

Topical Report

on

## **Gas Pipeline Pigability**

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## **Abstract**

In-line inspection equipment is commonly used to examine a large portion of the long distance transmission pipeline system that transports natural gas from well gathering points to local distribution companies. A piece of equipment that is inserted into a pipeline and driven by product flow is called a 'pig'. Using this term as a base, a set of terms has evolved. Pigs that are equipped with sensors and data recording devices are called 'intelligent pigs'. Pipelines that cannot be inspected using intelligent pigs are deemed 'unpigable'. But many factors affect the passage of a pig through a pipeline, or the 'pigability'. The pigability pipeline extend well beyond the basic need for a long round hole with a means to enter and exit. An accurate assessment of pigability includes consideration of pipeline length, attributes, pressure, flow rate, deformation, cleanliness, and other factors as well as the availability of inspection technology. All factors must be considered when assessing the appropriateness of ILI to assess specific pipeline threats.

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## **Executive Summary**

Pipeline inspection tools, commonly referred to as intelligent ‘pigs’ for historical reasons, have been used to detect corrosion and other pipeline anomalies since the 1960’s. However, these tools are useable on a fraction of transmission pipelines and few distribution lines. The term ‘pigability’ is used to describe the ability to have a pig enter and exit a pipeline without damage to the pipe or the tool. The pigability requirements of a pipeline extend well beyond the basic need for a long round hole with a means to enter and exit. An accurate assessment of pigability includes consideration of pipeline length, attributes, pressure, flow rate, deformation, cleanliness, and other factors as well as the availability of inspection technology. A flow chart that includes these factors can be used to assess the appropriateness of ILI to assess specific pipeline threats. Since other methods to assess the serviceability of pipelines exist, economic factors are also important and should be considered in the assessment of pigability.

## **Introduction**

Various types of devices have been used in pipelines for a long time, primarily for cleaning, liquid removal, etc. Such devices have been frequently referred to as “pigs,” which is a designator that was inspired by the sounds emitted by early applications of gas-driven internal cleaning devices such as scrapers. This name was inherited by applications of instrumented in-line inspection (ILI) tools (also known as “smart pigs”) for pipeline integrity assessment that began in the late 1960s.

## **Pipeline Integrity Assessment Using ILI**

Gas pipeline integrity assessment has been conducted using ILI tools since the late 1960s. These ILI tools were based on MFL technology tools, and were capable primarily of detecting the metal loss associated with corrosion. Over time, ILI tool technology has evolved to include detection and sizing (in some cases) of corrosion and other integrity threats that may be detected in gas pipelines.

Recent regulatory and industry emphasis on pipeline integrity management has resulted in development of ASME B31.8S, which outlines the process an operator may use to implement an integrity management program. ASME B31.8S forms the basis for the integrity management regulations that will be incorporated into 49 CFR 192 later in 2004.

ASME B31.8S describes the particular threats that must be evaluated and the integrity assessment methods that can be used to address each one. This includes ILI, pressure testing, and direct assessment. Each of these integrity assessment methods is appropriate for assessment of one or more of the specific threats described.

Prior to applying one (or more) of these integrity assessment techniques, a threat assessment should have been conducted to establish which threats are credible. This would make it possible

to select the appropriate integrity assessment method to evaluate a threat. In some cases more than one integrity assessment method would be used. Where ILI is determined to be an effective integrity assessment method, the appropriate ILI technology would then be selected to evaluate the threats. In addition, the suitability of the selected ILI technology(s) in the affected pipeline or segment must then be considered. ASME B31.8S and NACE Standard RPO102-2002 provide guidance on ILI technology applications.

**Definition of “Pigability”**

For the purposes of this document, the term “pig gable pipeline” means a pipeline that is suitable for the economic operation of a gas-driven, instrumented in-line inspection (ILI) tool. Within the context of this definition, it is also assumed that the pipeline internal conditions and operating parameters are such that acceptable inspection results suitable for integrity assessment can be obtained.

