NIGEL MONEY, TECHNICAL DIRECTOR, PIPELINES2DATA LTD, UK, AND GARY SMITH, PRESIDENT, INLINE SERVICES INC., USA, PRESENT A NEW SPEED CONTROL PIG UP TO THE TASK.

CONTROLLING THE SPEED, SECURING THE PERFORMANCE

Figure 1. A 42 in. SCP project in an ultra high velocity pipeline.

Pipeline cleaning and dewatering is most effective when a cleaning pig is travelling at no more than 11 mph (5 m/s). Above this speed the pig's cleaning performance is adversely affected meaning the pipeline will no longer be cleaned effectively. There are also pig receipt issues when running pigs at high velocities. In most cases, pig speed is not an issue as product flow velocity does not exceed the optimum pig speed and a standard cleaning pig such as a bi-directional steel mandrel pig can be used.

However, there are an increasing number of gas pipelines which have 'ultra high velocity flow', in which the product can be flowing at speeds of up to 35 mph (15.6 m/s). These pipelines tend to be large diameter (36 - 42 in.) trunk pipelines covering large distances (Figure 1).

The usual procedure for pigging these high speed pipelines is to reduce pressure and flow to suitable levels to allow the cleaning pig to run close to the magic 11 mph (5 m/s) value. From an operator perspective this is a costly exercise as flow often has to be reduced for a number of days. This needs extensive planning and leads to lost revenue from reduced gas flow.

Speed control pigs have been used for some time to provide inline inspection (ILI) companies with a stable platform to tow inspection tools. However, there has been very little use of speed control for cleaning pipelines. Pipelines2Data Ltd, UK (P2D) and Inline Services, Inc. (Inline) have developed a Speed Control Pig (SCP) that is suitable for cleaning of these high velocity pipelines. This tool has now been run in a number of pipelines with great success.

By using a cleaning pig capable of speed control it is possible to very effectively and safely clean a high velocity pipeline with very little operational disruption, negligible change in gas flow and minimal loss of revenue.

Theory of operation

It has long been understood that a pig's speed can be controlled by introducing bypass through the pig body. Usually pig speed reduction is accomplished by introducing a fixed amount of bypass through the body of the pig which will then have a 'fixed' effect upon speed reduction.

The SCP operates by allowing variable bypass through the body of the pig. The SCP includes all the sensors and technology that P2D has successfully developed for use in their Pipeline Environment Tool (PET), to this the company has added a control system to adjust the bypass, controlling the speed of the pig, Figure 2 shows a system block diagram.

The PET consists of sensors that are used to measure and record pipeline pressure and temperature profiles. A differential pressure (DP) sensor is used to measure DP across the pig enabling potential wall thickness changes and areas of debris build-up such as wax, scale and sand, to be identified. A three axis (XYZ) accelerometer measures the pigs ride characteristics as it travels down the pipeline, i.e., roll, pitch and yaw, along with vibration.

Bypass is controlled by rotating one disc with three vanes, whose area is half of the disc area, against a fixed disc of similar shape, Figure 3 shows the vanes in the open and closed positions. In this way the bypass can be adjusted from 0 - 50% of the cross-sectional area.

Control method

The system is a basic closed loop control system with one feedback sensor, Figure 4. A quasi-fuzzy logic system uses a number of states to determine the vane action required. System set-up would then require a set speed and speed (dead) band that the tool was required to operate within. The control electronics will then endeavour to keep the pig within the speed band around the given speed. Having a dead band reduces power consumption as in this region the electronics do not try to control the speed, hence the motor is active for less time.

In addition to the electronics, an interface programme was developed to enable simple set-up of the tool and download of the data stored on it.

Field trials

As part of the development of the SCP, Inline entered into a development contract to clean a number of 32 in. and 42 in. trunk lines using the SCP. As part of this agreement, the SCP would be used to clean the same sections of pipeline a number of times on a yearly basis. This would allow the SCP to be developed using the same pipelines, proving very useful to assess tool improvement. Figure 5 shows the 42 in. SCP used in the initial runs of the tool.

