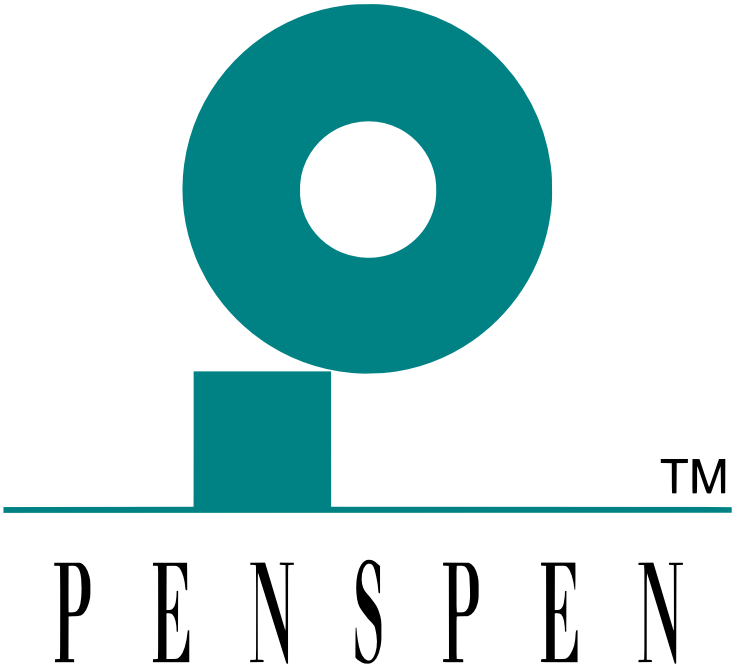

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OPERATIONAL ASPECTS OF PIGGING SLURRY PIPELINES

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Abstract

Transportation of mineral ores and other raw materials by mixing into slurry and pumping via pipelines is an economic and well proven method to move large quantities of materials from their source location, such as a mine, to a processing or storage facility. Pigs are used as part of maintenance and integrity activities to clean and inspect pipelines. Slurry pipelines can present particular challenges for pigging such as potential high wear to pig components or build up of solids that could cause restrictions or blockages. Pigs should be robust and designed to deal with a slurry environment. Special procedures and techniques may be required to overcome and clear the pipeline so that pigs can be launched or received without risk of becoming stuck. Slurry pipelines may have multiple Tees, Y pieces or other fittings through which pigs must transit safely. The potential consequences of a stuck pig in a slurry pipeline must be fully assessed and understood. Response plans must be in place and equipment available.

This paper discusses the operational aspects to consider when executing a pigging campaign in a slurry pipeline, what special procedures may be required and how pipeline design issues that may affect pigging are overcome in pig design.

1. Introduction

The US Oil Industry pioneered the use of pigs in the 1930's where they were first used to prove and clean pipelines. Many different types of cleaning pigs have been developed for use in a wide range of pipeline environments and products. New materials and more sophisticated designs continue to become available.
A major step change in technology came in the mid 1960's with the development of corrosion inspection pigs and geometry inspection pigs. Technology has continued to advance and there are now inspection pigs available that can detect cracks and map a pipelines precise location.

Pigging plays an essential role in the maintenance of pipelines. Historically the Oil & Gas industry has been the main driver and sponsor of pig developments. A wealth of knowledge and experience therefore exists relating to pigging in hydrocarbon and product pipelines some of the pigging experiences learnt from the Oil & Gas Industry can be relevant to Slurry pipelines. The Slurry referred to in this paper is pulverized mineral solids mixed with water.
There are basic pigging principles and design aspects that are universal for all pipelines, however there are specific operational challenges to consider when pigging Slurry pipelines such as potential accumulations of particulate solids or possible build up of surface scale. This may result in excessive wear to the pig seals and components that normally contact the pipe or if not properly managed the build up could restrict or block a pipe.