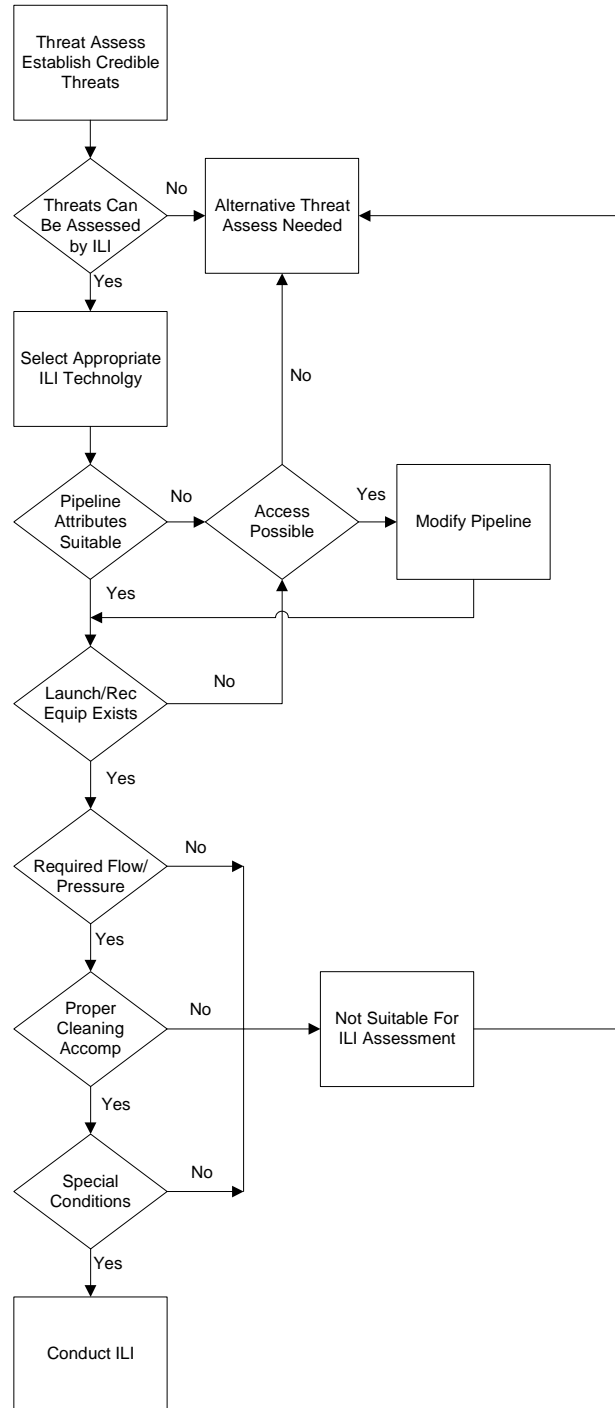
Historically, pigability has been defined according to criteria based primarily on the physical attributes of the pipeline or segment being considered. In one case, a pipeline or segment that has been constructed (or modified) to permit free passage of ILI tools has been considered as “pigable.” For instance, 49 CFR 192, Section 150 includes a clause requiring that new or replacement pipe sections must be “designed and constructed suitable to accommodate the passage of an instrumented internal inspection tool.” As such, this definition implies that pigability is based on pipe and component attributes, but does not imply that launcher/receiver facilities are required. Other definitions have also included the presence of launcher/receiver equipment necessary to operate an ILI tool as part of the definition. One example is a recent gas pipeline industry study (13) that investigated the pigability of pipeline systems. The results of that study were categorized according to a tiered definition shown in the following table:

Pipeline Attributes	Category
No pipeline modifications needed Launcher/Receiver installed	Pigable
Minor pipeline modifications required such as temporary launcher/receiver installation	Easy to pig
Pipelines requiring major modifications	Difficult to pig
Other (pipelines attributes not defined)	Impossible to pig

A fundamental part of the definition of pigability is that the pipeline has internal dimensions suitable for ILI tool passage. Likewise, the presence of launching and receiving equipment is essential for ILI operation. However, neither of these attributes provides assurance that a pipeline can be successfully assessed with an instrumented ILI tool (5). For the pipeline operator, the issues and realities of “pigability” are more far reaching. Pipeline attributes are one part of the issue, but other aspects of pipeline operations should be considered when determining the suitability of gas driven ILI tools.

## The Overall Pigability Issue

The following discussion covers the overall issue of pigability beginning with pipeline threat assessment described in ASME B31.8S through the various aspects that ultimately affect ILI operation. This discussion follows the flow diagram illustrated in Figure 1.