Initial runs

The first runs of the newly developed SCP were carried out in the Autumn of 2010 in three sections of a 42 in. gas trunk pipeline running for over 200 miles in the south of the US. These sections ranged in volume from 300 million ft^3/d to 1.4 billion ft^3/d, which equated to gas velocity of between 6 and 24 mph. For these runs the tool was set to try and achieve a pig speed of between 6 and 8 mph. The tool successfully cleaned all the sections of pipeline but a number of areas for improvement were identified from these runs.

Improving on performance

Although the SCP was able to reduce the speed of the pig compared to the gas flow it was not able to reduce the velocity to the desired 6 - 8 mph when gas velocity was above 12 mph. Figure 6 shows gas speed compared to SCP speed for one of the sections run in 2010.

As can be seen from Figure 6 there is a reduction in pig speed compared to gas speed but once pig speed goes above 12 mph and the vanes are fully open the tool is no longer able to keep the pig speed below 8 mph. The main cause of this lack of ability to control the speed was a lack of bypass area, even when the vanes were fully open.

To try and accomplish this additional bypass capability a new, larger diameter, pig body was designed (Figure 7). This included some features designed to facilitate smooth gas flow through the body of the pig.

Case study

P2D and Inline have now undertaken 12 SCP runs in both 36 in. and 42 in. sections of trunk pipelines. In December 2011, the SCP ran in a number of pipelines, one section was a 42 in. 71.1 mile (114.4 km) gas pipeline running across Louisiana. Data from this run is highlighted in this article.

Launch of the SCP

The SCP utilises the clients' approved pigging procedures and requires no special equipment to launch it. In the runs carried out so far, a backhoe was used to lift the SCP, in its tray, into position and to insert it into the launcher.

The SCP uses pressure activation to turn on the electronics, this occurs after the unit has been loaded into the launcher and the pressurisation process has started. This is carried out for safety reasons. After pressure equalisation has been completed, the SCP can be launched in the standard fashion. Typically around 14 psi (1 bar) differential pressure is required to kick the SCP into the pipeline.

In this pipeline section the SCP was configured to try and control its speed to between 6 - 8 mph.

SCP speed and gas flow velocity

Figure 8 shows the tool performance in this section of the Louisiana pipeline. This graph details the SCP speed for the entire run plotted along with calculated gas flow velocity. Gas flow velocity calculations are based on information given by the client. Unfortunately, few pressure and flow details were available to plot for this section, therefore the graph essentially shows an average gas velocity for the entire run. It is known that the flow did not change drastically for the duration of the run; however, actual gas flow velocity will be higher in heavier wall thickness sections, of which there were many. The average SCP tool speed for the entire run is around 7.3 mph indicated with the black dashed line.

The average vane position for the whole run is 77% open, showing increased gas flow velocity could be accommodated.

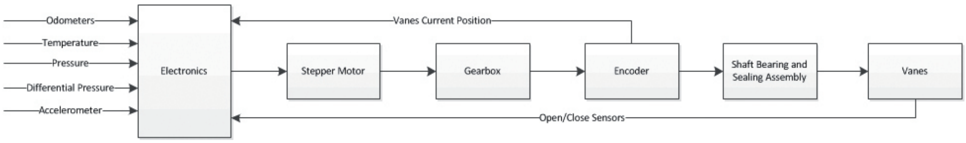

Figure 2. System block diagram.

