Benefits of Inline Pipeline Isolation as an Alternative to Line Stopping

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Abstract

Operators can often encounter difficulties in isolating sections of their pipeline to facilitate essential safe repair or maintenance activities if appropriate valves are absent from the line. In-line isolation pigs provide fully proven and monitored dual seal barriers that ensure the safe breaking of containment on pressurized systems in compliance with the highest industry standards.

Unlike traditional Line Stopping activities, piggable isolation tools require no welding or cutting into live lines, leaving no residual fittings or hardware on the pipeline. This eliminates project costs associated with fittings, welding and inspection and reduces the risk of leak paths from buried pipeline flanges post operations.

Line stopping often requires pipeline excavation and site establishment including lifting and rigging operations which is usually eliminated by deploying inline isolation pigs. Tracking, operation and communication with in-line isolation pigs can be achieved remotely through ground and pipe wall preventing the need for costly site establishment and reducing the risk of digging and lifting operations around the pipe.

In-line isolation tools significantly reduces, and in some cases eliminates, the requirement to vent or flare harmful emissions into the atmosphere during maintenance activities. One of the most significant environmental advantages is the substantial reduction in greenhouse gas emissions vs venting the pipeline. In the case of long, large diameter gas pipelines, this can prevent the potential discharge of thousands of tons of methane into the atmosphere.

Following the completion of the maintenance activities, a reinstatement leak-test of the replaced valve or pipework can be performed while the isolation is still in place. And provides an alternative to golden welds.

Real world examples will be discussed where double block inline isolation tools have facilitated pipeline modification, resulting in reduced project costs and production downtime, while minimising the discharge of emissions.

The utilization of in-line isolation tools not only enhances the efficiency and safety of pipeline repair and maintenance but also aligns with increasing demand to reduce emissions and create a more sustainable energy infrastructure for the future.

Challenges for this technology will also be discussed, including long distance deployments in gas pipelines where the tools must be stopped midline with suitable accuracy. Also, a high degree of confidence of pipeline condition (bore, wall thickness) is required before inline isolation tool pigging as the hard OD of the tools is close to the ID of the pipe and good information is sometimes difficult to obtain.

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Introduction

Operators often face challenges when a need arises to repair, replace, or install a new pipeline feature to a pipeline in service. Traditional means of isolating and evacuating a pipeline can be costly and meeting downstream throughput requirements may restrict an operator to how and when they can perform necessary pipeline maintenance and improvement activities. In-line isolation tools are one option that operators have to provide a fully proven and monitorable isolation barrier so that they can perform required maintenance activities in a timely and cost-effective manner.

Traditional means of preforming maintenance or improvement work on a pipeline in service include blanking or blinding a pipeline section from the pressurized system, venting and purging or displacing the hazardous substance, or using intervention isolation tools to provide the required isolation. Depending on the infrastructure in place, it may not be possible to disconnect and blind or blank off the pipeline, isolation valves may not be double block and bleed or do not sufficiently hold pressure, or there may be a downstream requirement which limits the duration in which a pipeline can be out of service, among various other reasons isolating and preforming maintenance on a pipeline can be challenging. Intervention isolation tools (line stopping) can be used to safely isolate a pipeline, however, this method requires in-service welding of fittings on the pipeline and preforming a hot tap. Although line stopping can reduce the amount of venting, flaring or fluid-handling, this means of isolation often requires land permits and excavation work, can be labour-intensive and leaves fittings on the pipeline that pose as a potential leak path on the pipeline system.

In-line isolation pigs are a piggable tool that can provide a fully proven and monitorable isolation that limits or eliminates the need for in-service welding and additional fittings on the pipeline. In-line isolation tools can also vastly reduce associated costs such as excavation, in-service welding and non-destructive examination, may eliminate land permit requirements, and reduces (or in some cases eliminates) outage time required when compared to traditional means of pipeline isolation. Similar to line stop tools, in-line isolation tools also limit the amount of fluid-handling or venting required which reduces the potential for harmful substance release or greenhouse gas emissions to atmosphere. In-line isolation pigs also make it possible to hydro or leak test newly installed pipework immediately after isolation by adding an additional isolation module.

