DYNAMIC SPEED CONTROL IN HIGH VELOCITY PIPELINES

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Abstract - High velocity pipelines often require significant cut backs in production to achieve safe operating parameters for routine pig runs or ILI programs. Pipelines2Data, UK (P2D) and Inline Services (USA) introduces their latest development in intelligent speed control, designed to maintain acceptable pigging speeds for routine pigging and intelligent cleaning for flow assurance management with minimal impact on production.

This paper discusses the development of the dynamic speed control system, initial field trials, operational success and its application for maintenance pigging, intelligent cleaning, debris mapping, and black powder removal as part of an operator's pipeline integrity management strategy.

1. INTRODUCTION

Pipeline cleaning and dewatering is most effective when a cleaning pig is traveling at no more than 11 mph (5 m/s). Above this speed the pigs 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 BD6 steel mandrel pig, figure 1.1, can be used.

Figure 1.1: Various 42" BD6 Cleaning pigs

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 35mph (15.6 m/s). These pipelines tend to be large diameter (36"-42") trunk pipelines covering large distances, figure 1.2.

Figure 1.2: 42” SCP Project in an Ultra-high Velocity Pipeline

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. P2D and 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.

2. DEVELOPMENT OF A SPEED CONTROL CLEANING PIG

2.1 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 by-pass through the body of the pig. Using an electronic control system the by-pass can be adjusted to control the speed of the pig, figure 2.1 shows a system block diagram for the SCP. 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 2.2 shows the vanes in the open and closed positions. In this way the by-pass can be adjusted from 0-50% of the cross sectional area. The rotating disc is moved using a motor, gearbox and shaft sealing assembly.

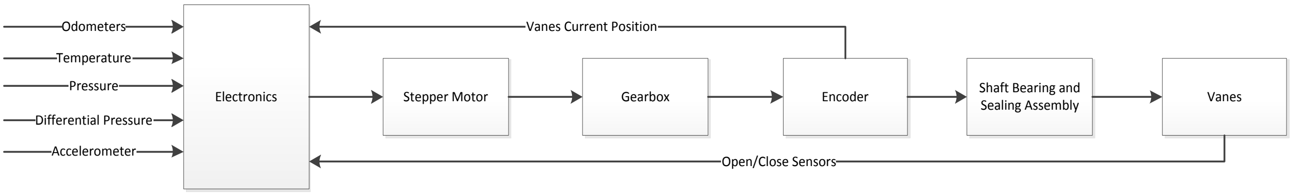

Figure 2.1: System Block Diagram

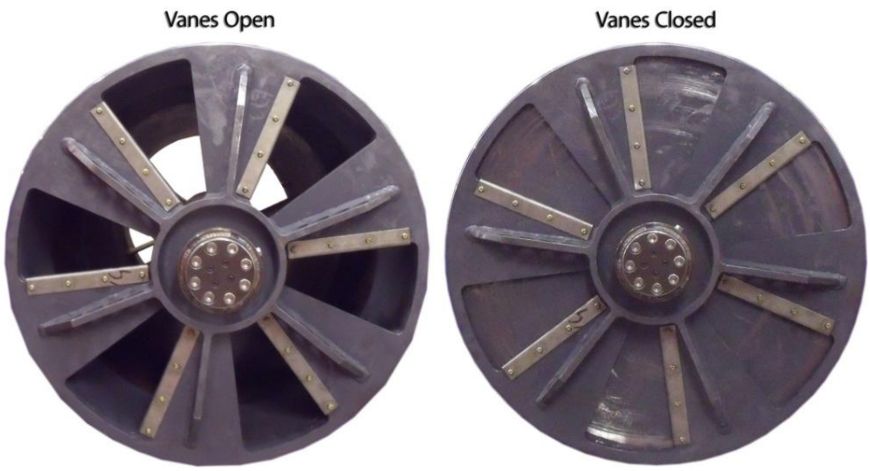

Figure 2.2: Vane Positions

2.2 Updating and Improving the System

The original speed control mechanism was built circa 1990. At an early stage is was decided to completely update the electronic control and logging system, taking advantage of the experience P2D already had gained with their Pipeline Environment Tool (PET) logger and Pipeline Profile Tool (PPT) and implementing newer technology.

The original system used a simple feedback mechanism to control vane position, very little logging capability was incorporated and there was no ability to log environmental conditions, such as pipeline pressure, impulse and tool rotation.

The electronics were completely redesigned with an FPGA processor at the heart of the logging and control. As the system is battery powered for the duration of any run, power consumption was a major concern during the design process.