In order to execute a successful pigging program a Slurry pipeline operator must work closely with the pig supplier or service companies to ensure risks are mitigated. The pipeline configuration must be assessed for pigging. If there are pipeline design issues it may be possible to overcome these with adaptations or special design of pigs, if this is not practical or feasible the pipeline may need to be modified. The pigs must also be robust enough to cope with the rigors of a slurry environment and procedures followed to ensure safe launch and receive of pigs and that pigs have an unimpeded transit through the pipeline.

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2. Pigging in Pipelines

Pigs are used as part of maintenance and integrity activities to clean and inspect pipelines. Their use can be traced back over many years and there are now a huge range of different pigs available from basic cleaning pigs to sophisticated inspection pigs capable of inspecting a pipeline for metal loss, cracks or physical damage. Slurry pipeline operators like all pipeline operators face the challenge of selecting the type of pig best suited to the needs of their pipeline. Whether for basic cleaning operations or high level inspection there are many supply companies and service operators to choose from. In order to execute a successful pigging campaign a pipeline operator will need to make a range of technical evaluations regarding the pipeline and types of pig to use. Detailed planning and preparations will also be required. The overall process of planning, preparation and execution can be complex and time consuming and should not be underestimated.

3. Slurry

Pumping Slurry through pipelines is a well established, economic and efficient method to ship large quantities of minerals. The most common form of Slurry (and focus of this paper) is pulverized mineral solids mixed with water. Typically the minerals might be extracted via open cast mining, then mixed with water and pumped via a pipeline to a process facility. The end process will likely involve drying and preparation ready for transport to market (i.e. iron ore pelletizing) or fed directly into a plant (i.e. coal mine to power station or chalk mine to cement works). The actual location of the mineral exaction site may be a long distance from the process plant and the pipeline might be routed through high elevations or difficult terrain. Slurry pipelines have been built up to 400km in overall length and longer pipelines are planned. Long pipelines are often divided into shorter sections with intermediate pig traps to facilitate pigging.

The use of pigging to maintain and inspect pipelines is a methodology applied to many types of pipeline systems. Pigging is a very common and routine activity in pipelines that transport hydrocarbons, chemicals or gases and pigging is also carried out in Slurry pipelines. Pigs must be selected and designed to deal with the internal environment associated with the fluid being transported. For example Gas lines can be very dry and dusty and result in high wear to pigs, crude oil pipelines may have high wax content that could build up in front of or around the pig causing pig damage or even a pipe blockage. The products in chemical pipelines may be reactive with pig components.

In Slurry pipelines solids suspended in the water may have dropped out over time and there may also be areas of internal surface scale that have built up. The result could be high wear to pig components that contact or run near to the surface of the pipe. Fortunately pigs can now be designed to cope with many extremes of environment and materials such as sealing discs and cups have been improved and developed for extra durability and resistance to high wear and high temperature. Pig wear can be mitigated by a combination of appropriate choice of pig design and correct selection of wear resistant materials plus a progressively staged proving and cleaning sequence.

4. Pipeline Design Issues when Pigging

Not all pipelines are built with full consideration for pigging or the range of pigs that may be run in its lifetime. Before pigging is considered in a pipeline a pigging feasibility assessment must be undertaken in order to identify if there are any issues with the configuration of the pipeline. When pigging a Slurry pipeline, or indeed any pipeline, particularly for the first time or when using a pig not previously used in the pipeline, the operator must carry out an assessment of compatibility to ensure the pig will transit through the pipeline intact and safely.

An assessment should be made regarding the pipeline physical configuration and compatibility for the different types of pigs that may be used whether basic cleaning pigs and / or specialist inspection pigs. The assessment will be a combination of physical on site measurements and document reviews that must confirm; the minimum Pipe Bore, the presence or otherwise of Internal Sleeves, the types of Tees, the design of Y's, the distance between large connections such as Tees, the internal dimensions of Check Valves, the size of any voids or restrictions in Valves and the critical dimensions of Pig Traps. The list is an example of the main issues; the aim is carry out a thorough step by step evaluation of the pipeline so that any problems or issues can be identified as early as possible. The process of selecting options to overcome those issues can then begin.