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Double Block and Bleed Regulations

Alberta, Occupational Health and Safety Code (A.Reg. 191/2021): Part 15, Section 215.5(1)

"To isolate piping or a pipeline containing a substance under pressure, an employer must ensure the use of

- (a) a system of blanking or blinding, or
- (b) a double block and bleed isolation system providing
  - (i) 2 blocking seals on either side of the isolation point, and
  - (ii) An operable bleed-off between the 2 seals."

USA, OHSA, 1910.146(b)

"*Isolation* means the process by which a permit space is removed from service and completely protected against the release of energy and material into the space by such means as: blanking or blinding; misaligning or removing sections of lines, pipes, or ducts; a double block and bleed system; lockout or tagout of all sources of energy; or blocking or disconnecting all mechanical linkages."

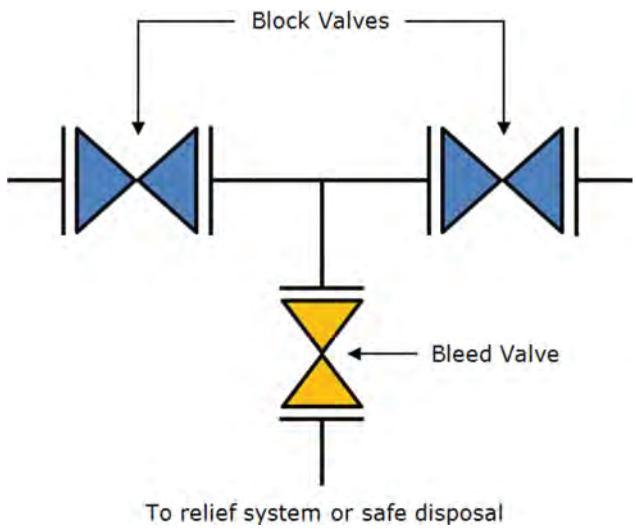

Figure 1. Double block and bleed arrangement for safe pipeline isolation.

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In-Line Isolation Pigs

In-line isolation pigs are a piggable tool that provide a double block and monitor pipeline isolation allowing for the system to remain pressurized, and in some cases, live and operational. Generally, an in-line isolation pigging train consists of one or two isolation modules and a control module. Depending on the pigging complexity and distance, a pigging module may also be used to aid in pigging drive through the pipeline system. When activated, the isolation module(s) grip and seal against the inner pipe wall using locks (grips) and seals (packers).

A single-module isolation tool uses dual seals separated by an annulus ring and set of locks. The annulus void between the seals is used to independently test the seals against full pipeline pressure to verify that both seals are leak tight before maintenance work is carried out. The annulus is also used to monitor the isolation and ensure the seals remain leak-tight throughout the duration of the work. The locks, which embed into the inner pipe wall, provide the grip required to secure the tool in place. A dual-module isolation tool uses the same principles as a single-module tool, however, there are two separate modules with a single packer and set of grips and the void between the isolation modules form the annulus for testing and monitoring. With either the single-module or dual-module isolation tool, an additional isolation module can be added to the tool train so that the newly installed pipework can be hydro or leak tested after installation.

Isolation modules also utilize the differential pressure acting across the tool to provide a fail-safe locking mechanism. When differential pressure is applied across the tool, the forces resulting from the differential overcome the method of activating the tool from the unset to set condition meaning that the tool remains set in place until the differential pressure is equalized across the tool (i.e. until the system behind the tool is made leak-tight and is able to be pressurized again).

A control module is used to operate and monitor the isolation module and for pig tracking. Through-wall communication is achieved using extremely low frequency (ELF) to operate and monitor the tool and for tracking. All communication and operational components are housed in a leak-tight body. Pigging discs are often fitted to the control module to provide pigging drive through the pipeline system.

Pigging modules can also be added to the in-line isolation tool depending on the pipeline layout and features encountered. For contingency, standard pig transmitters can be installed to the pigging module to assist in pig tracking or to conserve battery life of the control module if required. Wire brushes can be added to the pigging module in situations where build-up is expected on the inner pipe wall or for pipelines that are not often pigged or cleaned.

