DIFFICULT TO PIG PIPELINES

David Wint, Sr. Technical Advisor - Midstream

CHAMPIONX

AUCSC

Appalachian Underground Corrosion Short Course

Regulations

- In 1994 §192.150 / §195.120 regulations were passed that required each new transmission line and each replacement of line pipe, valve, fitting, or other line component in a transmission line must be designed and constructed to accommodate the passage of instrumented internal inspection devices.

- Design & Construction Standards to reduce internal corrosion on Gas Transmission Pipelines – Final Rule May 23, 2007
  - New and replaced gas transmission pipelines must be configured to reduce the risk that liquids will collect in the line
  - Have effective liquid removal features
  - Allow use of corrosion monitoring devices in locations with significant potential for internal corrosion

What is Pigging ?

A widely utilized process which is the act of propelling a properly sized spherical or cylindrical device through the interior of a pipeline by manipulating the pressure & flow of the existing media, or by artificially introduced media or by mechanically pulling the device through the pipeline for the specific purpose of cleaning, inspecting or distributing inhibitor throughout the pipeline.

Why Pig a Pipeline

During the 1940s pipelines in the United States were mainly pigged to remove paraffin to increase efficiency in crude oil pipelines in order to maximize flow conditions for the war effort. The pigging equipment utilized at that time was limited to a few applications while being very crude in nature. In today's world, pipelines are pigged for a variety of reasons and the pigging equipment used is designed by engineers to perform particular functions.

Piggability

Piggability

- Physical Characteristics (Pipeline Design)
- Line Pipe Grade
- Type of Welds
- Length
- Fittings
- Internal Diameter
- Elevation Profile
- Tees
- Bends
- Valves
- Spans

§192.105 - Design of Steel Pipe

$$P = (2St/D)(F)(E)(T)$$

P = Design Pressure
S = Yield Strength
D = Outside Diameter
t = Wall Thickness
F = Design factor - §192.111
E = Longitudinal joint factor - §192.113
T = Temperature de-rating factor - §192.115

$P=\frac{2St}{D}(F)$ §192.111

Class location	Design factor (F)
1	.72
2	.60
3	.50
4	.40

Types of Welds (Connection)

Type of Welds (Connections)

- Acetylene welding was first used around 1911 to join pipe segments together (girth welding) and just prior to 1920, arc welding was introduced.
- Chills Rings are sometimes called backup rings or spacers. These rings are machined pieces of metal that conform to the dimensions of the joint design used. Bell-to-bell joints that were welded together with the use of a chill ring.

Types of Welds (Connection)

Type of Welds (Connections)

Chill Rings

AUCSC

Appalachian Underground Corrosion Short Course

Type of Welds (Connections)

Dresser Coupling

Types of Welds (Connection)

Dresser Coupling
Pumpkin Repair Sleeve

Types of Welds (Connection)

Zap-Lok Connections

Piggability

Length

The distance between two pig traps is a variable and must be determined for each specific pipeline.

Some considerations:

- Wear on the Pigs
- Pipeline Product

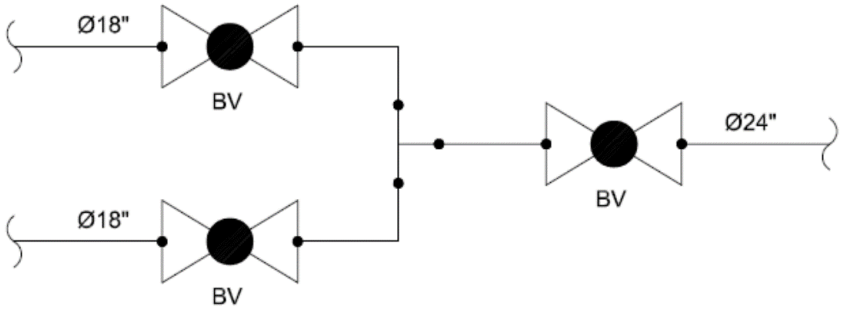
The following pipeline lengths are not uncommon;

- Natural Gas pipelines 50-100 miles between traps
- Refined Products Pipelines 100-150 miles between traps
- Crude Oil Pipelines 150-200 miles between traps

Piggability

Dual Diameter Pipelines

Pipelines that have been designed to accept input along their length may need to increase in diameter as the through-put increases. Instead of having traps installed at each change in pipe size reducers are used. Concentric reducers should be used for changes in diameter within a pipeline so that the center line of the pig can remain on the same plane as it makes the transition from one size to another.



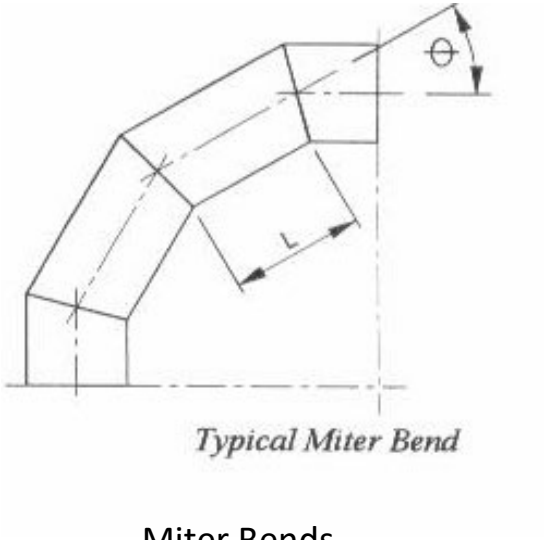
Piggability

Linings

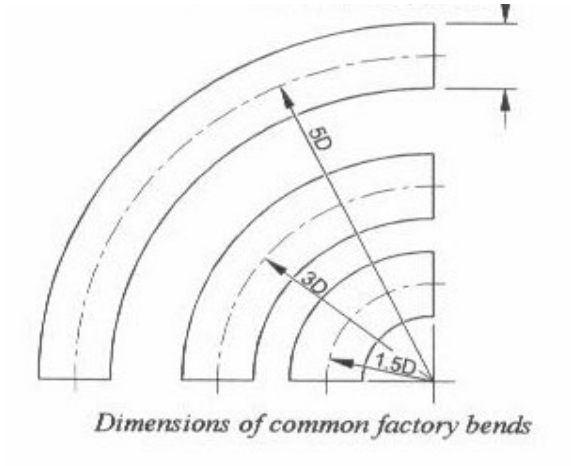
Pipelines are lined to help protect the inside of the pipe from the effects of the product and to create less flow resistance. Natural gas pipelines are usually internally coated with an epoxy fusion bonded coating applied under controlled conditions at the factory or a special field site. Wire brush pigs should not be used on pipelines that have been internally coated. A combination of urethane blades, discs and cups should be used for maintenance pigging.

Piggability

Bends



Miter Bends



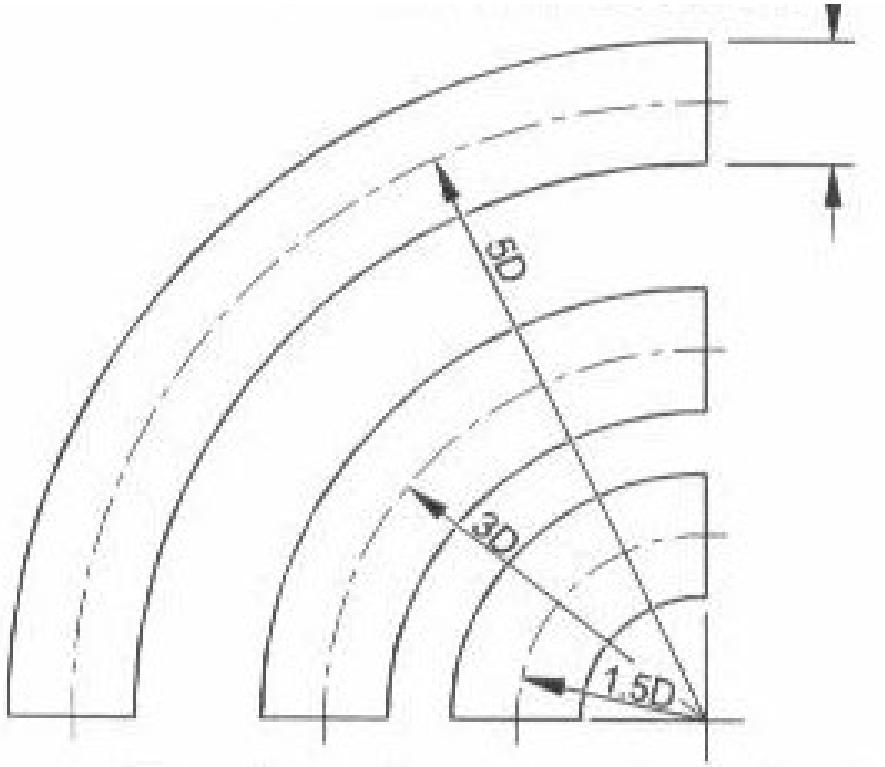
Examples of common Factory Bends w/ 5D, 3D and 1.5D Radius

5D Factory Bends and/or Field Bends

For pigging requirements, any local deformation from field bending should not exceed 2 or 3% of the pipeline diameter.