To provide speed input to the system two or three odometer wheels are used. A fastest signal system is then used to choose the fastest signal from these odometers; this is done to avoid any wheel slippage issues. This is then used to calculate and log the distance travelled by the SCP and calculate speed. In addition to this pressure, differential pressure, temperature, linear and rotational (6-axis) acceleration sensor data is logged. The acceleration data can then be resolved into pitch and roll information.

In a system like this failure of the electronics is a major concern. To reduce the risk of electronic failure causing pipeline operational issues, critical parts of the electronics are duplicated. Should the main electronics fail a backup system can then take control and put the vanes into a fail-safe position, either fully closed or fully open. This will ensure either the pig transverses the pipeline safely or that flow is not interrupted.

2.3 Control method

The system is a basic closed loop control system with one feedback sensor, figure 2.3. Two methods of controlling the system were investigated.

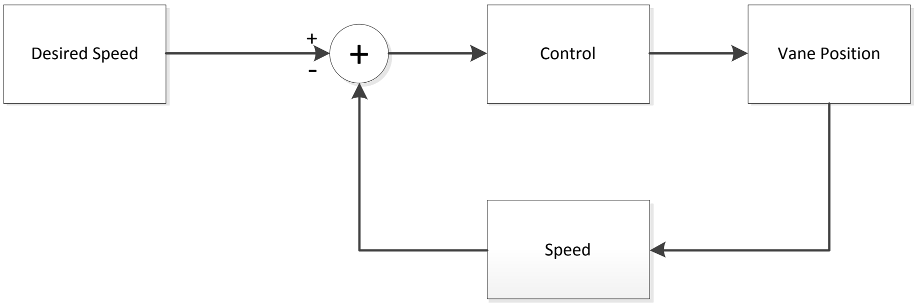

Figure 2.3: Closed loop control system

The first, 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 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.

The second, a P*roportional, Integral, Derivative (PID)* control system, would undoubtedly offer more precise speed control once it had been tuned correctly, but this can often take significant fine tuning and time. This control method results in the motor being active whenever the pig velocity is not equal to the desired speed. This would result in increased power consumption ultimately affecting the length of pipeline that could be run.

The first option was chosen as the most appropriate for the reasons given.

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. Figure 2.4 shows a screen grab of the configuration screen from the software.

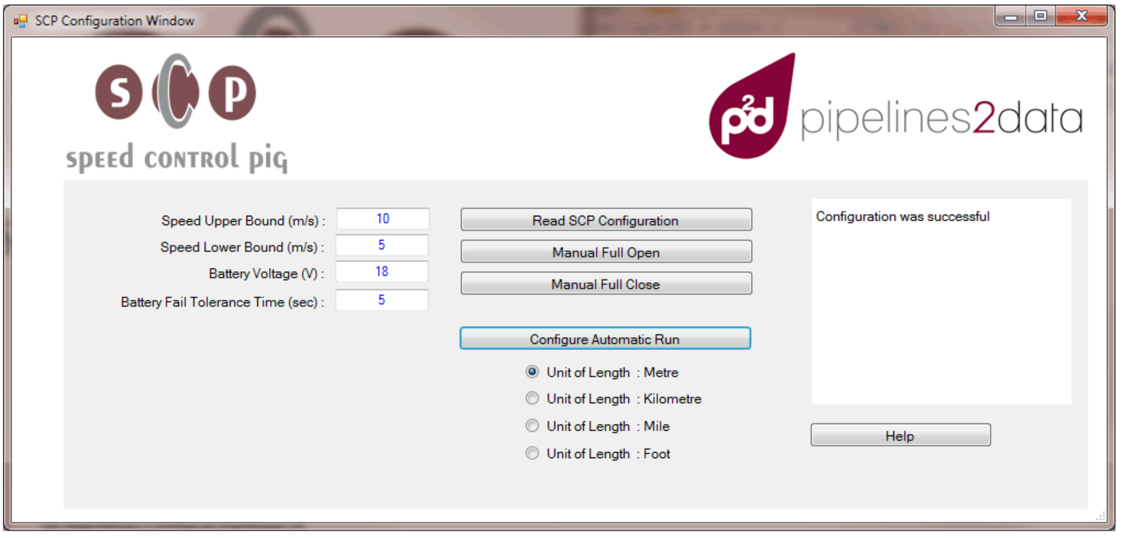

Figure 2.4: Configuration of the SCP in software

3. FIELD TRIALS

3.1 Introduction

As part of the development of the SCP, Inline entered into a development contract to clean a number of 36" and 42" trunk lines using the SCP. This 5 year contract would take the form of yearly cleaning programmes on each of the designated pipelines. This would allow the SCP to be developed using the same pipelines and meet regulatory requirements to clean the pipelines, whilst not effecting flow. Figure 3.1 shows the 42" SCP used in the initial runs of the tool.