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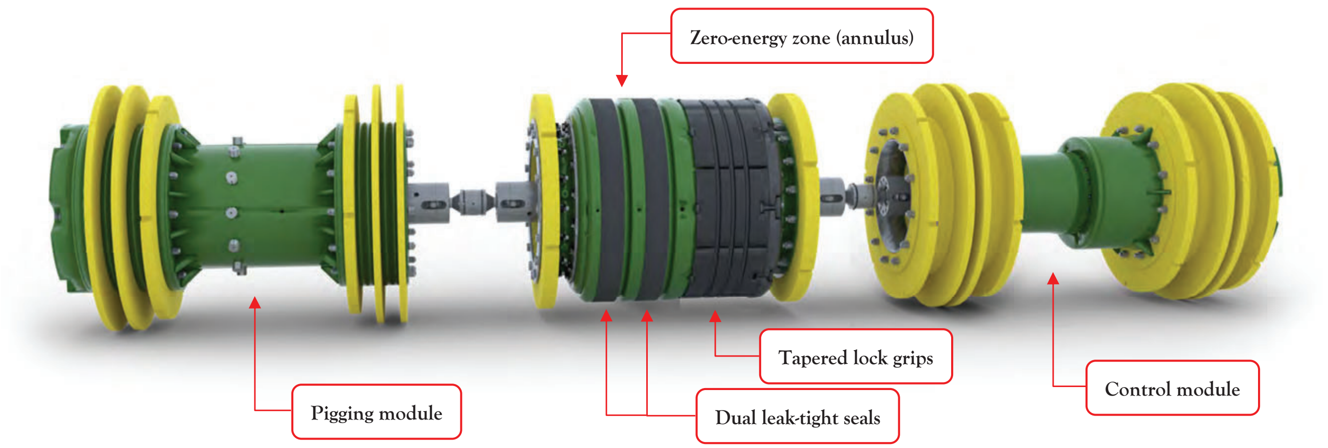

Figure 2. Example in-line isolation pig with single isolation module, control module, and pigging module.

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In-Line Isolation Tool Use

An in-line isolation tool can be used in a variety of different situations to suit an operator's requirements for a safe double block and bleed isolation of a pipeline. The tools can be used individually, or dual tool trains can be used to isolate specific pipeline segments. Some applications include:

- Pipeline valve replacement / repair
- Riser replacement / repair
- Pressure testing
- Midline pipeline or valve replacement / repair
- Pipeline diversion

Single Isolation

A common application for in-line isolation tools is at launcher or receiver sites for valve repair or replacement. In this situation, a tool is loaded into the pig trap then pigged to a pre-determined location using pipeline product or an alternative pigging medium such as water, glycol, or nitrogen. Movement of the tool is tracked using ELF communication and additional contingency measures such as non-intrusive magnetic pig-signallers and pigging volume records. When at the target isolation location, pigging is ceased allowing the tool to stop at the required position.

Once at the target isolation location, the tool is activated remotely via the control module and checked to confirm that the isolation module has been activated appropriately. Pressure behind the isolation tool can then be lowered to prove the integrity of the seals and ultimately lowered to ambient so that repair / replacement work behind the isolation tool can be conducted. During the repair / replacement work, the annulus between seals (packers) is monitored to ensure a leak-tight, double block and monitor isolation for the duration of the work.

Upon completion of the work being performed, pressure behind the isolation tool is equalized to the same pressure in front of the tool being isolated allowing the tool to be deactivated (unset) at which point the in-line isolation tool can be pigged to either the launcher or receiver. Depending on the design of the tool, pipeline pressure during isolation, and the proximity of the isolation location from the launcher, the bi-directional in-line isolation tool can be reverse-pigged back into the launcher. This can be achieved by using the residual line pressure in front of the isolation tool train as the pigging drive and venting pressure at the launcher to reverse pig the tool back into the launcher.

Dual Isolation

Another application for in-line isolation pigs is for isolating specific sections of pipelines for repair or replacement. This can include midline valve repairs, removing integrity concerns such as cracking or corrosion, or isolating riser sites to repair or replace pipework or valves, among many other applications.

