Hide and Seek – The Games Pigs Play

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Abstract

The use of in-line inspection (ILI) tools and cleaning pigs is a common and successful way to manage the ongoing integrity of operational pipelines. However, even with thorough planning, in some instances these tools and pigs can become damaged or, worse still, lodged in the pipeline. Conditions that can contribute to a failed pig run include excess debris in the pipeline, unknown pipeline bends or wall thicknesses, intrusive equipment not addressed prior to the run, improper management of pumps and compressors, the style of the pig or inspection tool and incompatible valves or fittings.

A lodged tool can disrupt flow and recovering it may result in the suspension of normal operations. Just as the interactions between the pig, the physical pipeline and the operating conditions are unique, so are the options to mitigate a lodged tool or pig, depending upon whether the pig is truly stuck in place or has just stopped or stalled. They include temporarily increasing pressure to the pig's drive cups, surging the line —which involves rapidly closing then opening a valve to send short bursts of pressure to help dislodge the pig — reversing flow or using a recovery tool to push the ILI tool to the receiver. If all other measures fail, the tool must be removed from the line by a cutout project. This involves accurately locating the tool inside the pipeline, isolating the affected pipeline section, cutting into the pipeline, retrieving the lodged tool and repairing the pipeline.

This paper will review the reasons a tool or pig can stop in a flowing pipeline, discuss how tool and pipeline conditions affect run success and provide guidance into planning a successful run. It will also describe the mitigation steps involved in locating a lodged tool, including using pipeline and tool data to evaluate why the tool stopped and evaluating the options to safely get the tool moving again. This paper will also explain the processes for retrieving the tool or pig, incorporating lessons from fields around the world.

A cascade of events.

Using in-line inspection (ILI) tools and cleaning pigs is a common and successful way to manage the ongoing integrity of operational pipelines and to satisfy regulatory requirements. Optimizing the run includes carefully selecting the appropriate tool or pig based on pipeline characteristics and conditions and selecting the right crew for the job.

Unfortunately, despite thorough planning, tools and pigs can become damaged or lodged within the pipeline, leading to operational disruptions. While it's possible to safely remove a lodged tool, that can also interrupt service. When non-intrusive measures such as temporarily increasing pressure, surging the line, reversing flow or pushing the ILI tool from its lodged position with a recovery tool fail, the tool must be cut out of the pipeline. That, of course, requires knowing exactly where the tool is stuck.

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Usually, a stuck pig is not the result of only one event, but a cascade of events. Avoiding this "perfect storm" starts with the pigging plan, a detailed document outlining procedures, equipment, frequency, and having detailed information about the pipeline and flow. To develop an effective pigging plan and make pig selection more confident we must first know the pipeline and why pigging is required.

Knowns and unknowns.

New construction pipeline activities involve a pre-commissioning phase and a commissioning phase.

During the pre-commissioning phase, the pipeline has been physically constructed and usually buried, and is ready for its first cleaning using pigs, inspection using in-line tools and testing its strength using water to pass through the pipeline to detect leaks and verify the pipeline's integrity to hold pressure.

While a new construction pipeline has known bends, wall thicknesses, elevations and barred tees, the variety and magnitude of pipeline construction debris left in the pipeline is a sizeable threat. A collection of loose timbers, welding wire, welding helmets and sometimes wildlife can create a blockage significant enough to stop a pig or tool. During re-commissioning, cleaning pigs will push debris out of the pipeline in preparation for instrumented tools being used to measure the pipeline for dents, ovality, and sometimes metal loss. Pigs are used in the initial line fill or line pack to manage how the transported product is introduced to the new pipeline.

A newly acquired pipeline is similar to buying a used car. The car looks mechanically sound, but there is no history of maintenance or possible abuse. The new pipeline owner doesn't have access to the exterior of the buried pipeline, therefore all measurements will be taken at the interior of the pipeline using inspection tools and gages. Unlike a new construction pipeline with known cleanliness, an acquired pipeline may hold debris of unknown quantity and unknown consistency in unknown locations. Operational and maintenance records can indicate the locations of intrusive equipment like pig signalers, corrosion coupons and temporary repairs.

