Tool Solutions for Unpiggable Pipelines

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INTRODUCTION
As a leading company in the field of pipeline integrity, GE has a wealth of experience inspecting pipelines, assessing the significance of defects, and recommending repair and mitigation strategies. The projects carried out by GE include many interesting and challenging examples. One of the most frequent challenges is the problem of inspecting multiple diameter or ‘unpiggable’ pipelines.

This paper describes the development of a specific dual diameter high resolution MFL inspection tool for Williams Gas Pipeline, and the evolution of even more adaptable tools for inspecting pipelines that were previously classed as unpiggable.

BACKGROUND TO DEVELOPMENT OF THE DUAL DIAMETER INSPECTION TOOL
For inspection of pipelines containing two diameters, standard pigs can be adapted to do the following:
- Accommodate a 2” difference in diameter for pipelines in the range 8” to 30”
- Accommodate a 4” difference in diameter for pipelines in the range 30” to 48”
- If the diameter change is greater than this, then specially developed pigs are needed

In 2004, Williams Gas Pipeline (WGP) asked PII to develop a 36” high-resolution magnetic flux leakage (MFL) pig capable of passing through 30” valves having a 28.000” minimum internal diameter. PII accepted the challenge and produced such a pig within seven months of being awarded the project.

Before shipping the tool over to the U.S. to be run for the first time, GE/PII completed a mechanical test of the pig to ensure the pig could pass through a pipeline with features expected in the Transco system.

After the mechanical test summary, details of WGP’s experience during the three runs completed in 2004 are provided. Velocity plots for each of the three MFL runs are provided and they reveal how the pig performed while passing through the valves.

THE NEED FOR A COLLAPSIBLE PIG
Williams Gas Pipeline has two interstate gas transmission systems: Northwest Pipeline and Transcontinental Gas Pipeline (Transco). The Transco system includes approximately 16,000 km of mostly 30”, 36”, and 42” pipelines. From 1948 through the 1970s, Transco reduced pipeline installation costs by installing valves one size smaller
than the mainline diameter. This reduction in valve size reduced the installation cost without a significant increase in pressure drop. However, when these decisions were made, the need for pigging was not fully appreciated. Prior to the development of the collapsible 36” pig, a high-resolution MFL tool was not available to Williams Gas Pipeline for pigging its 36” pipelines with 30” valves. If WGP wanted to inspect the lines with a high-resolution tool, the valves would need to be removed.

In accordance with Regulations, WGP will inspect approx 1,600 km of 36” pipeline by 2012 that have 30” valves. Without a collapsible tool, approximately forty-seven 30” valves would need to be replaced at a cost of approximately $16 million ($350K/valve). Similarly, the 800km of 30” pipeline that Transco must inspect by 2012 would require the replacement of approximately twenty-five 24” valves at a cost of $9 million. In addition, to inspect the 337 miles of 42” pipeline, WGP would need to remove seventeen 36” valves at a cost of $6 million.

Rather than spend $31 million on valve replacements, WGP sought the development of collapsible high-resolution tools capable of passing through the smaller diameter valves. For the 276 km of 36” diameter pipeline with reduced port valves scheduled for 2004, Williams Gas Pipeline began by asking PII North America to develop a 36” collapsible tool for 2004.

**WGP’S EXPERIENCE WITH LOW-RESOLUTION COLLAPSIBLE PIGS**
Williams Gas Pipeline first began working on developing collapsible pigs in the 1990s. A low-resolution 30” collapsible tool capable of passing through 24” valves was first run in June, 1995. The tool was designed to pass through a minimum diameter of 22.5 inches and through 1.5D ells. The tool was successfully developed and since 1995, 995 miles of 30” pipeline with 24” valves have been inspected.
24” gate valve with 30” x 24” concentric reducers.

30” x 24” collapsible low-resolution pig
In 1995, a 36” collapsible tool was also built and tested by another vendor. The vendor and design were the same as the 30” tool. By 1998, a new 36” tool was developed that was capable of traversing a valve with a minimum diameter of 27”. The 36” tool, like the 30”, is still an active tool for the ILI vendor.

Although the tools described above were successful at negotiating reduced port valves, they are nonetheless low-resolution tools. While the technology of MFL pigs has steadily increased every year, these particular collapsible tools have remained low resolution. In 2004, WGP’s desire was to have high-resolution collapsible tools capable of providing more accurate predictions of corrosion lengths and pit depths than the low-resolution tools.