When deploying dual in-line isolation pigs, the lead tool is installed in the launcher or receiver and pigged a pre-determined distance out which forms the desired separation between isolation points. The trailing tool is then installed in the launcher or receiver and the tools are pigged in tandem to

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the required isolation location. Accurate pigging planning and tracking is required to position the tools on either side of the target section of pipeline requiring isolation.

Once the tools are positioned appropriately, they are activated and the pressure between the tools lowered accordingly to prove the seals for the double block and monitor isolation. After proving the double block isolations, the isolated section of pipework can be repaired or replaced accordingly. Unlike single isolations, it is necessary to have a fill / vent port positioned between the tools in order to depressurize and remove product between the tools, then fill and equalize after the repair work is complete. In some cases, such as a dual isolation for riser site maintenance work, there may be offtakes on the line allowing the product to be handled. In other situations, such as replacing a pipe spool with corrosion or cracking features, it is necessary to install a fitting to allow the product to be removed, then added back in after the pipework is replaced.

Upon completion of the repair or replacement work, pressure between the in-line isolation tools must be equalized to the line pressure being isolated on either side of the lead and trailing tools. When unset (deactivated), the tools can then be pigged towards the receiver or back into the launcher depending on the distance being travelled. Often, the tools must be recovered from the launcher or receiver one at a time, but in some cases it may be possible to recover both tools in the launcher or receiver depending on the length of the pig trap and available equalization ports.

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Double Block Isolation Testing Sequence

To validate a double block and bleed isolation of an in-line isolation tool, a testing sequence is required. After the in-line isolation tool has been set (activated) at the target isolation location, a testing sequence is used to validate the primary and secondary seals of the tool. Below is the seal validation testing sequence of an in-line isolation tool comprising of a single isolation module with dual seals:

Stage 1: In-line isolation tool stopped at target isolation location

In this step, the position of the tool is confirmed utilizing the ELF communication system. Using the signal emitting from the control module, the location of the isolation module can be pinpointed to ensure that the isolation module is in straight pipe free of any girthwelds or offtakes.

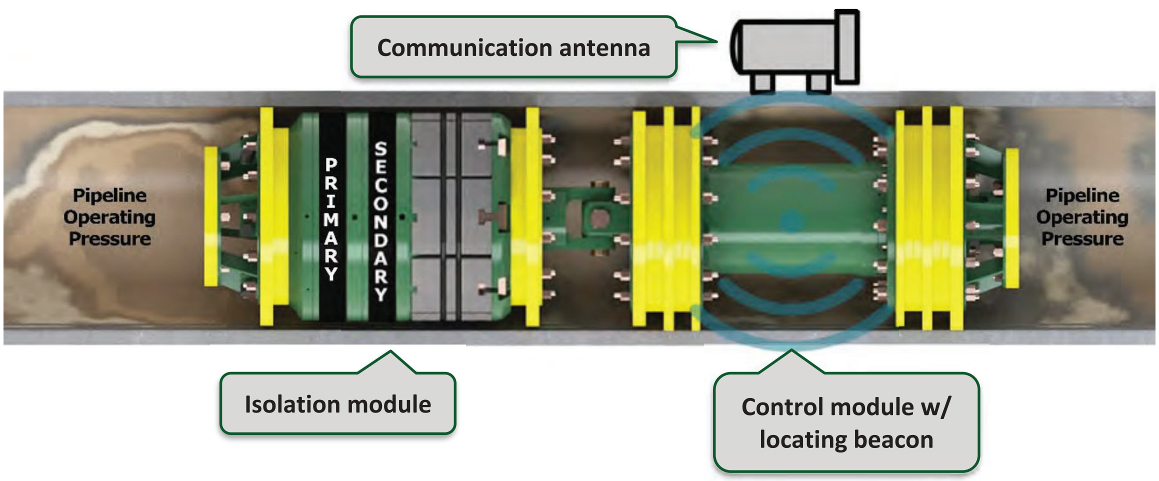

Figure 3. In-line isolation tool seal testing sequence, stage 1.

Stage 2: Set isolation module and monitor annulus

In this illustrated configuration of isolation module, the annulus pressure between the seals increases as the tool is set and the seals extrude to contact pipe wall. As the seals contact pipe wall and the rubber pressure increased, the volume of annulus space between the seals decreases, causing the pressure to increase. This increase in annulus pressure can be monitored allowing for an early indication of the quality of isolation prior to venting any product behind the tool.