The environment and dynamics of the product being shipped must also be considered such as Velocity, Temperature, Pressure plus Chemical and Physical properties. Slurry is a relatively dense fluid so the pressures required to transport the Slurry may be high especially if the pipeline has to traverse high elevations. Whilst this is not necessarily a problem for cleaning pigs it is important to ensure items such as pig transmitters which are used for tracking pigs can withstand the highest expected pressure in the line and the signal will penetrate the pipeline wall. Inspection Pigs are designed for a wide range of pressures such as the extremes of subsea operations, nevertheless it must always be confirmed with the service provider that the pigs are designed for the highest likely pressure in the pipeline. The inspection service companies will provide questionnaires to establish if there are any pipeline designs or internal environment issues. Pig supply companies should ask similar questions. The operator will be responsible for accurate completion of this data. It can be a very time consuming process and could ultimately require a modification to the pipeline so it is recommended that pipeline design and data reviews are carried out well before a pigging project is expected to start.

5. Pig Selection Process

Companies that design cleaning and proving pigs are constantly improving designs and will make every effort to ensure pigs will cope with the environment intended. A pipeline operator should always consult with the supplier or service company to ensure the pig matches the purpose and environment intended. The main objective is to be proactive rather than passive regarding pig selection. Create a dialogue with the company and have a clear understanding of the pig design and expected performance. Pig supply and service companies can provide data sheets describing the measurements, materials and build set up of a pig, they can also provide track record of customers and notable pipelines the pigs have been used in. There are many different types of pigs and options on the market and a wide choice of suppliers which can make it very confusing for the pipeline operator when trying to select the best pig to use for a pipeline. For cleaning pigs it is of course common for a pipeline operator to default to a preferred or known design they have personal experience of or familiarity with or has been proven in other pipelines. An operator should keep an open mind on pig options because a particular preferred supplier or design may no longer be available or a certain design is no longer used due to a design/performance problem being identified or a new improved alternative pig design has become available.

In the case of a change of pig to a different design or where pigging is being carried out for the first time it is very important that the operator makes a formal assessment of pig suitability. Simply selecting an off the shelf pig without matching its design and capabilities to the pipeline is not an option and could lead to inappropriate selection, poor performance or even a stuck pig situation. It is recommended that a checklist is developed for use during the pigging feasibility study to ensure key elements of design and performance have been taken into account and that the pig is suitable for the service intended. In fact pig selection should be seen as a defined formal process that is managed within a team where responsibilities are clearly identified. Even when pipelines are designed to be fully piggable and essentially similar in design it is often very surprising how different each individual pipeline or piggable section can be in terms of how a pig performs, particularly in relation to wear. For this reason it is advisable that operators consider each pipeline section on a case by case basis and keep good records of pigs used and document any issues that have occurred. All this information can be used to justify continued use of a particular pig, determine a modification or give reason to select an alternative design of pig.

A pipeline proving and cleaning program must be gradual and subject to review and assessment after each pig run. Running an aggressive cleaner pig too soon risks removing high volumes of scale or deposits and may block the pipeline. The right pig design and its sequence in the program are equally important.

6. Pig Design

Pigs have been designed to cope with many different types of environments and special designs can be produced for a particular situation. Using cleaning pigs as an example the basic design will comprise of the pig body, sealing discs or cups, guide discs and optional components such as brushes. The basic overall design is not complex but each element must match the requirements of the pipeline. For Slurry the pig should be designed for the issue of potential high wear. Sealing cups have good wear characteristics due to their shape and angle of contact with the pipe wall; multiple sealing discs in combination with guide discs have good cleaning characteristics.