GEOMETRICAL PERFORMANCE REQUIREMENTS
Williams Gas Pipeline required the 36” collapsible tool to meet the following specifications concerning pipe geometry:

- Minimum diameter – 28”
- 3D back-to-back bends
- Maximum diameter of a barred tee – 36”
- Maximum diameter of an unbarred tee – 24”
- Gas Temperature – 57 deg C

GE’s PII organization was able to meet all the above requirements. However, the temperature requirement should be qualified. As it turns out, none of the three runs in 2004 had temperatures higher than PII’s capability.

CORROSION DETECTION PERFORMANCE REQUIREMENTS
As far as corrosion detection capability, WGP asked that the tool meet the same specifications as PII’s standard high-resolution tool. This includes the following detection and accuracy capabilities for general corrosion for DSAW pipe:

- Detection of general corrosion of 4t x 4t
- Depth accuracy of 0.1t
- Corrosion Length - +/- 20mm
- Corrosion Width = +/- 20mm

PII designed the tool to meet the same specification as its standard tool.

PIPE AND OPERATING PARAMETERS
Below is information on the pipe and operating system for the three runs pigged in 2004 using the 36” x 30” collapsible tool:

- 36” pipe
- Wall thickness ranged from 8.7 to 16.9mm, with most in the range of 10.3 to 12.7mm
- Operating pressures: generally near 55 bar at launch, and 38 bar at the receiver
- Speed – goal was 2.2 m/s
- Actual gas temperatures at launcher was 40 deg C maximum

**DEVELOPMENT OF THE COLLAPSIBLE PIG**

A kickoff meeting was held in November, 2003 between PII and WGP. This meeting marked the beginning of the design efforts for PII on development of the collapsible pig. Within 7 months of this meeting, PII tested the 36” x 30” collapsible tool. However, it would not be the first high-resolution collapsible tool developed by PII - it was actually the fifth high-resolution collapsible tool.

When beginning this project, PII first assumed a previous 48” X 36” design would be the best to emulate. However, PII design engineers determined that the minimum ID of the valves would not permit the use of this design. Therefore, an adaptation of an alternative design was ultimately selected as the best solution. The high drag cups were replaced with the flap type arrangement (butterfly cups) from the 48” x 36” design with the specific intent of reducing the drag in the valves in order to minimize the speed excursions in the gas line. PII used a computer model to predict the speed excursions and this data was communicated to WGP during the design phase. By January of 2004, PII had completed design of the collapsible pig.

Fabrication of the tool began in January of 2004 and was completed by April of 2004. A mechanical test of the tool was completed on April 15, 2004, with a data test completed less than one week later. All tests were successful. The pig was shipped to the U.S. and by June 3, 2004, the first run was completed with the tool.

**PHOTOGRAPHS OF THE COLLAPSIBLE PIG**

Below are photographs of the collapsible tool taken in England during the mechanical pull tests. Descriptions of noteworthy features are included beneath the photographs.
The section shown in the photo above is the “drive section” that includes the magnetic brushes and the primary magnetism sensors. Features to note:

- Front cups are butterfly (minimize drag in the small bore)
- Long bristles – 50% of the bristle length will fold back in a valve

MECHANICAL PULL TESTS
Before running the collapsible tool in a live line, PII completed a mechanical pull test to confirm the pig was capable of traversing the various features expected during the run without suffering damage. The most important part of the test was passage through a 30” valve with concentric reducers.

For the mechanical test, WGP provided a 30” valve with concentric reducers to PII typical of 30” valves in the Transco system. PII constructed a run of pipe with the various features to be negotiated by the pig, including the valve. Below are photos showing the features PII included in the mechanical tests.
One of the first features passed by the pig in the mechanical testing was the 66% unbarred opening. The hot-tap size limit on the Transco system is 66% of the main pipe diameter. There are many such taps on the Transco system, with nearly all being side taps. However, to ensure the worst-case scenario was tested, PII placed the 66% opening on bottom. Above is a photo of the opening.
The most critical feature of the mechanical test – the 30” valve with concentric reducers

36” barred opening as the pig passes

The above feature would typically be encountered at the launcher and receiver (as the sidegate piping to the station is passed).
The blue equipment in the photo above is the winch that was used for the pull test. The equipment is capable of measuring and recording the force required to pull the pig through the piping. During the testing, ranges of speeds from 0.4 to 4 m/s were covered. The average pull force in the 36” diameter pipe was 10,080 lbf, equating to 0.7 bar differential pressure acting across the pig (were pressure differential the driving force). The peak force (15,680 lbf) occurred when the pig was collapsing through the 28.25” diameter valve. This equates to a 1.7 bar pressure differential acting across the pig.