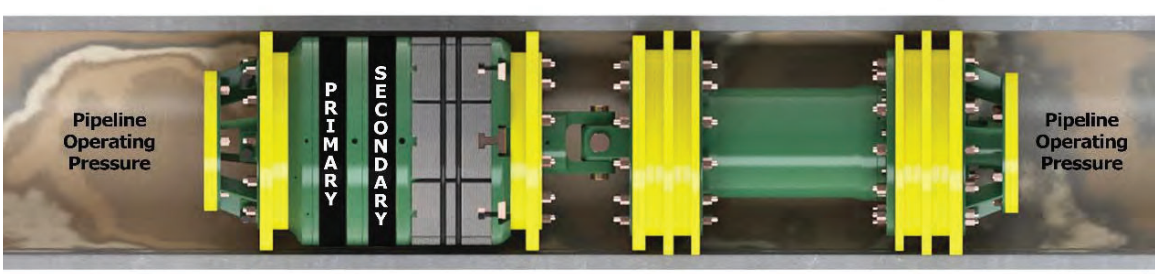

Figure 4. In-line isolation tool seal testing sequence, stage 2.

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Stage 3: Vent pressure behind isolation module to verify secondary seal

The next step in verifying the double block isolation is to vent the pressure behind the isolation module to ambient. The seal facing the pipeline pressure in front of the tool is identified as the primary seal, and the seal facing the annulus pressure is identified as the secondary seal. After venting the pressure behind the isolation tool, the secondary seal is now isolating against the pressure in the annulus, in this case being greater than the pipeline pressure in front of the primary seal. The annulus pressure is locked in and monitored for a predetermined duration to test the secondary seal. If no reduction in pressure is witnessed in the annulus, the secondary seal is verified as being leak-tight to greater than pipeline pressure.

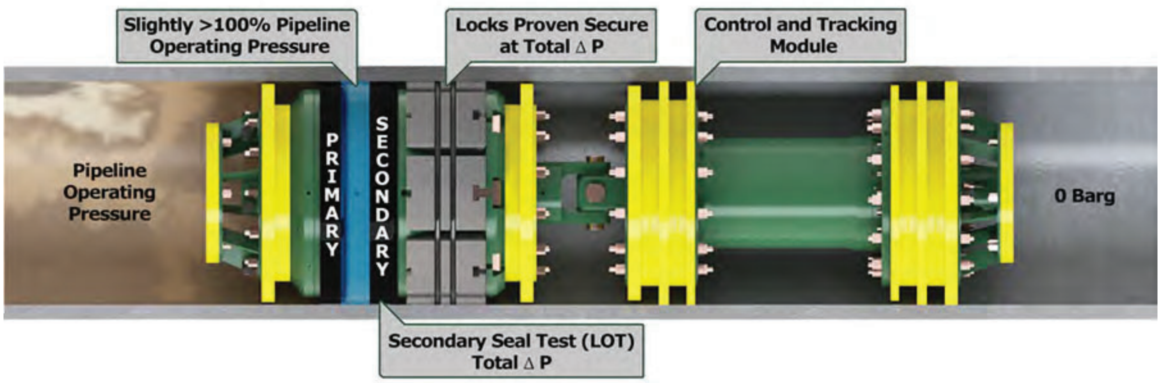

Figure 5. In-line isolation tool seal testing sequence, stage 3.

Stage 4: Vent pressure in annulus to verify primary seal

After the secondary seal has been tested, the annulus pressure is vented to ambient in order to verify the primary seal. Once the annulus pressure has been vented, it is locked in and monitored for a predetermined duration. If no pressure increase is witnessed in the annulus space for the duration of the test, the primary seal is verified as being leak-tight against pipeline pressure at which point both the primary and secondary seals have been independently tested to pipeline or greater than pipeline pressure, establishing a double block and monitor isolation.