Piggability

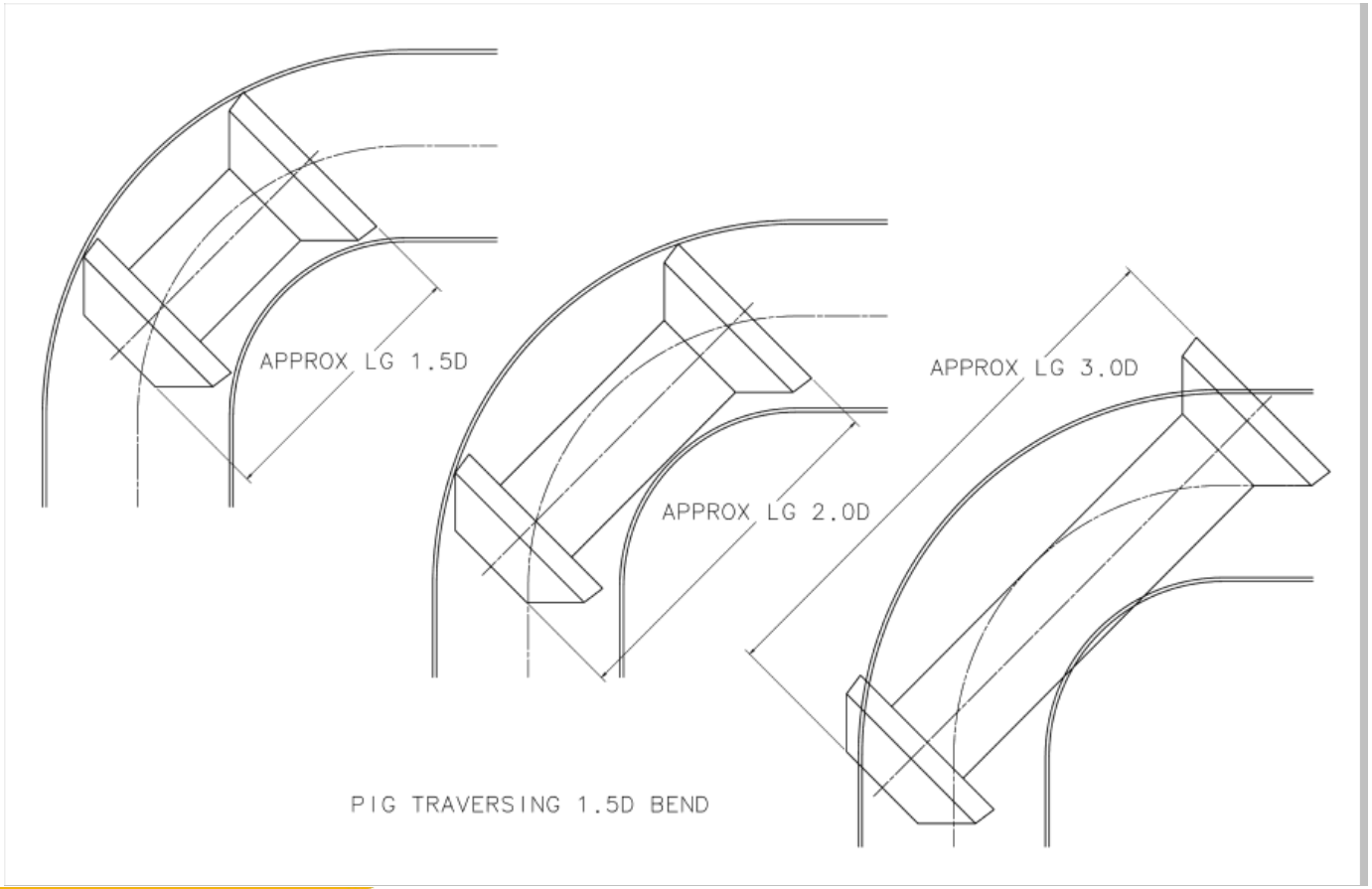
Bends



Dimensions of common factory bends

Piggability

Bends



Piggability

Diameter and Wall Thickness

- One of the largest cost of a pipeline is the cost of the pipe. In the process of the design engineering phase the through-put is used to determine the pipe diameter and the pipe wall thickness.

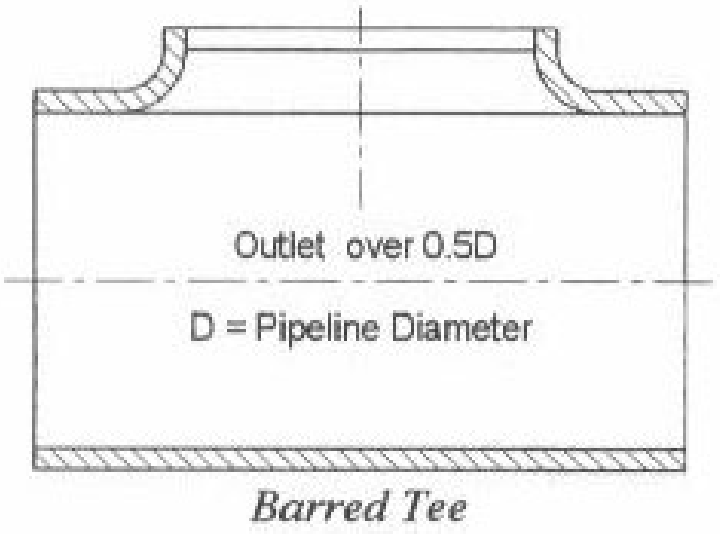
- The wall thickness may vary due to external conditions such as High Consequence Area's, Road Crossings, Railroad Crossings, etc.

- As long as the wall thickness is such that the inside pipe diameter is within the tolerances allowed by the pig manufacturer the varying wall thickness should not be a problem.

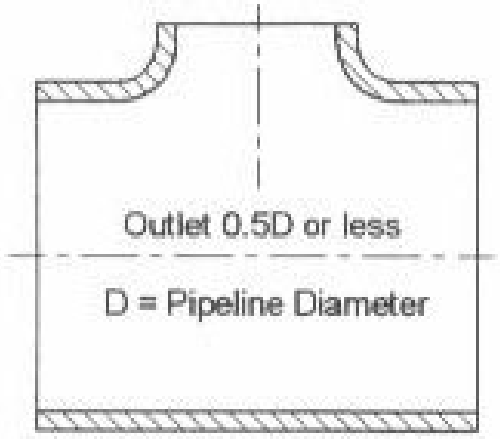
Piggability

Tees

Tees with outlets greater than 50% of the main diameter should be barred to reduce the risk of sticking pigs. This is especially true in laterals with high flow conditions



Barred Tee



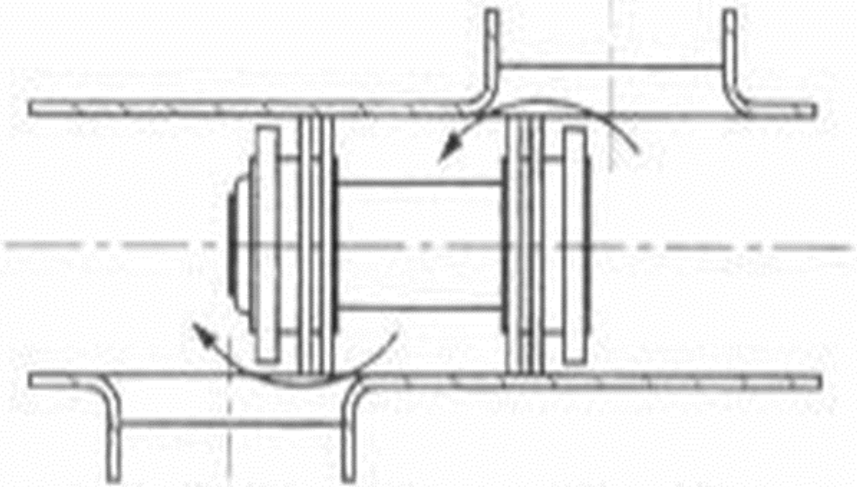
Unbarred Tee

Piggability

Off-Takes

Forged tees are usually used for installing off takes (outlets) in a pipeline during construction. Most conventional pigs will safely transverse tees with outlets up to 60% of the nominal line size. However it is good practice to install guide bars in all outlets above 50%.

Off takes should not be installed adjacent to one another. At least three diameters of straight pipe should be installed between any two fittings.