**Figure 1. Flow diagram for determining pigability from the aspect of threat assessment.**

In terms of implementing an integrity management plan (IMP), the first step is the evaluation of potential threats that exist in the pipeline or segment being considered and their credibility. Once the credible threats are established, the appropriate integrity assessment method(s) are then selected. Where instrumented ILI tools are deemed appropriate, several preliminary aspects must then be considered. Otherwise, alternative integrity assessment methods that may include pressure testing and direct assessment will be required.

The first decision point shown in Figure 1 concerns the availability of inspection technology. Each inspection technology implementation must be examined to determine suitability of both assessment of threats and passage of pipeline attributes.

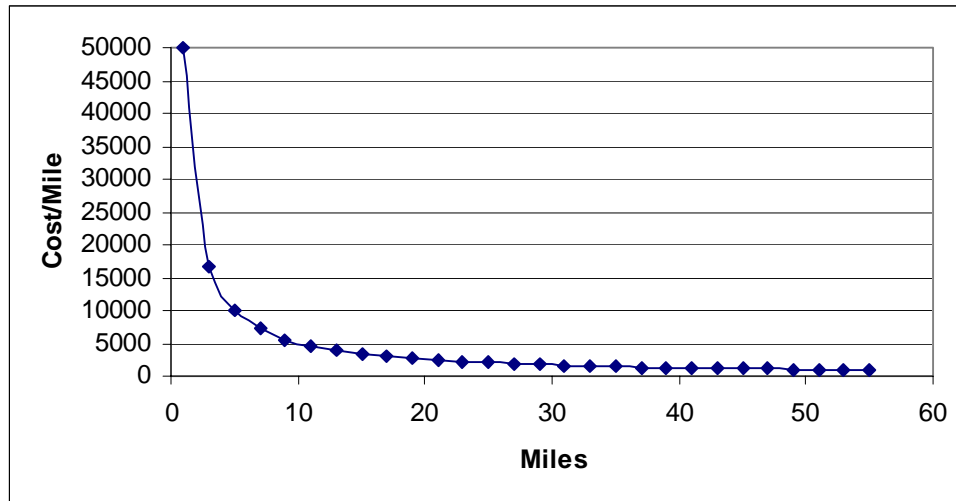
Some pipelines may constitute a single source of gas supply to a locale that cannot be easily interrupted, even for scheduled ILI or other maintenance operations. If an interruption does occur, alternative (and often very expensive) gas supply sources, such as truck-transported bottled gas, may be required to maintain service. Even where suitable permanent launchers and receivers (or some temporary configurations) are available, pipeline operating characteristics may need to be modified to conduct a successful ILI integrity assessment. Such operating parameter modifications can impact gas delivery and may not be acceptable to the operator. Furthermore, a more detailed pigability assessment should be performed to ensure free passage of ILI tools.

The length of the pipeline or segment to be assessed is also an important initial consideration. It is rarely practical to run gas driven ILI tools in short segments of pipeline that might include a short, high consequence area (HCA), crossovers between pipelines, and short length laterals. Equipping such pipelines or segments for periodic ILI tool operation would be expensive unless the equipment was also used for other pipeline operational purposes, such as liquid removal. Furthermore, the required gas flow conditions for proper ILI operation may be difficult to achieve in short segments. Costs for gas-driven ILI tools are typically compared on an approximate cost/mile basis that includes the ILI vendor's fixed mobilization charge. Figure 2 is a typical cost/mile curve that illustrates that gas-driven ILI run lengths should exceed about 30 miles to approach the least unit cost. Other types of instrumented ILI tools (i.e., wireline ILI tools) are more appropriate for shorter lengths of pipe.<sup>1</sup>

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<sup>1</sup> Wireline ILI tools are typically suitable for up to 20-inch OD pipe with bend radii no less than 15 times the pipe diameter.





**Figure 2. Plot of cost per mile for pipeline lengths to about 55 miles.**

Some other initial considerations include the particular instrumented ILI technology that is capable of assessing the established threats, and the suitability of that technology in gas pipelines. Each of the available ILI technologies has its strengths and limitations; no specific ILI technology is applicable in gas pipelines in all cases. ILI tools equipped with MFL technology can be applied in gas pipelines primarily for detection and sizing of ID/OD corrosion. However, these ILI tools cannot accurately size narrow corrosion grooves nor can they detect axial planar defects oriented parallel to the pipe axis. In order to overcome this problem, transverse flux MFL tools have been recently introduced as an ILI technology. These are intended to locate and size longitudinally oriented defects, but they have not been fully proven to date.