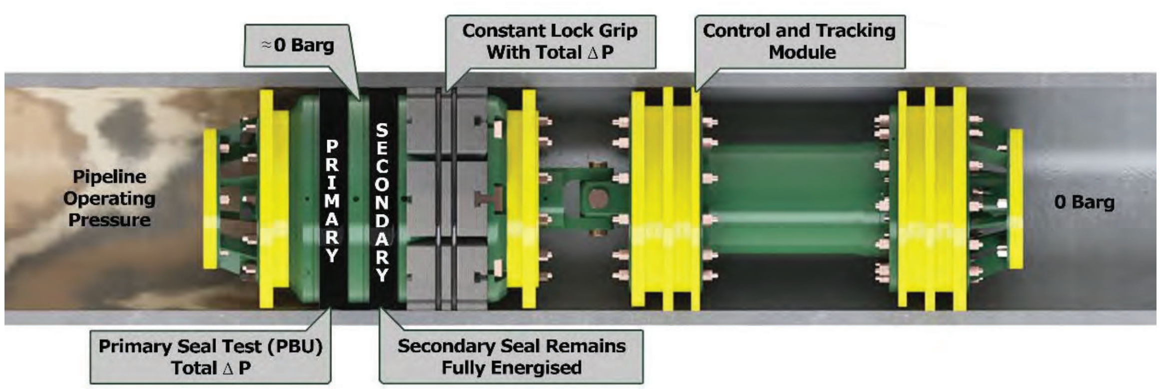

Figure 6. In-line isolation tool seal testing sequence, stage 4.

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Considerations for Utilizing In-Line Isolation Tools

As with any pipeline isolation scope, use of an in-line isolation tool to provide the necessary safety barrier against pressurized pipeline product requires careful planning and consideration. A successful isolation needs input and planning from both the operator and vendor. Below is a summary of some of the considerations that must be made to ensure a safe and successful isolation.

Table 1. Considerations for assessing and planning in-line isolation tool use.

Parameter	Considerations
Pigging	Review of in-line inspection data to ensure in-line isolation tool is appropriately sized and capable of traversing all features encountered. Caliper data is useful to ensure appropriate size of isolation tool and magnetic flux leakage data is useful to ensure the planned isolation location is free from cracks and corrosion. In some cases, a gauging pig is used to ensure the isolation module is capable of passing all features such as valves, tees, and bends. Gauging pigs are particularly useful for long-distance pigging runs or where ILI data or sufficient drawings are not available. Pigging procedure with a tracking locations, anticipated pigging speeds, and steps necessary to land tool at required isolation location(s).
Pipe Stress	When an isolation tool is set in a pipeline, the seals (packers) and locks (grips) impart stresses on the pipe wall. Accurate information about the pipe material and grade (strength) at the target set location along with wall thickness and anticipated isolation pressure are required to assess the stresses imparted on the pipe and to ensure that they do not exceed code allowables.
Launcher / Receiver Infrastructure	In-line isolation tools are either pushed or pulled into a launching or receiving trap prior to deployment. It is important to ensure there is sufficient length in the major and minor barrels for the in-line isolation pig and that there are adequate fill and vent points for equalizing the trap pre- and post-deployment. It is also required to ensure that there is sufficient access and space behind the launching and / or receiving trap to install and recover the in-line isolation tool.
Battery Life	The control module of the in-line isolation tool is powered and operated via batteries. Battery lifespan of the tool depends on how the tool is utilized during the lifespan of the scope of work. It is imperative to accurately anticipate the required battery usage for a particular scope of work and build in contingencies for battery life.
Communication	In-line isolation tools utilize extremely low frequency for communication while the tool is in the pipeline. At a minimum, tests must be performed at the site the tool will be launched from and at the target isolation location. The tests are conducted to ensure that there are no background frequencies that would impede or inhibit communication with the isolation tool. There are also limitations to the depth of cover and pipe wall thickness in which the ELF communication system is capable of penetrating through. It is imperative to ensure that the communication system is programmed appropriately for the launching and receiving sites and target isolation location.

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Operator Benefits

Reduction in Pipeline Downtime and Pipeline Medium Handling

Use of in-line isolation tools for pipeline maintenance can reduce or even eliminate pipeline downtime. Consider replacing a receiver trap valve; by using an in-line isolation pig, the tool can be loaded into the receiving trap, pigged to the isolation location just meters upstream of the valve using pipeline product, water, or nitrogen, then set in place to provide the necessary isolation. From the time of opening the receiver valve once the outage starts to when the tool is set in place providing the isolation can take only a few hours, depending on the hold times for seal testing. Product behind the tool can be recompressed or drained to sump and the valve can be replaced in a short outage window.