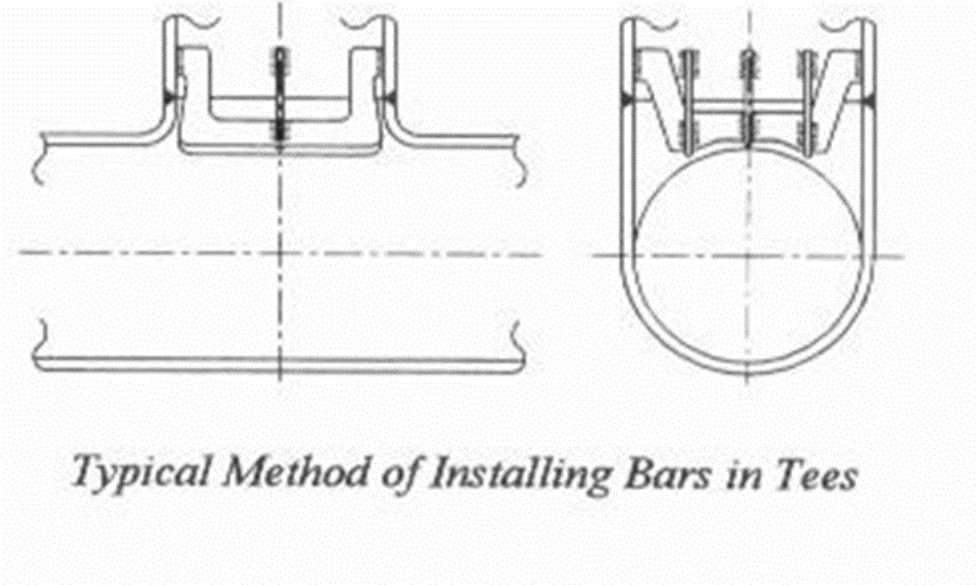
Pig Stalling Between Two Tees

Piggability

Barred Tees

Any off take that is more than 50% of the pipeline size should have bars installed to assist the pig past the opening without any damage.

The bars should be installed parallel to the axis of the pipe and spaced from about 2” apart for small off takes to about 4” apart for larger sizes.



Typical Method of Installing Bars in Tees

Piggability

Laterals/Tees

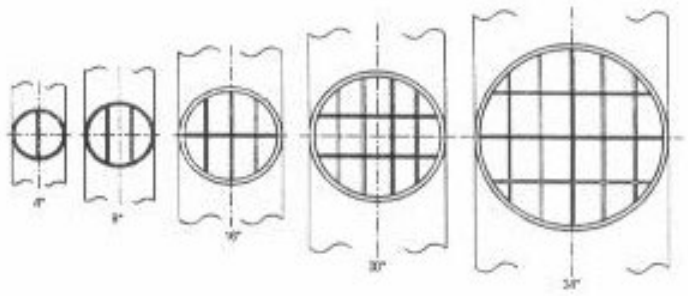
Typical Specification for Barred Tees:

Minimum Requirements

- 4” to 8” laterals – 1 single bar centered in tapped hole.
- 4” thru 10” Laterals w/ bars ¼” thick
- 10” and larger laterals – 2 bars equally separated in tapped hole.
- 12” and larger laterals bars ½” thick

Conservative Specifications

- 4” thru 10” - ¼ ” bars w/ 2” spacing
- 12” and larger – ½” bars w/ 2” spacing

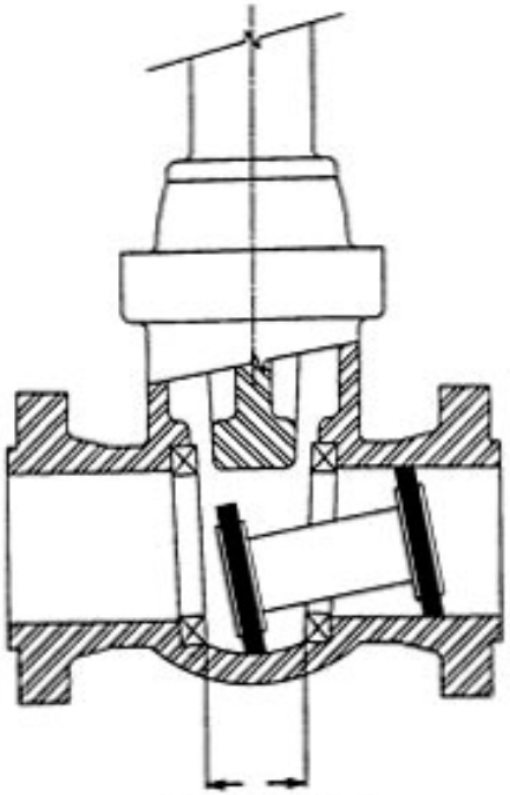


Typical Arrangement of Bars in Tees of Different Branch Sizes

Piggability

Valves

- Valves are the biggest single cause of pigging problems. Full bore valves are essential. If gate valves must be used, they should be the through conduit type so that no voids, seat rings or other features are present which might affect the smooth passage of a pig. The inlet and outlet bores must also be concentric.
- If wedge gate or parallel slide valves are installed, it is important to know the dimensions of the gap between the seat rings to be able to select the proper pig for the line.

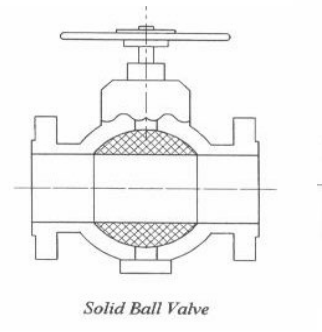


Seat Ring Spacing

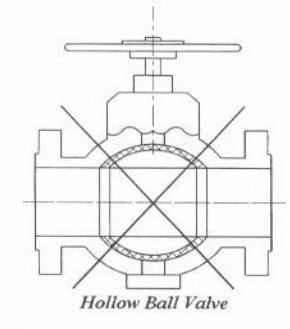
Piggability

Valves

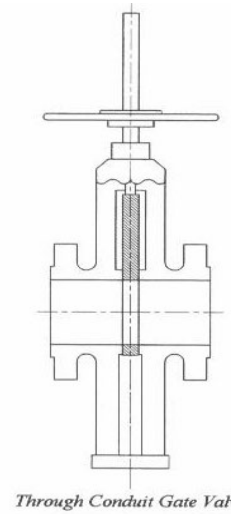
Valves can be a significant source of aggravation relative to Stuck Pigs. Appropriately designed valves should be considered when making piping systems piggable. Full bore or Pipeline ID is recommended.



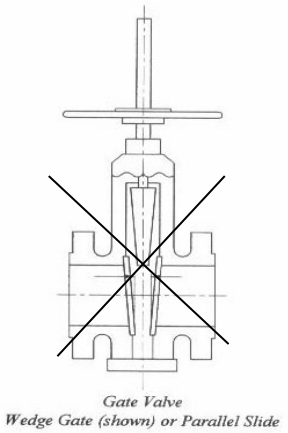
Solid Ball



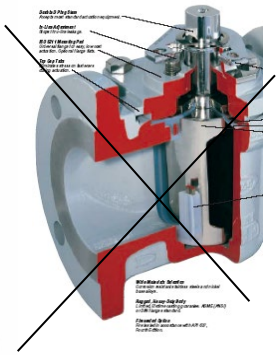
Hollow Ball



Thru-port Gate



Wedge Gate



Tapered Plug

Piggability

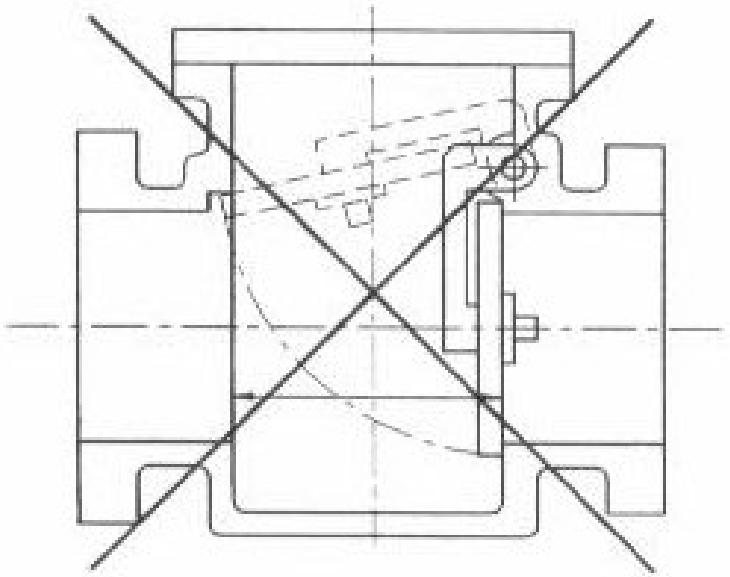
Check Valves

By the nature of their design, check valves require an area in the valve body that is larger that the pipe inside diameter. This requires the cups and/or discs on the pig to be spaced far enough apart to span the oversized area in the valve body. In addition, the pig must provide the force required to open the check valve fully for it to pass through.

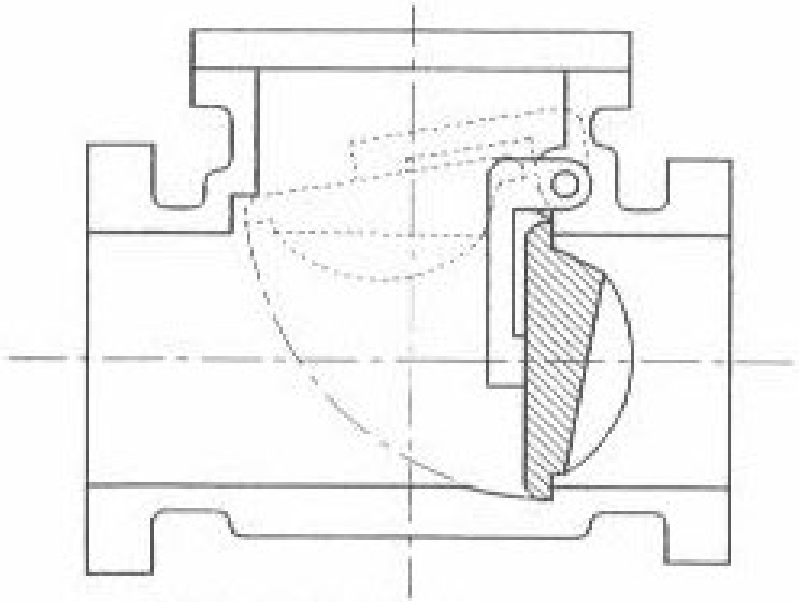
Spheres are not suitable for pigging lines with check valves. The sphere will drop into the oversize body and bypass. You must use the bump and run method if you are going to pig with spheres.