Figure 3.1: Initial 42" Speed Control Pig

3.2 Initial Runs

The first runs of the newly developed SCP were carried out in the fall of 2010 in three sections of pipeline, a 42” gas trunk pipeline running for over 200 miles from Texas into Louisiana. These sections ranged in volume from 300 mcfpd (million cubic feet per day) to 1.4 bcfpd (billion cubic feet per day) which equated to gas velocity of between 6 and 24 mph. For these runs the tool was set to 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.

3.3 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 3.2 shows gas speed compared to SCP speed for one of the sections run in 2010.

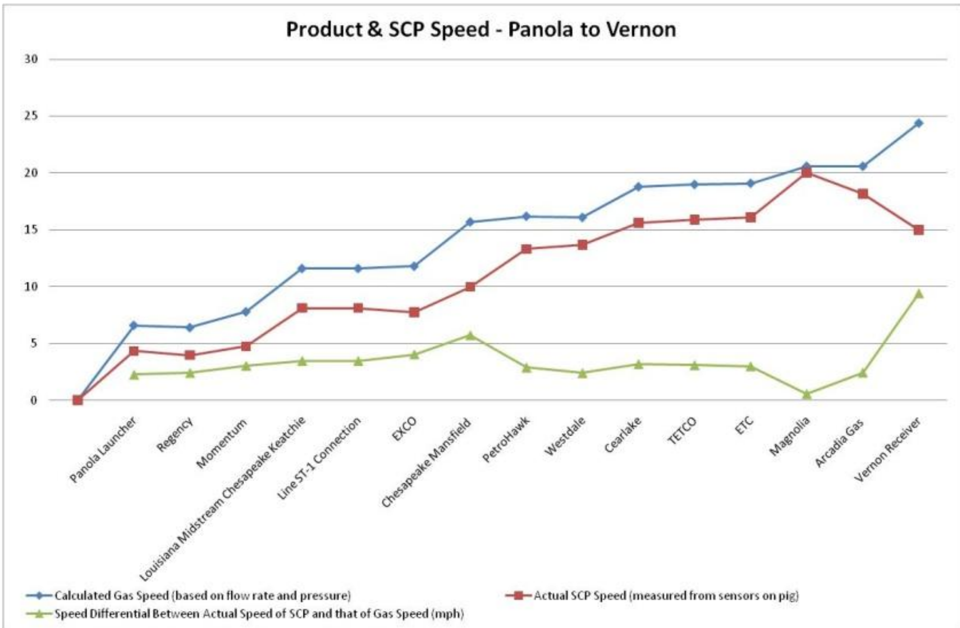

Figure 3.2: Gas and SCP speed

As can be seen from the above graph 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 8mph. 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 3.3. This included some features designed to facilitate smooth gas flow through the body of the pig.

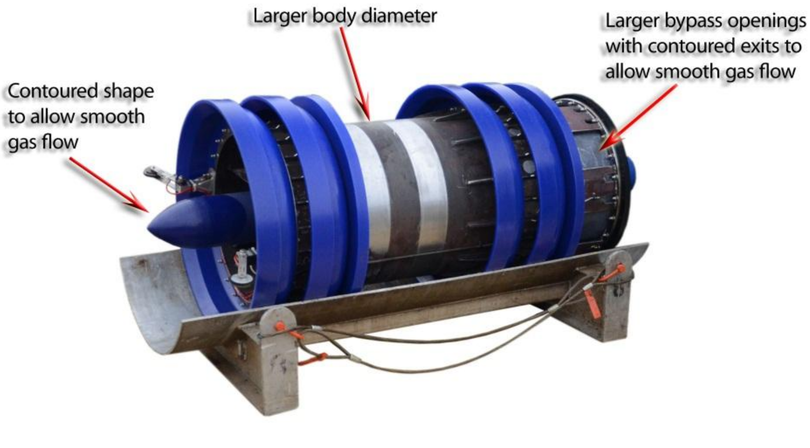

Figure 3.3: New 42” SCP

A control issue was also identified in these initial runs. This arose when the pig was slowing down either after the vanes had opened slightly or a change in terrain. In this circumstance the electronics did not react quickly enough and allowed the SCP to stop before the vanes started to close. To rectify this issue the control firmware was changed to speed up the reaction time.