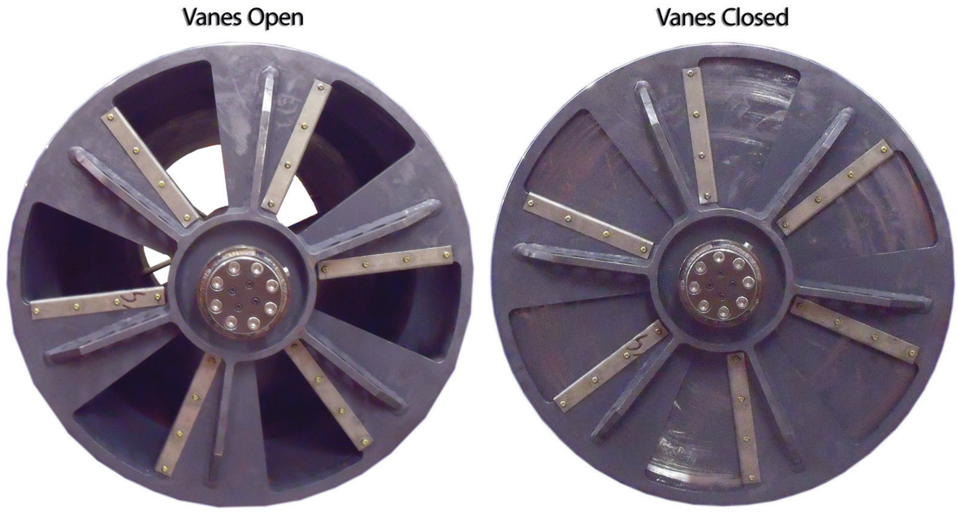

Figure 3. Vanes positions.

Tool travel

The graph in Figure 9 shows in more detail the conditions experienced by the SCP as it transited through the pipeline. The first, Figure 10, shows SCP speed, calculated flow velocity, vane position and distance travelled.

The graph in Figure 10 shows data for the full run length. It can be seen that the vane position is effectively adjusted to keep the pig speed to within the desired set band.

Figure 11 shows SCP speed, differential pressure, pipeline pressure and distance travelled.

It can be seen that the differential pressure required to drive the pig is approximately 2.2 psi (0.15 bar) for the whole run.

Receipt of the SCP

Receipt of the SCP, again, requires no special equipment and the receipt procedure is the same as with any other pig.

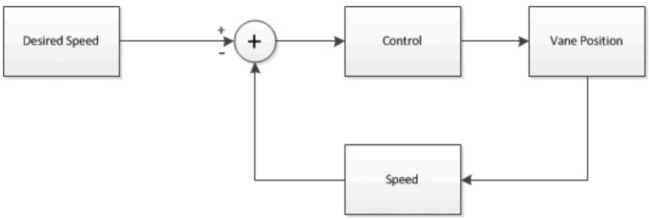

Figure 4. Closed loop control system.

Figure 5. Initial 42 in. SCP.

Performance of tool controlling speed

As can be seen from Figure 9, the SCP was very effective at reducing its transit velocity. For the whole run the average speed reduction compared to gas velocity was 15 mph and the average tool speed was 7.3 mph, well within the set speed of 6 - 8 mph and independent of gas flow velocity. It is very difficult to completely avoid speed excursions where the tool goes well outside its control parameters. This is always the case in gas pipelines and unfortunately there is very little that can be done to completely eliminate the problem. However, during the run there were minimal speed excursions and they were controlled quickly by the electronics.

By managing to control the pig speed, pipeline cleaning is much more effective. The chances of the cleaning pig hydroplaning over any water in the pipeline are also minimised and the best possible debris removable is sustained due to high velocity bypass acting as a forward jet, keeping particles in suspension. This combined with a minimal loss in revenue makes the SCP a very valuable tool.

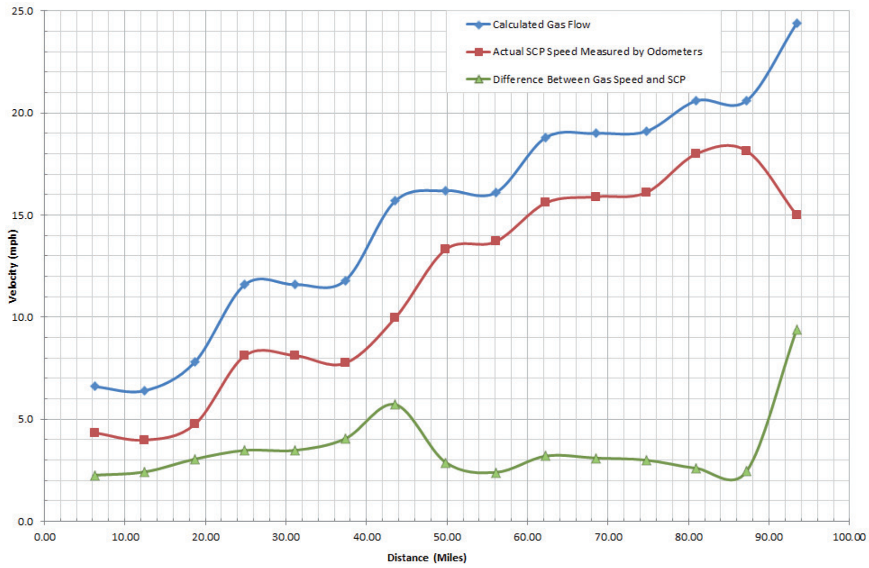

Figure 6. Gas and SCP speed.