Piggability

Check Valves



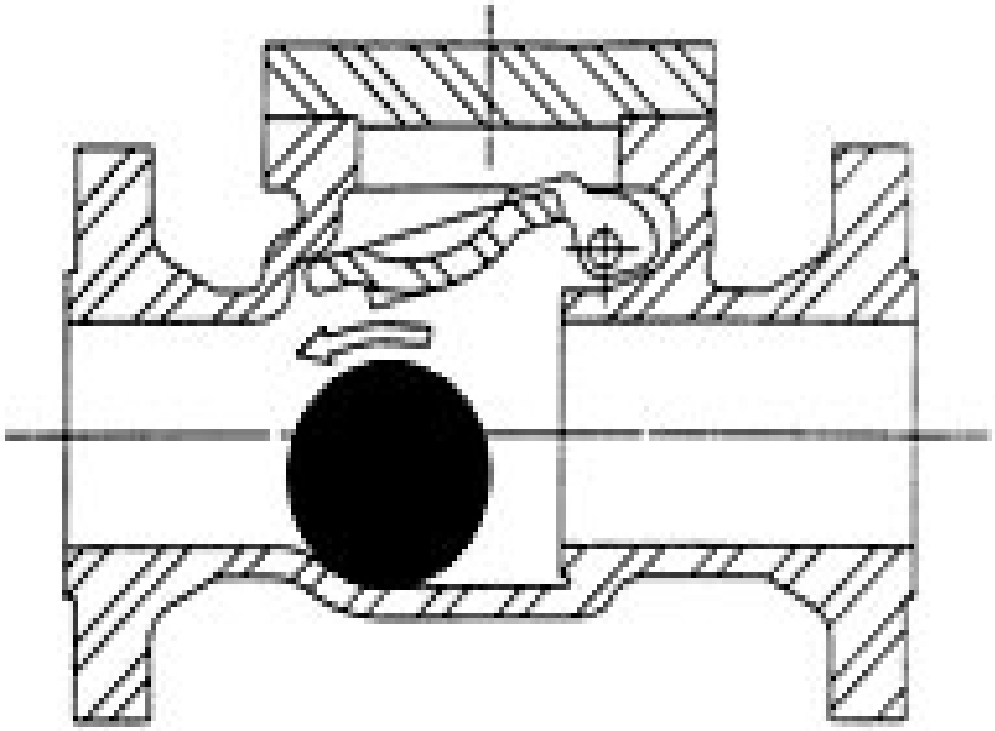
Check Valve Unsuitable for Pigging



Check Valve for Pigging

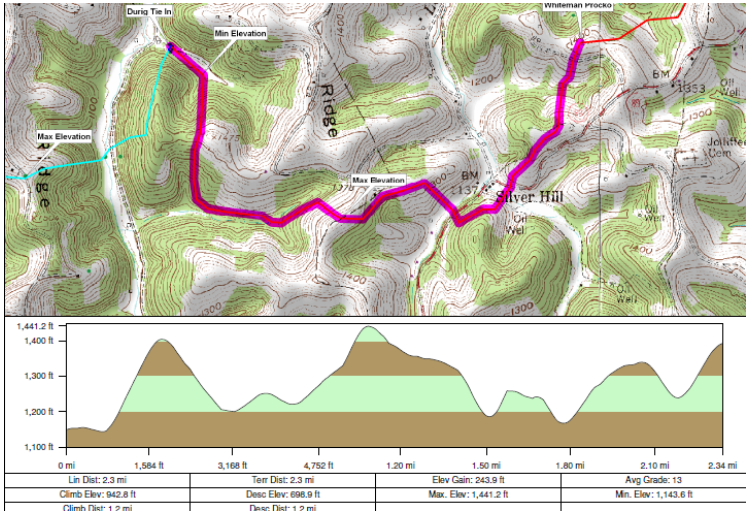
Piggability

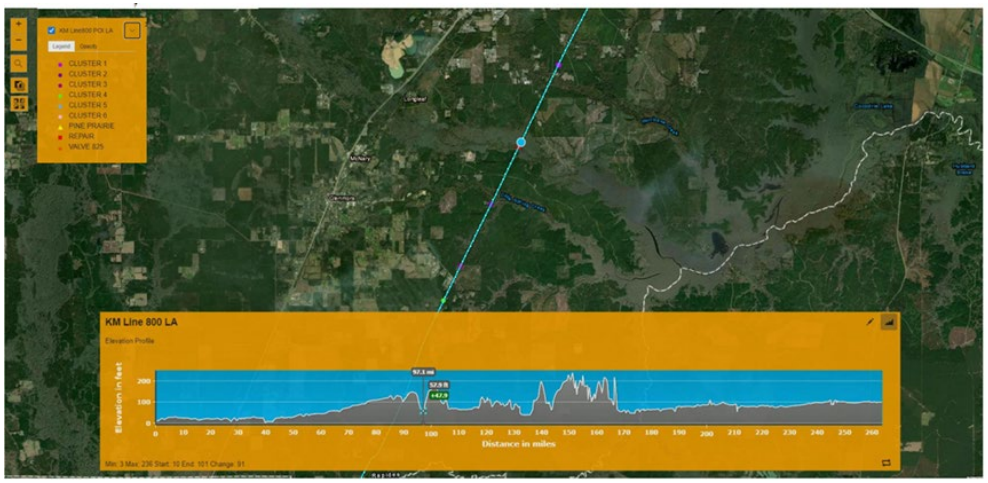
Check Valves



Appalachian Underground Corrosion Short Course

Piggability
Elevation

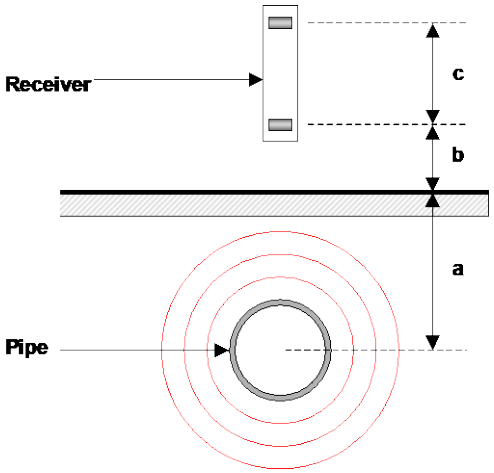




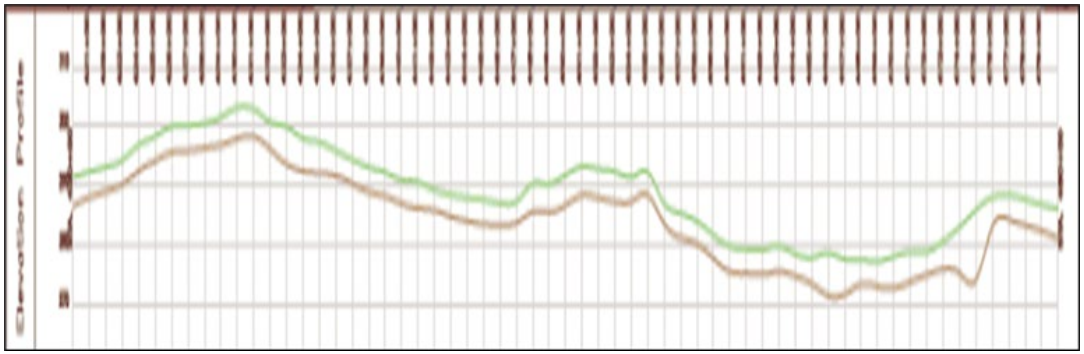
Appalachian Underground Corrosion Short Course

Piggability
Elevation

Depth of Cover (DOC)