3.4 Case Study

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

3.4.1 Launch of the Speed Control Pig

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

Figure 3.4: Launch

The SCP uses two pressure switches to turn on the electronics, this occurs after the unit has been loaded into the launcher and the pressurisation process has started. After pressure equalisation has been completed the SCP can be launched in the standard fashion. Typically about 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 miles per hour.

3.4.2 SCP Speed and Gas Flow Velocity

One of the runs was a 71.1 mile section of 42 inch pipeline. The figure below shows the tool performance in this section.

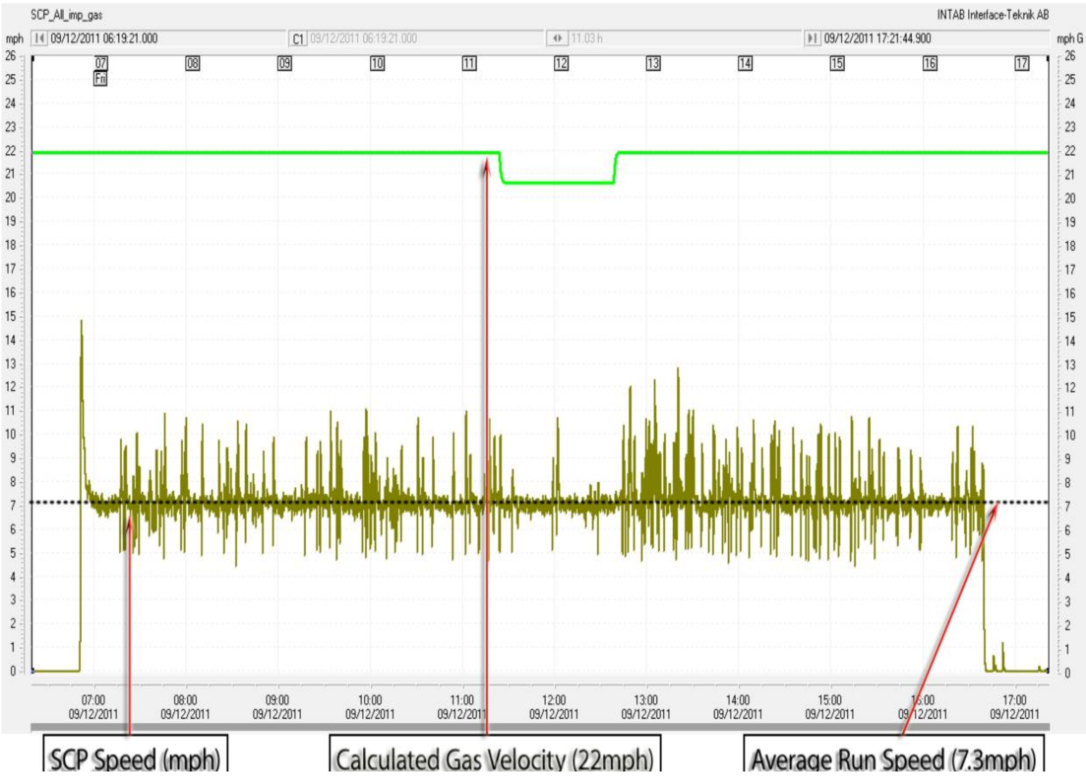

Figure 3.5: Gas Speed Velocity, SCP Speed

The above graph details the SCP (Speed Control pig) speed for the entire run (gold) plotted along with calculated gas flow velocity (green). 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. The conversion is based on a .427" (10.8 mm) wall thickness assumption, however, actual gas flow velocity will be higher in all 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.

3.4.3 Tool Travel

The graph below shows in more detail the conditions experienced by the SCP as it transited along the section of pipeline. The first, figure 3.6, shows SCP speed (gold), calculated flow velocity (green), vane position (pink) and distance travelled (red).