Cups, Seals and Discs are usually made from Polyurethane which is supplied to various specifications depending upon the expected duty of service required. The types of brushes available are also varied; they can be a twisted wire design, a compacted wire bunch arrangement or a thick rigid strips, they are usually metal (Steel) but can also be made from non metallic material. The choices, options and specifications are therefore wide-ranging so Slurry pipeline operators face the challenge of deciding what the best design for their pipeline should be. The operator must review the market and develop a shortlist of pig suppliers. Once a supplier is chosen the operator and supplier should work together in the pig selection process. There is no universal standard design for a 'Slurry Pig' therefore the operator must be satisfied that the design of the pig and all the various components are compatible with the pipeline configuration and will match the demands of running in their type of Slurry.

7. Record Keeping

Pigging projects, especially for inspection can be complex and require many levels of information and data to be compiled. It is essential that a project file is set up and records kept. All documents must be scanned and stored electronically. Pre-run check sheets and Run sheets should be completed for each run and photographs taken of pigs before and after a run. The photographs should be digital and placed in the record system together with the dates and time of the run, pig number and commentary of pig condition. A central project file should be set up for each pigging campaign and for maintenance cleaning operations. Relevant Emails relating to the project should stored and be accessible to authorised members of the operators team. Pigs should be stored in clean areas away from sunlight because UV can over time degrade the Polyurethane that the seals and cups are made from. Record the date of purchase and number all pigs and components in storage.

8. Pig Traps

Pigs are available in various assemblies, sizes and lengths. Cleaning pigs are often single module units but there are dual module cleaning pigs. Inspection pigs are available in a range of assemblies depending on the pipe diameter, technology and the service providers' particular designs. It is not uncommon for inspection pigs to be several meters long. The pig traps should therefore be designed where possible to accommodate the full range of pigs that may be used during its operational life. The final decision on pig trap dimensions is sometimes a compromise of available space and minimum necessary dimension required for the longest pig. The choice is made even more complex by the fact inspection pig designs have evolved and continue to change over time. Improvements in battery capacity, compacted memory storage and miniaturised electronics reduces the space needed in the pig this has allowed pigs to be made shorter in overall length compared to previous designs and in some cases it is possible to have single module inspection pigs. However, in contrast, inspection technology options have increased and combinations of technologies can be fitted on one pig therefore pig systems can sometimes be very long in length depending upon the inspection choices or additional options selected by the customer. The receive pig trap must also have some capacity to capture scale, particulates and recovered materials or items that are pushed through ahead of the pig. When planning for a pigging campaign the pig traps must be measured to ensure all pigs to be used will fit into launch traps adequately and can be received into receive traps safely. Figure 1 shows a generic pig trap layout with the principle measurements shown. One of the key measurements for a receive trap is G and is often referred to as the nominal pipe length. This is important because the pig must travel through the nominal pipe far enough that the rear of the pig is clear of the valve when the pig stops. For single module pigs this is not usually a problem but for multi module pigs this can be an issue, especially for inspection pigs such as Magnetic Flux Leakage (MFL) tools that may only have drive seals on the front magnetic module and will stop almost immediately once in the oversize section (known as the barrel) because of the magnetic drag.

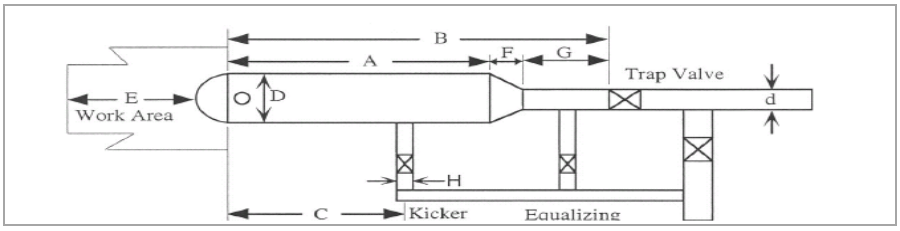

Figure 1. Key Pig Trap Dimensions

The space in front of the pig trap is also very important. It must be level, hard standing ground, and have clear space with enough room for the pig extraction /loading equipment to be placed. For inspection pigs this equipment will normally take the form of a height adjustable tray combined with a mechanical drive system powered by air or hydraulics that pulls the pig from the trap or pushes the pig into the trap. The example in Figure 2 shows a receive pig trap on a slurry pipeline designed for a long inspection pig. There is good access and level space for pig extraction equipment.