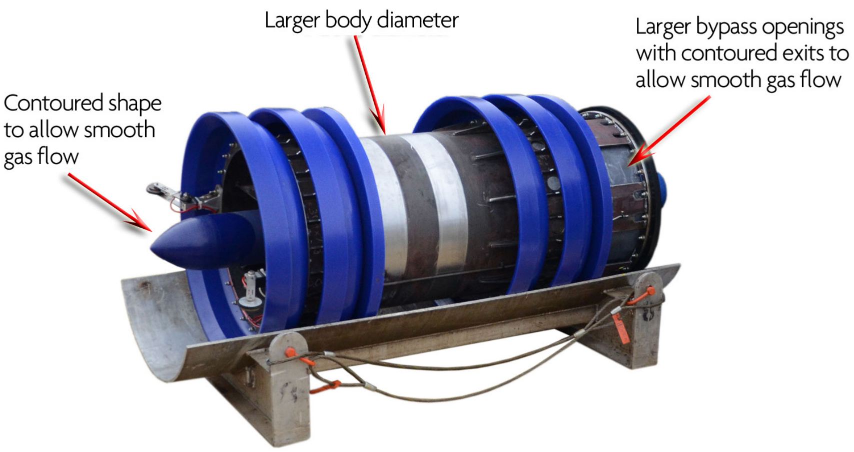

Figure 7. New 42 in. SCP.

Future developments

After every run the performance of the tool is evaluated and a constant programme of development is in place to continue to improve the effectiveness of the tool. The SCP has already been fitted with a six-axis IMU to give accurate pitch and roll information and this will eventually be improved to include mapping information. In this way it will be possible to identify any low points in the pipeline that are likely to collect liquids, useful additional information from an SCP run.

Black powder removal

Black powder can be found in both dry and wet gas pipelines. Typically made up from a combination of iron, sulphur iron oxides, corrosion inhibitors and solvents along with other contaminates such as liquid hydrocarbons, water and sand etc. In wet conditions it can form a sticky tar-like substance. In dry condition it forms a powder that can have a significant impact on gas flow. It can also be very abrasive and have a longer-term impact on the operation and performance of valves, flow measuring equipment and other process instrumentation, along with excessive wear on pig seals.

With high flow bypass through the SCP body, by design, the tool can be used for the removal and management of black powder in dry gas pipelines as part of the operators flow assurance strategy.

Figure 8. Launch of SCP.

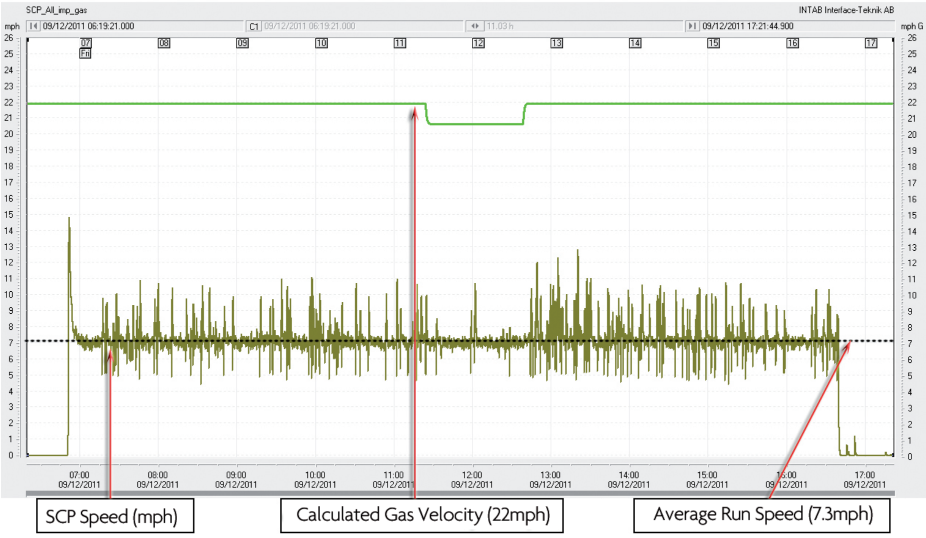

Figure 9. Gas velocity and SCP speed.