Depth of Cover (DOC) versus Mapping



Piggability

Spans

Appalachian Underground Corrosion Short Course

Piggability

Spans

Appalachian Underground Corrosion Short Course

Piggability

Non-Engineered Spans

AUCSC

Appalachian Underground Corrosion Short Course

Piggability

Drips

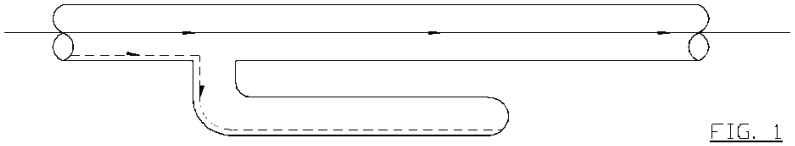


FIG. 1

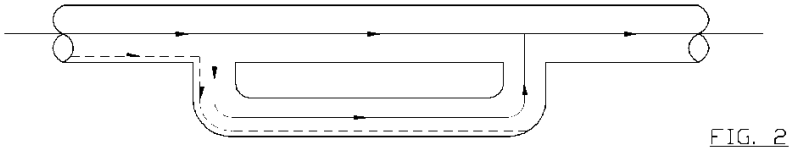


FIG. 2

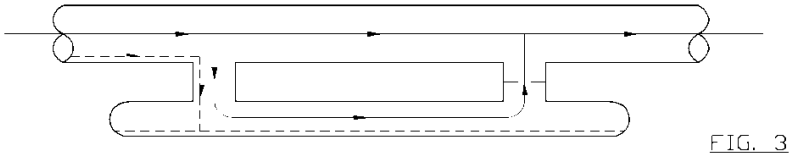


FIG. 3

GAS FLOW

LIQUID

Appalachian Underground Corrosion Short Course

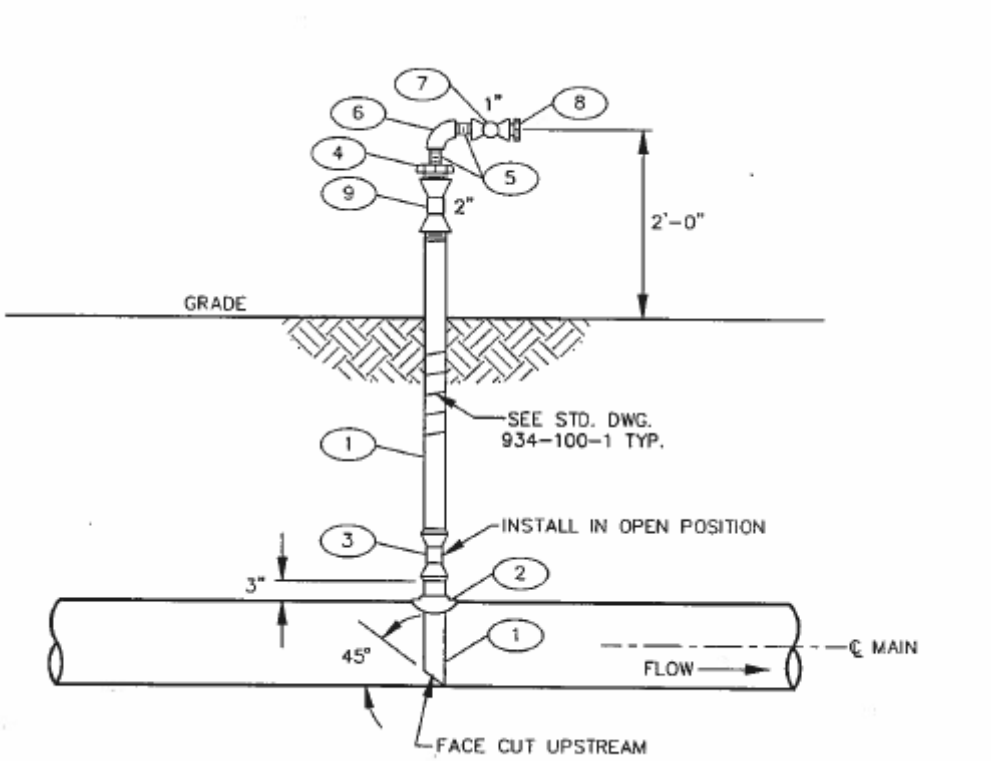
Piggability
Drips

Appalachian Underground Corrosion Short Course

Intrusive Repairs – Pipeline Carrot

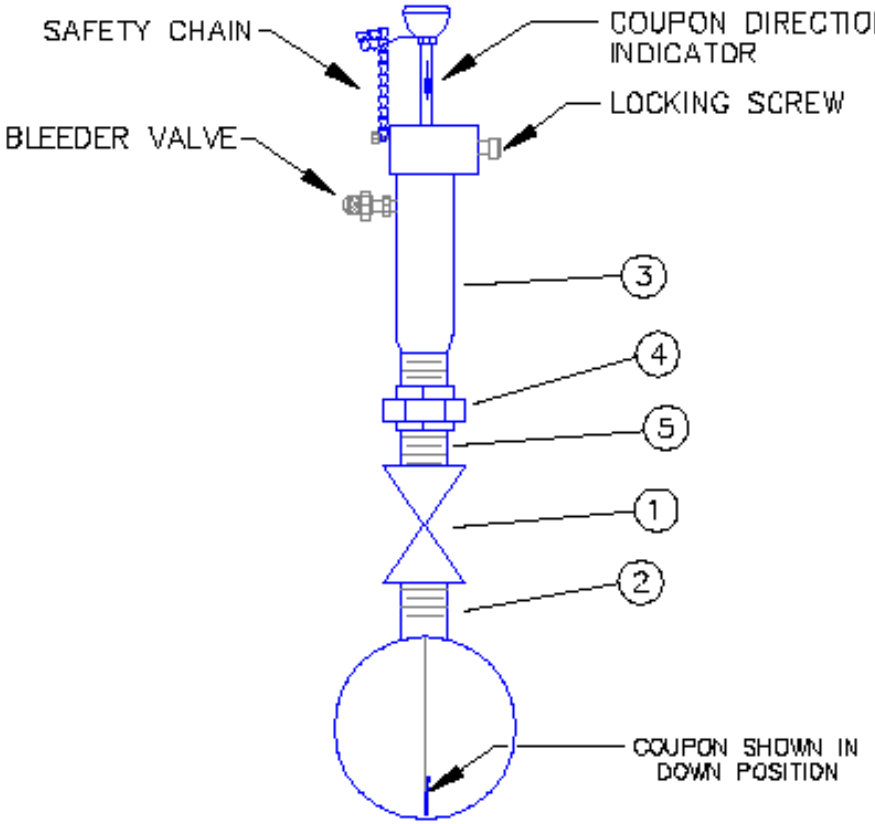
Piggability
Other

Siphons



Piggability
Other

Coupon Holders



Pressure

A specific minimum pressure cannot be stated as both the diameter and condition of the pipeline must be considered.

In-line Inspection vendors will always discuss this aspect during the planning stage for each instrument pig survey.

Flow Rate

Most cleaning, batching and swabbing applications are run on-stream and will have to be carried out at the velocity of the product stream.

Pigs are most effective if run at a near constant speed. When the flow rate is low the pig may run in a series of start and stop motions, and it will not be very effective under these conditions.

Pigs will not be effective if run at too high a velocity. This is seldom a problem with on-stream pigging as the flow rates are usually quite moderate. However, during construction, flow rates cannot always be controlled and it is then difficult to achieve maximum effectiveness.

Flow Rate

Application	Speed (mph)
New construction	1-5
On-stream gas	2-8
On-stream liquids	1-8
ILI tools	2-7

Taitel-Dukler-Barnea Interpretation

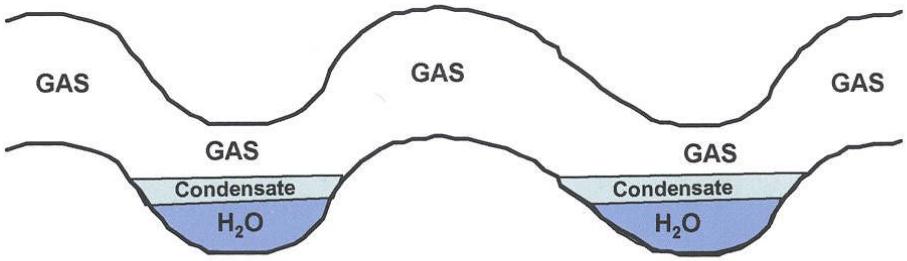
Flow Rate

$$V_a = \frac{31210 \text{ x MMCFD}}{\text{PSIA x ID}^2(in)}$$

- V_a is the Actual Gas Velocity (Horizontal, No Liquids)