Ultrasonic ILI tools are more successful at detecting planar defects such as cracks, but typically they must be run in a liquid medium to provide a coupling to the pipe surface. In gas pipelines this can be accomplished by running the ILI tool in a liquid slug confined between two poly pigs. For gas pipelines with few appurtenances (i.e., laterals, etc.) that can be isolated, this can be a practical approach. In other cases, properly isolating the section to maintain a liquid slug may not be feasible practically and/or economically. Therefore, if a threat such as SCC is determined to be an issue in a segment that cannot be suitably isolated, the pipeline could be considered “unpigable” with respect to the assessment of that particular threat. Depending on the threats identified, more than one ILI tool may be needed, thus requiring multiple ILI tool runs.

Pipeline operating pressure and flow conditions can dictate if it is feasible to satisfactorily operate an ILI tool. Low pressure (400 to 600 psi) and flow conditions may not be sufficient to efficiently drive a pig. A minimum gas pressure is needed to assure stable ILI operation since higher pressures create a higher density fluid column behind and in front of the pig, thus minimizing speed variations and surges. The effects of low pressures can be more extreme in hilly terrain, because the gas column would not effectively restrain the tool, thus permitting velocity variations. Instrumented ILI tools should be operated within their recommended velocity ranges to achieve optimum inspection results. For example, MFL tools operate typically at

speeds of 3 to 7 mph; inspection results can degrade when an ILI tool is operated out of the recommended range, especially where excessive velocities occur.

Typical pipeline operating parameters may require modification to control flow rates and product pressures in order to optimize ILI inspection results. In some pipelines, the pressure increases needed to assure satisfactory ILI operations may be precluded by MAOP or other pressure limiting restrictions. This may include pressure regulator adjustments, compressor station operation modifications, and flow throttling with valves. ILI tools equipped with gas bypass technology are now being applied to provide improved inspection velocities in a wider range of flow conditions.

Other operating conditions that can affect ILI operations include gas corrosivity that may damage ILI tool components, and high temperatures (> ~150 F) that can damage on-board electronic components.

Some pipelines contain identified threats that can potentially affect ILI passage, including deformation and mechanical damage such as dents. Deformation may result from the action of outside forces such as slides or floods. ILI passage can be limited by more localized pipe deformation, such as dents resulting from rocks in the right of way and impacts on the pipe, a leading cause of pipeline incidents. Deformation may reduce the pipe internal cross section to the point that ILI tool passage may be impaired and repair would be required prior to attempting an ILI tool run.

Other construction-related threats such as wrinkle bends can have sufficient associated pipe deformation to impede pig passage. Mechanically coupled pipelines can be another issue affecting ILI tool applications. Although some coupled pipelines have been successfully assessed. ILI passage is not restricted by mechanical couplings, but there is a potential safety issue due to the lateral deformation that may be result when the tool passes a coupling that is not sufficiently supported by the backfill.

Pipelines can contain dirt, debris, debris, and deposited solids such as salt. Solid deposits (i.e., salt) can form an adherent solid barrier that affects pig passage and adversely impacts ILI data quality and that can be very difficult to remove. Depending on conditions, pre-ILI cleaning can be an essential element in obtaining good quality integrity data. Such foreign materials can interfere with the sensors on instrumented ILI tools and also affect the accuracy of geometry tools that may be run prior to the ILI. Cleaning can be accomplished by various methods including chemical and dry (scrapers, brushes, magnets) (4). Although an ILI tool could be run in a dirty pipeline, the resulting data would be questionable, thereby implying a “pigability” issue.