For comparison, the low-resolution tool developed in 1998 (and described previously) had a pull force of 63,000 lb through a similar valve. This is equal to approximately 4.1 bar of differential force required to drive the pig through the valve, versus 1.1 bar for the high-resolution tool.

The pig successfully completed all mechanical testing. Within a few days of mechanical tests, the pig was pulled through pipe with known anomalies as part of a data test. Several tests were required to calibrate the tool.

**PERFORMANCE OF THE PIG IN 2004**
The collapsible pig successfully completed three pig runs in 2004 totaling 173 miles in 2004.

Although all three runs were ultimately successful, there were lessons learned and modifications made in order to complete the runs.

**Lesson One – Geometry Drive Cups**
The first lesson learned during actual field operations on the collapsible runs involved the geometry tool. Prior to running all MFL tools, WGP runs a geometry tool. For the 2004
Transco smart pig program, Positive Projects (a PII subsidiary) provided the geometry tools.

A few weeks before the first MFL from Station 130 to 140, the geometry tool was run. When the tool went through the valves, it came to a complete stop (as expected). The field personnel tracking the pig said they could hear the cups pop as the pig slowly progressed through the valve. When the pig left the valve, it left at a very high speed, resulting in damage to the tool. After studying the run data, Positive Projects determined that the cup style would need to be changed and installed butterfly cups similar to those used on the MFL tool. Photos of the original cup design are below.

Once the new cups were installed, the geometry pig performed very well when encountering reduced port valves. Out of fourteen reduced port valves, the geometry tool came to a complete stop only once when passing through the valves. As such, the velocities when exiting the valve were not excessive; none were above the limit of 3.5 meter/sec.

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Lesson – 1.5D Fittings
This lesson learned involved the geometry tool, although indirectly. WGP initially requested that PII design the collapsible tool to negotiate back-to-back 3D fittings. This was based on the assumption by WGP Engineering that all ells in the system were 3D. However, many of the geometry runs completed in 2004 (12 total) revealed 1.5D fittings.
In the collapsible runs, two 1.5D 30-degree ells were found on the 130 to 140 run. No 1.5D fittings were found in the 505 to Roseland or the 180C15 to 190 run.

PII determined that the collapsible tool is capable of traversing a 1.5D fitting, provided it is not back-to-back with another fitting and provided the fitting angle is 30 degrees or less. Fortunately, all 1.5D fittings discovered thus far have been 30 degrees or less.

**Speed Excursions**

One of the pleasant surprises to WGP was the performance of the tool entering and leaving valves. Based on experience with the low-resolution tools, WGP expected the tool to stop in the valve and for the pressure to increase 0.7-1 bar. After a sufficient differential pressure was reached, it was expected that the tool would leave the valve at a high rate of speed (exceeding the speed at which anomaly data could be collected). It was expected that the pig would slow down to acceptable speeds within 300 to 600 m.

However, the actual performance was much better than expected. On two of the runs, the speed never exceeded the maximum limit for grading anomalies (5 m/s). On the third run, the speed was exceeded on three of the five valves. However, the distance at which the speed was exceeded was immeasurably short. All data was usable. PII noted that this performance was not a surprise to them – it was what they intended to achieve with their design.

![Velocity Plot for the Station 130 to Station 140 Run](image-url)
OTHER DEVELOPMENTS
GE’S PII is developing a new suite of collapsible pigs based on a new design concept. WGP will use the first of these pigs to be developed in the size 26” x 20”. These tools are designed to be launched conventionally or through purpose-designed 45 degree hot tap Tees that are installed on the pipeline for this purpose.

CONCLUDING REMARKS
The development of the 36” x 30” high-resolution pig in 2004 by PII was a success. The tool is capable of passing through 28” diameter valves located on the WGP-Transco system. This tool should save WGP $16 million in valve replacement costs. Assuming the 30” and 42” collapsible tools are also developed, a total savings of $31 million should be realized. This tool also reduces the outages required to replace the valves, minimizing interruptions to WGP Operations and to WGP Customers. Also, eliminating valve replacements reduces the number of opportunities for Company and contract personnel to become injured during gas handling and construction activities associated with the valve removals.

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