Increase Pipeline Flow Efficiency

DSc Dževad Hadžihafizović (DEng)

Sarajevo 2024

TABLE OF CONTENTS

SECTION I: PURPOSE OF PIGGING

1.0 Introduction 1
2.0 Cleaning 1
3.0 Batching 2
4.0 Displacement 3
5.0 Internal Inspection 3

SECTION II: PIPELINE DESIGN CONSIDERATIONS

1.0 Introduction 5
2.0 Pipeline Design for Pigging 5

SECTION III: PIG LAUNCHING AND RECEIVING TRAPS

1.0 Introduction 9
2.0 Launch and Recovery Procedures 10
3.0 Sample Pigging Systems 15

SECTION IV: SELECTING THE RIGHT PIPELINE PIG

1.0 Introduction 17
2.0 Pig Selection 18

SECTION V: PIGGING NEW CONSTRUCTION

1.0 Introduction 23
2.0 Selecting the Pig 23
3.0 Propelling the Pig 24

SECTION VI: ONSTREAM PIGGING OF NATURAL GAS LINES, NATURAL GAS LIQUIDS AND REFINED PETROLEUM PRODUCTS

1.0 Introduction 29
2.0 Selecting the Pig 30
3.0 Speed 31
4.0 Frequency 32
5.0 Performance 32

SECTION VII: ONSTREAM PIGGING OF CRUDE OIL LINES

1.0 Introduction 33
2.0 Selecting the Pig 34
3.0 Pigging Speed 35
4.0 Frequency 35
5.0 Performance 36

SECTION VIII: INLINE INSPECTION TECHNOLOGY
1.0 Introduction 37
2.0 Preparing the Line 37
3.0 Inline Inspection 38
4.0 Survey Selection 38
5.0 Geometry Inspection 39
6.0 Metal Loss Inspection 41
7.0 Seam Weld Inspection and Other Longitudinally Oriented Anomalies 43
8.0 Geometry, Metal Loss, Long-Seam, Longitudinal, Hard Spot Inspection 44
9.0 Crack Inspection 46
10.0 Pipeline XYZ Mapping 46
11.0 Leak Detection and Location 49
12.0 Survey Results 50
SECTION IX: Maintenance, Cleaning and Storage of Pigs and Components
1.0 Introduction 53
2.0 Maintenance 53
3.0 Cleaning 53
4.0 Storage 55
Appendix I:
Pipeline Pigging Questionnaire 57
Appendix II:
Inline Inspection Questionnaire 61
Appendix III:
Useful Conversion Factors 67
Appendix IV:
Common Acronyms 69

Purpose of Pigging

1.0 Introduction

There are four basic reasons to pig a pipeline:

A. Cleaning: Lines are cleaned to improve flow (throughput) and to control internal corrosion.

B. Separating Products (Batching): Pigs are often inserted between two dissimilar products to avoid mixing. This is referred to as batch pigging.

C. Evacuation (Displacement): Pigs are used to displace one product type with another. For example: In a new construction application, the air is displaced with water, the water is displaced with air and the pipe dried; the dry air is displaced with nitrogen or the primary product to be moved through the pipeline (oil, refined products or gas).

D. Internal Inspection: Federal law requires pipeline owners to periodically inspect their pipelines. See Section VIII for more information. Most pipeline operators are required to implement an IMP (Integrity Management Plan). Most IMP's incorporate the use of internal inspection pigs. These inspection pigs come in a variety of shapes and sizes with each providing data which detects dents, buckles, metal loss and cracking.

2.0 Cleaning

2.1 Increase Pipeline Flow Efficiency

Pigs are run to maintain line efficiency. Any decrease in pipeline efficiency reduces the throughput of a pipeline, leading to lost revenue. The importance of operating at high efficiency is illustrated by the following examples:

A. A one percent increase in efficiency of a natural gas pipeline transporting 100 million cubic feet a day (2.8 million cubic meters) can increase throughput by one million cubic feet a day (.028 million cubic meters).

B. A three percent increase in efficiency of a crude or product pipeline transporting 50,000 barrels a day (135,950 cubic meters) can increase throughput by 1,500 barrels a day (4,078.5 cubic meters).

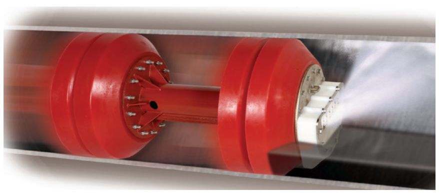
It is difficult to make a pipeline 100 percent efficient. Friction and other physical factors reduce flow. In a natural gas transmission line, compressor overflow oil, corrosive elements, mill scale, dust, distillate, and condensation can form to coat the inside of the pipe. Paraffin and sand buildup in crude lines, increased liquids in multiphase gas lines, and solids buildup in product lines present somewhat the same problem. In all cases, the contamination buildup increases resistance to flow which decreases pipeline efficiency or increases cost of transmission.

Flow, pressure drop, and operating cost are factors used to determine line efficiency. Should a line need cleaning, a pig is inserted into the stream to clean the pipe wall, thereby increasing flow. Figure 1 shows a cleaning pig being loaded into launcher.

Fig 1. Loading a Cleaning Pig

2.2 Corrosion Control

Fig 2. V-Jet® Corrosion Inhibitor Pig



Pigs are used to improve and maintain internal pipe cleanliness by removing contaminates and deposits on the pipe wall. Periodic line cleaning with pigs can remove many of the corrosive elements. Pigs can also be used with chemical corrosion inhibitors to mitigate the effects of corrosion. For example, a specialty pig can distribute corrosion inhibitor onto the inside of the pipe walls as shown in Figure 2.

Corrosive situations which can be remedied, at least in part by pigging, include:

A. Water and other fluids which settle out of gas, crude, or products due to insufficient flow velocity for entrainment, intermittent flow, or pressure/temperature related solubility changes. These fluids can contain oxygen, hydrogen sulfide, carbon dioxide, chlorine, salts, acids and other corrosives.

B. Loose sediment, including corrosion products, scale, sand and dirt, which usually promote formation of local corrosion cells on a pipe's bottom quadrant, especially in conjunction with conditions listed above.

C. Corrosion products such as wax or other solid deposits adhering to the pipe wall can shield corroding areas, thereby limiting effectiveness of other corrosion mitigation measures such as chemical inhibition.

3.0 Batching

Fig 3. OptionAll™ Batching Pig

The mixing of two products as they are pumped through the line is sometimes referred to as contamination. There are at least three sources that create this contamination in a products pipeline, namely:

A. Flow regime

B. Pipeline design

C. Operating procedures

When contamination occurs between two products, the mixture must be handled in some manner. The most frequent occurrence is to cut out the mixture and re-blend it with one of the two products or another product being currently handled.

To prevent contamination, a batching pig, shown in Figure 3, is inserted into the stream, either at the interface or at the beginning and end of a buffer batch which is inserted between the two products. When the product arrives at the final terminal, contamination and re-blending are minimal.

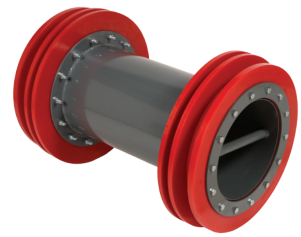
4.0 Displacement

Hydrostatic testing involves purging a section of pipeline of all air, filling it with water, and then pressurizing the line to a specified test pressure for some period of time. Upon completion of the test, the water is removed so the line can go on-stream.

Displacement pigs are used to displace air ahead of the hydrostatic test water, and to displace water after the hydrostatic test.

Displacement pigs are also used to displace a hazardous hydrocarbon material with an inert gas to perform field repairs. A bidirectional displacement pig is shown in Figure 4. In some cases, multi-cupped and foam pigs can also be used for displacement.

Fig 4. 24-inch Displacement Pig for Bidirectional Applications



5.0 Internal Inspection

Internal inspection pigs, sometimes referred to as “smart pigs,” are used to detect pipe anomalies which may result in pipe failure, loss of life, and property damage. Refer to Section VIII to gain a better understanding of inline inspection (ILI) pig technology.

Fig 5. Magnetic Flux Leakage Tool (Smart Pig)

Pipeline Design Considerations

1.0 Introduction

Pipelines should be designed to ensure a trouble-free pigging operation. Basically, a pipeline needs a consistent open bore from start to finish if it is to be pigged successfully and consistently. In designing a pipeline to be pigged, the following should be considered:

- Length of pig run
- Bend radius and degree of bend
- Valve type
- Pig passage indicators
- Tees
- Laterals
- Pipe inside diameter
- Dual diameter lines

2.0 Pipeline Design for Pigging

2.1 Length of Pig Run (Distance between Launching and Receiving Traps)

The distance between pig traps is often determined by either the pump station locations, natural length of pipeline, and/or the availability of a site capable of launching and receiving pigs. The following are maximum recommended distances for given product types. These recommended distances are based upon a pig being able to traverse a distance in a given product and remain relatively effective throughout the length. Natural gas lines, due to the nature of a dry gas containing sand or mill scale, tend to be most abrasive, causing pigs to wear-out more quickly. Crude oil pipelines offer a natural lubrication, prolonging the life of pigs.

A. 100 miles (160 km) for gas pipelines.

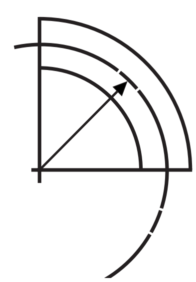
B. 150 miles (240 km) for product lines.

C. 200 miles (320 km) for crude oil lines.

2.2 Bends

A. Bend Radius is defined as: the arc length taken from the radius point to the center of the bend, measured in pipe diameters. See Figure 6.

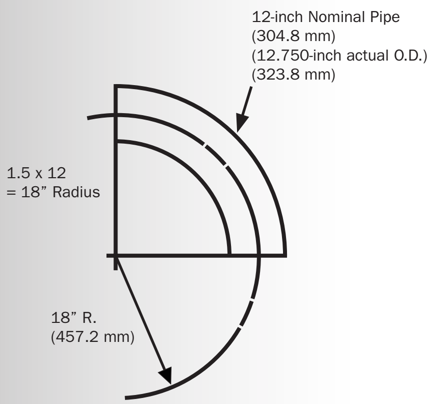
Fig 6. Radius



B. Each pig is designed to traverse a certain minimum radius bend. One pig may traverse a 1.5 DR -90 degree bend; another may traverse a 1.5 DR- 45 degree bend while a third may only traverse a 3 DR - 90 degree bend. It is common to find 1.5 DR bends in natural gas lines, 3 DR bends in liquid systems, and possibly 1 DR bends in small refinery piping, A bend has two identifying components: 1) Bend radius 2) Degree of Bend.

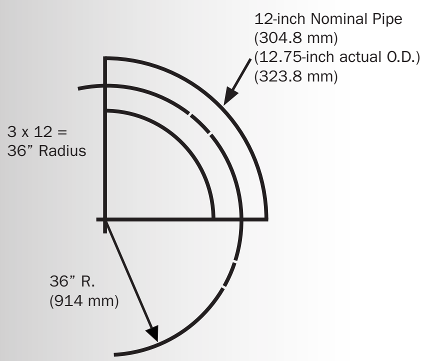
C. Degree of Bend is defined as the angle change in direction of the pipe, measured in degrees. The degree of bend in Figure 6 is 90 degrees. Most pigs will not traverse 1 DR bends nor miter bends. Examples of typical bends include:

Fig 7. 1.5 DR Bend



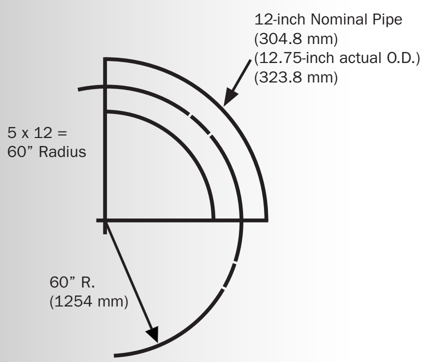
- 1.5 DR Bend: A 1.5 DR elbow has a bend radius equal to 1.5 times the nominal pipe diameter. A 1.5 bend in a 12” pipeline would have a bend radius of 18” and is shown in Figure 7.

Fig 8. 3 DR Bend



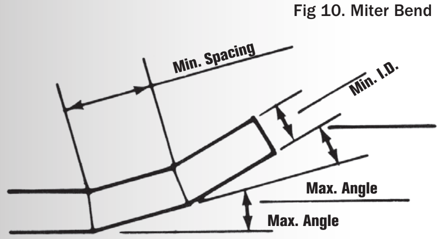
- 3 DR Bend: A 3 DR elbow has a bend radius equal to 3 times the nominal pipe diameter. A 3 DR bend in a 12” pipeline would have a bend radius of 36”, as shown in Figure 8.

Fig 9. Field Bend



- Field Bend: A field bend is a bend conducted in the field during the pipeline construction. This is normally accomplished using a bending machine and the bend radius in usually 5 DR or greater. See Figure 9.

Fig 10. Miter Bend



- Miter Bend: Miter bends sometimes occur in older pipelines when the direction change is accomplished by miter cutting short sections of pipe, then welding them together to change the pipe direction, as shown in Figure 10. Today’s pipeline construction codes do not allow the use of miter bends in energy related pipelines due to the pressure containing weakness.

2.3 Valves

Full-opening/Full-bore through conduit gate valves and ball valves provide unobstructed pig passage through the line. However, if older gate valves, such as that shown in Figure 11 are used, compare their seat ring spacing with the maximum seat ring spacing specified for the pig.

If check valves are used, the pig must be able to span the bowl length (see Figure 12). Spheres and short pigs will often stop in the bowl and allow the product to bypass around them in this oversized area.

If motorized automated valves are used in station piping, electric pig signal indicators (Figures 13-15) can be considered as switches to open and close valves as the pig traverses through the station main line piping.

2.4 Pig Passage Indicators

Pig passage indicators, shown in Figures 13-15, are used to detect a pig passing a given point. They are commonly used to show that a pig has left a launcher or has entered the receiver trap.

Pig signal indicators are also used as switches to automatically control valving at pump or compressor stations as the pig passes through.

Fig 11. Seat Ring Spacing

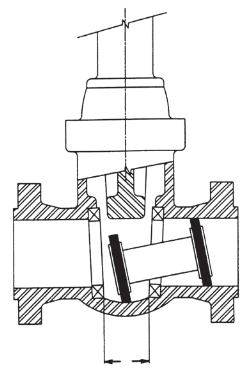


Fig 12. Sphere in a Check Valve

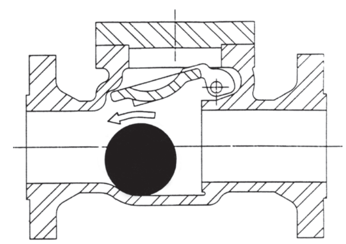


Fig. 13. PIG-SIG® IV Pig Passage Indicators

Fig 14. PIG-SIG® V with Electrical and Flag Indicators

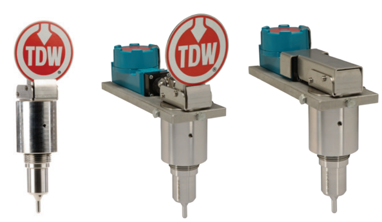


Fig 15. PIG-SIG® NI^{XT} Pig Passage Indicator

Fig 16. Coupon Attached to Completion Plug

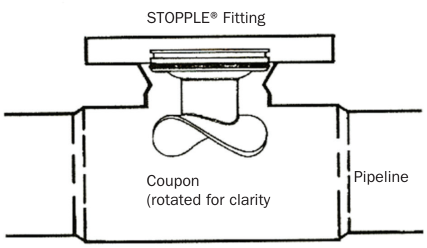


Fig 17. LOCK-O-RING® with Guide Bars

Fig 18. Bypassing at Side Openings Causes Pig Stoppage

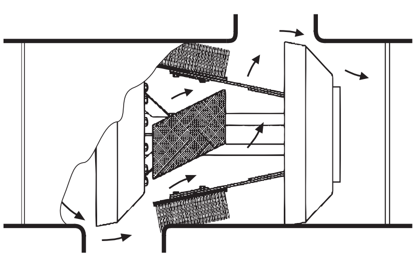
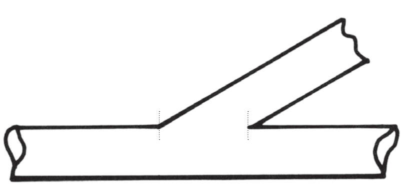


Fig 19. Typical Lateral



2.5. Tees

Inline tees with outlets which are 50 percent or greater of main line pipe size should have guide bars installed across the branch. This prevents the pig or cleaning element from entering the branch outlet. The coupon should be replaced in the tapped hole (Figure 16) on STOPPLE® fittings. On tapping tie-in fittings it is recommended a flow-through plug assembly be installed (Figure 17).

Avoid welding tees adjacent to one another. Such fabrication can cause a pig to stop in the line because of the large volume of bypass around the cups. See Figure 18.

2.6. Laterals

Figure 19 illustrates an angled lateral. Compare the lateral branch length to pig length. The pig must be able to span the lateral opening.

2.7 Pipe Inside Diameter

Drastic changes in the pipe inside diameter (ID) should be avoided. Compare the (ID) of the line to the pig cup's minimum and maximum pipeline inside diameter. Line ID changes should be within these specifications.

2.8 Dual Diameter Lines

Pipelines containing different diameters of pipe should be avoided. However, there is a selection of dual-diameter cleaning, batching and inspection pigs. We recommend carefully selecting a dual-diameter pig for the given application.

Pig Launching and Receiving Traps

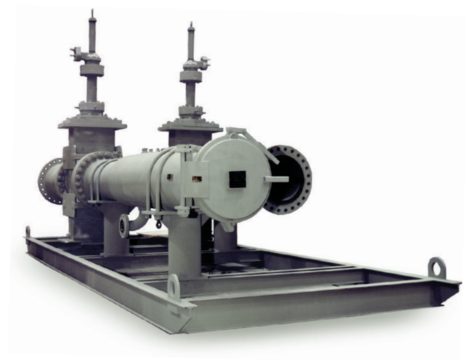
1.0 Introduction

The primary purpose of a pig launcher and receiver is to launch and/or receive a pipeline pig into/from a pipeline system without interruption of the flow. Pipelines operate 24 hour a day, seven days a week, 365 days a year delivering product to their users. Operators cannot afford to shut down the operating system just to pig the line. Besides that, it is product flow through the pipeline that moves the pig along. Therefore, a pigging system allows the pigs to be launched and received without flow interruption.