In some instances, existing pipelines are repurposed to transport a different product. A pipeline designed for liquid purposes can be evaluated to safely transport a gas product under pressure. Check valves are used in liquid pipelines to control flow but have little value in pipelines designed to transport gas. In these cases, the cleaning pigs and inspection tools must comply with the valves and geometry of the pipeline design.

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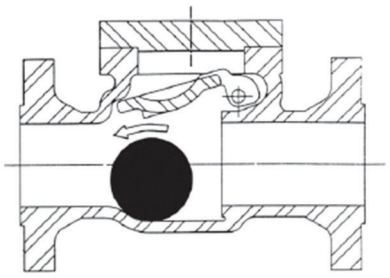

Figure 1. Check valve.

Pipelines maintained under your integrity management plan (IMP) have a good selection of resources to examine to understand the characteristics of the pipeline. Field technicians and corrosion personnel will bring insight into the history of the pipeline, how the pipeline has been maintained, and will share information on issues that operations in monitoring. With good scheduled pigging, the accumulation of debris in the pipeline can be estimated. If the pigging history is not consistent, running pigs and tools can introduce some risks. Fortunately, there will be flow and filtration history on an operating pipeline from the supervisory control and data acquisition (SCADA) or similar system used to monitor the pipeline.

Pigging plans driven by knowledge.

Ideally, we plan for an optimized pig run by knowing and evaluating the pigs we will run, their configurations and their ability to navigate the pipeline. Additionally, we will know our pipeline in its current state as well as at the time of the run, and we will know the experience and experiences of the pigging crew. Usually a "stuck pig" is not the result of only one thing. To understand the overlapping impacts of multiple variables and avoid the "perfect storm," let's take a closer look at the pigging plan.

This starts with knowledge of your line and the reasons why you are pigging. Is the line of new construction, an acquired line with limited or no pigging history, an existing line in your system with no or inconsistent pigging history or an existing line in your system with a consistent pigging history and record? Your pigging plan will be driven by this initial knowledge.

Next, you need to identify your reason for pigging. What is your objective? Your objective will determine your steps in developing a pigging program for the line or a pigging program specific to a project culminating in a multi-tool inspection and reporting on the line condition.

Regardless of the pipeline's age or pigging history, it is imperative to know the pipeline contents, normal operating pressure and the pressure anticipated during the tool or pig run, as well as flow conditions, temperatures and physical characteristics of the pipeline. Knowing the details about the

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pipeline and the flowing contents is necessary when evaluating the type of pipeline pig or inspection tool to use for cleaning or inspections.

The process of knowing your line includes reviewing as-built drawings, which show how the system was built, as opposed to how it was designed, as well as documented changes. Identify existing wall thicknesses or possible pipe diameter changes. Know what valves are in the line. What are the locations and relative proximities of branches? Are the branches barred or do they require bars. Identify the bends. What are the diameter ratios of the known bends? Do they comply with the requirements of your pigs or tools? Lastly, are there miter bends or non-compliant field bends?

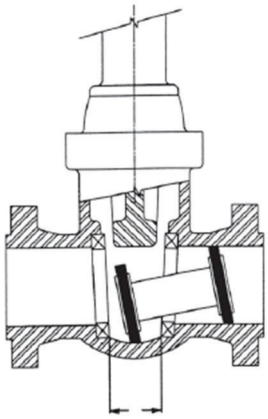

Figure 2. Gate valve seat ring spacing.