Figure 2. Pig Trap for a long inspection pig

9. Pipe Connections

The design of Y's and Tees must be thoroughly checked to ensure there will be no problems with pig transit. The principle concern is potential loss of drive and the pig stalling if seal positions on the pig allow large volumes of fluid to by pass the pig when across adjacent connections. Figure 3 indicates an example of close adjacent connections, in this case a Y and a Tee.

Figure 3. Example Y and Tee

Figure 4 indicates a situation where the seal separation distances on the pig is the same as the connections separation distance so the fluid would by pass the pig. The pig may not actually stall fully because fluid will impinge on the back of the pig and there may be enough force to push the pig forward clear of the connections. Also if the pig has other modules other modules there may be some drive from the rear. Nevertheless it is advisable to design large adjacent connections with enough separation to reduce the risk of a pig stalling. Where Tee's and Y's are already installed they should be measured and that information passed to the pig supply company or inspection service provider so that, if possible, the pigs are designed / modified to deal with the spacing.

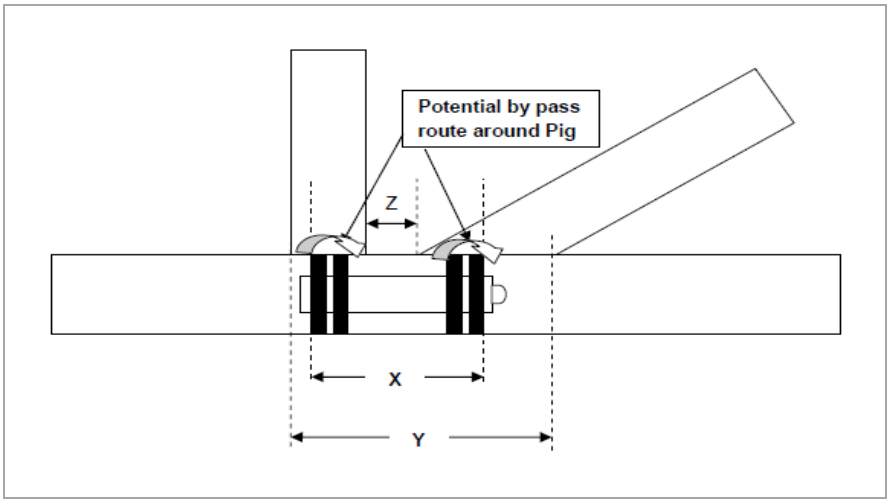

Figure 4. By pass route around pig seals

10. Special Procedures

One issue that may occur in Slurry pipelines is build up of particulate solid deposits in pipe sections that may not normally have flow. Figure 5 indicates an example of a section of pipe on a launch trap where deposits can build up. During normal flow the Slurry passes through the Y and into the pipeline, over time the pipe section between the valve and the Y can build up with solids that drop out from the Slurry. There is potential for this solid build up to cause problems when launching pigs or even cause damage to pigs as they pass through or over the solid build up.