Pig launching and receiving systems vary from one to another depending on specific purpose and product. Variations include placement of valves, length of launch/receive tube, and type of closure door, to name a few. In recent years, the design of “standard” launchers and receivers has changed because of federal regulations requiring in-line inspection, the length and weight of in-line inspection tools, and resultant safety considerations. Thus, procedures for operating a system will vary from one system to another. Specific launch and receive procedures must be developed for each system. Various systems are shown at the end of this section. A typical pig launch system is shown in Figure 20.

Use of all the identified valves is required to complete a safe and successful pig launch. If the valves are not opened or closed in the proper sequence, damage to pig and pipeline system may occur. Therefore a proven operating procedure must be followed in each launch operation.

Fig 20. Typical Pig Launching System

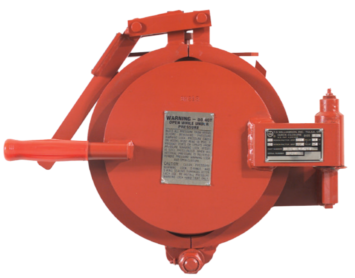


2.0 Launch and Recovery Procedures

Due to the varying configurations, launching and receiving procedures must be established for each unique system design. The following procedures are to be used as guidelines for a basic pigging system and may not be appropriate for any given system.

One of the most critical operations is opening the closure door (access to the trap). The operator must ensure that the trap has been drained and that there is no pressure inside before opening. Examples of closures shown below have a pressure warning lock which must be opened prior to opening the closure door. Opening this lock provides a positive indication of whether pressure exists or not.

Fig 21. Trap Closures



D-2000 Clamp Ring Closure

D-500 Threaded Closure

Shown in Figure 21 are a threaded closure for smaller traps and a clamp ring closure, which can be used on the largest closure. On the larger clamp ring closure, ratchet assists are available to help the operator open the clamp rings, then open the door. Each of these types has a pressure warning lock that must be opened prior to opening the door.

Things to remember in launching and receiving a pig:

- Never open or close a valve without knowing the specific function of that valve.
- Open and close valves slowly.
- When the closure door is open during the insertion or removal of a pig, there is a risk of explosive gas-air mixture. Any ignition source should be eliminated.
- Never stand in front a closure door when opening or closing.
- Before attempting to open a closure door, confirm that there is no internal pressure in the trap. Make sure vent and drain valves are fully open.
- Wear appropriate safety clothing when conducting pigging operations.
- Have appropriate safety equipment available in case of emergency.
- Avoid breathing hazardous material, and always follow described procedures for the disposal of hazardous waste.
- The following are generic launch and recovery procedures for typical operating systems. Since the procedures for liquid and gas systems are different, they are covered separately. A liquid launcher must be drained into a sump tank whereas a gas launcher is normally vented to the atmosphere.

2.1 Launch Procedures Liquid Service *

Refer to Figure 22. Starting condition: The trap is pressurized and full of liquid. Valves A, B and C are open. Valves D, E and F are closed.

A. Close Mainline Trap Valve A and Trap Kicker Valve C.

B. Drain the launching trap by opening Drain Valve E and allow air to displace the liquid by opening Vent Valve(s) D.

C. When the trap is completely drained and vented (zero psig), with valves D still open, open the closure door and insert the pig so that the first cup forms a tight fit in the reducer at point X. If a large and heavy inline inspection pig, it can be pulled into the trap by opening and using the pulling nozzles.

D. Close and secure the closure door. Close Drain Valve E and leave Vent Valve(s) D open. If the pulling nozzles were used, close these valves or replace the flanges. Slowly fill the trap through the Trap Kicker Valve C and Equalization Valve F, and vent the air through Vent Valve(s) D. When filling is completed, close valve(s) D to allow pressure to equalize then close valve C and F.

E. Open Valve A first and then Valve C. The pig is now ready for launching.

F. Partially close the Mainline Bypass Valve B. This will increase the flow of liquid through Valve C and into the trap behind the pig. Continue to close Valve B until the pig moves out of the trap into the main line as signaled by the PIG-SIG® pig passage indicator.

G. When the pig leaves the trap and enters the main line, open Valve B fully.

* This publication is not intended to replace product manuals. Please see the appropriate product manuals for complete instructions/procedures.

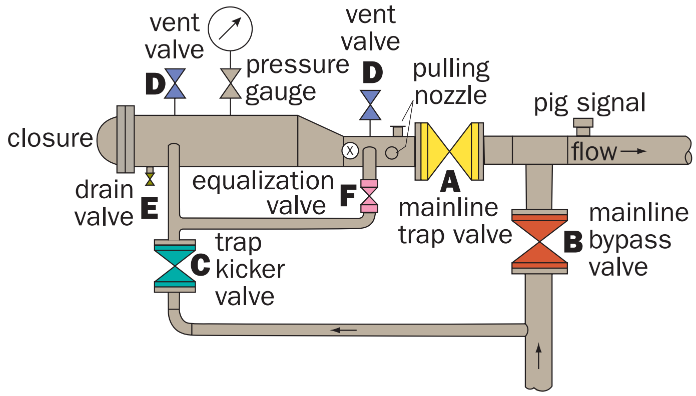


Fig 22. Launching Procedures, Liquid Pipeline

* This publication is not intended to replace product manuals. Please see the appropriate product manuals for complete instructions/procedures.

2.2 Receiving Procedures Liquid Service *

Receiving systems are slightly different than launch systems. The most notable differences are length of piping, location of PIG-SIG Indicator and bypass piping.

As in launching a pig, receiving a pig should follow a described sequence to avoid similar problems. Therefore, the following procedures should be utilized to receive pigs. Refer to Figure 23.

Starting Condition: Trap is empty at atmospheric pressure. The Mainline Bypass Valve B, Drain Valve(s) D and Vent Valve E are open. The Mainline Trap Valve A, and the Return Line Valve C is closed. The closure door is closed and secure.

A. Close Drain Valve E. Slowly fill the trap by opening Return Line Valve C, venting air through Valve(s) D.

B. When trap is full, close Vent Valves D to allow trap pressure to equalize with line pressure through Return Line Valve C.

C. With Return Line Valve C open, open Mainline Trap Valve A. The trap is now ready to receive a pig.

D. When the pig arrives, it may stop between the tee point X and the Mainline Trap Valve A.

E. Partially close Valve B. This will force the pig into the trap due to increasing flow through Valves A and C.

F. When the pig is in the trap as signaled by the PIG-SIG pig passage indicator, open Valve B completely and close Valves A and C.

G. Open Drain Valve E and Vent Valves D and drain the trap of liquid and pressure.

H. After the trap is fully drained (0 psig), with valves D and E still open, open the closure door and remove the pig.

I. Close and secure the closure door.

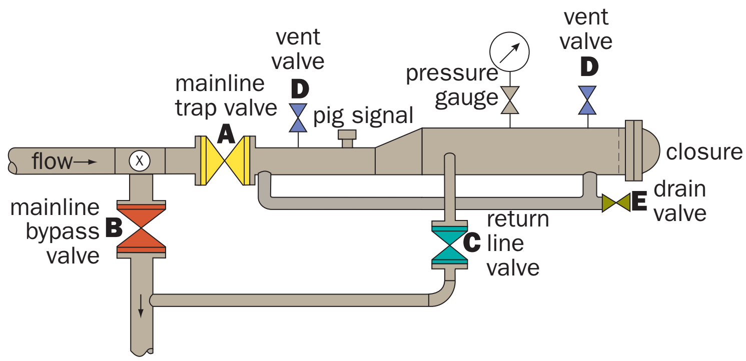


Fig 23. Receiving Procedures, Liquid Pipeline

2.3 Launch Procedures Gas Service *

Refer to Figure 24. Starting condition: Trap is pressurized and full of gas. Mainline Trap Valve A, Main-line Bypass Valve B and Trap Kicker Valve C are open. Vent Valve(s) D, Drain Valve E and Equalization Valve F are closed.

A. Close Mainline Trap Valve A and Trap Kicker Valve C.

B. Open Vent Valve(s) D and Drain Valve E to vent trap to atmosphere.

C. When the trap is completely vented (zero psig) with Vent Valves D still in the open position, open the closure door and insert the pig so the first cup forms a tight fit in the reducer (point X). If a large and heavy inline inspection pig, it can be pulled into the trap by opening and using the pulling nozzles.

D. Close and secure the closure door. Open Equalization Valve F to allow permit pressure equalization in front of and behind the pig. If the pulling nozzles were used to load the pig, close them or replace and secure blind flanges. Purge air from trap through Vent Valves D and Drain Valve E by slowly opening Trap Kicker Valve C. When purge is completed, close Vent Valves D and Drain Valve E to allow pressure in trap to equalize with pipeline pressure. Then, close Valves C and F.

E. Open Mainline Trap Valve A, then Trap Kicker Valve C. The pig is now ready for launching.

F. Partially close Mainline Bypass Valve B. This will increase gas flow through Valve C and behind the pig. Continue to close Valve B until the pig moves out of the trap as signaled by the PIG-SIG scraper passage indicator.

G. When the pig leaves the trap and enters the main line, open Mainline Bypass Valve B fully.

* This publication is not intended to replace product manuals. Please see the appropriate product manuals for complete instructions/procedures.

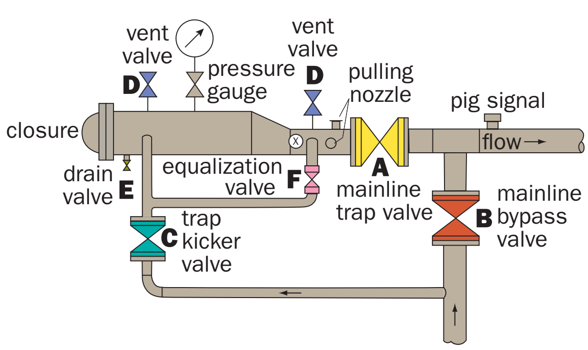


Fig 24. Launching Procedures, Gas Pipeline

2.4 Receiving Procedures Gas Service *

* This publication is not intended to replace product manuals. Please see the appropriate product manuals for complete instructions/ procedures.

Pig receive systems are slightly different than launch systems. The most notable differences are length of piping, location of PIG-SIG Indicator and bypass piping.

As in launching a pig, receiving a pig should follow a described sequence to avoid similar problems. Therefore, the following procedures should be utilized to receive pigs. Refer to Figure 25. Starting Condition: Trap is empty at atmospheric pressure. Mainline Bypass Valve B, Vent Valve(s) D and Drain Valve E are open. Mainline Trap Valve A and Return Line Valve C are closed.

A. To purge air from the trap, close Drain Valve E. Slowly open Trap Kicker Valve C.

B. After purging, allow the trap pressure to equalize to pipeline pressure by closing Vent Valve(s) D, leaving Trap Bypass Valve C open.

C. With Trap Bypass Valve C still open, open Mainline Trap Valve A. The trap is now ready to receive the pig.

D. When the pig arrives, it may stop between the tee (point X) and the Mainline Trap Valve A.

E. Partially close the Mainline Bypass Valve B. This will force the pig into the trap due to increasing flow behind the pig through the Mainline Trap Valve A and Return Line Valve C.

F. After the pig is in the trap, as indicated by the PIG-SIG pig passage indicator, open Mainline Bypass Valve B and close Mainline Trap Valve A and Return Line Valve C.

G. Open Drain Valve E and Vent Valves D to vent the trap to atmospheric pressure.

H. After the trap is vented (zero psig) and drained, with valves D and E open, open the closure door and remove the pig.

I. Close and secure the closure door.

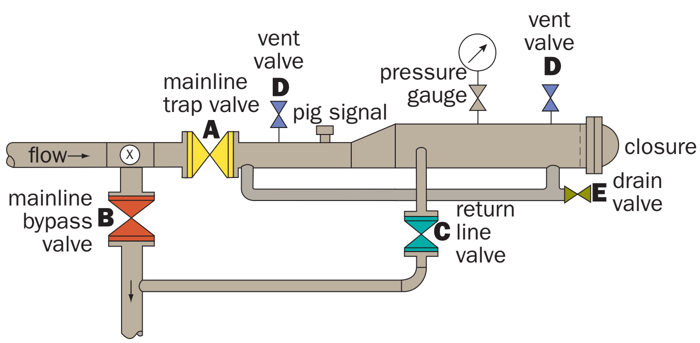


Fig 25. Receiving Procedures, Gas Pipeline

3.0 Sample Pigging Systems

Pig launcher and receivers may look the same in a piping and instrumentation diagram (P&ID) or schematic drawing; however, they may look totally different in the field. Pigging systems are designed to fit the specifics of a pipeline and often to fulfill a specific purpose. The following are some examples of the various configurations used to launch/receive pigs.

3.1 Vertical Launcher

Figure 26 shows a vertical automated system that will hold three displacement pigs. This launcher was installed in a water flood system on the North Slope of Alaska. The launcher can be operated remotely to launch pigs on a pre-set time schedule to remove water from piping before freezing if the system wrere to fail.

3.2 Standard Pig Launcher

Figure 27 shows a “standard” pig launcher if there is anything such as standard. It is designed to launch one pig. Clearly shown are the mainline trap valve, mainline bypass valve and the trap kicker valve.

3.3 Dual Launcher

Figure 28 shows a unique combination of two launchers, serving two pipelines, installed on the same skid. This system was designed for use in close quarters on an offshore drilling platform.

3.4 Automated Batch System

Figure 29 shows a 42-inch automated batch system. Five batching pigs are loaded and will be launched in-dependently. After loading, all launches are done from a remote location. The five devices on top of the barrel are launch pins that hold the pigs in position. During launch operations, the valves are sequenced and a launch pin retracted, launching a pig. Pig passage indicators confirm the launch.

Fig 26. Vertical Launcher

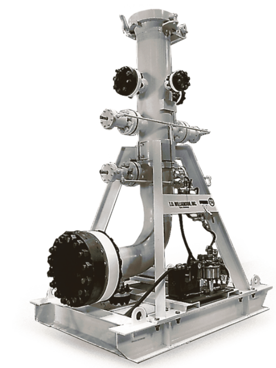


Fig 27. Standard Pig Launcher

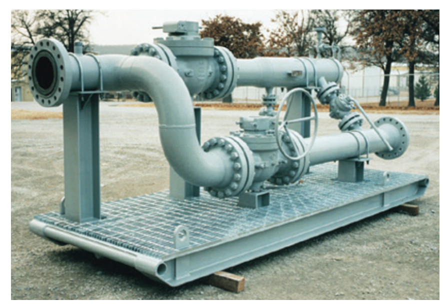


Fig 28. Dual Launcher

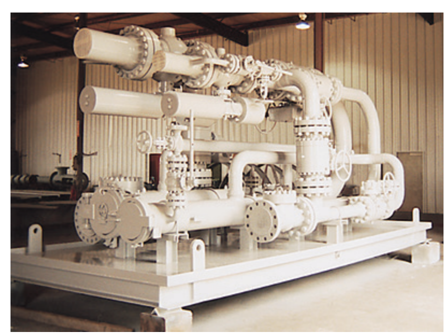


Fig 29. Automated Batch System

Fig 30. Sloped Launcher

Fig 31. Combo Pig/Sphere Launcher

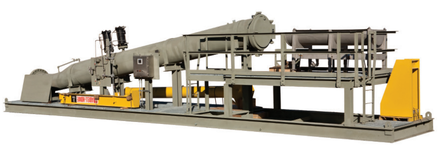


Fig 32. Inline Inspection Pig Launcher

3.5 Sloped Launcher

As opposed to the vertical launcher shown in Figure 26, the launcher shown in Figure 30 is constructed on a slope. It holds four pigs and is designed to launch pigs that will batch multiple products. The pigs are controlled by two launch pins on top of the trap. Except for loading, the trap, which has two trap kicker lines, is online all of the time. To launch a pig, a launch pin is retracted and the pig slides down into the line.

UNISPHERE™ launchers can be constructed in a similar manner, with launch pins controlling the launch of as many as twelve spheres. A diagram of one is shown in Figure 31.

3.6 Combo Pig/Sphere Launcher

When it is necessary to run multiple spheres to remove liquids but retain the option to run a cleaning pig or inspection tool, a combination pig/sphere launcher is desirable.

3.7 Inline Inspection Pig Launcher

An inline inspection pig launcher is similar to the standard launcher except that it has a much longer barrel to accommodate the longer inline inspection tools. Clearly shown are the mainline trap valve, mainline by-pass valve and the trap kicker valve. The reducer, the point at which the barrel size reduces to pipeline size, can be seen. Access flanges (pulling nozzles) shown on the line size pipe provide access to the trap for pulling an inspection tool into the trap. This pulling nozzle configuration is shown on the diagram in Figure 24.

Selecting the Right Pipeline Pig

1.0 Introduction

Pigs are available in a variety of combinations to perform various functions in a pipeline. Figure 33 shows an almost endless combination of pigs that perform a variety of functions in several different types of lines.

Fig 33. Variety of Pigs

Pigs are designed to perform a specific function. To select a proper pig configuration, the operator must know the following things:

- Pipeline Size
- Wall Thickness(es):
- Minimum Bend Radius (radius & degree of bend)
- Pipeline Length
- Product Media (gas, oil, etc.)
- Flow Rate / Velocity:
- Side Connections (tees barred/unbarred)
- Valve Type (Valves should be full bore/full opening. Valves have internal cavity)
- Pigging Application
- Pigging History

1.1 Pig Components

Pigs can be configured with different components to perform specific functions. The following is a list of these components and their functions.