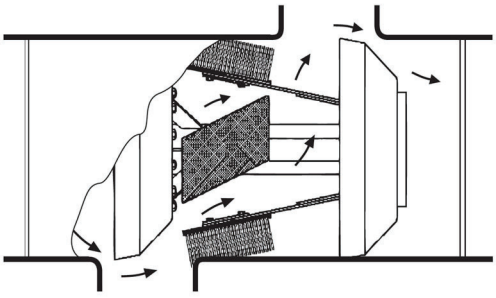

Figure 3. Adjacent branches causing bypassing and pig stoppage.

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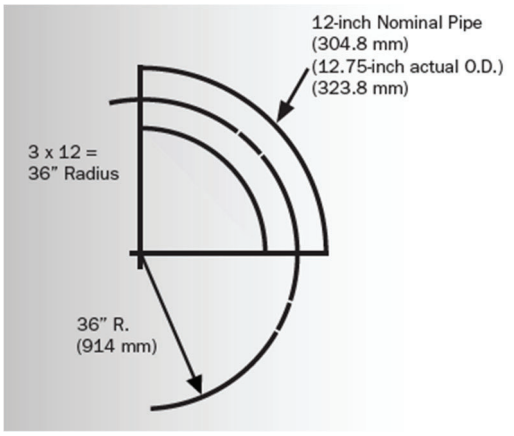

Figure 4. Bend ratio.

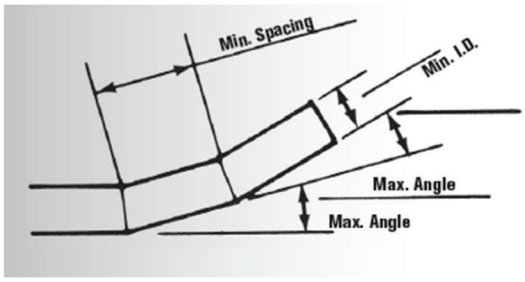

Figure 5. Miter bend.

Progressive pigging.

The next step in pigging plan development is identify the reason and objective for pigging. If your goal is to inspect your line, inspection tools require a clean line provided by progressive pigging.

Your knowledge of the line will drive which tools you select for progressive pigging, and each of the progressive configurations will help you learn more about your line and promote the success of your next stage of pigging. If this is an initial pig run in a new line or in an acquired line with no pigging history, will you start with a foam pig? Once a foam pig has successfully travelled the pipeline and resulted in minimal or no damage to the pig, you may choose from a variety of urethane molded pigs with cups, discs and possibly brushes. Beyond urethane body pigs you may move to a more rigid body pig with combinations of cups, discs, brushes, blades, magnets and/or gauging plates. An important consideration that while practicing a progressive pigging program assure your pigs are in good condition and sized for the work to be achieved to meet your objective. With each step of progressive pigging use of a transmitter and tracking will serve you well in the long run. As with any pig run or tool run, the possibility is always present of abnormal conditions that would contribute to

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a pig's stoppage. The use of transmitters on each run is a low-cost addition that can make it easier to locate a stuck pig.

Figure 6. Consider available pig options.

Figure 7. The effectiveness of a magnet pig.

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Figure 8. Risk of not utilizing progressive pigging.

Figure 9. Lack of progressive pigging.

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Once you have achieved the desired cleanliness level, you can progress to geometry, mapping and inspection tools.

Experience and experiences.

Another important consideration is the experience and experiences of your pigging crew and the entire pigging team, which can refer to the broader functional interactions of individuals from operations, corrosion, engineering, pressure control and health, safety, and environmental (HSE).

Among other things, it's important to determine if the pigging crew's experience includes executing a complete pigging program. Are they knowledgeable in planning a pig run as part of a team? Do they coordinate with your corrosion team in collecting and evaluating the resulting pigging debris? Do they time the pig runs to develop an expectation of in-line transit performance? Have they coordinated with a line survey team to assist in the selection of above-ground markers (AGM) positions?

Improving the odds of success.