$$V_c = \frac{70}{\sqrt{\text{PSIA}/14.7}}$$

- V_c is the Velocity the Gas Has to Go to Transition from Slug to Annular Flow



Taitel-Dukler-Barnea Interpretation

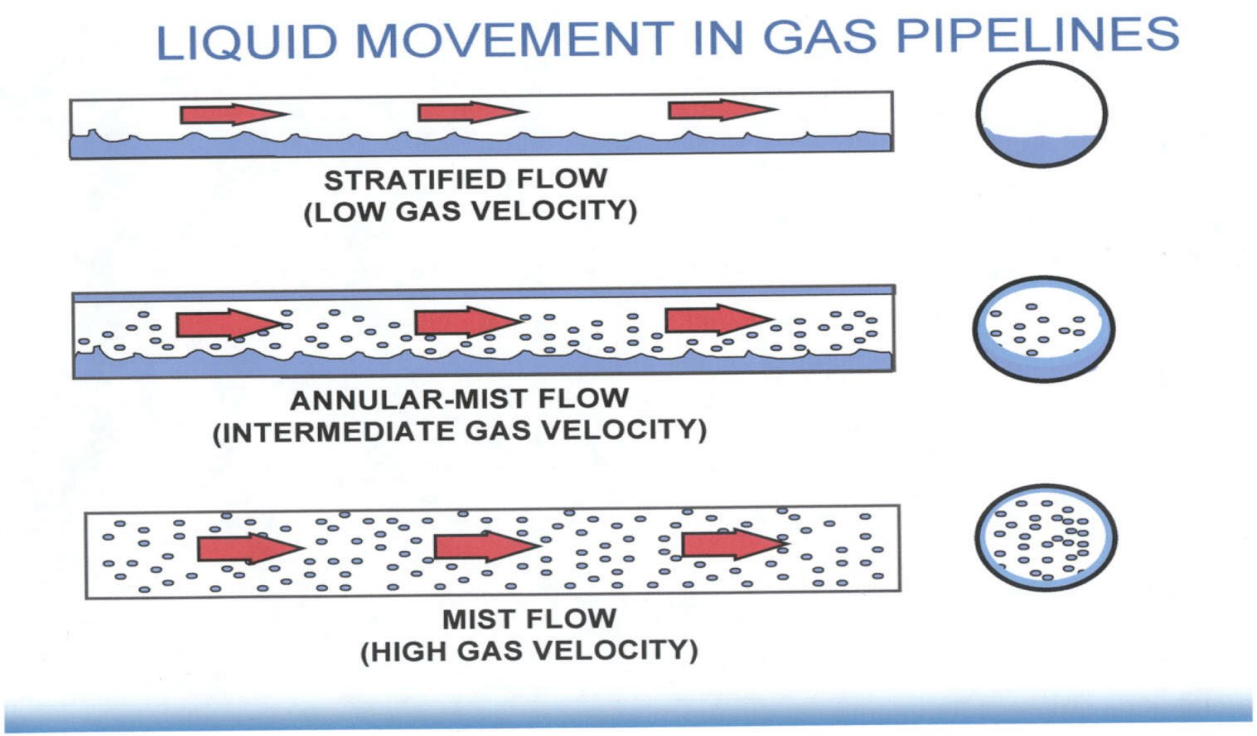
V_a/V_c ~ 0 – 0.5: Stratified Flow (Fluid Bottom Quadrant, Accumulates in Low Spots)

V_a/V_c ~ 0.5 – 1: Transitional Flow (Slug Flow – Bottom Quadrant, Less Pooling)

V_a/V_c ~ 1 – 2: Annular Flow (All Quadrants Can be Water Wet)

V_a/V_c > 2: Mist Annular Flow (All Quadrants Can be Water Wet – Shear on Inhibitor Film)

Flow Rate


LIQUID MOVEMENT IN GAS PIPELINES
STRATIFIED FLOW
(LOW GAS VELOCITY)
ANNULAR-MIST FLOW
(INTERMEDIATE GAS VELOCITY)
MIST FLOW
(HIGH GAS VELOCITY)

Piggability

Operations

Turbulent Flow

- Water Will be Suspended in the Oil Phase
- Internal Corrosion Should Not Occur

Laminar/Stratified Flow

- Water Will Flow on the Bottom of the Pipe
- Internal Corrosion Will be Possible

System Pump Time

- If System is Not Pumping Constantly, Water will Fall Out
- Internal Corrosion Will be Possible

Flow Regime Dictates

- The Best Inhibitor Application Method
- The Preferred Inhibitor Solubility to Use
- How to Best Monitor a Line Segment
- How Susceptible a Line Segment is to MIC

Understanding Liquid Flow Regime is Critical

Contaminants

Bacteria

Sulfate Reducing Bacteria (SRB) - SRB's use the sulfate ion in water as a food source. Through their metabolic process, the sulfate is converted to H2S.

Acid Producing Bacteria (APB) - APB's produce carboxylic acids and/or CO2 as a by-product of their metabolic process

Contaminants

Solids

- Iron Sulfide (pyrophoric material will ignite spontaneously in air)
- Iron Carbonate
- Iron Oxide
- Paraffin
- Sand

Other

- PCBs (acute poisoning – source is typically from compressors)
- NORMS (Natural Occurring Radioactive Materials) – source is radium-226 and radium-228 are the decay products of uranium and thorium that are present in subsurface formations.

Operational Pigging

Hydrogen Sulfide
- Acute poisoning (>20 ppm)
- Explosive (4% - 44% in air)

Mercaptan
- Unnecessary calls to emergency response personnel

Carbon Dioxide
- Asphyxiation
- Frostbite

Oxygen
- Explosive in Methane

Piggability

Purpose of Launcher & Receivers

The primary purpose of a Pig Launcher and Receiver is to Launch and/or Receive a pipeline pig into a pipeline system without interruption of the flow.

Launcher
Design

Pressure Indicator (gauge) connections

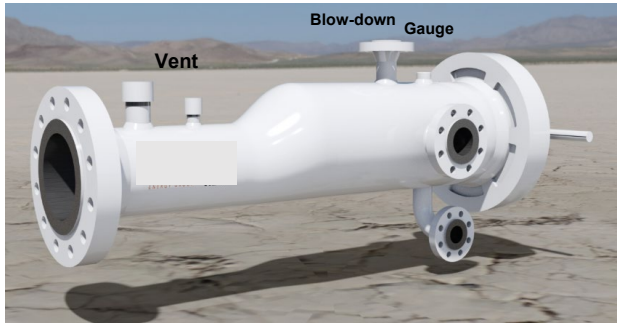
- A gauge connection is provided next to the closure so that the pressure gauge can be seen while operating the closure.
- Gauge connections are ¾” or 1” NPT.

Blow-down

- An extruded blow-down connection is located on the oversize barrel at the highest elevation on the centerline or 12 o’clock position of the pipe
- The blow-down allows the pressure to be release for the loading of pigs and the fill/purge of the trap, removing atmospheric air
- Blow-downs should be valved and piped to be above head level (10 feet or more)
- Blow-down sizes for piping up to 14” = 2”, 16” to 34” = 4”, and 36” and larger = 6”

Vent

- A vent connection is located on top-of-the-line size pipe centerline to allow pressure in front of a tool to escape while loading
- Vents for piping up to 12” and 1” NPT and 16” and larger are 2” NPT or flanged



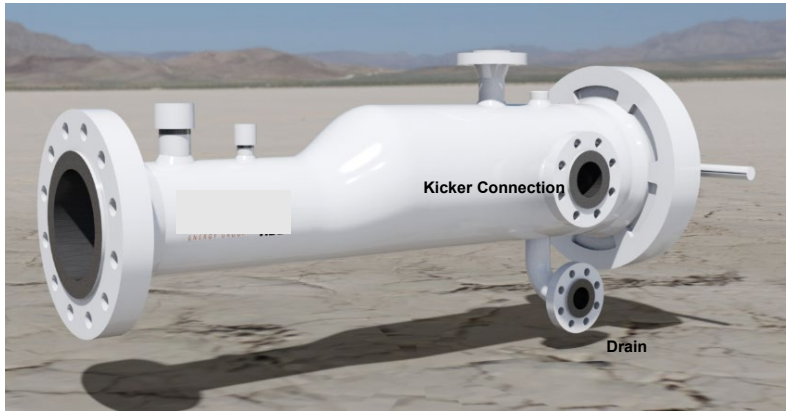
Launcher
Design

Kicker Line Connection

- The kicker line is placed approximately 1 to 1.5 nominal pipe diameters from the closure on the oversize barrel
- This allows all flow to be applied to rear most section of the tool.
- Kicker liners are 1/3 of the pipeline diameter.

Drain Line Connections

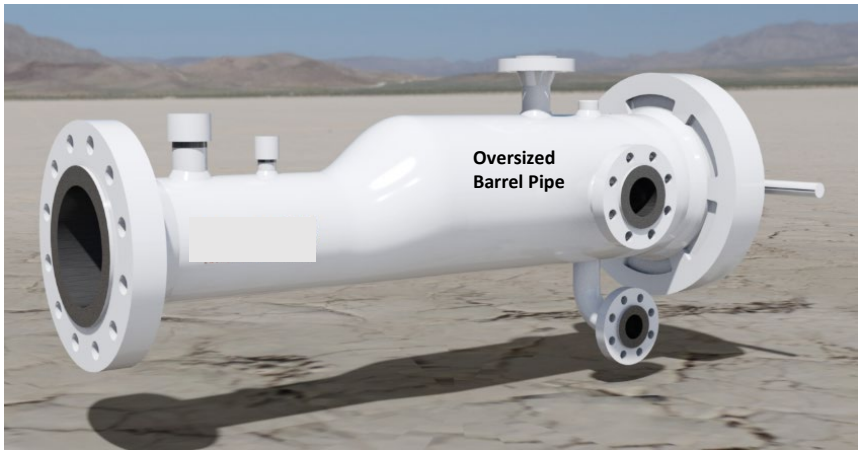
- Drain lines are provided on the oversize pipe to allow quick and full draining of the trap.
- Drain sizing: 2”-10” pipe = 2”, 12”-14” = 3”, 16”-34” = 4”, and 36” & larger = 6”