A. Brushes: Brushes are used primarily for removing hard internal deposits such as scale and corrosion off pipe walls. Some brushes are wear-compensating. Another type of brush is used to remove deposits from pits to allow corrosion inhibitors and biocides to deter corrosion in the pipeline.

B. Cups: Cups provide the seal of the pig inside the pipeline and permit the flow in the pipeline to move the pig along. They also provide some cleaning of the pipe wall. They are also used for batching products.

C. Discs: Discs are used to enhance cleaning and provide support to the pig while in the pipeline. A pig equipped with discs may run bidirectionally.

D. Blades: Blades are used to remove soft deposits such as paraffin and sludge that form on the walls in crude oil lines.

Fig 34. Pig with Brushes, Cups and Discs

Fig 35. Pig with Discs Only

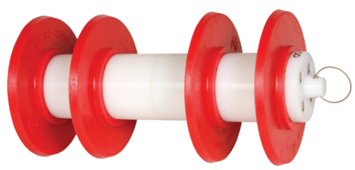
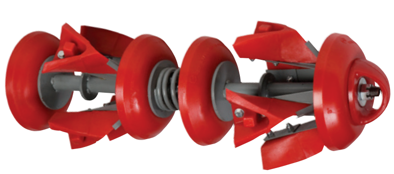


Fig 36. Pig with Cups Only

Fig 37. Pig with Spring Mounted Brushes

Fig 38. Pig with Urethane Blades



E. Magnets: Magnets are used to remove ferrous metals like metal chips, used welding rods and iron oxides contained in black powder. Magnets are also used to trip non-intrusive pig passage indicators.

F. Foam Pigs: Foam pigs are normally used in drying pipelines following hydrostatic testing.

1.2 Reasons for Pigging

A. Construction

1. Removing construction debris from the line.
2. Hydro-test (water filling, dewatering).
3. Gauging.

B. Operation

1. Commissioning.
2. Cleaning.
3. Condensate/water removal.
4. Product separation (batching).
5. Application of inhibitors.

C. Inspection

1. To check for physical damage (geometry).
2. To detect mill defects, corrosion, laminations or cracking.

D. Maintenance and Repair

1. Pre-inspection cleaning.
2. Isolation.

E. Renovation/Rehabilitation.

1. Chemical/gel pigging.
2. Scale removal.
3. Cleaning for product conversion.
4. Decommissioning.
5. Recommissioning.

2.0 Pig Selection

The following are general guidelines to apply when selecting a pig. Completing a pig application form, a sample of which is contained in Appendix I, and providing it to your supplier will assist them in recommending a pig.

2.1 Cleaning a Line (New Construction, Refined Products, Natural Gas or Crude Oil)

A. The best choice of a pig is one with discs, conical cups, spring mounted brushes or urethane blades, and bypass ports, as shown in Figure 34.

B. Discs (Figure 35) are effective at pushing out solids while also providing good support for the pig.

C. Conical cups, shown in Figure 36, provide excellent sealing characteristics, are able to traverse significant reductions and wear well.

D. Spring mounted brushes (Figure 37) are wear-compensating and provide continuous forceful scraping for removal of rust, scale and other buildups on the pipe wall.

E. When cleaning waxy crude oil from the walls of crude oil lines, urethane scraper blades, shown in Figure 38, are often preferred because they are easier to clean than brushes.

F. Bypass ports allow some of the pipeline product to flow through the pig, as shown in Figure 39. This helps minimize solids build-up in front of the pig. Bypass may also reduce the speed of the pig through the pipeline.

G. When cleaning new construction, pigs with magnetic cleaning assemblies, shown in Figure 40, are recommended for removing ferrous metal debris such as welding rods, nuts and bolts, and tools.

2.2 Displacement Applications

Displacement applications include filling and dewatering, commissioning and decommissioning applications, nitrogen purging/inerting and batching products in refined product lines.

The best choice would be a four cup pig with multi-lipped conical cups.

A. Conical cups will maintain contact with the pipe wall, even in out-of-round pipe. As the pipe size increases, the out-of-roundness condition becomes more common. Conventional cups and discs cannot maintain a seal in out-of-round or dented pipe.

B. Multi-lipped cups have numerous independent sealing lips on each cup, such as those shown in Figure 41, which greatly improves its ability to maintain a seal.

Other alternatives include:

A. Foam Pigs. Some foam pigs provide a relatively good seal over short to moderate distances. The costs are low and there is little risk of getting stuck. Low density foam pigs are commonly used in large numbers for drying purposes after initial water removal.

B. Bidirectional disc pigs are typically used in filling and dewatering operations associated with hydrostatic testing when the water used to fill the line has to

Fig 39. Flow Through Bypass Pushes Debris Ahead of Pig

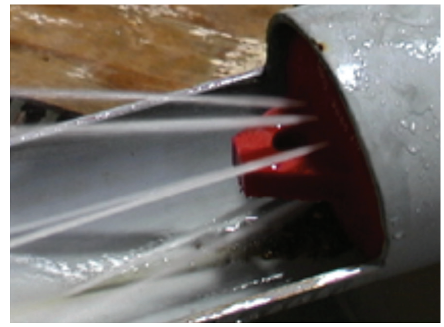


Fig 40. Pig with Magnets to Collect Debris

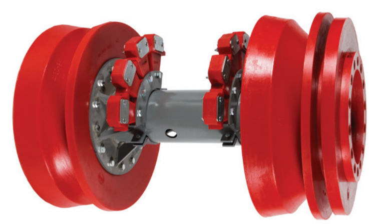


Fig 41. Multi-lipped Cup

Fig 42. Foam Pigs

Fig 43. 6-Disc Bidirectional Pig

Fig 44. UNISPHERE™ Pigs

be pushed back to its source after completion of the test. If it is possible to reverse flow, this pig can be returned to its launch point if there is a fear of the pig getting stuck.

2.3 Removing Liquids from Wet Gas Lines

A. UNISPHERE™ pigs (Figure 44) are the preferred choice for removing liquids from gas lines.

B. Sphere pigging systems are usually designed to automatically launch and receive spheres. A number of spheres can be loaded into the automatic launcher and are launched at predetermined frequencies.

C. At the receiving end of the line, a slug catcher is installed to capture the liquid pushed in by the sphere. Spheres are launched at a frequency that prevents exceeding the capacity of the slug catcher.

Fig 45. Pig with Magnets to Collect Debris

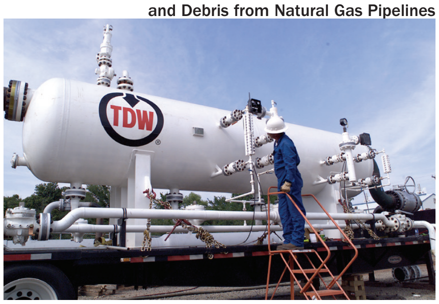
D. At the receiving end, spheres are captured in a receiving trap. Pig passage indicators are installed on the launchers and receivers to count the sphere launches and recoveries. A launcher may also be equipped with vertical launch pins that will extend and retract, cycling the launching of spheres.

E. Pipeline systems are normally designed for the use of spheres or pigs, but not both. Systems designed for launching and recovery of spheres may require modification of launchers and receivers before conventional pigs can be used.

2.4 Removal of Ferrous Debris

Debris such as welding rods, bolts, tools, etc., left after pipeline construction, must be removed before attempting to run corrosion inspection or other types of inspection pigs. It is very difficult to remove this debris with conventional pigs. Conventional pigs will push these objects for a distance then ride over them. The most effective way to remove this debris is attaching a magnetic cleaning assembly to a conventional pig. A magnetic cleaning assembly normally consists of a magnetic belt that wraps around the body of a pig. Figure 45 shows the ferrous debris that can be picked up by magnets attached to the pig.

Fig 46. Portable Separator - to Remove Liquids and Debris from Natural Gas Pipelines



2.5 Removal of Hard Scale Deposits

Cleaning hard, large deposits is a special application that would normally be provided by a pipeline cleaning service company. Aggressive pigs combined with cleaning fluids are required for this application. Referred to as chemical cleaning, they are often used with cleaning detergent fluids that help to attack the deposits and keep the removed debris in suspension while being pushed out of the line. This permits removal of large volumes of solids in one pig run.

A. The cleaning fluids are captured between batching and cleaning pigs. Normally, a slug of the fluid is introduced in front of the first pig.

B. Samples of the deposits may be required for chemical analysis and to determine the best type of cleaning fluids.

2.6 Applying Corrosion Inhibitors

Corrosion inhibitors are normally injected into the line on a continuous basis and carried through the line with the product flow. Often, inhibitors are batched between two pigs. Since the majority of the flow is in the bottom half of the pipe, there is little assurance that the top wall of the pipe (12 o'clock position) is treated by the inhibitor.

Special pigs have been developed that spray inhibitor to the top of the pipe as they travel through the pipeline, as shown in Figure 47. This is done by using a siphoning effect created by bypass flow through an orifice specifically designed to pick up inhibitor from the bottom of the pipe.

Fig 47. Corrosion Inhibitor Distributed to Top of the Pipe

2.7 Pre-Inspection Cleaning

Prior to conducting an inline corrosion inspection survey, the pipeline must be clean. The cleaner the line, the more accurate the survey data.

Lines carrying refined products require very little cleaning while a crude oil line may require extensive cleaning. Dozens of individual pig runs, or one or more train pigs (two or three pigs coupled together with flexible connectors) may be required. Train pigs normally have multiple discs, cups, extra brushes and magnetic cleaning assemblies.

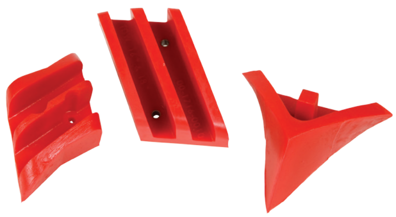
Chemical cleaning, described in paragraph 2.5, may be required on long lines containing excessive paraffin, iron oxide or other solids.

2.8 Cleaning Lines with Known Internal Corrosion

Special pigs available for this application have independent scraping wires that will go into a pit to break up and remove deposits. Such deposits, if left, would prevent corrosion inhibitors from getting into the corrosion area. Such a pig is shown in Figure 48. Brushes on conventional pigs will not extend into pits in the line.

Fig 48. PitBoss™ Pigs

Fig 49. Urethane Blades and Plow



2.9 Cleaning Internally Coated Lines

The preferred choice for this application is a pig with discs and cups. Because of the characteristics of epoxy coatings, discs and cups will normally remove deposits without harming the coating.

Conventional cleaning pigs with "prostran" brushes or polyurethane blades is another option for cleaning internally coated pipe.

2.10 Pigging Offshore Pipelines

Offshore pipelines usually require specially designed pigs in order to accommodate:

A. Very heavy wall pipe.

B. Large variations in wall thicknesses due to different design codes for platform and riser piping versus subsea mainline pipe.

C. Laterals and wye fittings are often used which require extra long pigs.

Effective pigs can be provided for these systems but may require special design features.

Pigging New Construction

1.0 Introduction

Pigging a new construction line, before it is placed in service, is done for a number of reasons. First of all, the operator wants to remove construction debris left in the pipe. The line must be filled with water and hydrostatically tested. Once hydro-testing is completed, the water must be removed. The line then must be inspected using a Geometry Inspection Tool to assure the line is free of dents or buckles. The line must be further cleaned and dried normally to a dew point specification (-20°F to 40°F).

- If the purpose of pigging is to ensure that the line has a full round opening from one end to the other, a gauging pig can be used. The gauging pig will also remove most construction debris such as skids and welding rods.
- If the purpose is to clean rust, dirt, or mill scale, a standard cleaning pig can be utilized.
- If the purpose of pigging is to fill with hydrostatic test water, a displacement pig is used.

Fig 50. KALIPER® 360 Inspection Tool

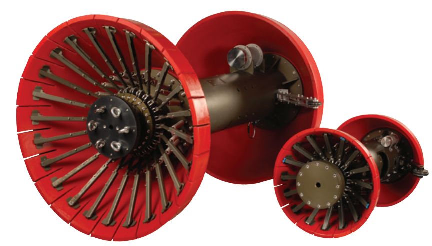


Fig 51. Conventional Gauging Pig

Fig 52. Cleaning Pig with Wear-Compensating Brushes

2.0 Selecting the Pig

2.1 Gauging Pigs

A. The KALIPER® 360 Survey device, shown in Figure 50, is a self-contained, instrumented tool which records size and location of pipe diameter reductions. It can detect dents, buckles, flat spots and construction debris. The KALIPER 360 tool can also detect a change in pipe wall thickness. Additionally, the KALIPER 360 tool will provide information on the o-clock positioning of the anomaly.

B. A conventional gauging pig, shown in Figure 51, is equipped with a slotted aluminum “gauging flange”. This gauge plate pig will provide limited information on minimum bore within a given section of pipe.

2.2. Cleaning Pigs

TDW cleaning pigs may employ magnets for removal of ferrous metals, discs and cleaning elements, including brushes or urethane blades. Brushes can be used in new line construction to remove mill scale or construction debris. Figure 52 is an example of a pig with wear-compensating brushes.

2.3. Displacement Pigs

Displacement pigs are also used for displacing air and hydrostatic water prior to commissioning a new pipeline. They can be used bidirectionally (run in both directions).

Fig 53. 6-Disc Bidirectional Pig

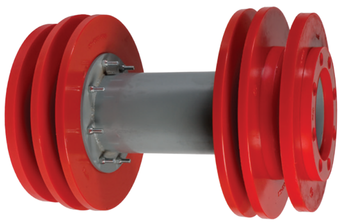


Fig 54. OptionAll™ Batching Pig

Fig 55. Inflatable UNISPHERE™ Pigs

A. A bidirectional pig, shown in Figure 53, is effective for displacing air or hydrostatic test water. The bidirectional pig may be left in the line while the test is being conducted, then reversed for water removal if desired.

B. The urethane disc is an effective cleaning element, provides pig support and can run bidirectionally.

C. The OptionAll™ Batching Pig, shown in Figure 54, can be used to displace air or hydrostatic test water. It is fitted with polyurethane conical cups that permit the pig to pass over obstructions in the line without pig damage. Conical cups conform to out-of-round pipe, providing a continuous seal.

D. The Inflatable UNISPHERE™, shown in Figure 55, is a seamless, liquid cast polyurethane ball. It will traverse short radius bends where the body type pig will not. UNISPHERE Pigs are ideal for removing liquids from natural gas lines where frequent runs are required. Automated sphere launchers and receivers are normally used in these applications. They can be sized to match most pipe IDs, ranging from standard wall to ultra-thin wall pipe.

   UNISPHERE Pigs are filled completely with liquid (usually glycol and/or water). The inflating valve is removed and liquid is poured directly into the sphere. The valve is replaced and the sphere is sized by pumping in additional liquid.

3.0 Propelling the Pig

3.1 Speed

The most effective speed for pigging during construction is considered to be 1 to 5 miles (1.60 to 8 km) per hour. Pig velocities much greater will cause the pigs to become less effective.

3.2 Propelling the Pig with Air

Many times a gauging or cleaning pig is pushed with air through short test sections of pipe. It is recommended that the line be prepacked with 50 - 100psi and carefully controlled as the pigs are propelled through the line.

WARNING: High speed runs through bends can cause damage to the pipeline, the pig, or both.

Table 1 lists various pipe sizes, recommended cubic feet per minute (CFM) and meters cubed per hour (m3/h), at atmospheric conditions.

Table 1. Compressed Air Required vs. Pipe Size			
Pipe Size (in.)	mm	CFM @ 150psi	M3/h
6	200	100	170
12	300	300	510
18	450	700	1,190
24	600	1,200	2,040
30	750	1,900	3,230
36	900	2,800	4,750
42	1,050	3,800	6,450
48	1,200	5,000	8,500

A. Pigs often require more pressure to start movement. Depending upon pigging application, compressors should be able to deliver the desired CFM at 150psi.

B. The pig will stall if the air output volume is not large enough to fill the line at a uniform rate and pressure. If the pig stops, pressure will build until the pressure reaches a sufficient level, then the pig will be propelled at a high rate of speed and will continue at this rate until the flow and pressure is insufficient to keep it moving consistently. This is why it is important to have sufficient flow, pressure and experience in conducting this operation.

3.3 Propelling the Pig with Water

A. Water is one of the more common fluids used to propel pigs through a new line.

B. When a hydrostatic test is conducted, a pig is placed ahead of the water to remove air from the line. It is critical to achieve a complete line fill, allowing no air in the hydrostatic water line fill.

C. The principal consideration for filling the line is:

1. Water availability and fill rate. It is recommended to size fill pumps that will fill the line at a rate of 1 mph or greater.
2. Fill pumps are considered high volume - low pressure pumps.

D. Table 2 lists pump recommendations for different size pipe. The flow rates shown in the table will propel the pig at a speed of approximately one mile (1.6 km) per hour. The following formula may be used to determine the speed of the pig.

$$S = \frac{.278}{d2} \text{, where:}$$

S= speed, miles per hour

GPM = gallons per minute

d = Inside diameter of pipe, in inches

TABLE 2. Pump Recommendations vs. Pipe Size			
Pipe Size (in.)	mm	Gallons Per Minute (GPM)	Liters Per Minute (LPM)
6	200	150	570
12	300	500	1,900
18	450	1,000	3,800
24	600	2,000	7,600
30	750	3,000	1,400
36	900	4,500	17,000
42	1,050	6,000	22,700
48	1,200	8,000	30,300

E. Hydrostatic test pumps are considered low volume - high pressure. A test pump must have the ability to increase the line pressure to the test pressure. A high pressure pump rated at 95 gallons per minute (gpm) at 5,000 psi (360 liters per minute,LPM, at 345 bar) should be suitable for the pressurizing operation.