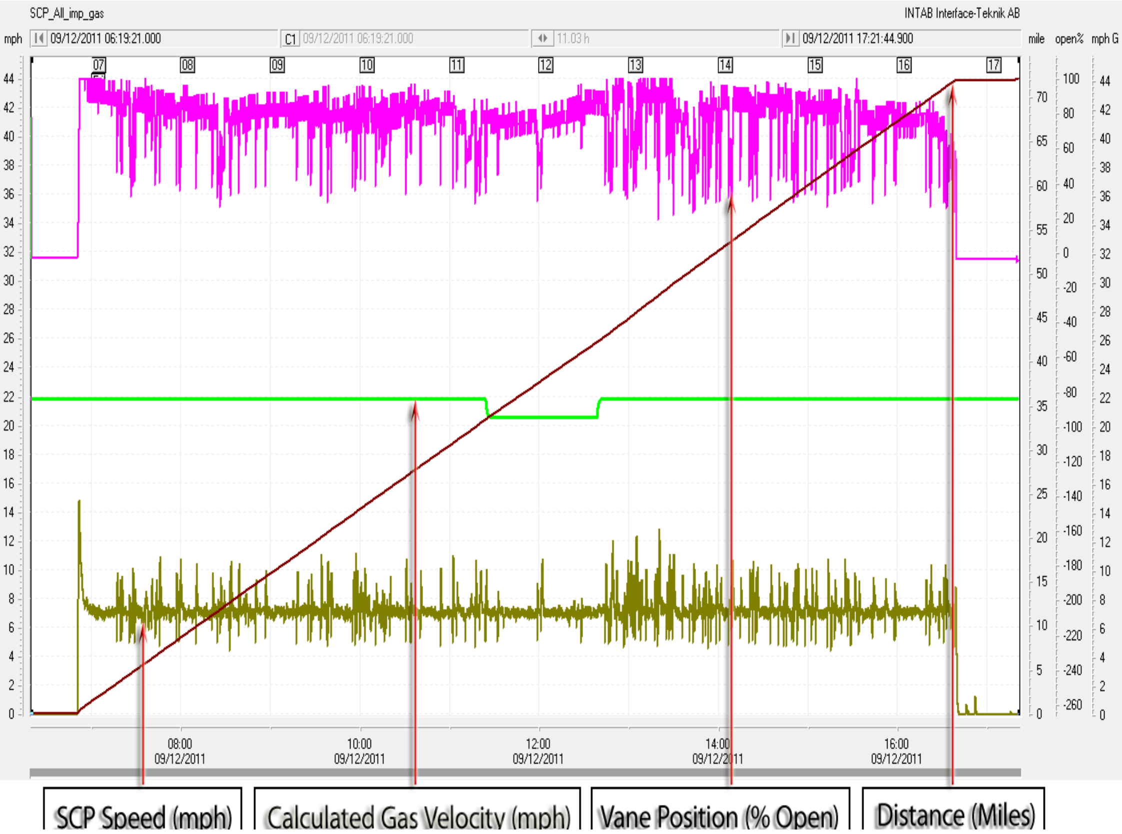

Figure 3.6: SCP Speed, Calculated gas flow velocity, Vane position and Distance

The above graph 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.

3.4.4 SCP receipt

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

Figure 3.8: Receipt of the SCP

3.5 Performance of Tool Controlling Speed

As can be seen from figure 3.5 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. 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 possible due to high velocity by-pass acting as a forward jet to keep particles in suspension. This combined with a minimal loss in revenue makes the SCP a very valuable tool

4. FUTURE FOR TOOL

4.1 Future Developments

After every run the performance of the tool is evaluated and a continuous programme of development is in place to continue to improve the performance of the tool. The SCP has already been fitted with a 6-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.

4.2 Black Powder Removal

Black powder can be found in both dry and wet gas pipelines along with other contaminates like liquid hydrocarbons, water and sand etc. Typically made up from a combination of iron, sulphur iron oxides, corrosion inhibitors and solvents, in wet conditions it can form a sticky tar like substance. In dry condition it forms a powder which can have a significant impact on gas flow. It can also be 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.

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.

Black powder removal can be further enhanced by the addition of jetting nozzles and heavy duty pencil brushes and high strength magnets.

4.3 Other Cleaning Options

The SCP has substantial unused space on the body where other cleaning options can be fitted. The SCP 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. However, it would 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 (4 cups and 2 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.

- ‘Smart’ Pipeline gauging. Used to confirm minimum bores and indicate 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.

- Other more advanced innovative technologies such as debris mapping and pipeline profiling options could also be added.

4.4 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 done 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 (DMT’s), Advanced Geometry Tools (AGT’s) or Pipeline Profiling Tools (PPT’s) 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 **Debris Mapping Tool**, 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 DMT will identify the thickness, linear location, clock position and the volume of debris deposited along the length of the pipeline.

The **Advanced Geometry Tool**, AGT, provides a detailed geometry (calliper) survey along the length of the pipeline. Like 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 **Pipeline Profile Tool,** 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.

4.5 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.

4.6 Conclusions

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.

References

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