Earlier, this paper referred to line features which may require mitigation to prevent a stuck pig event. Pre-run line mitigation may be required as a result of you better knowing your line. Bends that are too tight for a pig or tool to navigate, miter bends and non-navigable field bends may be replaced prior to a more complex or demanding pigging or tool passage operation. Are the valves in the line fully functional and full-bore opening so the pig can pass through them? Are there corrosion coupons, sensors or monitors which need to be removed prior to the pig run? These items and other intrusive equipment can impede the travel of a pig or tool. Pigs usually have more flexibility and tolerance to intrusions due to their designs. The inspection tools with sensors held near the inner diameter of the pipeline have less tolerance to intrusion, meaning just because a cleaning pig can traverse the pipeline section successfully is not an assumption that the inspection tool will traverse with the same success. Will your pig or tool selection need to anticipate heavy wall pipe or dual diameter pipe?

Coordinating with your pressure control team to assure your line pressure and flow conditions will be appropriate for your requirements during your planned run. In addition, line survey and setting of AGMs will complement your transmitter selection, allowing you to monitor the timing and progress or your run to completion.

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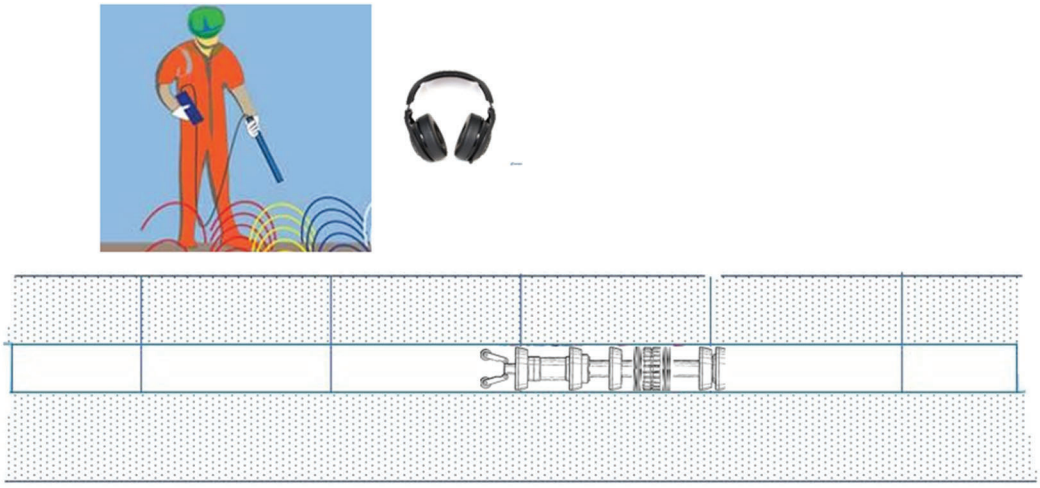

Figure 10. AGMs and transmitters enhance the tracking of pigs and tools during a pipeline run.

Evaluation after a successful pigging run will facilitate planning the next runs of your progressive pigging program, and lead to the success of more complex runs. The evaluation should include debris analysis, timing of pig passages and if pig indicators function as anticipated or need to be repaired, whether the pigs were received in good condition and if there was good coordination between pressure control and operations, among other things.

When all doesn't go well.

All goes well until it doesn't. What happens when the cliché becomes a phone call, "Houston we have a problem." Did the pig or tool not arrive in the receiver? Were there delays in AGM tracking? Did the transmitter go silent?

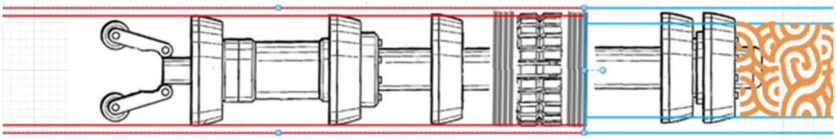

Figure 11. What caused the stoppage? It's time for teamwork.

Keep in mind the Apollo 13 maxim: "Let's work the problem, people. Let's not make things worse by guessing."