Fig 56. Launching Test Header for Filling Two Test Stations

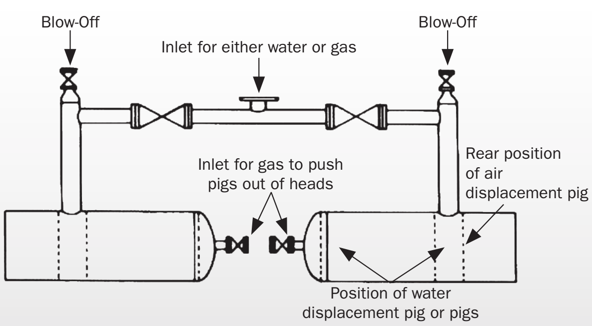
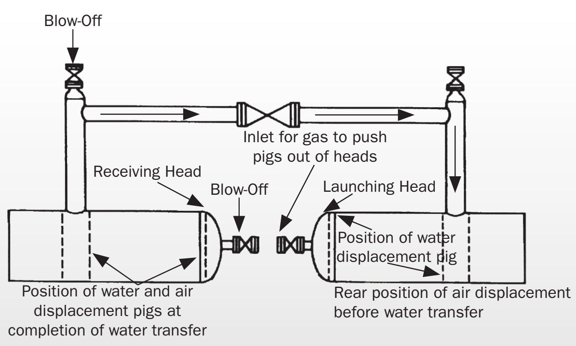


Fig 57. Launching and Receiving Test Header for Water Transfer from One Section to Another



F. On completion of the pressure test, the water can be displaced by pushing the displacement pig with air. Pig speed should be regulated by controlling the flow of water out of the discharge end of the section.

3.4 Launching and Receiving Test Headers and Traps

A. Pigs can be launched in new pipelines by providing a header/trap on the upstream end of the line. The header/trap will allow the pushing fluid to enter behind the pig.

B. A receiving header/trap is necessary on the downstream end of the line. The receiving header/trap will allow the fluid to exit ahead of the pig.

C. Figures 56, 57, 58 and 59 are four general types of design for launching and receiving test headers. Figure 56 is for filling two sections in opposite directions. Figure 57 transfers water from one section that has been tested into another section to be tested. Filling at one end of a section only is shown in Figure 58. A setup for running several pigs is shown in Figure 59. These test headers may be and often are replaced with temporary pig traps with valves that allow for multiple pig runs: cleaning, fill, dewatering, inspection and drying.

Fig 58. Launching Test Header Equipped for Filling of One Test Section Only

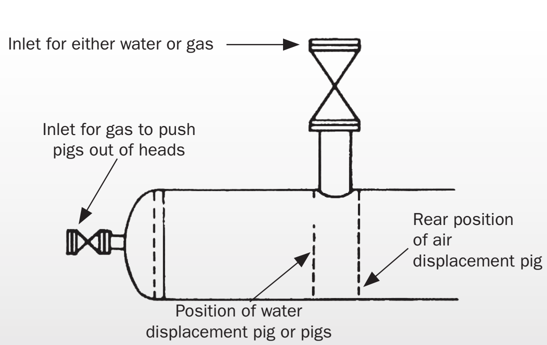
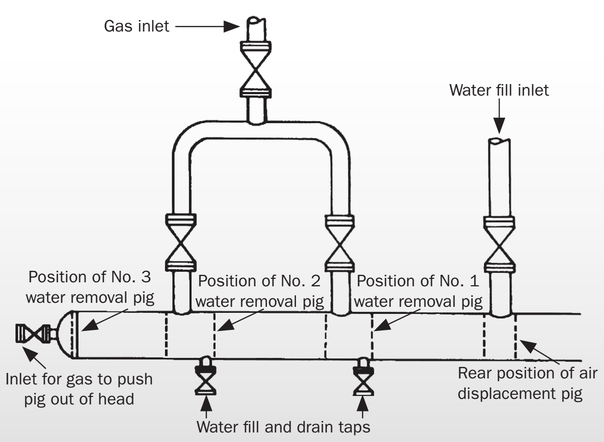


Fig 59. Multiple Pig Launching Test Header



Onstream Pigging

Natural Gas Lines, Natural Gas Liquids and Refined Petroleum Products

1.0 Introduction

1.1 Raw Gas (Gathering Systems)

Raw natural gas typically consists of methane containing varying amounts of the following:

A. Heavier gaseous hydrocarbons such as ethane, propane, normal butane, isobutane and pentanes

B. Water vapor and liquid water

C. Liquid hydrocarbons.

D. Acid gases such as carbon dioxide, hydrogen sulfide, and mercaptans such as methanethiol and ethanethiol.

Produced gas from the well head is transported to processing plants through a network of gathering pipelines, which are usually small-diameter lines. A complex gathering system can consist of thousands of miles of pipes, interconnecting more than 1000 wells.

1.2 Processed Gas (Transmission Systems)

Processed gas is that gas which is transported via transmission lines from the processing plant to the utility and power companies.

1.3 Refined Products

Refined petroleum products are derived from crude oils through processes such as catalytic cracking and fractional distillation. Several examples of refined petroleum products and their properties include:

A. Gasoline: A lightweight material that flows easily, and may evaporate completely in a few hours.

B. Kerosene/Jet Fuel: A lightweight material that flows easily and evaporates quickly.

C. No. 2 Fuel Oil: A lightweight material that flows easily and is easily dispersed.

D. No. 4 Fuel Oil: A medium-weight material that flows easily, and is easily dispersed if treated promptly.

E. Lubricating Oil: A medium weight material that flows easily and is easily dispersed if treated promptly.

F. No. 5 and No. 6 fuel oil, Bunker B and Bunker C, are also refined products, but are included in Section VII.

Fig 60. VANTAGE® Plus Pig with Brushes

Fig 61. VANTAGE® Plus Pig with Blades

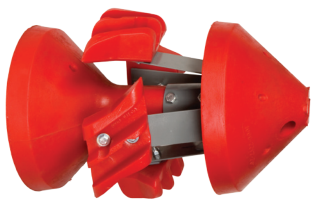


Fig 62. Debris Suspended in Front of the Pig

Fig 63. Batching Pig

Fig 64. Inflatable UNISPHERE™ Pigs

2.0 Selecting the Pig

If the purpose of pigging is to remove internal build-up on the pipe wall which may shield corroding areas, a cleaning pig should be utilized.

If the purpose of pigging is to remove corrosive or heavy liquids, a displacement pig or sphere can be utilized.

If more than one type of product is transported through a pipeline, batching pigs can be used to separate the products.

2.1 Cleaning Pigs

TDW cleaning pigs employ four types of cleaning elements: brushes, urethane blades, discs and magnets.

A. Brushes can be used if the line contains mill scale or hard deposits adhering to the pipe wall. Figure 60 is an example of a pig with steel wire brushes.

B. Urethane blades can be used to remove soft, sludge deposits. Figure 61 is an example of a pig with urethane blades.

C. Bypass ports are incorporated into most cleaning pigs. By opening the bypass plug(s), part of the flow is diverted through or around the pig body to create turbulence ahead of the pig. This helps to keep foreign matter suspended in front of the pig instead of allowing the dirt to accumulate in and around the cups and cleaning elements. Figure 62 shows debris suspended in front of the pig.

2.2. Batching/Displacement Pigs

A. TDW batching/displacement pigs employ multiple cups or discs that maintain a seal through bends and full-diameter branch openings.

B. The VANTAGE® V Pig, shown in Figure 63, is fitted with conical cups that permit the pig to pass over obstructions in the line without pig damage. Conical cups conform to out-of-round pipe, providing a continuous seal.

C. The Inflatable UNISPHERE™ Pig, shown in Figure 64, is a seamless, liquid cast polyurethane ball. It will traverse a short radius bend where a body type pig will not. They can be sized to match any size pipe ID ranging from standard wall to ultra thin wall pipe. Two inflating valves are incorporated for use in systems that do not have oversize barrels for sphere insertion or removal.

   UNISPHERE Pigs are filled completely with liquid (usually glycol and/or water). One inflating valve is removed and liquid is poured directly into the sphere. The valve is replaced and the ball is sized by pumping in additional liquid. Any hand pump capable of pumping fluid at 250 psi (17 bar) can be used.

3.0 Speed

Normally, pigs are run "on stream" with the speed being the same as the stream velocity. However, the most efficient speeds for body type pigs are 3-7 mph (4.8 -11.2 km per hour).

The speed of cleaning pigs can be varied slightly by opening the bypass port(s).

How fast does gas move in a pipeline? The following formula provides a close approximation of the speed of gas.

$$S = \frac{1447\ Q\ P_b}{P\ (Fpv)\ 2\ d2}$$,where

S = Speed, miles per hour

P_b = Absolute base pressure (barometric) (pressure at compressor)

P = Absolute line pressure,

Fpv = Supercompressibility Factor (See Table 3)

d = Inside diameter of pipe in inches

Table 3. Super-Compressibility Factors Fpv Base Data – 0.6 Specific Gravity Hydrocarbon Gas

Pressure		20° F (-7° C)		60° F (16° C)		100° F (38° C)	
psig	bar	Fpv	Fpv2	Fpv	Fpv2	Fpv	Fpv2
200	13.8	1.0212	1.0428	1.0160	1.0323	1.0123	1.0248
400	27.6	1.0442	1.0904	1.0327	1.0665	1.0247	1.0500
600	41.4	1.0690	1.1428	1.0499	1.1023	1.0370	1.0754
800	55.2	1.0955	1.2001	1.0674	1.1393	1.0492	1.1008
1000	69.0	1.1231	1.2614	1.0847	1.1766	1.0609	1.1255
1200	82.7	1.1506	1.3239	1.1013	1.2129	1.0719	1.1490
1400	96.5	1.1764	1.3839	1.1166	1.2468	1.0818	1.1703
1600	110.0	1.1978	1.4347	1.1298	1.2764	1.0904	1.1890
1800	124.0	1.2126	1.4704	1.1400	1.2996	1.0974	1.2043
2000	138.0	1.2202	1.4889	1.1470	1.3156	1.1026	1.2157

4.0 Frequency

The frequency of pig runs and the number of pigs to be run will depend on the conditions existing in the line. Each section of a system can have different requirements, depending on varying accumulations of dirt, iron oxide, liquids, etc.

The sections closest to production often have condensates as well as some dirt that was not removed at the dehydrating plant. All sections may have accumulations of compressor oil from time to time. Periodic efficiency tests should be made on each section to determine pigging schedule. The cost of running a pig can be compared to the efficiency drop (and associated loss in throughput) to determine the economics of pigging.

5.0 Performance

A pig's performance can be determined by several methods:

A. Measurable increase in line efficiency.

B. Measurable increase in throughput.

C. Pressure drop.

D. Dew point differential before and after pigging.

E. Amount of foreign matter in the pig receiver.

F. Amount of liquids in a reservoir barrel.

G. Reduced corrosion.

1.0 Introduction

Crude oil is the term for unprocessed, or unrefined oil, as it comes out of the well. It varies in color and in viscosity. It contains hundreds of different hydrocarbons, basic sediments and water that have to be separated by refining into different types of hydrocarbons to produce products such as gasoline, plastics, etc.

1.1 Light Crude

Light crude oil is a low viscosity crude oil, normally with a low-wax content.

1.2 Heavy Crude

Heavy crude is any type of crude oil which does not flow easily. It presents special challenges with regard to transporting by a pipeline. Bitumen, from the tar sands in Canada, is considered to be extra heavy crude as it does not flow at all in ambient conditions. To facilitate flow, extra-light forms of oil or liquid natural gas are added at regular distances in pipelines.

1.3 Waxy Crude Oils

Whenever a waxy oil comes in contact with a cold pipe wall, solid paraffin crystals can precipitate and deposit on the pipe wall surface. Eventually, this may significantly reduce or even block the area open to flow.

A. Waxy crudes are widespread in the world. The major problems related to the transportation of this crude through pipelines is not just crystallization of their wax content at low temperatures, but the formation of deposits which do not disappear upon heating. They will not be completely removed by pigging.

B. Waxy crudes are not clean and, in addition to wax, they contain other organics such as asphaltene and resin. These other heavy organics do not generally crystallize upon cooling and, for the most part, they may not have definite freezing points. As a result, application of chemical anti-foulants and frequent pigging become necessary.

C. Several methods have been used to remove paraffin deposits, including mechanically scraping the pipe walls (pigging), contacting the paraffin deposits with various organic solvent systems and the application of hot oils or external heat. Refer to Section IV for information on cleaning pigs. Figure 65 shows cleaning pigs after a run through a crude pipeline with paraffin deposits.

Fig 65. Cleaning Pigs Packed with Paraffin

1.4 Sour Crude

Sour crude is crude oil containing sulfur. When the total sulfur level in the oils is greater than 0.5 percent, the oil is called “sour.” It is generally low in paraffin, and not waxy.

A. Impurities need to be removed before this lower quality crude can be refined into gasoline and diesel fuel. This results in higher priced fuels than those made from sweet crude.

B. Sour crude can be toxic and corrosive, especially when the oil contains high levels of hydrogen sulfide. At low concentrations, the oil has the smell of rotten eggs, but at high concentrations, the inhalation of hydrogen sulfide is instantly fatal.

C. At high levels of hydrogen sulfide and pressure, some steels will fail due to sulfide stress cracking. When these conditions exist, normal spring steels and brush bristles will break under very little load. Alternative materials are required for springs, and stainless steel wires for brushes. Most structural steels used for pig bodies are not affected by these conditions.

1.5 Refined Products

Some refined products, because of their weight and density, are included in this section also:

- No. 5 Fuel Oil (Bunker B): A medium-weight to heavyweight material. Preheating may be necessary in cold climates, and this fuel oil is difficult if not impossible to disperse.
- No. 6 Fuel Oil (Bunker C): A heavyweight material that is difficult to pump and requires preheating for use. This fuel oil may be heavier than water, is not likely to dissolve, is difficult or impossible to disperse, and is likely to form tar balls, lumps and emulsions.

2.0 Selecting the Pig

If the purpose of pigging is to remove foreign matter and paraffin deposits or scale which may shield corroding areas, a cleaning pig can be utilized.

If the purpose of pigging is to separate products or remove unwanted liquids and corrosion products, a batching/displacement pig can be utilized.

Refer to Section IV for selection of the proper pig to do the job.

Bypass ports are incorporated into most cleaning pigs. By opening the bypass plug(s), part of the flow is diverted through or around the pig body to create turbulence ahead of the pig. This helps to keep foreign matter suspended in front of the pig instead of allowing the dirt to accumulate in and around the cups and cleaning elements.

3.0 Pigging Speed

Normally, pigs are run “on stream” with the speed being the same as speed of flow through the pipeline. However, the most efficient speeds for body type pigs are 3 - 7 mph (4.8 to 11.3 km per hr.). Flow can be determined using the following formula. Appendix III contains helpful conversion factors.

$$S = \frac{0.0081 \times Q}{d2}$$, where

S = Speed, MPH

Q= Throughput, bpd

d= Inside diameter of pipe in inches

The speed of cleaning pigs can be varied slightly by opening the bypass port(s).

4.0. Frequency

The frequency of pig runs, and the number of pigs to be run, will depend on the conditions existing in the line. Each section of a system can have different requirements, depending on varying accumulations of dirt, paraffin, liquids, etc.

Periodic efficiency tests should be made on each section to determine pigging schedule.

The cost of running a pig can be compared to the efficiency drop (and associated loss in throughput) to determine the economics of pigging.

5.0. Performance

5.1 Cleaning Pig Performance

A cleaning pig's performance can be determined by several methods:

A. Measurable increase in line efficiency.

B. Measurable increase in pump efficiency.

C. Measurable increase in throughput.

D. Pressure drop.

E. Amount of foreign matter in the pig receiver.

F. Millipore test.

G. Reduced corrosion.

5.2 Batching Pig Performance

A batching/displacement pig's performance can be determined by several methods:

A. Pig on or off stream.

B. Length of interface.

C. Amount of contamination at interface.

D. Reduced corrosion.

1.0 Introduction

Inline inspection (ILI) techniques have been used since the 1960s to help assess integrity of pipelines. While not a requirement this was the best method to determine whether a pipeline was fit-for-service. In 2001, the United States Office of Pipeline Safety (OPS) introduced new federal rules and regulations requiring liquid pipeline owners and operators to inspect their lines for defects which could cause failures in high consequence areas. Two years later, the OPS extended these regulations to include natural gas pipeline systems.

Stringent regulations called for pipeline owners to make integrity assessments using hydrostatic testing, ILI or Direct Assessment (DA). Most operators elect to utilize ILI tools since they provide detailed information about the pipeline's condition. Prescriptive repairs based on ILI data were established including immediate, 60-day and 180-day timeframes for hazardous liquids operators and immediate, one-year and monitored for natural gas transmission operators. The two primary uses of ILI tools are to detect and quantify bore changes (such as dents, ovalities and expansions) and metal loss (such as corrosion and gouging). From 1990 through 2009, excavation damage, which includes third party damage, accounted for 20.3 percent of all Significant Incidents related to onshore hazardous liquids pipelines; excavation damage in onshore natural gas transmission lines equated to 22.0 percent for the same time period. Corrosion, another leading cause of Significant Incidents among onshore hazardous liquids and natural gas transmission, accounted for 23.6 percent and 18.6 percent respectively of all incident causes. See Figures 66 and 67 for more details on Significant Incident Causes for U.S. onshore pipelines. While this level of historical detail is not available in all regions, similar threats are known to exist which indicate the need for assessments to secure public safety and prolong asset life.

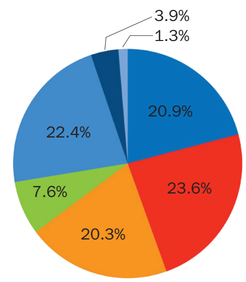
2.0 Preparing the Line

Pre-survey preparations should not be curtailed in an attempt to reduce the overall time and the cost of a survey. This is invariably counter-productive because a rerun is all too often required, which immediately eliminates any gains that may otherwise have been made.

Wax deposits, ferrous material and other debris can affect the performance of integrity inspections. A thorough cleaning program is usually essential prior to the inspection run. The cleaner the pipe, the more accurate the inspection results. Please refer to Section IV for more details on cleaning options.

