalies greater than the reporting criteria were identified, 15 of these showing bore reductions greater than 20% of nominal bore. Follow up excavations have been carried out at three locations to date, two of these revealing hot taps.

10"/8" Crude Oil Line – UK North Sea

The pipeline operator reported that a Bi-Di pig had become temporarily stuck in a 10" x 8" pipeline. The most likely location for the pig sticking was thought to be a tight 8" bend in the 10" topsides on the receive platform. The pipeline operator also had concerns over wax in the line and were routinely running 8" foam pigs with bypass to control wax build-up.

The primary objective of Pathfinder geometric survey was to identify any potentially out of specification pipework , bends or any other features that could present pigging issues along the pipeline length. A further requirement of the survey was to provide information on the thickness and distribution of wax deposits in the line to assist with the planning of a cleaning programme prior to running an ILI tool.

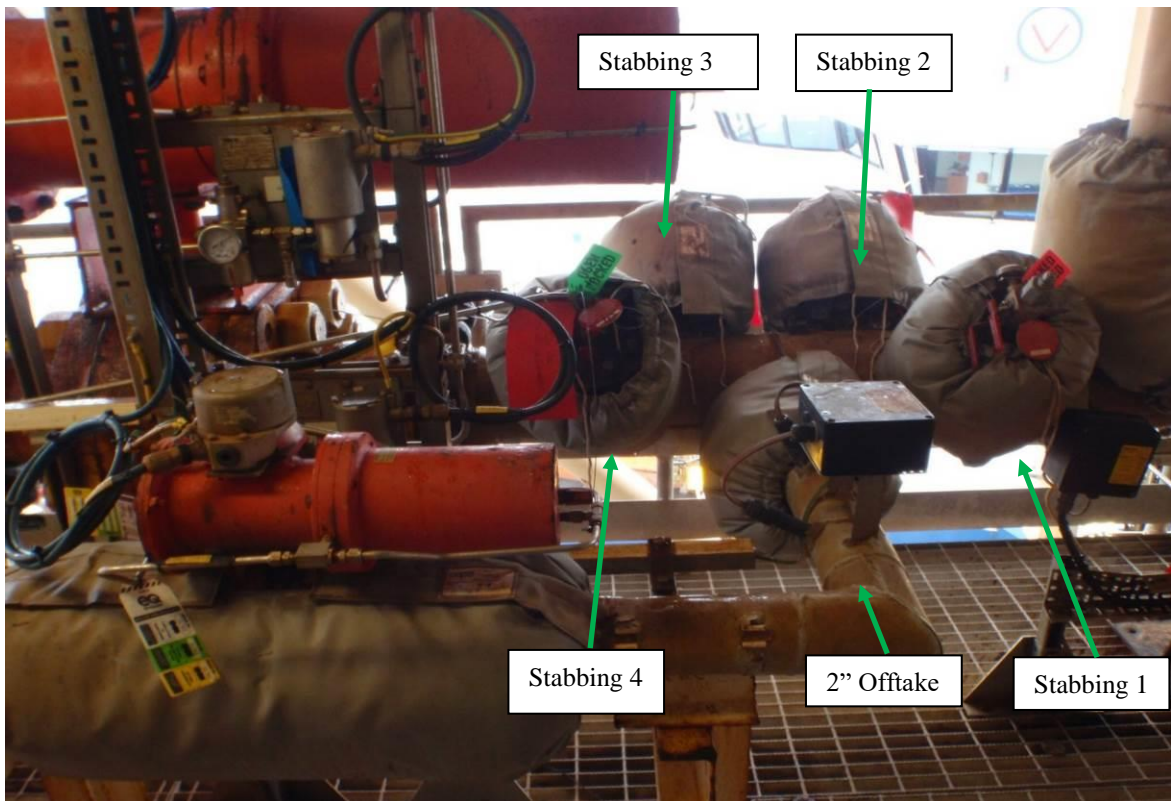
In order to minimise the risk of the pig sticking, the Pathfinder was designed to-replicate the existing operational foam cleaning pigs with same OD, same bypass and same foam density. When the Pathfinder run was carried out the pig passed through the line OK but the nose of the tool was damaged and there were tear marks down the length of the body.



Pathfinder After Run

The Pathfinder data shows that the pig performed normally until entering the topside pipework on the receive platform when a very large anomaly occurred in the caliper data. The anomaly occurred on the caliper sensor running in the 10 o'clock position. The nature of the damage to the pig suggested that it was caused by a tube or probe protruding about 100mm into the bore of the pipe

By matching the Pathfinder data to known features in the line, it was possible to narrow down the location of the object protruding into the pipe to an area containing four 2" stabbings and a 2" offtake. This would indicate that the most likely candidates would be the fittings in stabbing 1 or stabbing 4 on the photo



Pathfinder Performance

RELIABILITY

Considering the relatively high-risk nature of many of the Pathfinder applications, the operational reliability has been astonishing with a better than 95% first run success rate. A major factor in achieving this level of reliability is the mechanical simplicity in the design of the tool and the novel caliper measurement system which uses no external cables, wires or sensors. The data acquisition and measurement system is contained within a centrally located stainless steel pressure vessel at the rear of the pig providing maximum protection even when the pig body has taken heavy damage.

SURVIVABILITY

Medium density polyurethane foam is a very tough but flexible material and it can survive severe mistreatment. Initially Pathfinder pigs were produced with PU coated nose sections to provide additional protection. However, it was found that the thin PU coating could be easily torn and flaps of PU material tended to snag on girth welds and other protrusions into the pipeline causing the nose to be distorted and sometimes to fold over on itself. As a result, we have moved away from PU coating the pig bodies and use bare pig bodies.

RANGE

In oil pipelines Pathfinders have run in excess of 200km without losing drive. In gas pipelines the longest run to date has been 60km. Pathfinder pig bodies are normally sized for a 5% compression in nominal pipe bores but this does vary depending on the application. Experience has shown that the foam body does wear, particularly as expected in dry gas pipelines but generally the OD of the pig wears down to the nominal pipe diameter and then, as the pigs are relatively lightweight, very little further wear occurs.

Summary

The Pathfinder had been specifically designed for initial pipeline proving in lines with no pigging history and or potential reductions in bore due to debris build up where an operator plans to initiate a pipeline pigging or ILI campaign.

It can be seen that since 2013 and with continued development the Pathfinder is establishing a growing track record as a low risk, cost effective and innovative technology solution for measuring pipeline geometry, internal pipe diameter, detecting and measuring dents, ovality, buckles wrinkles and the presence of debris and pipe wall deposits not just in pipeline commissioning and proving workscopes but also more commonly in supporting operational workscopes including cleaning, pre inspection cleaning and debris assessment as part of a pipeline operators production pigging strategy.