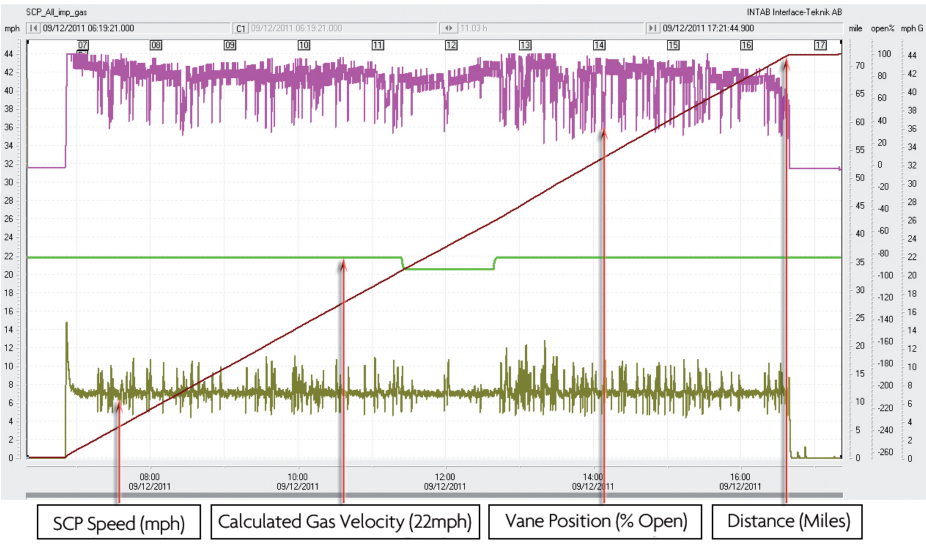

Figure 10. SCP speed, calculated gas flow velocity, vane position and distance.

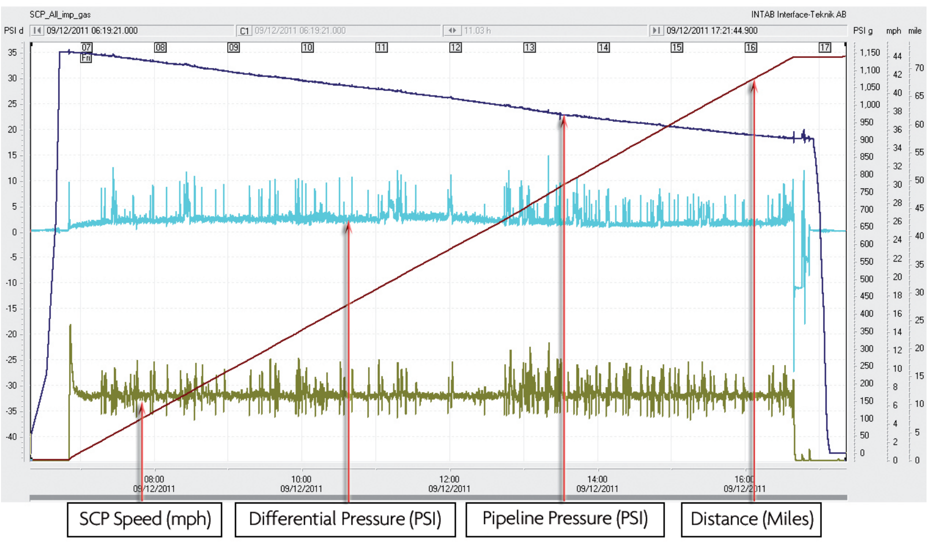

Figure 11. Pig speed, differential pressure, pipeline pressure and distance.