Prior to running any inspection tool it is recommended to launch a gauging pig to confirm pipeline bore. This is a cost-effective way to determine whether the scheduled inspection device will be able to negotiate the line. Pipelines being inspected for the first time are recommended to have a separate geometry inspection performed. This instrumented tool will confirm pipeline bore and obtain information about the general pipeline configuration, including fitting wall thickness, bend radius, degree and direction. Gathering this information on a line

Fig 66. Pipeline and Hazardous Materials Safety Administration Hazardous Liquids Significant Incident Cause Breakdown for years 1990 through 2009. Significant Incidents are those incidents reported by pipeline operators when any of the following conditions are met: 1) Fatality or injury requiring in-patient hospitalization. 2) $50,000 or more in total costs, measured in 1984 dollars. 3) Highly volatile liquid releases of 5 barrels or more or other liquid releases of 50 barrels or more. 4) Liquid releases resulting in an unintentional fire or explosion.

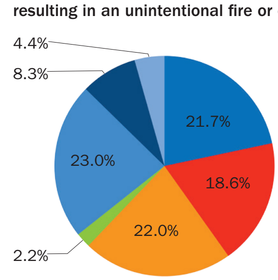


ALL OTHER CAUSES
CORROSION
EXCAVATION DAMAGE
INCORRECT OPERATION
MATERIAL / WELD / EQUIPMENT FAILURE
NATURAL FORCE DAMAGE
OTHER OUTSIDE FORCE DAMAGE

Source: PHMSA Significant Incidents Files October 29, 2010

Significant Incident Cause Breakdown
National, Hazardous Liquid Onshore, 1990 - 2009

Fig 67. Pipeline and Hazardous Materials Safety Administration Natural Gas Transmission Significant Incident Cause Breakdown for years 1990 through 2009. Significant Incidents are those incidents reported by pipeline operators when any of the following conditions are met: 1) Fatality or injury requiring in-patient hospitalization. 2) $50,000 or more in total costs, measured in 1984 dollars. 3) Highly volatile liquid releases of 5 barrels or more or other liquid releases of 50 barrels or more. 4) Liquid releases resulting in an unintentional fire or explosion.



ALL OTHER CAUSES
CORROSION
EXCAVATION DAMAGE
INCORRECT OPERATION
MATERIAL / WELD / EQUIPMENT FAILURE
NATURAL FORCE DAMAGE
OTHER OUTSIDE FORCE DAMAGE

Source: PHMSA Significant Incidents Files October 29, 2010

Significant Incident Cause Breakdown
National, Natural Gas Transmission Onshore, 1990 - 2009

not previously inspected is critical to the success of subsequent inspections. In cases where the line has been previously inspected a gauging pig run may be sufficient prior to launching an inspection tool. The inspection service provider can assist in determining best path forward to help ensure the tool run is successful.

3.0 Inline Inspection

Inline inspection services utilize an “intelligent pig” to provide information about the pipeline. Inspection tools will measure and record both the magnitude and the position of anomalies or features they are designed to detect. These tools will be used to inspect the line while it is in service. The ILI tool gathers the data which is then interpreted by technicians or analysts to develop a report on the condition of the line.

The information provided by these ILI services covers a wide range of pipeline features. The two most common are metal loss, including internal and external corrosion, and geometric anomalies such as dents, ovalities and pipeline expansions. Other pipeline threats include longitudinal seam-weld anomalies, longitudinal features in the pipe body (i.e. gouging) and stress corrosion cracking.

4.0 Survey Selection

Once risk ranking has been performed including pipeline segments required for inspection, threat identification for each segment, High Consequence Area locations, etc. the next step is to draft the requirements or scope-of-work for the information required. Many ILI companies can support building the inspection requirements if necessary. The scope-of-work can then be matched with technology capabilities and service providers.

Having determined the type of survey required, the selection of the individual pig or service company to carry out the survey will depend on a number of factors:

- The pipeline specifications, when compared with various tool specifications, will automatically eliminate some options. Where the pig specifications are close to the requirements, or where some particular data is unpublished, it is recommended to contact the supplier for clarification. Frequently, intelligent pigs can be easily modified to meet a particular requirement.

- Assuming there is more than one instrumented pig which seemingly meets the requirements, there are a number of other considerations such as track record of the service provider, level of customer service, availability and accuracy of results, and the overall cost of the inspection.

Completion of a Pipeline Questionnaire, which requests specific information about a pipeline requiring inspection, is typically the next stage in the survey selection process. Examples of pertinent information include pipeline diameter, length of line, wall thicknesses, product type, pressure, flow, bend radius, launcher and receiver dimensions and so on. While the information requested by the inspection company may seem excessive, the data is extremely important to helping ensure first run success and accuracy of results. A sample questionnaire is contained in Appendix II, which includes all information required prior to an inspection.

Understanding the threats to a given pipeline is required in order to ensure the appropriate technology is selected for identification of those threats. The following sections will detail specific inspection technologies and their capabilities.

5.0 Geometry Inspection

A pipeline is a pressure vessel and is subjected to relatively high stress levels and often to cyclic pressures. Being buried provides a high level of protection, but it cannot provide complete protection. There are natural hazards such as earthquakes, landslides, subsidence and floods. There are also the more common risks such as third party damage.

Any of these events may cause physical damage, resulting in dents, buckles, gouges etc., but they rarely cause the line to rupture immediately. Mostly, they result in deformation of the line. Such deformations may have grave consequences over a period of time. Therefore, it is vitally important that every significant deviation from the original shape of a pressure vessel is investigated. To investigate these deviations, it is necessary to find them, and this is the main purpose of the range of pigs which are designed to locate and measure reductions in diameter. Furthermore, U.S. regulations require remediation of dents via prescriptive repair criteria.

5.1 Gauging Pigs

The gauging pig has been used for many years to verify reductions in the internal diameter. This is a cleaning pig equipped with a mild steel or aluminum plate. Gauge plates are machined to a percentage, commonly 95 percent, of the nominal inside diameter of the pipeline. It is important to note that there are no odometers, sensors or electronics onboard the tool. This is a basic method to prove pipeline bore. If the pig is removed from the receiver with dents, scratches or other abrasions to the plate, measurements are taken to determine if the minimum bore as detected by the gauge plate is sufficient for inspection tool passage. A pig that successfully negotiates the pipeline without damage to the plate is assumed to reveal the pipeline does not have reductions in diameter greater than the predetermined percentage amount, and safe passage of subsequent inspection tools is expected. In some cases a damaged gauge pig run may result in the need to make a separate geometry inspection to better understand what caused damage to the gauge plate. A gauging pig is shown in Figure 68.

Fig 68. Gauging Pig

5.2 Geometry Tools

Geometry inspections are performed to identify changes to the internal diameter of the pipeline caused by ovality, dents, partially closed valves, changes in wall thickness, etc. Geometry tools were designed to accurately detect and quantify

Fig 69. KALIPER® 360 Geometry Inspection Tool

Fig 70. Dent from High Resolution Deformation Tool

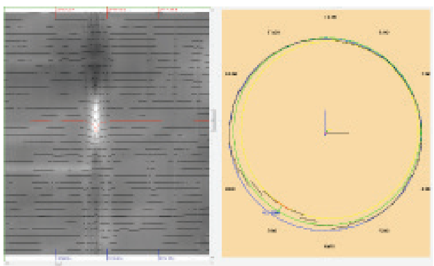


Fig 71a. Expanded Pipe

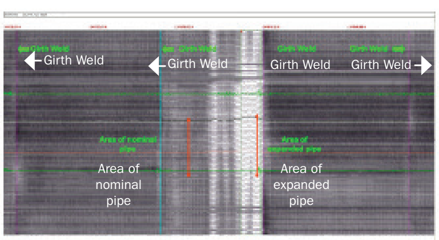
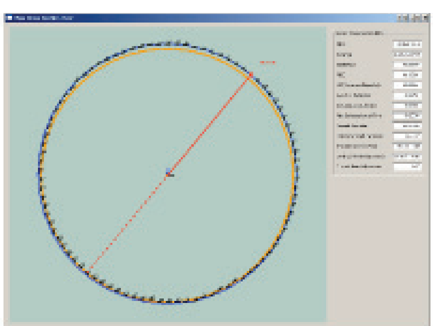


Fig 71b. Expanded Pipe



these changes in pipeline bore. These tools are equipped with arms, or fingers, which are spring loaded in order to keep them pressed against the pipe wall. They may either contact the pipe wall directly, or indirectly by being mounted inside the drive cup at the rear of the tool. Any change in diameter causes these arms or fingers to move mechanically. These movements are then recorded in onboard electronics along with odometer information for sizing and location of the anomalies along the pipeline.

The TDW KALIPER® pig was introduced in the 1960s to overcome the uncertainties left when using gauge pigs. It used an odometer wheel to measure the distance traveled and a stylus to indicate the extent of the dent damage. Skilled analysis could not only provide a measure of the reduction but also a reliable estimate of its shape and physical location.

The KALIPER technology has been continuously advanced to increase performance and resolution. The KALIPER 360, shown in Figure 69, contains an electronic package and computer analysis that greatly enhances both the accuracy and level of detail reported versus the original KALIPER technology. This technology will report the location, clock orientation and severity of the anomaly detected within two percent of the outside pipe diameter. KALIPER 360 was primarily designed for use in new construction geometry applications to prove pipeline bore after construction. Its single-body, lightweight design is propelled easily with compressed air after hydrostatic testing of newly constructed pipelines.

5.3 Deformation Tools (DEF)

Deformation tools provide an unparalleled level of accuracy in measuring dents and ovalities that rivals hand measurements. These tools also detect and accurately size other crucial anomalies such as pipe expansions and girth-weld misalignments. Examples of geometric anomalies are provided in Figures 70 through 71b.

Each line on the graph is indicative of a sensor or arm on the tool (refer to Figure 73 for view of tool configuration). Data on the left reveals the dent as depicted in raw data. The cross-section on the right shows various diameter readings and minimum bore at the dent location. Note the dent appears to be at 7 o'clock. Deformation data provides details such as minimum, average and maximum bore, calculated wall thickness, orientation, individual arm deflection, etc. at any prescribed distance interval.

The top example shows a section of three joints of large diameter pipe. The joint in the center exhibits an increase in the inside diameter of the pipe that reaches a maximum diameter near the downstream girth weld. The outward movement of the sensor arms is noted by an upward deflection of the traces and a lightening of the background gray scale. The increased diameter ends abruptly at the girth weld. The cross-section on the bottom shows the expanded pipe orientation from 10 o-clock to 4 o'clock around the circumference. The orange circle represents nominal internal diameter while the blue represents actual internal diameter due to expansion at the location.

Differing from KALIPER 360, measurement arms ride directly on the internal pipe wall rather than behind a cup for increased sensitivity. Arm spacing is also significantly tighter, averaging 0.50 inches when contracted in the internal diameter. High resolution data from these tools is also utilized for induced material strain analysis, as shown in Figure 72.

DEF technology can be joined with other tools to obtain multiple datasets from a single inspection. A DEF tool is shown in Figure 73.

Fig 72. Dent strain analysis. DEF inspection data provides high-quality representation of dent shape. Local dent strain can be estimated by analyzing the deformed shape.

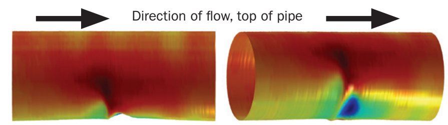


Fig 73. Deformation Tool: each arm rides independently and travels along the internal diameter with direct pipewall contact.

6.0 Metal Loss Inspection

Corrosion is one of the most common pipeline threats, next to excavation damage, and can be categorized in two main areas: internal and external. External corrosion may result from disbonded coatings or coating damage, stray currents, inadequate cathodic protection to name several. Internal corrosion causes are linked to debris, water and other corrosive contaminants. Billions of dollars are spent annually to mitigate corrosion and its cause. Utilizing advanced instrumented tools for metal loss inspection is a critical component of a pipeline operator's integrity management program.

The two main inspection techniques used to detect and quantify corrosion are Magnetic Flux Leakage (MFL) and Ultrasonics (UT). These approaches to metal loss inspection differ in that MFL is an indirect measurement of a magnetic field while UT is a direct measurement of the pipewall. Each has its advantages and disadvantages as a result. Some are listed below.

Sizing Accuracy:

- UT sizing tolerances are tighter than MFL due to direct measurement technique

Line Cleanliness:

- Pipeline cleanliness is critical to successful inspection though UT requires cleanliness to an extremely high level for accurate inspection

Inspectable Wall Thickness:

- UT has difficulty inspecting lower wall thickness while MFL may have difficulty with significantly thick wall depending on pipe diameter

Tool Velocities:

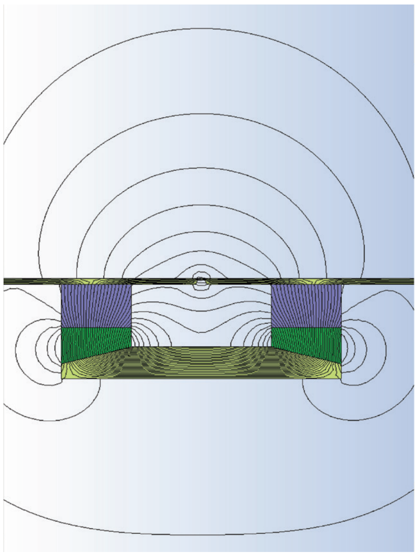
- MFL generally has no minimum velocity specification and can be run up to 7 mph (3 m/s) while UT requires very slow speeds ranging from 0.2 to 2 mph (0.1 to 1.0 m/s)

Couplant:

- MFL requires no couplant, thus it can be run in a multitude of inspection mediums. UT requires a couplant similar to a UT probe, which limits application.

MFL will be detailed in Section 6.1.

Fig 74. Magnetic Flux Leakage Principle: (A) magnets are oriented in opposing poles to create a magnetic current. (B) mechanism used to transfer magnetism into the pipewall, usually wire brushes or skid plates. Refer to Figures 75, 76, 77 and 78 for more details on types of magnetizers and how they appear on a physical ILI tool.

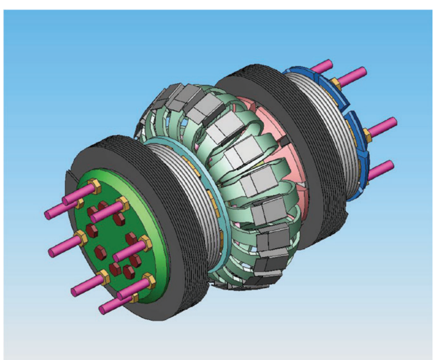


6.1 Magnetic Flux Leakage (MFL)

MFL tools have been used to inspect pipelines for metal loss since the 1960s. At that time only the bottom quadrant was inspected. The technology advanced to include full circumference inspection along with depth ranges of any indicated metal loss. This robust technology continued its evolution to include anomaly dimensions such as depth, length and width; increased sampling distance, sensor count, resolution and inspection ranges; and later the ability to be combined with other technologies such as deformation tools for enhanced analysis and operational improvements for the pipeline owner.

The technology works by inducing magnetism into the pipewall to “saturation.” Sensors oriented within the magnetic field then detect any changes. If there are no conditions that disturb the field no “leakage” occurs. When the field is disturbed the sensors oriented within the field detect the changes and record the information. This information is stored onboard the tool and later downloaded for analysis. All changes in the magnetic field are recorded, including girthwelds, valves, fittings, metal loss, extra metal, casings and other pipeline features with ferrous characteristics. Metal loss is also categorized between internal and external anomalies via a secondary set of sensors specifically designed for this purpose. See Figure 74 for more details on the magnetic field.

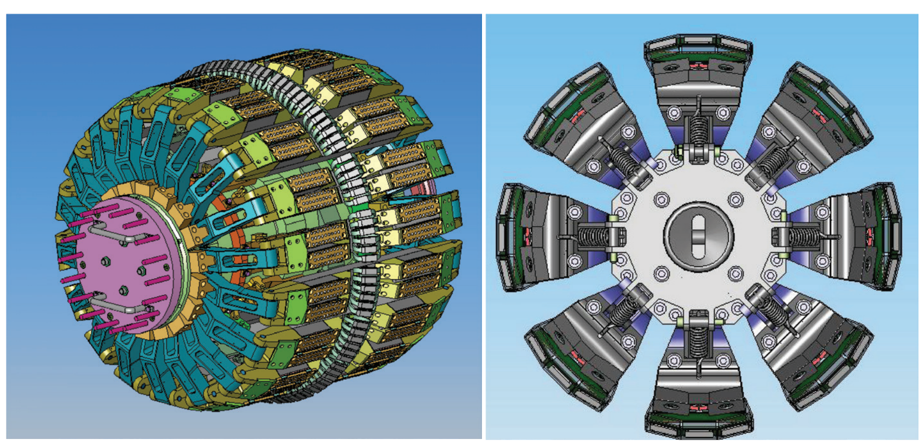
Fig 75. Solid Body Magnetizer: note the fixed body design, wire brushes to transfer magnetism and ring of sensors mounted around circumference.



Historically MFL tools were designed with a solid magnetizer using wire brushes to induce magnetism (see Figure 75).

Solid magnetizers work well in liquid lines, are able to negotiate 1.5D bends and generally have the ability to negotiate up to 15% reductions. This design, however, has not been conducive to successfully inspecting natural gas pipelines due to the drag and friction created by the design. Therefore, another magnetizer design exists for inspecting pipelines in compressible mediums (see Figure 76). This design allows for up to 25% reduction capability and significantly reduced drag due to its collapsible nature and use of skid plates to transfer magnetism versus

Fig 76. Collapsible (floating) Magnetizer. On right: note the separate magnetizer bars with plates to transfer magnetism; each bar contains its own sensors. On left: cross-section view showing collapsibility once the tool is inserted into the pipeline.



wire brushes. As a result, less pressure is required to move the tool. This creates a more consistent velocity profile and helps eliminate speed excursions outside of the upper limits. The result is successful magnetization of the pipewall and accuracy in the reported data. Actual photos of each tool can be found in Figures 77 and 78.