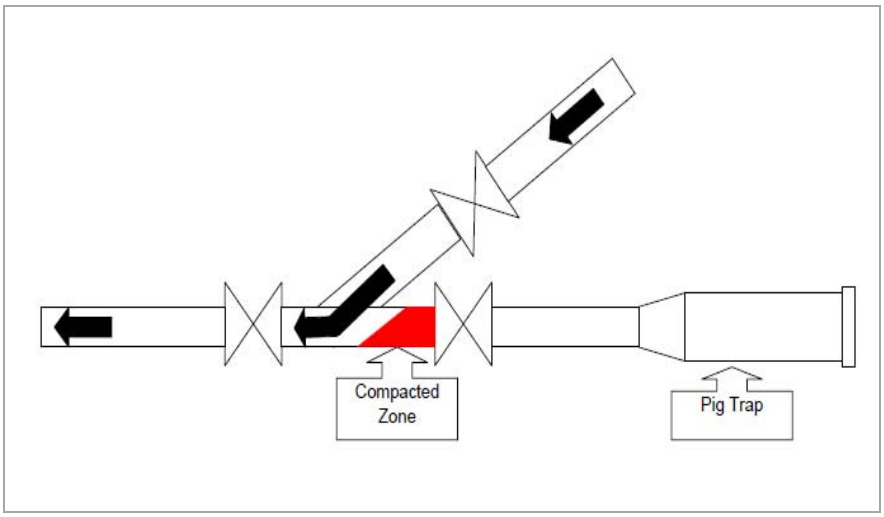

Figure 5. Example of compacted material position

Samarco Mineração S.A an iron ore mining and pipeline operator in Brazil has been developing a procedure to clear the solids each time before running a pig. The procedure has been trialed successfully and is likely to be adopted as standard for all their pig launches. Figure 6 indicates the launcher pipe work set up downstream of a pump. The basic

summarised procedure involves firstly introducing water instead of Slurry into the pipeline for a short period. The pig trap pressure is reduced to zero, the main valve (V230) is then opened; this creates a short rapid back pressure that loosens the compacted solids, the main valve is closed and the trap drained and refilled. Slurry is then pumped forward though the pig trap into the pipeline.

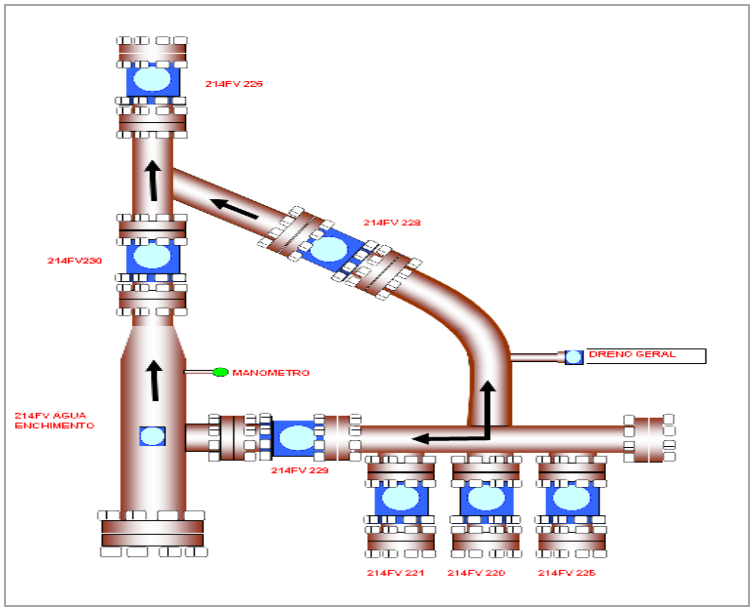

Figure 6. Samarco launcher arrangement

11. Pig Tracking

Knowing the position of a pig when it is moving through a pipeline or has stopped is vital especially if a problem arises such as a stuck pig. It can often be the case that pipeline operators overlook or underestimate pig tracking operations in terms of the amount of work, resources and manpower required.
In this regard Slurry pipelines are no different than other pipelines and recommended best practice is to track every pig and fit each pig with an electronic transmitter. Tracking is always required when running inspection pigs. There are various systems available on the market, usually based on Electromagnetic principles. The transmitter is bolted to the pig and an external hand held antenna is used to track and locate the pig. The route should be planned for vehicles to travel along the pipeline and a minimum of 2 teams for tracking to follow the pigs should be used. Geophone listening devices can also be used to listen for the pig as well as using transmitters for location.