Polyurethane guide discs provide an effective scraping and bulldozing action ideal for pushing out loose debris. However, there is a risk that debris can build up in front of the pig and potentially block the line. Bypass through the SCP body creates turbulent flow in front of the pig, keeping the black powder in suspension mitigating the risk of pipeline blockage by preventing it from building up into a solid mass.

Other cleaning options

The SCP has substantial unused space on the body where other cleaning options can be fitted. It has now been proved as a standard cleaning pig and these other options can be explored as client requirements dictate. Already the SCP has been fitted with high power Neodymium magnets with great success at removing metallic debris and black powder. However, it would be possible to fit other cleaning options such as brushes, ploughs, pin wheels or scrapers.

Bypass provides a significant benefit with any cleaning application especially where there is a potential for debris build up. The SCP design is such that it can be easily configured to suit a wide range of applications.

- In standard configuration (four cups and two guides), the SCP can be used for the removal of loose debris such as black powder, dust, sand and soft pipewall deposits (wax).
- The addition of brushes increases cleaning performance further by improving the sweeping effect, brushing debris directly from the pipewall and also cleaning into corrosion pits. Brushes can be fixed or spring mounted.
- The addition of de-scaling pins or scraper blades can be considered for the removal of hard pipewall deposits such as scale and wax.
- The addition of high strength magnets will enable the SCP to clean and pick up ferrous debris such as pipeline cuttings after tie-in or hot tapping workscopes.
- 'Smart' pipeline gauging – used to confirm minimum bores and indicate

Figure 12. Receipt of SCP.

pipeline damage, gauge plates can be easily added. In the event of a gauge plate being damaged, background data already collected by the SCP, in particular ride profile and linear distance, will enable the operator to accurately pinpoint the location where the damage occurred.

Mounting of calliper and debris sensors

As there is significant unused space on the SCP body it is possible to add P2D's callipers and debris mapping sensors for use as part of an intelligent cleaning programme. An initial pipeline survey can be carried out as part of operational pigging to assess the volume of debris in a given pipeline. A tailored pigging programme could then be conducted and a final survey carried out to assess the effectiveness. This could all be achieved using the SCP, which would have a minimal effect on product flow and therefore cost.

P2D have developed and successfully launched a range of innovative, ATEX-certified technologies that add intelligence to pipeline cleaning.

Debris Mapping Tools (DMTs), Advanced Geometry Tools (AGTs) or Pipeline Profiling Tools (PPTs) can be used to measure, monitor and record pig performance providing a real-time view on the effectiveness of any mechanical cleaning strategy or campaign by confirming and qualifying the actual level of internal cleanliness attained. The same technologies can also be applied to chemical cleaning performance management.

The DMT can be fitted to the SCP. In addition to the standard SCP sensors, it can accommodate up to 48 debris measurement sensors, depending on the nominal pipeline diameter. The DMT sensors provide 360˚ coverage, are in direct contact with the pipewall and are used to accurately measure hard or soft pipewall deposits and or debris. The tool will identify the thickness, linear location, clock position and the volume of debris deposited along the length of the pipeline.

The AGT provides a detailed geometry (calliper) survey along the length of the pipeline. Similar to the DMT, an array of up to 48 calliper sensor arms, providing full 360˚ coverage, accurately measure the inside diameter of the pipeline providing details on orientation and measurement of dents, ovality and deformation.

The DMT and AGT technologies combined to form the PPT. Comparison of the data sets provides clear differentiation between pipeline anomalies or features and debris or pipe wall build-up. This provides the operator with a comprehensive and detailed pipeline profile survey.

Ability to tow other tools

The SCP also has the ability to tow other pigs either as part of a more advanced cleaning programme or for an inline inspection. No changes would need to be made to the control electronics to allow this to happen and the only requirement for the pig being towed would be that it has substantial bypass.

Conclusions

Periodic use of tools such as the PET, DMT and PPT, either as stand alone tools or combined with the SCP, will confirm that the level of cleanliness originally established is monitored and maintained as part of an operator's flow assurance strategy.

Intelligent cleaning removes the mystery, eliminates uncertainty and mitigates the risk of a failed inspection, or even worse, a blocked line as a result of debris build-up.

The SCP is ultimately a 'vehicle of opportunity': it can be specifically configured and tailored to suit the client's application and satisfies many requirements on one run. WP

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