Now is the time for the pigging team to pull together, to return to the plan and what you know and to begin gathering facts. Is there flow? What are the known pressure readings from available gauges? Are there measurable pressure build ups or drops along the line? Were AGMs, transmitters and

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trackers utilized? Are they functioning? If AGMs, transmitters were not used or have failed to function revert to the consideration of known features in your system such as valves, heavy wall pipe, possible monitors and sensors remaining in the line.

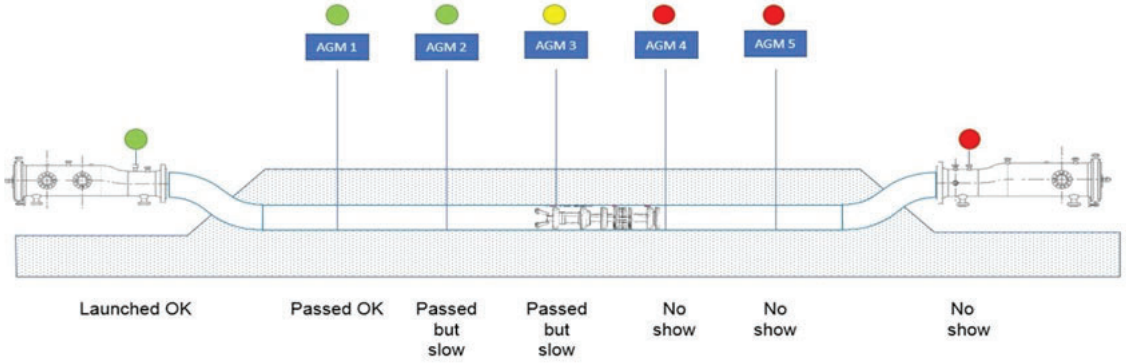

Figure 12. The benefits of AGMs in locating a pig or tool.

Correlate possible pig movement impediments with pressure variations that could be indications of the pig's location. Remember to consider monitoring pressure at branches should guide bars be missing with the pig diverted and blocking the branch, causing a pressure reduction.

When the location of a pig or tool is not known, there are techniques to use to close the gaps in the missing information. Hunting for a lost pig is similar to hunting challenging animals in the wild. The creature may be directly in front of your field of view, but if it is not moving, you may never detect it. If a pig is slowed, then it is still moving and will be detected by downstream AGMs. If a pig is considered stalled, pressure differentials can be measured upstream and downstream to confirm a partial or full blockage has occurred.