12. Contingency Planning

The potential consequences of a stuck pig must be fully assessed and understood well ahead of any pig runs. An Emergency Response Plan should be developed and agreed in advance which identifies actions and responsibilities if an incident occurs. Spares, repairs and containment systems must be available and contactors available if a response is needed. A risk assessment should be completed and a stuck pig procedure should be produced prior to any operations. In the case of stuck pigs it may be necessary to send a Rescue Pig to try and push out the stuck pig or find its position. The important aspect is to ensure the Rescue Pig is available and ready at short notice; it is advisable to have a pig purchased and ready stored on site so it can be run quickly if required. The type of rescue pig to use is open to choice, key factors to consider in selection are: can a transmitter be fitted, is the pig robust and solid enough to bulldoze a pig forward if that is the objective, should it be designed with high DP or adapted in any special way and does the front of the pig need to be modified with a special bumper nose or flat front face?

The decision to send a Rescue Pig may depend on the type of pig that is stuck, if it is long multi module pig or even a module that has separated from a pig it may jam even more if pushed from behind making the situation worse. Before a Rescue pig is sent the situation, risk, benefits and possible outcomes must be fully evaluated.

13. Potential consequences of stuck pig in a Slurry pipeline

Clearly when a pig becomes stuck the flow of Slurry may be compromised, this will have an effect on delivery to the end process and contingencies of supply or impacts on plant operations must be planned if this was to occur. Another issue when a pig becomes stuck in a Slurry pipeline is possible high levels of fluid impingement on the pipe wall that might occur if the pig is by passing flow across its outer edges such as the seals. The concentrated flow near the pipe wall may cause a jetting action and rapid wear to the pipe and if left long enough a leak might occur. The immediate response may require flow to be minimised when a pig becomes stuck until there is a decision made on actions to recover or locate the pig. Whilst running a Rescue Pig is likely to be considered it is important to take account of the risk of continued or increased jetting across the stuck pig during the rescue run. This depends on how far the pig is stuck from launch and whether a flow can even be established. A thorough risk assessment should be carried out.

14. Summary

Pigging is an important element in pipeline maintenance and requires detailed planning. The challenge of pigging Slurry pipelines can be matched by a proactive, planned and focused selection process and elemental assessment of pig design. Pig technology is improving and more options and choices are available than ever before, for this reason the pipeline operator should always review the market and keep up to date on development even if the operator has developed a track record with a particular design there may be new designs that have improved performance or certain advantages that could be beneficial. Each pipeline section to be pigged should be evaluated separately and on its own merits. Internal conditions may be different from section to section which may affect pig performance.

The Slurry pipeline operator should work closely with its pig supplier or inspection or cleaning company when developing plans and create a technical partnership to ensure the most appropriate and effective design is chosen for best performance in the pipeline. Each pig run whether routine cleaning or inspection should be managed as a project and documented within a project system. There should be a structured team with responsibilities identified. Training and procedures are very important to the success of a pig run. New procedures may be required to overcome issues such as solid build up in launcher pipe work and an Emergency Response Plan should be agreed well in advance. Pigging programs for cleaning or inspection should be planned as progressive stages to ensure the most suitable pig is run at the most appropriate point in the program. A proving and cleaning program must be gradual and subject to review and assessment after each pig run. Removing too much scale or deposits too soon may block the pipeline.

Slurry pipelines can present certain challenges for pigging such as pig wear. Technology and knowhow is always developing and many of the issues faced by other industries such as Oil & Gas have been overcome and much of the gained knowledge is transferable to Slurry pipelines. Learning from the experiences of others in the same industry is also very important and communication through forums such as conferences and technical papers is an essential part of that process.

15. Acknowledgements

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