7.0 Seam Weld Inspection and Other Longitudinally Oriented Anomalies

Insufficient quality and manufacturing practices of pipe built prior to 1970 has created integrity threats outside of deformations and metal loss. Longitudinal seam weld anomalies such as lack-of-fusion and hook cracks have resulted in flaws that go undetected by MFL or traditional UT, and many have resulted in leaks or ruptures. Additionally, there are various longitudinally oriented anomalies that go undetected in MFL due to their orientation to the axial magnetic field.

In Section 6.1 the MFL technique was discussed in detail; magnetism is induced in the pipewall, changes in the pipewall disturb the magnetic field and sensors oriented in the field record the changes. Anomalies that are narrow; i.e. little or no width around the pipe circumference, and longitudinal in nature can go undetected by MFL. This can occur simply because there is not enough width to disturb the axial magnetic field induced by MFL tools. As a result the MFL technique was modified to orient magnetism transversely, or circumferentially, to bisect longitudinal features and thus create the “leakage” required to detect such anomalies. Refer to Figure 80.

Fig 77. MFL Tool with Fixed Brush Magnetizer

Fig 78. MFL Tool with Collapsible Magnetizer

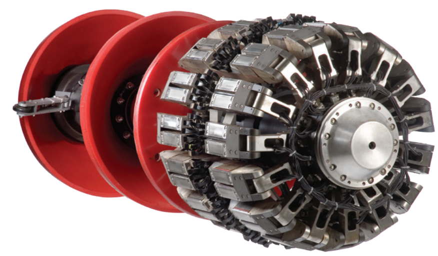
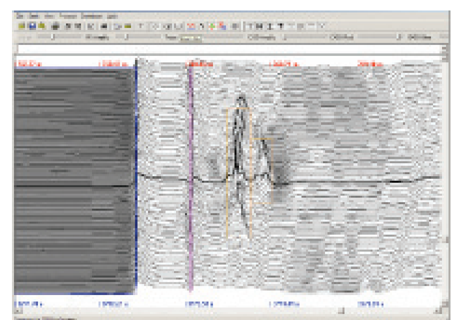


Fig 79. Patch of Metal Loss Detected by an MFL Tool.



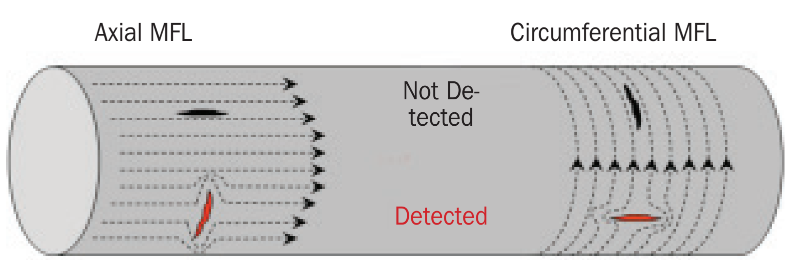


Fig 80. Axial MFL is excellent at detecting volumetric flaws or anomalies with circumferential width. Longitudinally oriented anomalies can go undetected by axial MFL. Circumferential or transverse MFL was developed to detect those anomalies oriented longitudinally and narrow in width.

Fig 81. TFI: Magnetism induced circumferentially between poles as depicted here creates inspection gaps where magnets are located. An offset magnetizer is required to ensure one-hundred percent coverage is achieved.

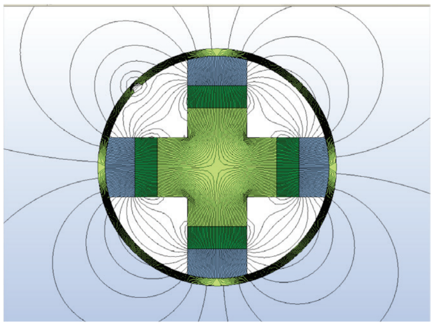


Fig 82. SMFL: Magnetism induced diagonally or spirally along the pipeline. This design facilitates one-hundred percent coverage with a single magnetizer.

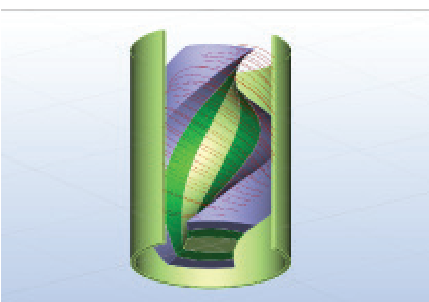


Fig 83. SMFL and MFL magnetizers combined for superior seam assessments and metal loss inspection with a single tool.

7.1 Transverse Field Inspection (TFI)

TFI tools were developed to detect longitudinally oriented anomalies. These tools induce magnetism at a ninety-degree angle, or circumferentially, rather than along the axis as with MFL tools. This design allows for detection of seam weld and other longitudinal anomalies, though its design creates some disadvantages. In order to induce magnetism around the circumference, and achieve one-hundred percent coverage, two offset magnetizers must be utilized. This makes for a longer tool and would require multiple inspections if there is a need for metal loss, deformation and longitudinally oriented anomalies in a single inspection. See Figure 81.

7.2 Spiral Magnetic Flux Leakage (SMFL)

An innovative approach to detecting seam weld and longitudinal anomalies in the pipe-body resulted in SMFL. This technology provides assessment of the longitudinal pipe axis in a single compact magnetizer (see Figure 82). The benefit is complete assessment of longitudinal anomalies and its ability to be combined with MFL for superior accuracy (refer to Figure 83). In many cases TFI will indicate “crack-like” or “possible crack-like” anomalies, causing the pipeline operator to make verification digs. When pairing SMFL with MFL there is extreme clarity brought to seam defects and whether they are truly “crack-like”, i.e. lack of fusion, hook cracks, etc. (see Figure 84). These enhanced results brought about by fusing MFL and SMFL data results in reduced excavations for the pipeline operator and thus significant costs savings relative to stand-alone TFI.

8.0 Geometry, Metal Loss, Long-Seam, Longitudinal, Hard Spot Inspection

Until recently, inspecting for various pipeline threats required multiple inspections. Within the last ten years, combining deformation with MFL became the standard for many inspection service providers. These advancements assisted both the inspection company and pipeline operator. The service provider only had to manage one tool, and integrating both datasets into a single final report enhanced the analysis process. For the pipeline operator, they only needed to schedule product for one inspection and track a single tool, among other benefits (see Figure 85 for example of a deformation and MFL combination tool).

When an operator required geometry, metal loss and seam assessments, multiple inspections were still required. That is, until recent developments in creating a multiple dataset platform that can include Deformation, MFL, SMFL and Residual sensors for detection of hard spots and mechanical strain. Combining these datasets on a single tool builds upon the benefits to both the inspection company and pipeline operator as described previously. Not only are geometry, metal loss, long-seam and strain anomalies detected and reported, analyzing all datasets from a single inspection produces superior results compared with performing individual inspections.

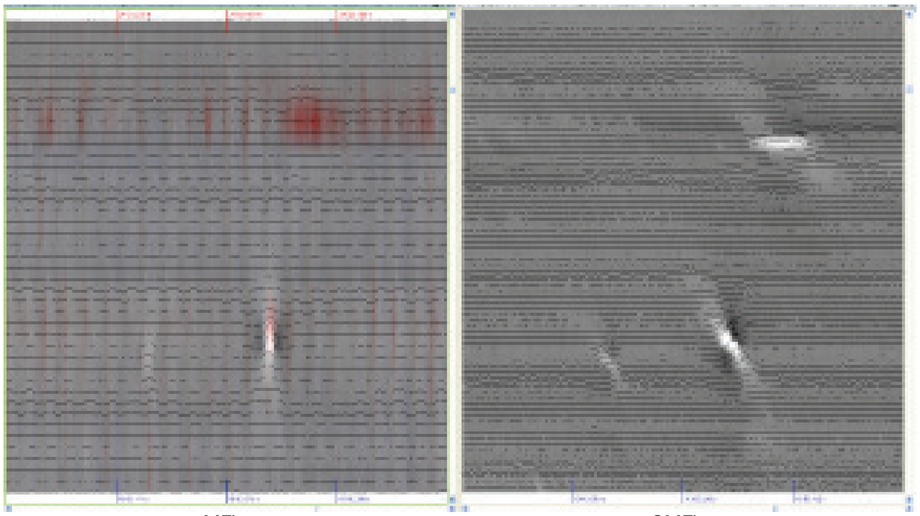
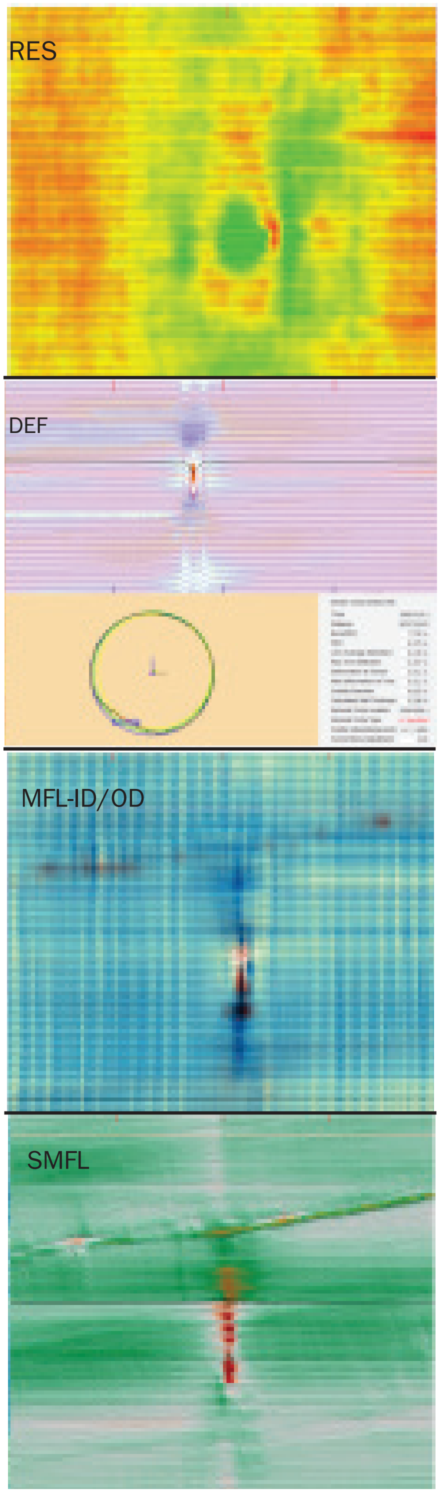


Fig 84. Data from an MFL+SMFL inspection. MFL data on the left indicates two slight metal loss anomalies. The SMFL data on the right confirms those two anomalies but also reveals a planar seam-weld feature that is not detected in MFL.

Fig 85. Example of a "combination tool" with deformation and MFL datasets.

Fig 86. Data from a multiple-dataset tool; dent with metal loss. First from top left reveals dent with mechanical strain in Residual Data; top right is the deformation data showing the dent in raw data and orientation in the cross-section view; bottom left is MFL data inclusive of ID/OD data which also depicts the dent but does not show metal loss; bottom right screen from left is the SMFL data which reveals the long-seam and the dent; note that in this view metal loss in the dent is confirmed.



For example, Figure 86, is indicative of the benefits of utilizing a multiple dataset approach. Additional strain caused by a potentially insignificant dent by depth percentage can impact prioritization of such anomalies. On top of the identified strain is confirmation of metal loss in the dent from the SMFL data. Due to the nature of the metal loss shape it is not detected in MFL (refer back to Section 7.0 for details on this subject). Figure 87 shows an example of a multiple dataset tool used to provide the data represented in Figure 86.

9.0 Crack Inspection

Cracking can come in many forms, such as stress corrosion cracking (SCC), and goes undetected by any of the previously mentioned technologies. The most commonly used, and widely accepted, technology for crack detection is Ultrasonic Technology (UT). The same operational requirements exist as with UT tools for metal loss inspection, including line cleanliness, tool velocity range and required couplant. UT crack tools differ from UT metal loss inspection tools mainly in the angle of the transducer. An emerging technology for crack detection is Electromagnetic Acoustic Transducer (EMAT).

While implementation of EMAT technology is different from UT the approach is similar: transmit a sonic wave into the pipewall to detect cracking. UT utilizes a piezoelectric transducer to impart a sonic wave to a material through a "mechanical" couplant. If the acoustic wave is altered, a reflection occurs and a reflected wave indicates an anomaly is present. UT transducers impart and measure the sonic wave and reflections. EMAT relies on an interaction between a magnetic field and a wire coil to impart a sonic wave within the pipewall. Eddy currents created by the wire coil interact with magnetic field to impart sonic waves within the inspected material. If the acoustic wave is altered, a reflection occurs and a reflected wave indicates an anomaly is present. EMAT sensor sets utilize transmitters and receivers to impart and then receive the reflected signals, respectively. Figure 88 graphically depicts the difference between UT and EMAT.

10.0 Pipeline XYZ Mapping

Submeter mapping information for a pipeline can be extremely valuable. Uses include refining geographic information system (GIS) data, pipeline displacement, bending strain (Figure 89) and pinpoint location of anomalies in the field. Data is provided via an onboard inertial measurement unit (IMU) in conjunction with an above-ground survey. Control points must be established along the pipe centerline trajectory spaced at periodic intervals between the launcher and receiver. These control points are used to provide coordinate updates to aid the final processing of the inertial data gathered from the instruments onboard the inspection vehicle.

Fig 87. 10-inch multiple dataset tool. From right to left: drive section including odometers, Spiral MFL, Deformation with IDOD Sensors, MFL and Residual Sensors (SMFL+DEF+IDOD+MFL+RES).

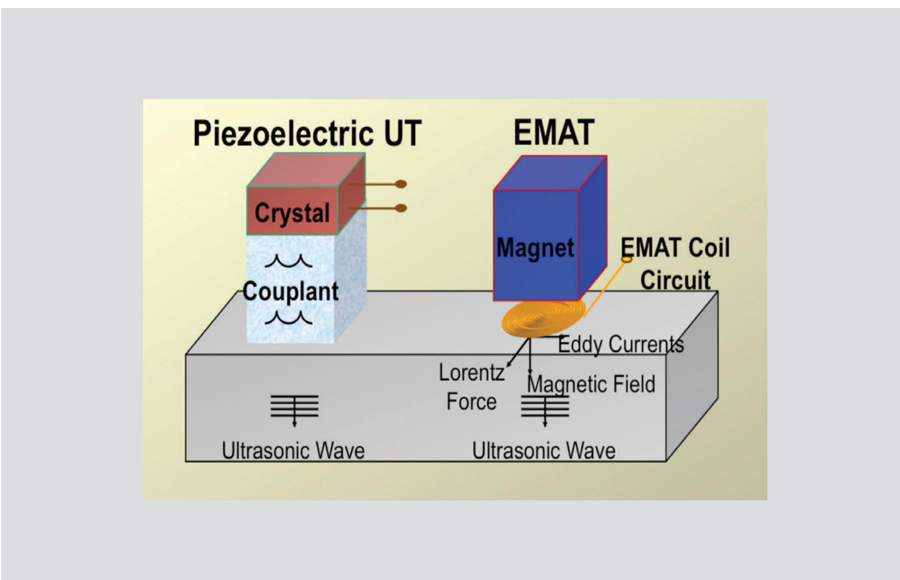


Fig 88. Ultrasonic Technology (UT) versus Electromagnetic Acoustic Transducer (EMAT)

Most control points will also serve as locations for tool tracking by means of above ground markers (AGMs).

For inspections to be run at tool speeds at or above 1 m/s (3.3 ft/s), select control point locations spaced no more than 2 km (1.24 mi) apart along the pipe centerline trajectory. For inspections slower than 1 m/s (3.3 ft/s), select control point locations spaced such that the tool will pass a control point every 20 to 30 minutes. Closer intervals will improve the accuracy of the data provided. When selecting locations and considering survey strategies at each location, remember that the eventual coordinates of interest are located along the centerline of the pipeline.

Required locations:

- Launcher door, upstream weld of launcher reducer, and launcher valve
- Receiver door, downstream weld of receiver reducer, and receiver valve

Recommended locations:

- Fixed pipeline features such as valves, tees, flanges, or exposed girth welds that are physically attached to the pipeline. These features are readily recognizable in the inspection tool data and, therefore, provide very accurate control points for the map processing.
- Straight sections of pipe, ideally in flat terrain, well downstream from any tight bends so that vehicle velocity is as steady as possible. These locations provide optimal conditions for above-ground markers to precisely record the passage of the inspection vehicle.

Poor locations:

- Downstream of any combination of fittings or heavy wall pipe that could cause

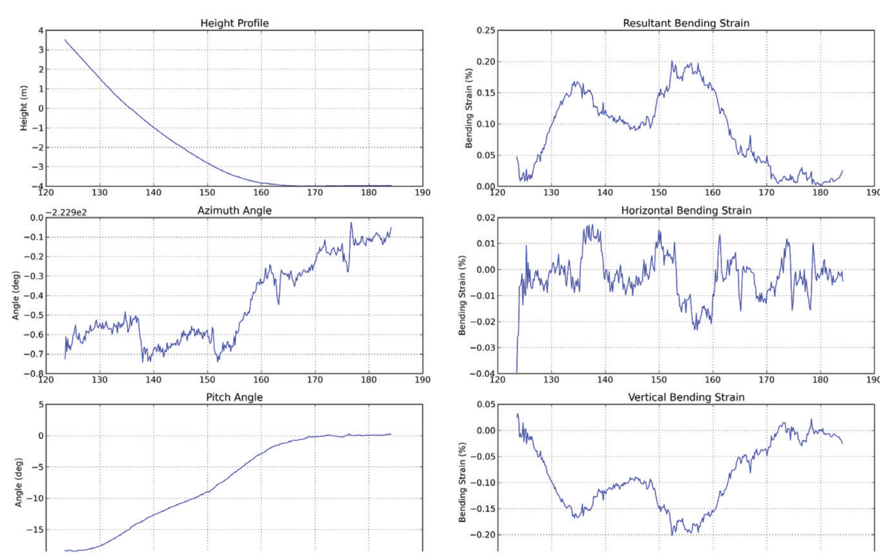


Fig 89. Example of bending strain analysis utilizing IMU data.

the inspection vehicle to surge as it exits the section. Detecting vehicle passage during a surge is much less reliable than at steady speeds.