Launcher
Design

Oversize Barrel

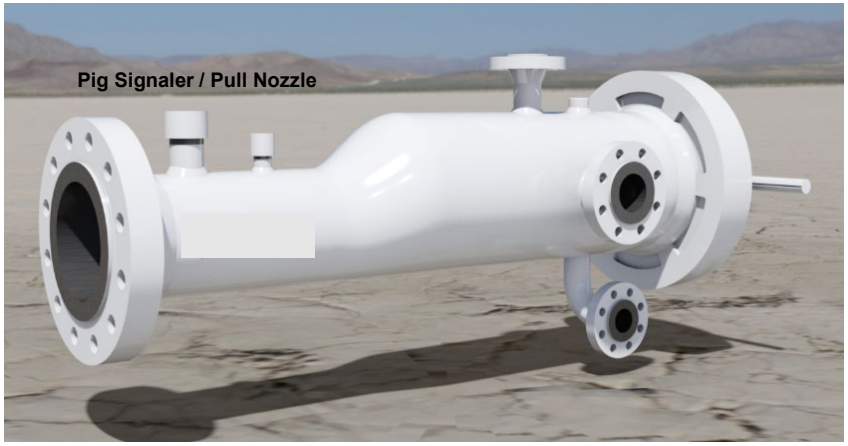
- The oversize launcher barrel length is sized for two typical cleaning pigs (2xD) or ILI tool as requested.
- The oversize barrel is 2 pipe sizes larger than the nominal pipeline size or greater.
- For uncommon oversized line pipe sizes, the next larger diameter line pipe should be used. Example: 24” pipeline requires an oversize of 28”. The more common 30” diameter line pipe would typically be used for 24” line size pipelines.
- Extruded nozzles to eliminate reinforcement pads or additional girth welds



Launcher
Design

PIG SIGNALER / PULL NOZZLE

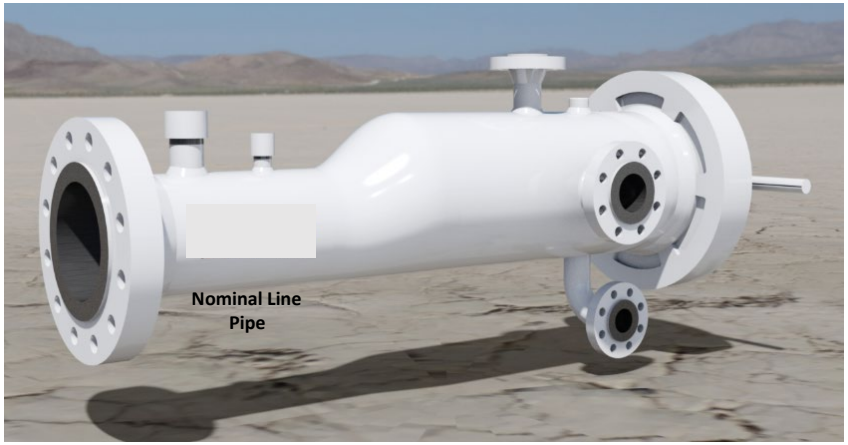
- 2” TOR for the installation of a pig signaler or pull nozzle to pull and seat ILI tools at the eccentric reducer.
- The 2” TOR is located close to the downstream nominal flange to detect the passage of pigs.
- Pig Signalers at the launcher are typically located downstream of the mainline valve a minimum of two nominal pipe diameters



Launcher
Design

Nominal Line Pipe

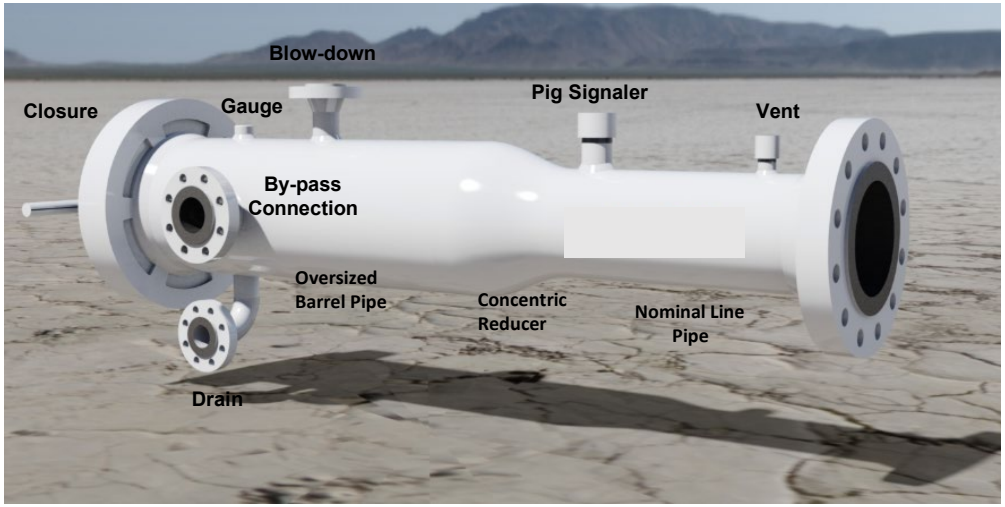
- The nominal line size piping length is sized to allow the appropriate space for welding of all nozzles.
- The nominal line size pipe length must allow the insertion/seating of a pig's drive section between the weld of the line pipe to the reducer (approximately 1.5 to 0.75 nominal pipe diameters).



Receiver

Design

- Standardized design for safe operation with a design option to receive ILI tools
- Flanged connections for ease of installation
- All connections sized based on industry standards
- Concentric reducer for ease of receiving
- Full data packet included for standard code compliance



Receiver
Design

Pressure Indicator (gauge) connections

- A gauge connection is provided next to the closure so that the pressure gauge can be seen while operating the closure.
- Gauge connections are ¾” or 1” NPT.

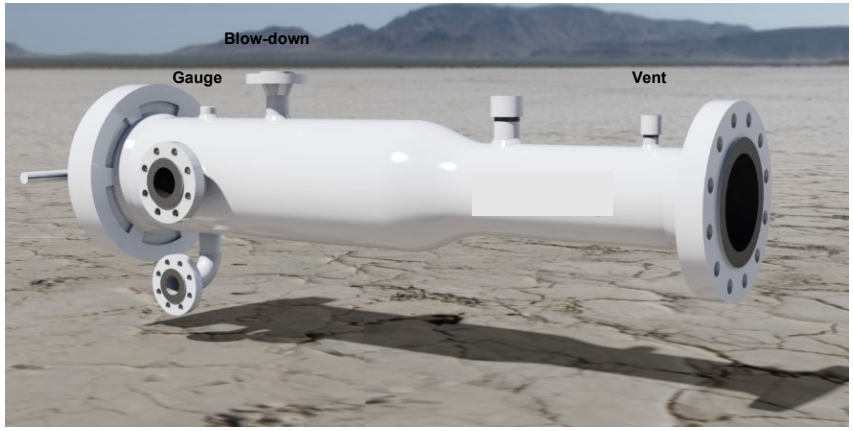
Blow-down

- An extruded (3” and larger) blow-down connection is located on the oversize barrel at the highest elevation on the centerline or 12 o’clock position of the pipe
- The blow-down allows the pressure to be release for the loading of pigs and the fill/purge of the trap, removing atmospheric air
- Blow-downs should be valved and piped to be above head level (10 feet or more)
- Blow-down sizes for piping up to 14” = 2”, 16” to 34” = 4”, and 36” and larger = 6”

  and larger are 2” NPT or flanged

Vent

A vent connection is located on top of the line size pipe centerline to allow pressure in front of a tool to escape while retrieving pig. Vents for piping up to 12” and 1” NPT and 16”



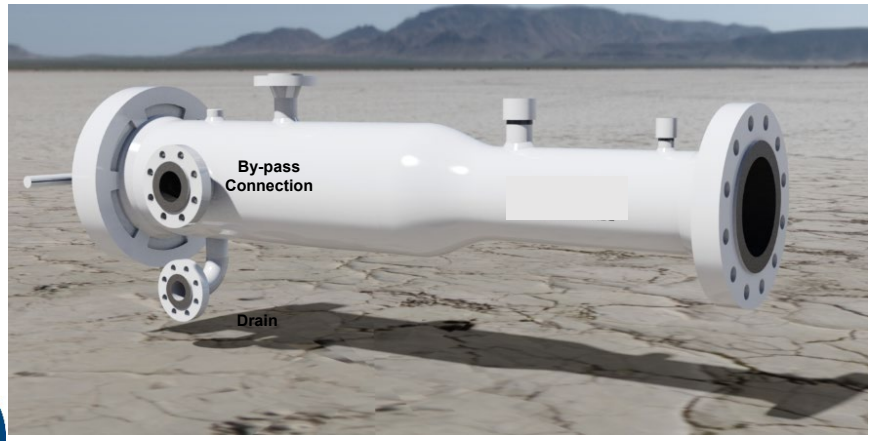
Receiver
Design

By-pass Connection

- The by pass line is placed one pig length (1.5 mainline pipe diameters) from the closure to allow a cushion of pipeline medium to keep the tool from impacting the closure.
- All bypass lines are to be installed with pigging guide bars in the appropriate size, quantity and configuration for the branch connection.
- By-pass lines are sized 1/3 of the nominal pipeline diameter.