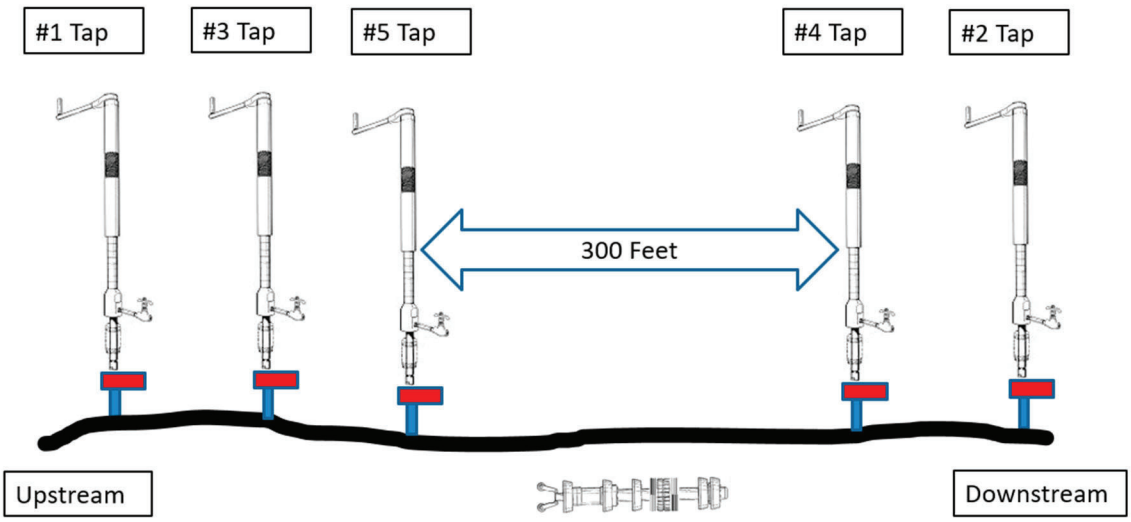

Figure 13. Using differential pressure in the line to locate a stuck pig or tool.

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Transparent communication is important when a pig becomes stuck. The urgency of action is determined by the flow available to the downstream customers and the operating pressures of the pipeline. Flow that is reduced and can satisfy the needs of downstream customers creates a condition where added time is available to locate and evaluate removal processes. Flow that is completely blocked will limit the methods to mitigate the issue and will drive toward a faster response to remove the blockage.

The material used on pigs and tools to create the seal within the pipeline that is used to propel the pigs is usually urethane of medium density. This is an excellent material for creating the consistent 20 psi to 150 psi differential required to drive the pig; however, urethane alone cannot hold elevated pressure differentials and will tear, thus preventing a complete blockage. In this scenario, the good news is that complete blockage is not possible, and the bad news is that the pig or tool lost the ability to drive forward on its own.

Let's take a look at the situation where the pig is lost, but there's sufficient flow downstream to customers. Earlier, we established that having sufficient flow created less of an emergency in regard to recovering the pig. As we set up this pigging or inspection project, the pipeline conditions were aligned to provide a successful run. Have any of the pipeline conditions changed? First call is to operations to verify flow conditions and pressures within the pipeline system are within the expectations of the project. Given the launch time and recent records of flow conditions, the pig should be no farther than a specific point along the pipeline. Use this point as a maximum travel distance and start working upstream, evaluating physical changes on the pipeline. These physical changes include elevation changes, bends, valves, changes in wall thickness, off-takes or in-takes, pumps and compressors. Evaluate the existing pipeline data from the last inspection, looking for dents or ovality.

While a pig can stop in plain, straight pipe, it is usually a secondary element that contributes to the stoppage. If the pig had a transmitter or was being tracked, the area to search can be reduced using these deductive methods. Magnets on a cleaning pig or on an inspection tool can greatly assist in pinpointing the pig's location using a compass. Working with pipeline operations, flow can be regulated to create a high pressure upstream and a low pressure downstream of the blockage. Multiple welded fittings and hot taps upstream and downstream that indicate pressure differentials will help reduce the search area until the pig is located. As an option, a radiographic inspection on the excavated pipe section suspected of containing the pig can confirm the presence of the pig and possibly the pig's condition.

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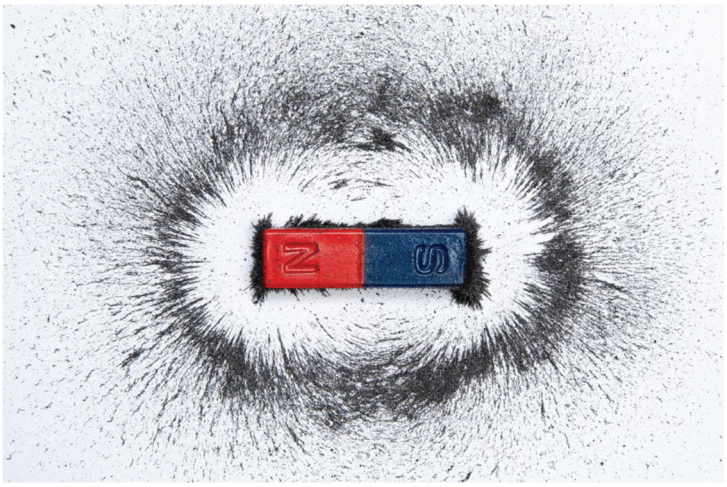

Figure 14. The magnetic field can be used to located a magnet pig or an inspection tool utilizing magnets.