On the other hand, the alternative may be utilizing an upstream mainline valve likely many kilometres away from the receiving trap to provide the isolation. Product between the upstream mainline valve would need to be purged, vented, flared, or recompressed which could take a significant amount of time and effort associated with a gas purging, recompression, or product handling.

Another scenario is use of dual in-line isolation tools to provide a mainline isolation for riser pipework repair, pipeline spool replacement, etc. The isolated section of pipework can be reduced to meters compared to many kilometres between mainline valves. Furthermore, the line can remain operational as the tools are pigged to and from the target isolation location.

Safe Breaking of Containment

As discussed previously, use of an in-line isolation tool has the advantage of providing a proven double block and monitor isolation. By going through the testing sequence, the positive isolation can be provable and monitorable prior to breaking containment.

Limited or No Requirement for Welding Fittings to Pipeline

In scenarios such as launcher and receiver trap valve or riser maintenance work, there is often no requirement for installing new offtakes for product handling. Infrastructure often exists at these sites that can be utilized for product venting/purging and filling/equalization. Alternatively, small offtakes may be necessary in some cases such as midline isolations using dual in-line isolation tools. However, the size and quantity of fittings can be significantly reduced. Using in-line isolation tools for the isolation may require one or two small offtakes compared to multiple size-on-size fittings and additional small purge and equalization fittings for an isolation provided by a line stop tool.

Limited or Eliminated Requirement for Land Permits and/or Excavation

Use of in-line isolation tools can also reduce or eliminate land permit and/or excavation requirements. Communication with the control module of the tools can be achieved through depth of cover such that it is not a requirement to excavate the pipeline at the target isolation location.

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Therefore, operators only need to expose the pipe or features requiring repair and replacement which can reduce or eliminate the amount of excavation work required when compared to other methods of pipeline isolation.

Case Study: In-Line Isolation for Receiver Valve Repair

This case study highlights some of the key benefits of using in-line isolation tools for pipeline isolation. For this scope of work, an operator was required to repair a leak from the stem of a receiver trap valve on a 36" natural gas pipeline. On this particular system, the nearest mainline valve was approximately 28 km upstream of the receiver trap valve. The receiver trap valve requiring repair was buried below grade, therefore there was no pipework above grade available to install a split tee fitting for an intervention style of isolation. Furthermore, at this receiver site, there was enough space between the receiver trap valve and production tee for an in-line isolation tool. Therefore, there was no requirement for an outage to complete the valve repair work when using an in-line isolation tool.

After selecting to use an in-line isolation tool to provide the isolation for the receiver valve repair, the tool was loaded into the receiver and pigged against flow to the target set location upstream of the receiver trap valve. Being at a compressor station, the operator was able to pig the in-line isolation tool using natural gas through the kicker line delivered at a pressure higher than the incoming pipeline pressure. Once at the target isolation location, the in-line isolation tool was activated and a positive isolation was confirmed by carrying out the seal verification tests. Because the tool was set only a few meters upstream of the receiver trap valve, the volume of gas requiring blowdown between the in-line isolation tool and receiver was minimimal.

Following the blowdown and seal verification tests, the operator was able to safely repair the leak from the stem of the receiver trap valve while the isolation was monitored and the pipeline remained in service. After completing the valve repairs, the pressure between the receiver and in-line isolation tool was equalized allowing the tool to be unset (deactivated). The tool was then reverse-pigged back into the receiver by lowering the pressure at the receiver.

Below is a comparison of the methods of isolation that could have been used for this scope of work:

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Table 2: Comparison of isolation alternatives for receiver trap valve repair.