- Within 3 m (9.8 ft) of a casing end or directly over a casing. Casings cause distortion on AGM signals, making passage time difficult to determine.
- Near cathodic protection transformers, pumping stations, generators, high voltage power lines, or any other known source of electrical noise that might interfere with the AGMs.
- Areas with very weak Global Positioning System (GPS) signal strength due to poor sky visibility.

Control Point Survey Specifications

- Survey results should be reported in the WGS 84 datum using ellipsoidal heights.
- Absolute accuracy of each surveyed location to true WGS 84 coordinates should be better than ±0.1 m (4 in) in any direction.

Data is provided in tabular form for easy integration into GIS and maps such as Google Earth (Figure 90).

11.0 Leak Detection and Location

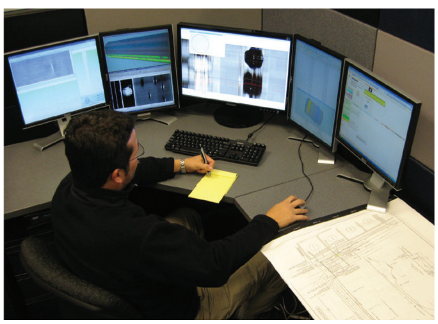
Most pipeline systems are equipped with automatic leak detection alarm systems. The majority work on the principle of the volume of fluid entering the pipe equaling the volume received at the terminal. The inability to maintain the line at its normal working pressure will also be an indication of a leak.

Land pipelines are also monitored using helicopters or light aircraft to visually identify leaks. There are also numerous other methods, including the infrared detection of hydrocarbons and the use of sniffer dogs. Generally, the detection of a leak is relatively simple; the main problem is in accurately locating it.

Fig 90. XYZ Mapping

Fig 91. Field Technician performing post-run checks to ensure completeness and quality of data prior to demobilizing from the jobsite

Fig 92. Data Analyst



Research has shown that the hissing sound made when a liquid is escaping under pressure through a small orifice occurs within a relatively narrow wave band. One ILI tool developed utilizing this basic principle has been in continual use for well over 20 years.

The liquid escaping due to a leak in a pipeline may cause a small but perceptible flow disruption due to the residual pressure, even when it is shut down. Modern instrumentation has allowed this flow to be measured and recorded. The flow rate will vary with the position of the instrument from the leak and so the approximate position can be calculated with some degree of accuracy.

12.0 Survey Results

The tools described in the previous sections are only the mechanism to gather data. The primary goal of utilizing ILI tools is to obtain the information recorded in a useable format to make solid engineering decisions to improve integrity of the inspected pipelines. Data is downloaded by the Field Technician within hours of tool removal (Figure 91). The primary checks done onsite are to understand tool performance and determine run success. A technician will confirm the run prior to demobilizing from the jobsite.

Data is then transferred to the local analysis center for further processing and detailed analysis (Figure 92). Preliminary reports are provided for each inspection

Fig 93a. Sample Inspection Results. Depth-based Orientation Plot

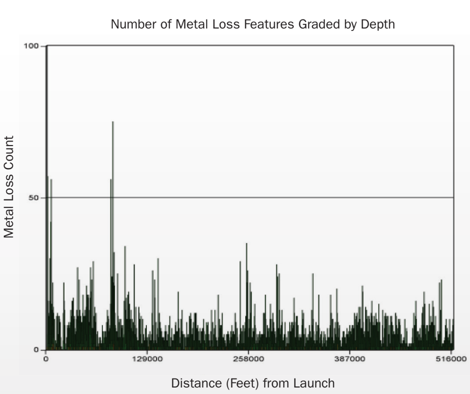
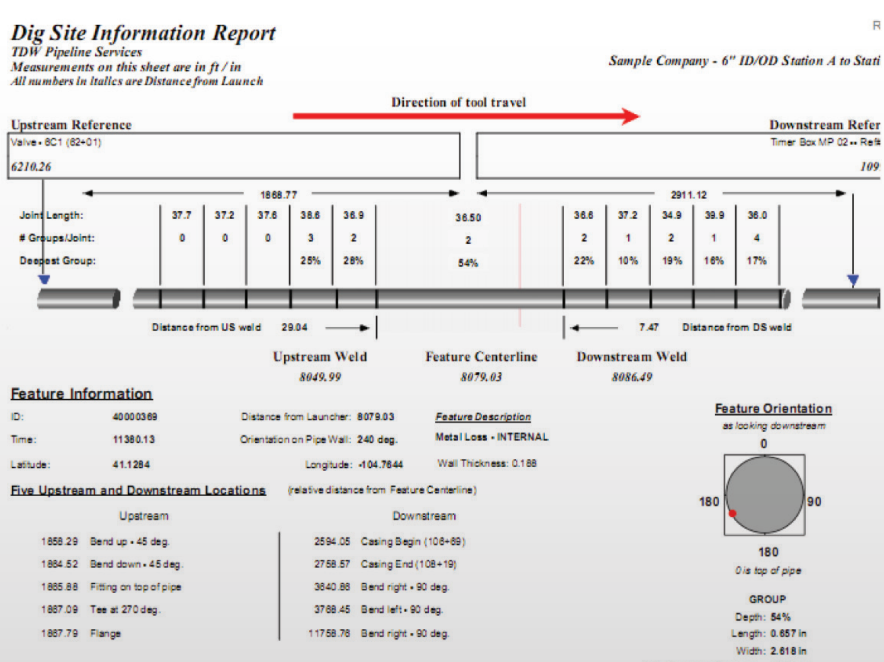


Fig 93b. Sample Inspection Results. Dig Sheet



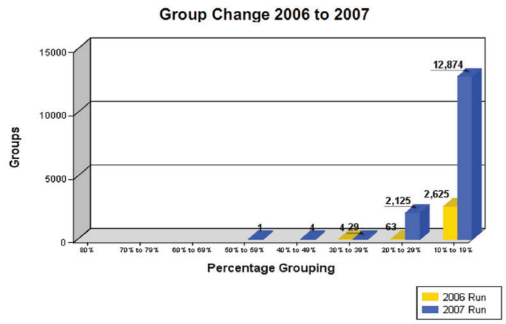
with the timeframe prescribed by the pipeline operator. Once analysis is complete a Final Report is delivered to the customer. Deliverables include dig sheets, pipe tally and other listings, graphical data presentation, client specific spreadsheet for easy integration into their internal systems and Client Software for reviewing data from the inspection. Figures 93a - d (see below) depict some examples of reported information. Onsite report presentations and software demonstrations are provided to ensure the pipeline operator completely understands the information received.

Depending on the inspection performed, onsite analysis can be provided. Expedited analysis is also an option, when required, which greatly reduces the number of days to receive inspection results.

Growth analysis can be performed and reporting provided as an additional deliverable (Figure 94). Previously inspected lines should be correlated back to the past run to determine if any changes have occurred. Any variations in dents or other indications related to third party damage may indicate encroachment not previously identified. Furthermore, changes in number of metal loss features over the pipeline or increase in depth severity could signify active corrosion growth. Integrating inspection results, growth analysis and other pipeline data can aid in mitigating threats to pipeline integrity and prolonging asset life.

NACE RP0102 Inline Inspection of Pipelines and NACE 35100 Inline Nondestructive Inspection of Pipelines are additional resources detailing inspection technologies, requirements, tool selection, etc.

Fig 94. Example Data from Growth Analysis.



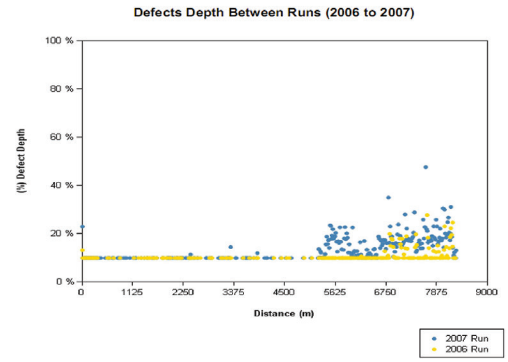


Fig 93c. Sample Inspection Results. Dig Sheet

Pipeline Tally

Girth Weld	Absolute Distance (ft)	Relative Distance (ft)	Joint length (ft)	Nominal Wall (in)	Feature Type	Feature Identification	Anomaly Class	Surface Location	Length (in)	Width (in)	Peak Depth (%)	Orientation hh:mm	ERF	Pipe Type	Comments
340	437.980	-	6.6	0.28	WELD	-	-	-	-	-	-	-	-	ERW	
340	438.056	0.1	6.6	0.28	LOCATION	Bend right - 30 deg.	-	-	-	-	-	-	-	ERW	
350	444.564	-	5.5	0.28	WELD	-	-	-	-	-	-	-	-	ERW	
360	450.052	-	5.2	0.28	WELD	-	-	-	-	-	-	-	-	ERW	
360	455.245	5.2	5.2	0.19	PIPE	Change in Wall Thickness	-	-	-	-	-	-	-	SEAMLESS	
370	455.300	-	22.7	0.19	WELD	-	-	-	-	-	-	-	-	SEAMLESS	
370	469.531	14.2	22.7	0.19	GROUP	-	PINH	INT	0	1	10	06:48	0.822	SEAMLESS	
370	472.171	16.9	22.7	0.19	GROUP	-	PINH	INT	0	1	10	07:36	0.822	SEAMLESS	
380	478.032	-	1.5	0.19	WELD	-	-	-	-	-	-	-	-	SEAMLESS	
390	479.566	-	36.9	0.19	WELD	-	-	-	-	-	-	-	-	SEAMLESS	
390	509.276	29.7	36.9	0.19	GROUP	-	PINH	INT	0	1	10	00:00	0.824	SEAMLESS	
390	511.906	32.3	36.9	0.19	GROUP	-	PINH	INT	1	3	10	00:12	0.839	SEAMLESS	
400	516.507	-	37.9	0.19	WELD	-	-	-	-	-	-	-	-	SEAMLESS	
410	554.357	-	36.1	0.19	WELD	-	-	-	-	-	-	-	-	SEAMLESS	
410	581.515	27.2	36.1	0.19	GROUP	-	PINH	INT	1	1	16	05:24	0.855	SEAMLESS	
410	588.340	34.0	36.1	0.19	GROUP	-	PINH	INT	1	1	18	06:12	0.835	SEAMLESS	
410	588.735	34.4	36.1	0.19	GROUP	-	PINH	INT	1	2	18	06:48	0.835	SEAMLESS	
420	590.477	-	37.7	0.19	WELD	-	-	-	-	-	-	-	-	SEAMLESS	
430	628.130	-	37.0	0.19	WELD	-	-	-	-	-	-	-	-	SEAMLESS	
430	630.529	2.4	37.0	0.19	GROUP	-	PINH	INT	2	4	35	01:24	0.954	SEAMLESS	
440	665.093	-	37.7	0.19	WELD	-	-	-	-	-	-	-	-	SEAMLESS	
440	671.129	6.0	37.7	0.19	LOCATION	Bend right - 36 deg.	-	-	-	-	-	-	-	SEAMLESS	
450	702.746	-	35.2	0.19	WELD	-	-	-	-	-	-	-	-	SEAMLESS	
450	710.174	7.4	35.2	0.19	LOCATION	Bend right - 30 deg.	-	-	-	-	-	-	-	SEAMLESS	
460	737.978	-	31.9	0.19	WELD	-	-	-	-	-	-	-	-	SEAMLESS	

Fig 93d. Sample Inspection Results. Depth-based Histogram

Maintenance, Cleaning and Storage of Pigs and Components

1.0 Introduction

Proper maintenance, cleaning and storage of pigs and pig components will contribute significantly to their performing in the pipeline as designed. A pig with a deformed cup or a damaged blade or spring will not perform properly.

Remember that pigs are usually run in a caustic environment. When cleaning and maintaining pigs, make sure proper personal protective equipment (PPE) is worn at all times.

2.0 Maintenance

Little maintenance is required on foam and all-urethane pigs. Cleaning is about all that can be done. See paragraph 3.0. These are designed to be discarded when worn out: Pigs with steel bodies have many components, such as cups, blades and brushes that can be replaced when worn.

A. Cups: Replace the cups when they are severely worn in one area, or if the diameter is such that the pig will not stay on stream.

B. Springs: Maintaining the springs is essential because deformed springs cause accelerated or uneven cup and cleaning element wear on the side of the pig where the damage is located. Spring damage can be caused by deformation in the pipeline, or by careless handling and transportation methods.

C. Cleaning Elements: Replace brushes or blades on wear compensating type pigs before they wear down to the mounting bolts or nuts, or when they do not extend out at least 3/8” (9.7 mm) past the cup O.D.

D. Bolts, Nuts, Cotter Pins: Replace damaged hardware and check all nuts and bolts for tightness. If cotter pins are removed, or show signs of wear or corrosion, replace them with new ones of the same size.

E. Body: Clean and paint scratches or nicks on steel bodies to prevent corrosion.

3.0 Cleaning

Clean pigs or spheres as soon as possible after removal from the pipeline. This is especially important when the pig or sphere has been used in a line containing a high percentage of hydrogen sulfide (H_2S). The following paragraphs describe methods of removing various pipeline residue from pigs. A pig washer, shown in Figure 95, will clean pigs automatically without the use of solvents.

When removed from the line, clean the pig immediately with hot water or water soluble cleaning agents to prevent corrosion and facilitate inspection for worn or damaged parts. Do not use steam on urethane parts.

Fig 95. Front Loading Pig Washer

Fig 96. Cleaning Pigs Packed with Paraffin

3.1 Removing Paraffin

A. If the pig is heavily packed with paraffin, as shown in Figure 96, much of it can be removed by scraping immediately after removing from the trap.

B. Submerge the pig in a water bath heated to 160°F for no more than one hour. When the bulk of the paraffin has been removed, clean remainder with a high-pressure water jet.

3.2 Removing Liquid, Powder or Mud

Clean with high pressure water jet.

3.3 Cleaning with Steam

Steam cleaning is acceptable for cleaning metal body parts and spring assemblies. However, 180°F is the maximum temperature to which urethane should be exposed. A maximum of 30 minutes at this temperature is recommended.

3.4 Cleaning with Solvents

Diesel fuel or kerosene are acceptable cleaning solvents. Urethane components may be immersed in or wiped with either one.

3.5 Post Cleaning

Once the pig is cleaned, spot painting of the scraper body and scraper parts is recommended where bare metal is exposed. A light coating with spray lubricant will also extend the product life.

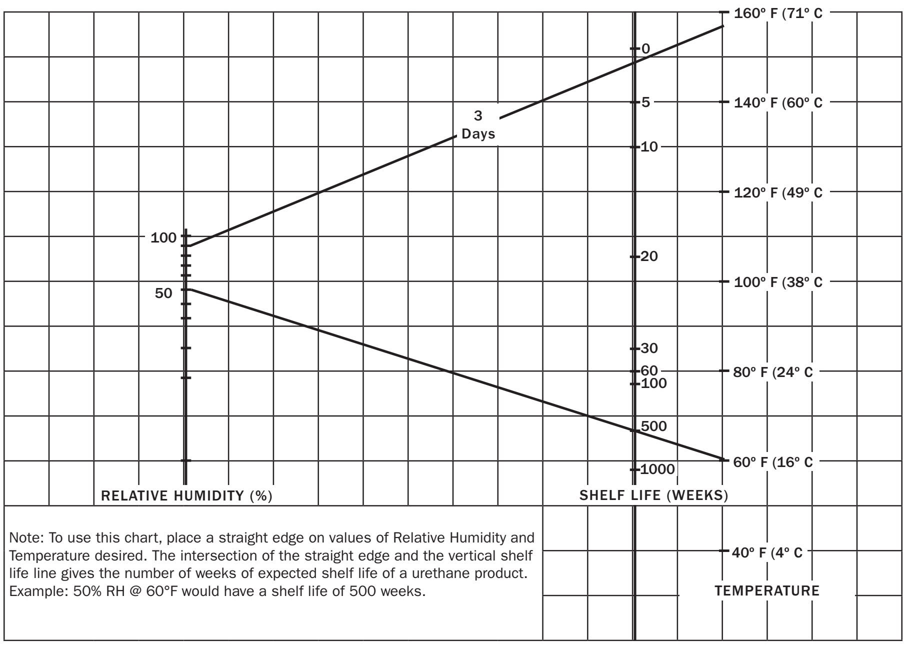
4.0 Storage

Combinations of temperature and humidity have a negative effect on the shelf life of urethane parts. Components should be stored in an area where humidity and temperature are monitored and controlled.

Table 4 provides guidelines on the effects of these factors on shelf life.

Table 4

Relationship of Relative Humidity (RH), Temperature and Urethane Shelf Life



Note: To use this chart, place a straight edge on values of Relative Humidity and Temperature desired. The intersection of the straight edge and the vertical shelf life line gives the number of weeks of expected shelf life of a urethane product. Example: 50% RH @ 60°F would have a shelf life of 500 weeks.

4.1 General

Extremes of temperature and humidity will hasten the deterioration of urethane components. Shelf life will be maximized when the temperature is maintained below 75°F and relative humidity less than 50 percent.

A. Urethane components should not be stored in direct sunlight.

B. Urethane components become brittle when stored in extremely cold temperatures. They should be warmed to the 50°F to 80°F range before use.

C. Components will take a “set” if deformed over a period of time. They should be stacked so that deformations will not occur. This is especially applicable to pig cups.

D. When a shelf inventory is maintained, adhere to a “first in/first out” usage system.

Fig 97. Typical Method for Storage of Assembled Pig

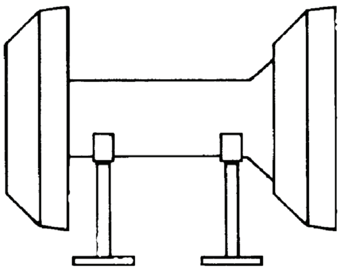


Fig 98. Pigs with Blades and Brushes Standing on End

Fig 99. Pig Cups Stacked

Fig 100. Blades Stored on Their Side

4.2 Assembled Pigs

A. The ideal storage for pigs is on a stand, with the stand supporting the pig weight, as shown in Figure 97.

B. Brush or blade pigs should be stored standing on end, as shown in Figure 98. Storage on the side with blades, springs or urethane cups supporting the weight will cause deformations of cups and blades.