Figure 15. Compasses to assist in locating a pig or inspection tool carrying magnets.

If the pig is located in a plain, straight pipeline section and the section is excavated and shows no obvious physical pipeline obstructions, it is tempting to increase upstream pressure in the effort to re-start the pig downstream. Be cautious with this step. The project team needs to evaluate the benefits of finding the pig and knowing where to start the cut-out process versus the liability of losing the pig again and requiring a new search downstream with a new excavation. If the team cannot determine why the pig stopped from examining the exterior of the pipeline, then the cause of the pig stoppage must be related to the interior of the pipeline and the interaction with the pig or tool. Depending on the flexibility of the pipeline system and the proximity to the pipeline launcher, in

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some instances the flow can be reversed in an attempt to push the pig back to the launcher. The configuration of the pipeline and the style of the pig need to be reviewed before this process is considered.

If the pig or tool needs to be removed from the line in its current position, stabilize the pressure and flow and prepare for a line isolation and removal. This is a point where pre-planning contingency services can pay dividends. Contingency planning may include locating fittings suitable for use on this pipeline system, identifying a welding team with the acceptable welding qualifications and current operator qualifications (OQ) per ASME B31Q, welding inspectors, contractors available to perform the excavations, the service provider to hot tap and isolate the pipeline, and a section of pre-tested line pipe that is compatible with the pipeline system.

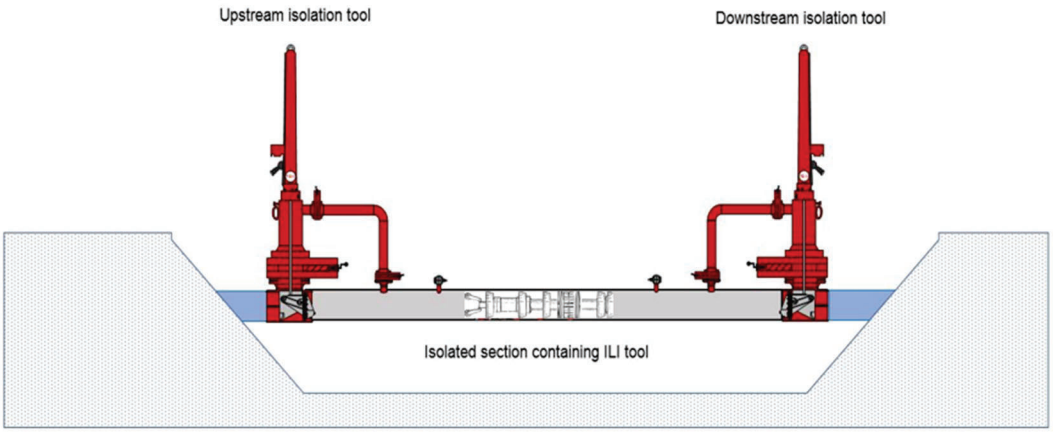

Figure 16. Removing the pig or tool from the line using isolation techniques.

Once the decision to cut out the pig is established, all flow and differential pressure should be minimized to avoid inadvertently causing the pig to move. After the isolation equipment fittings are welded to the pipeline, the pig must remain within the planned isolation section.

CONCLUSION

As with any complex process, diligent planning for a successful pig run includes developing a process should abnormal conditions arise, like a stuck or lost pig. The more information about the pipeline, flow conditions, pig or tool design and the field team's level of experience, the more likely the project will be a success, with less need for reactive efforts if abnormal conditions are present. As unique as the events are that contribute to a stuck pig, so are the mitigation steps to locate and remove the pig from the pipeline. This paper shared knowledge from past experiences in the field and identified several processes that can be considered when searching for a lost pig.

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