Method of Isolation	Considerations for Selecting Method of Isolation
Blowdown of mainline between nearest upstream MLV and receiver	Nearest upstream MLV was approximately 28 km upstream of the receiver valve equating to roughly 707,352 Sm^3 of natural gas or 13,589 tonnes of CO_2e if vented, or 1,742 tonnes of CO_2e if flared. Required pipeline outage for blowdown and receiver valve repair (potentially longest downtime of the alternatives considered). Given the age of the pipeline and infrastructure, operator was not confident in the quality of isolation of the upstream MLV.
Line Stop (Intervention)	Required excavation of pipeline upstream of receiver trap valve to install a fitting. Potentially highest cost due to excavation, NDE, fitting cost, and in-service welding. Added integrity concern with buried flanged fitting.
In-Line Isolation Tool	Non-intrusive in-line isolation. No excavation required. Lowest emission footprint. No pipeline outage required. Lowest overall cost and least amount of time in the field.

Carbon Pollution Pricing and Restrictions

In June of 2018, Canada adopted the Greenhouse Gas Pollution Pricing Act (GGPPA) which is a two-part system; a regulatory charge on fossil fuels (fuel charge) and a performance-based system for industries known as the Output Based Pricing System. The approach to pricing carbon pollution is flexible such that jurisdictions may design their own pricing system to suit their local needs, however, the Canadian government has set a "federal benchmark" that each jurisdiction must meet.

In August of 2021, the Canadian government updated the minimum national standards for carbon pollution pricing for the 2023 – 2030 period. The federal benchmark for carbon pollution pricing for the 2023 – 2030 period is summarized in the table below[1].

Table 3. Canadian government minimum carbon pollution price for the 2023 - 2030 period.

Year	2023	2024	2025	2026	2027	2028	2029	2030
Minimum Carbon Pollution Price ($ CAD / tonne CO_2e	$65	$80	$95	$110	$125	$140	$155	$170

Looking back at the case study previously presented, the benefit of utilizing an in-line isolation tool to limit greenhouse gas emissions becomes evident. It was calculated that using an in-line isolation tool to provide the isolation required to repair the receiver valve prevented the emission of approximately 13,589 tonnes CO2e if vented, or 1,742 tonnes of CO_2e if flared. If repeating this

[1] Update to the Pan-Canadian Approach to Carbon Pollution Pricing 2023-2030 (2021) Government of Canada. Available at: https://www.canada.ca (Accessed 10 January 2024)

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scope of work in 2024, at a minimum, the operator would save approximately $140,000 in carbon emissions taxes.

Summary

In-line isolation tools are an effective solution to reduce pipeline downtime and product handling requirements when an operator must isolate their pipeline to preform maintenance or improvement activities. The tools are piggable and provide a non-intrusive barrier that is a provable double-block and monitor isolation. In-line isolation tools can be used alone as a single isolation barrier (typical for launcher/receiver valve replacements scopes), or in tandem as a dual isolation to isolate a specific pipeline span or feature (pump station riser site isolations, isolations for removing integrity concerns such as cracks, corrosion, or strain, and mainline valve repair/replacement, among other scopes). Furthermore, additional isolation modules can be added to the in-line isolation tool train that can be used to hydro or leak test new or repaired pipeline features post-installation.

Testing the quality of the isolation and confirming a double block and monitor isolation prior to breaking containment is a critical feature of in-line isolation tools that ensure the safety of individuals working behind the isolation barrier and limits the amount of pipeline downtime and product handling requirements on site.

Pipeline isolation scopes utilizing in-line isolation tools requires involvement from both the operator and tool provider to ensure a safe and efficient deployment, however, there are many advantages for use of an in-line isolation tool, some of which include:

- Reduction in pipeline downtime and product handling requirements
- Safe breaking of containment
- Limited or no requirement for in-service welding of fittings onto pipeline
- Limited or eliminated requirement for pipeline excavation

In this paper, a case study was presented which highlights some of the key benefits of in-line isolation tools. In the case study presented, an in-line isolation tool was used to provide an isolation at a receiver site of a 36” natural gas pipeline so that the receiver trap valve could be repaired. Use of an in-line isolation tool was selected over alternative pipeline isolation methods due to the benefits provided.

Finally, an emerging trend of carbon pollution pricing and greenhouse gas emissions restrictions and taxing was highlighted in Canada. Such restrictions can present new challenges to operators in terms of how they isolate and maintain aging pipelines further demonstrating the effectiveness and benefits of the utilization of in-line isolation tools.

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