The most frequently quoted criteria that impact pipeline “pigability” include physical attributes such as reduced port or plug valves, short radius or miter bends, back-to-back bends, and branches or tees (side or inverted positions) without bars. Pipelines with any of these attributes must be modified prior running an instrumented ILI tool. Other common features such as pipe diameter changes (> 2 inches) can also prevent a continuous ILI run but can usually be assessed

in separate segments.<sup>2</sup> Another similar issue is the presence of pipeline drips for fluid collection. In some cases, a larger diameter pipe section (expansion chamber) is installed in the pipeline above the drip to reduce the gas velocity and promote liquid drop-out into the offline drip barrel.<sup>3</sup> Some check valves can have internal dimensions larger than the pipeline. Depending on the magnitude of such internal diameter increases, the ILI tool driving force imparted by the flowing gas may be reduced to the point the tool stops.

Heavy wall pipe sections, such as those at road crossings and required by 49CFR 192 for class 2 to class 4 locations, are another pipeline attribute that can affect pig passage. Line pipe is purchased based on outside diameter tolerances, so the internal cross section is reduced as the wall thickness increases. This reduced internal cross-section diameter of heavy wall pipe can encroach on the minimum required diameter for ILI passage. Although some ovality is present in most line pipe, its effect is more critical when considering ILI passage in heavy wall pipe through further reduction of the internal bore. Pipeline components such as induction bends and ells are often formed from heavy wall pipe to allow for thinning that occurs during the forming process. The combination of heavy pipe walls and ovality in induction bends have caused ILI tools to become stuck in a pipeline.

Other attributes that are less frequently cited can also impact pigability. One such feature is a suspended, aerial pipeline crossing. The additional dynamic stress created by the moving ILI tool should be considered. Also, the configuration of the pipeline entering and exiting such a crossing may preclude ILI passage. This type of feature would impede the continuous pigability of a pipeline or segment, although the adjacent pipeline could be evaluated separately.

The tiered definition of “pigability” described above includes the presence of launcher/ receiver equipment. Several typical launcher/receiver configurations are:

- Permanent launcher/receiver equipment installed.
- Pipeline equipped with permanent piping transitions to the mainline that include full opening valves and flanges that permit attachment of launcher/ receivers and associated piping while the line is in operation. ILI tools can then be run without removing the pipeline from service.
- The pipeline or segment is removed from service, cut, and temporary launcher/receiver equipment is attached at the open ends to run the ILI tool. The temporary equipment is then removed and the segment is re-inserted into the line following completion of the ILI tool run.

The first two launcher/receiver configurations facilitate ILI tool runs since the pipeline does not have to be removed from service. These would be acceptable options for pipelines that serve areas without redundant gas supply. The third option requires service interruption and access to

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<sup>2</sup> Multiple diameter pipelines present an economic issue since more than one ILI tool and additional launcher/receiver equipment would be required.

<sup>3</sup> Instrumented MFL ILI tools have been developed that can accommodate diameter changes > 2 inches but can only be used in certain circumstances and is not applicable for general commercial applications.

two locations for launcher/receiver installation and removal. In locations where access to the pipeline is an issue and continuous supply is required, this option would significantly impair “pigability” even though the pipeline attributes are suitable for ILI tool passage. Another related issue concerns some pipelines that are equipped with permanent launcher/receiver equipment that are too short to accommodate instrumented ILI tools.

Some pipes are not suitable for in-line inspection. For example, pipelines constructed of seamless pipe can present unique log interpretation problems, especially for MFL ILI tools. Welded pipe produced from plate or skelp typically has a uniform wall thickness with good surface quality. Seamless pipe, however, is often eccentric with a systematic wall thickness variation around the pipe circumference. Also, the piercing process used in seamless pipe production tends to introduce deformation at the pipe ID surface which is detected by ILI tools. Compared to welded pipe, the inherent surface roughness of seamless pipe is another issue. These features combine to produce higher ILI signal “noise levels” (high signal/noise ratio) that are difficult to separate from defect signals when interpreting the log. This reduces the accuracy of the integrity assessment made from the ILI log. For ultrasonic ILI tools, the inclusion content is an important factor. The inclusion content can vary significantly from joint to joint, such that one joint permits a high-quality inspection and the next is cannot be inspected.

## Conclusion

The pigability requirements of a pipeline extend well beyond the basic need for a long round hole with a means to enter and exit. An accurate assessment of pigability includes consideration of pipeline length, attributes, pressure, flow rate, deformation, cleanliness, and other factors as well as the availability of inspection technology. All factors must be considered when assessing the appropriateness of ILI to assess specific pipeline threats.

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