4.3 Pig Components

A. Pig cups can be stacked as shown in Figure 99 as long as the weight is not enough to distort the lower cups.

B. Three-ribbed blades and plow blades can be stored on their side as shown in Figure 100.

4.4 Spheres

A. New spheres should be left in the shipping carton until ready for use.

B. On return to storage after use, liquids can be left in the sphere and the sphere left pressurized.

4.5 Long Term Storage

Stored and used urethane parts should be examined carefully prior to use. If material becomes soft or darkens in color, it should be inspected closely before use and discarded if in question.

A good method to detrmine if urethane has deteriated is to use a Shore “A” Durometer Tester to asure the urethane meets the hardness specifications.

APPENDIX I

Pipeline Pigging Questionnaires

T.D. Williamson, Inc.

TDW Pigs
Application Data Form

Form No: **pi 5/11**
Date: May 2011
Supersedes: pi 3/99

Company: ______________________ *Date:* ______________________

Address: ______________________ *City:* ______________ *State:* ______________ *Country:* ______________

Contact: ______________________ *Phone:* ______________ *Email:* ______________________

■ ***Required Information***

Flow Rate (ft/sec): ________ Primary Nominal Diameter: ________ Length: ________ Wall Thickness: ________

Product Media: ________ Secondary Nominal Diameter: ________ Length: ________ Wall Thickness: ________

Multiphase: Yes ☐ No ☐ % of Liquids: ________ Operating Pressure: ________ Maximum Pressure: ________

Side Connections: Barred ☐ Unbarred ☐ Valve Type: Gate ☐ Check ☐ Ball ☐

Maximum Size Outlet: ______________________ Other: ______________________

Specify pipe mfg method: Longitudinally Welded (SAW & DSAW) ☐ Spiral Welded ☐ Seamless (SMLS) ☐ Electric Resistance Welded (ERW & HFI) ☐

Other (Cast Iron, Concrete, etc.) ☐ If "Other", Please Specify: ______________________

Minimum Bend Radius

	Minimum Bend Radius on 45º		Minimum Bend Radius on 90º		Minimum Bend Radius on: _____	
	Radius	Back-to-Back	Radius	Back-to-Back	Radius	Back-to-Back
Primary Diameter:	________	Yes ☐ No ☐	________	Yes ☐ No ☐	________	Yes ☐ No ☐
Secondary Diameter:	________	Yes ☐ No ☐	________	Yes ☐ No ☐	________	Yes ☐ No ☐

Purpose for pigging the line? Cleaning ☐ Displacing ☐ Batching ☐ Gauging ☐ Pre-Inline Inspection ☐ Applying Inhibitors ☐ Other ☐

Describe: ______________________

____

____

If Cleaning, check all that apply: Scale ☐ Paraffin ☐ Sediments ☐ Ferrous Debris (weld-rods, cutter chips, etc.) ☐ Iron Sulfide ☐ Other ☐

If Displacing, check all that apply: Purging ☐ Decommissioning ☐ Batch Separating ☐ Commissioning ☐ Liquid Removal ☐ Line Isolation ☐ Other ☐

If Other, please provide details: ______________________

■ ***Pigging History***

Have pigs been run previously? Yes ☐ No ☐ If yes, when: ______________________

Type(s) of pigs used: Cup Pig ☐ One Piece Urethane ☐ Disc/Cup Pig ☐ Foam ☐ Attachments: Brushes ☐ Magnet Wrap ☐ Transmitter ☐

Pigging frequency: Weekly ☐ Monthly ☐ Quarterly ☐ Semi Annually ☐ Before Inspection Tools ☐ Never ☐

Type of debris recovered ______________________ Amount of debris: None ☐ Light ☐ Medium ☐ Heavy ☐

Additional Information: ______________________

____

TDW Pigging Products
10727 East 55th Place
Tulsa, Oklahoma 74146-6702
USA

Fax: 918-664-7091
Toll Free: 800-571-7447
Phone: 918-447-5400

T.D. Williamson (U.K.) Ltd.
Faraday Road, Dorcan Way,
Swindon, Wiltshire
ENGLAND SN3 5HF

Fax: (44) 1-793/603601
Ph: (44) 1-793/603600

Inline Inspection Questionnaires

T.D. Williamson, Inc.

Form No: **ii 2/11**
Date: February 2011
Supersedes: n/a

Inline Inspection Application Data Form

To help us better serve you in providing the right TDW products for your piping system requirements, please complete this form and return to TDW by mailing or by fax (see below).

TDW Services, Inc, Pipeline Integrity Products and Service
6747 South 65th West Avenue, Tulsa, Oklahoma 74131-2444;
or Fax: 918-446-5550.

OR

TDW Services, Inc, Pipeline Integrity Products and Service
4085 South 300 West, Salt Lake City, Utah 84107;
or Fax: 801-169-1516.

*Company:*____________________ *Date:*__________

*Address:*____________________ *City:* __________ *State:*__________ *Country:* __________

Analysis Contact: __________ *Email:*__________ *Phone:* __________ *Cell:*__________ *Fax:*__________

*Field Contact:*__________ *Email:*__________ *Phone:* __________ *Cell:*__________ *Fax:*__________

Type of Inspection Tool: *MFL* ☐ *IDOD* ☐ *Deformation* ☐ *Combo* ☐ *LGT* ☐ *KALIPER® Tool* ☐ *Mapping* ☐ *KALIPER® 360* ☐

*Report Delivery Address:*__________ *City:* __________ *State:* __________ *Country:* __________

*Invoice Delivery Address:*__________ *City:* __________ *State:* __________ *Country:* __________

■ *Location of Pipeline*

Launch Site Name:____________________ Onshore ☐ Offshore ☐

Launcher GPS Lat/Long or Directions:____________________

City: __________ *State:*__________ *Country:* __________

Receiver Site Name:____________________ Onshore ☐ Offshore ☐

Receiver GPS Lat/Long or Directions: ____________________

City: __________ *State:* __________ *Country:* __________

■ *Reporting*

Select measurement unit for reporting: English ☐ Metric ☐

Provide sizing algorithm: __________ Evaluation pressure: MOP: __________ MAOP: __________

Provide pit interaction rule: ____________________

Preferred final report media: DVD qty:______ CD qty:______ Printed Report qty: ______ Other: ______

Line ID or section name to be used on final report: ____________________

■ *AGM & ROW Information*

Marker Boxes: Quantity:__________ Type: Magnetic ☐ 20HZ Receiver ☐

Tracking Company Name: ____________________

Tracking Company Contact:__________ Phone: __________ Cell:__________

Pipeline Right of Way: ____________________

Type of Terrain: ____________________

Accessibility: ____________________

GPS Survey available: Yes ☐ No ☐ Line Maps available: Yes ☐ No ☐

Is Pre-launch meeting required "AGM" training, etc? Yes ☐ No ☐

■ ***Product Pressure & Flow***

Product Type: Temp:_________ ºC ☐ ºF ☐ Gas ☐ Liquid ☐ Gas & Liquid ☐

Line pressure during inspection: _______ PSIG ________ KPA Other: ________________________

Flow rate during inspection: Units: ___________ Predicted tool velocity during inspection:__________________

Interruptions in flow: ________________________________ Bi directional pump stations: Yes ☐ No ☐

Product related chemistry:

Parafin ☐ _________ *% =* *Iron Sulfide* ☐ CO_2 ☐ _________ *% =*

H_2S ☐ _________ *% =* *Iron Oxide* ☐ *Inhibitor* ☐ _________ *% =*

Norms ☐ *Do you have procedures for decontamination and disposal of radioactive debris?* Yes ☐ No ☐

■ ***Pipe Description***

Total Length: _________________ Check if fill information is attached: ☐

Pipe Diameter	Pipe Material and Grade	Wall Thickness	Pipe Length on W.T.	Minimum bend Radius in W.T.	ERW, Seamless Spiral

■ ***Fittings***

Bends:

Are there any back to back bends with less than 3 diameters of straight pipe between them? Yes ☐ No ☐ Unknown ☐

Details ____

Are there any heavy wall bends? Yes ☐ No ☐ Unknown ☐

Details ____

Are there any miter bends? Yes ☐ No ☐ Unknown ☐

Details ____

What is the minimum bend radius in the line? ____

Tees:

Are there any tees with less than 2 diameters of straight pipe between them? Yes ☐ No ☐ Unknown ☐

Details ____

Are there any heavy wall tees? Yes ☐ No ☐ Unknown ☐

Details ____

Are all full bore tees barred? Yes ☐ No ☐ Unknown ☐

Details ____

Are there any flow tees? Yes ☐ No ☐ Unknown ☐

Details ____

Are there any cross tees? Yes ☐ No ☐ Unknown ☐

Details ____

■ ***Main Line Valves***

Main Line Valve Types: ____

Any check valves in this line? Yes ☐ No ☐ Unknown ☐

Details ____

Any valves with restrictive bore? Yes ☐ No ☐ Unknown ☐

Details ____

Can check valves be pinned open? Yes ☐ No ☐ Unknown ☐

Details ____

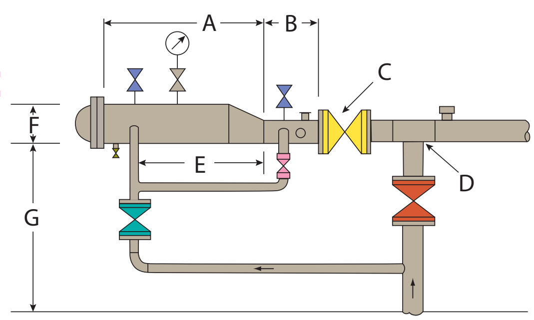
Are all valves full opening? Yes ☐ No ☐ Unknown ☐

Details ____

■ ***Trap Information***

	Launcher		Receiver	
Length of oversize launcher/receiver barrel (A):	____________		____________	
Length of nominal diameter (B):	____________		____________	
Type of Valve (C):	____________		____________	
Tee branch O.D. (D):	____________		____________	
Distance from bypass/kicker to reducer (E):	____________		____________	
O.D. of oversize pipe (F):	____________		____________	
Trap height from work surface (G):	____________		____________	
Reducer concentric or eccentric:	Concentric ☐	Eccentric ☐	Concentric ☐	Eccentric ☐
Closure door full open:	Yes ☐	No ☐	Yes ☐	No ☐
Pressure equalizing line installed:	Yes ☐	No ☐	Yes ☐	No ☐

Working distance in front of trap: ____



■ ***Miscellaneous Information***

What equipment will be available to launch and receive the inspection tool? ______________________

What equipment will be available to clean the inspection tool at receiver? ______________________

Is there any site specific or specialized training required? ______________________

■ ***Pigging Frequency***

Has line been cleaned? Yes ☐ No ☐ Unknown ☐ Details ______________________

Types of cleaning pigs used? Known ☐ Unknown ☐ Details ______________________

Has line ever been inspected? Yes ☐ No ☐ Unknown ☐ Details ______________________

Types of previous inspection tools? Known ☐ Unknown ☐ Details ______________________

Has gauge pig been run? Yes ☐ No ☐ Unknown ☐ Details ______________________

Useful Conversion Factors

Cubic Measure (Volume)				
Input:				Output:
1.00	Gallon(UK) x	1.20095	= Gallon(US) :	1.201
1.00	Gallon(US) x	231	= Cubic Inches :	231.0
1.00	Gallon(US) x	0.1337	= Cubic Feet :	0.134
1.00	Gallon(US) x	3.7854	= Liter :	3.79
1.00	Gallon(US) x	0.02381	= Barrel :	0.024
1.00	Cubic Foot x	28.3168	= Liter :	28.317
1.00	Cubic Foot x	7.4805	= Gallon(US) :	7.481
1.00	Cubic Foot x	0.1781	= Barrel :	0.178
1.00	Barrel x	5.6146	= Cubic Feet :	5.61
1.00	Barrel x	42.0	= Gallon(US) :	42.00
1.00	Liter x	0.2642	= Gallon(US) :	0.264

Pressure				
Input:				Output:
1.00	Ft of Water (60°F) x	0.4331	= lbs/sq-in (psi) :	0.4331
1.00	Lbs/sq-in (psi) x	2.309	= Ft of Water (60°F) :	2.309
1.00	Bar x	14.504	= lbs/sq-in (psi) :	14.504
1.00	Kg/sq-cm x	14.223	= lbs/sq-in (psi) :	14.223
1.00	Kilopascal (KPa) x	0.14504	= lbs/sq-in (psi) :	0.145
1.00	Megapascal (MPa) x	145.04	= lbs/sq-in (psi) :	145.04
1.00	Lbs/sq-in (psi) x	0.06895	= bar :	0.07
1.00	Lbs/sq-in (psi) x	6.895	= kilopascal (KPa) :	6.89

Flow Rates				
Input:				Output:
1.00	Gallon/min (GPM) x	0.13368	= cu-ft/min :	0.134
1.00	Gallon/min (GPM) x	0.22712	= cu-m/hr :	0.227
1.00	Gallon/min (GPM) x	1.428571429	= barrel/hr :	1.429
1.00	Gallon/min (GPM) x	34.286	= barrel/day (BPD) :	34.29
1.00	Barrels/hour x	0.09358	= cu-ft/min :	0.094
1.00	Barrels/hour x	0.70	= gal/min (GPM) :	0.700
1.00	Barrels/day (BPD) x	0.02917	= gal/min (GPM) :	0.029
1.00	Cu-Ft/min x	7.481	= gal/min (GPM) :	7.48
1.00	Cu-Ft/min x	256.475	= barrel/day (BPD) :	256.5

Velocity				
Input:				**Output:**
1.00	Feet/second (FPS) x	0.3048	= meters/sec :	0.30
1.00	Feet/second (FPS) x	0.6818	= miles/hr (MPH) :	0.68
1.00	Meters/second x	3.2081	= ft/sec (FPS) :	3.21
1.00	Meters/second x	2.2369	= miles/hr (MPH) :	2.24
1.00	Miles/hour (MPH) x	1.4667	= ft/sec (FPS) :	1.47
1.00	Miles/hour (MPH) x	0.4470	= meters/sec :	0.45
1.00	Miles/hour (MPH) x	1.6093	= Km/hr (KPH) :	1.61

Temperature											
°C	°F	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F
-18	-0.4	4	39.2	26	78.8	48	118.4	70	158	92	197.6
-17	1.4	5	41	27	80.6	49	120.2	71	159.8	93	199.4
-16	3.2	6	42.8	28	82.4	50	122	72	161.6	94	201.2
-15	5	7	44.6	29	84.2	51	123.8	73	163.4	95	203
-14	6.8	8	46.4	30	86	52	125.6	74	165.2	96	204.8
-13	8.6	9	48.2	31	87.8	53	127.4	75	167	97	206.6
-12	10.4	10	50	32	89.6	54	129.2	76	168.8	98	208.4
-11	12.2	11	51.8	33	91.4	55	131	77	170.6	99	210.2
-10	14	12	53.6	34	93.2	56	132.8	78	172.4	100	212
-9	15.8	13	55.4	35	95	57	134.6	79	174.2	101	213.8
-8	17.6	14	57.2	36	96.8	58	136.4	80	176	102	215.6
-7	19.4	15	59	37	98.6	59	138.2	81	177.8	103	217.4
-6	21.2	16	60.8	38	100.4	60	140	82	179.6	104	219.2
-5	23	17	62.6	39	102.2	61	141.8	83	181.4	105	221
-4	24.8	18	64.4	40	104	62	143.6	84	183.2	106	222.8
-3	26.6	19	66.2	41	105.8	63	145.4	85	185	107	224.6
-2	28.4	20	68	42	107.6	64	147.2	86	186.8	108	226.4
-1	30.2	21	69.8	43	109.4	65	149	87	188.6	109	228.2
0	32	22	71.6	44	111.2	66	150.8	88	190.4	110	230
1	33.8	23	73.4	45	113	67	152.6	89	192.2	111	231.8
2	35.6	24	75.2	46	114.8	68	154.4	90	194	112	233.6
3	37.4	25	77	47	116.6	69	156.2	91	195.8	113	235.4

Common Acronyms

AGM .... Above Ground Marker

BPD....................... Barrels Per Day

CFM....................... Cubic Feet Per Minute

DA......................... Direct Assessment

DEF .... Deformation

DS......................... (Natural Gas) Distribution

DS......................... Distribution Systems

EMAT .... Electromagnetic Acoustic Transducer

FPS .... Feet Per Second

GIS........................ Geographic Information System

GMFL..................... Gas Magnetic Flux Leakage

GPM .... Gallons Per Minute

GPS....................... Global Positioning System

H_2S....................... Hydrogen Sulfide

HCA....................... High Consequence Area

HP......................... High Pressure

ID.......................... Inside Diameter

ILI .... Inline Inspection

IMP .... Integrity Management Plan

IMU .... Inertial Measurement Unit

KPa .... Kilopascal

KPH....................... Kilometers Per Hour

LPM....................... Liters Per Minute

MAOP .... Maximum Allowable Operating Pressure

MFL....................... Magnetic Flux Leakage

M3/H .... Meters Cubed Per Hour

MPa....................... Megapascal

MPH .... Miles Per Hour

NACE .... National Association of Corrosion Engineers (formerly; now NACE International)

NDE....................... Non-Destructive Examination

NDT....................... Nondestructive Testing

OD .... Outside Diameter

OPS....................... Office of Pipeline Safety (U.S.)

PHMSA .... Pipeline and Hazardous Materials Safety Administration (U.S.)

P&ID...................... Piping and Instrumentation Diagram

PPE .... Personal Protective Equipment

PSI .... Pounds Per Square Inch

RH......................... Relative Humidity

SCC....................... Stress Corrosion Cracking

SMFL .... Spiral Magnetic Flux Leakage

TFI......................... Transverse Field Inspection

UT .... Ultrasonic Technology