Drain Line Connections

- Drain lines are provided on the oversize pipe to allow quick and full draining of the trap.
- Drain sizing: 2”-10” pipe = 2”, 12”-14” = 3”, 16”-34” = 4”, and 36” & larger = 6”

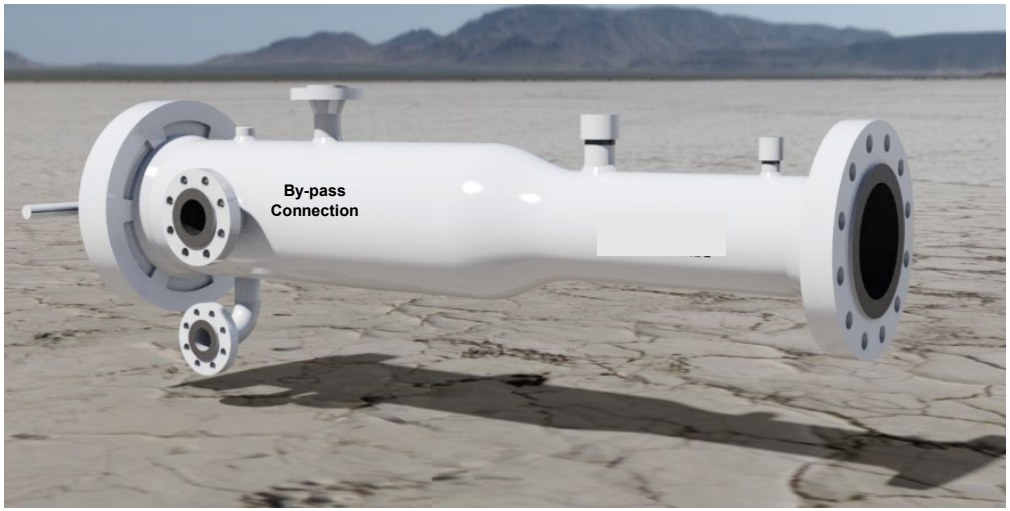


Receiver

Design

By-pass Connection – Pig Guide Bars

- All bypass lines are to be installed with pigging guide bars in the appropriate size, quantity and configuration for the branch connection.



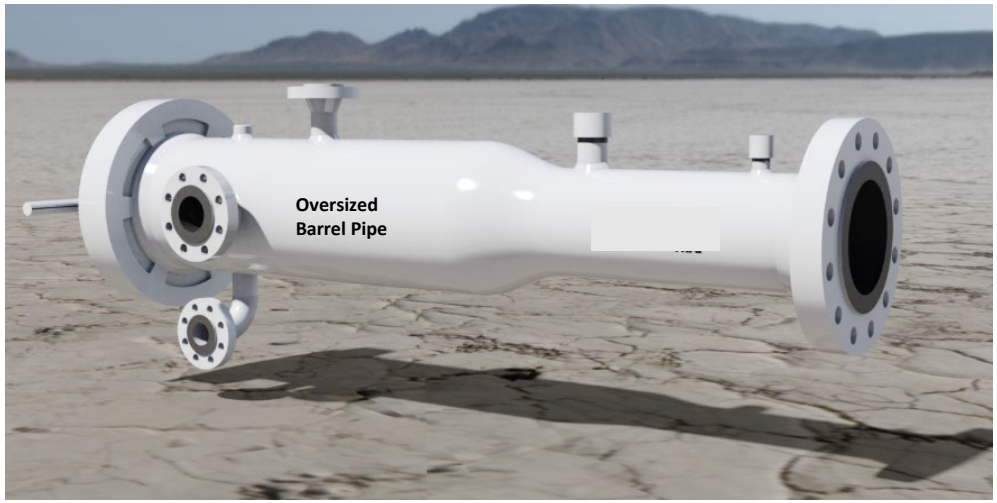
No guide bars

Receiver

Design

Oversize Barrel

- The oversize launcher barrel length is sized for two typical cleaning pigs (2xD) or the longest ILI tool length as requested.
- The oversize barrel is 2 pipe sizes larger than the nominal pipeline size or greater.
- For uncommon oversized line pipe sizes, the next larger diameter line pipe should be used. Example: 24” pipeline requires an oversize of 28”. The more common 30” diameter line pipe would typically be used for 24” line size pipelines.
- Extruded nozzles to eliminate reinforcement pads or additional girth welds

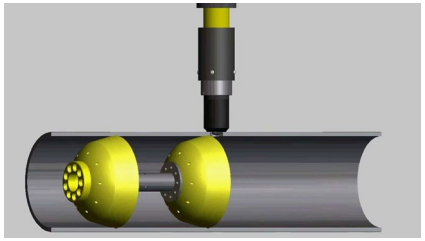


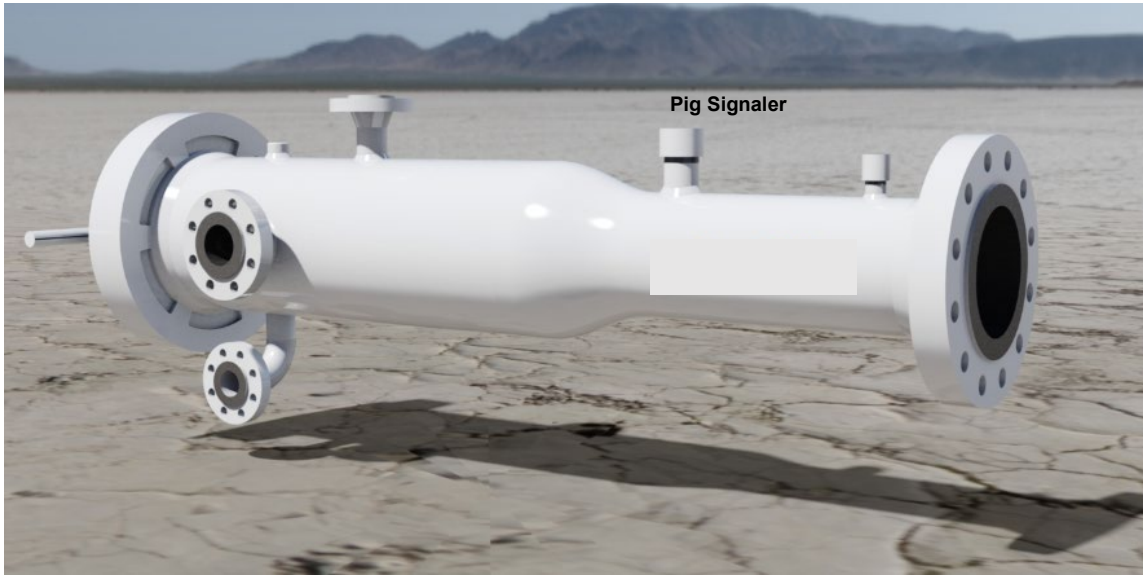
Receiver

Design

Pig Signaler

- 2” TOR for the installation of a pig signaler to detect whenever the pig has cleared the mainline valve.
- The 2” TOR is located close to the downstream end of the nominal pipe (upstream of oversized barrel) to detect the passage of pigs.



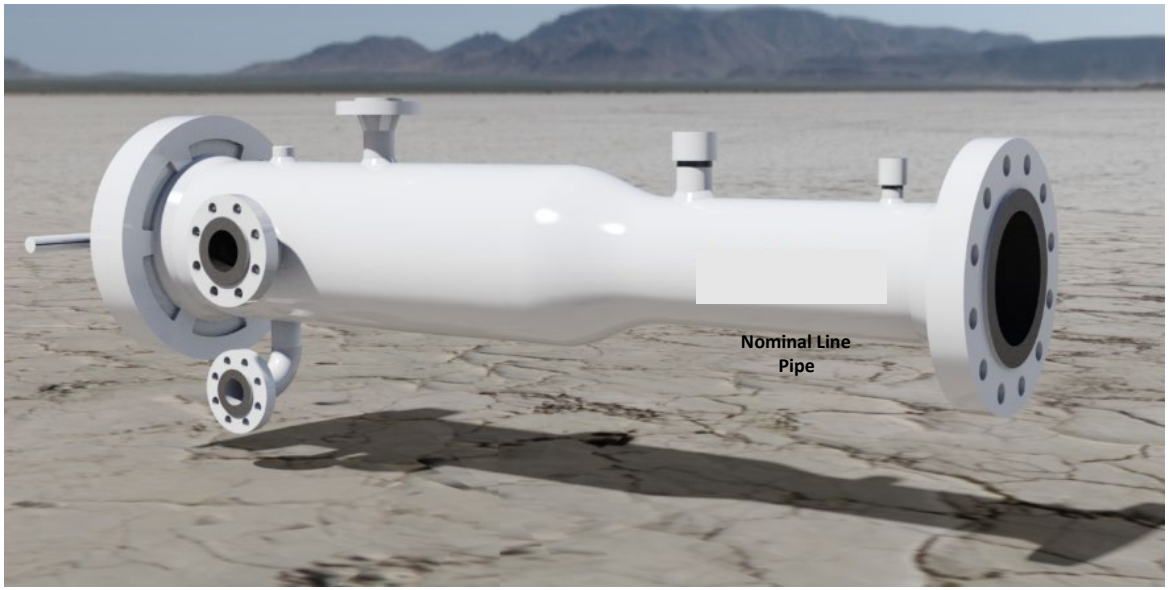


Receiver

Design

Nominal Line Pipe

- The nominal line size piping length is sized to a length equivalent to the length of the longest pig to be launched plus 6-inches to allow the pigging tool to enter the trap before the drive section clears the reducer.
- Receivers are always longer than the launcher with exception to bi-directional systems where both traps will be configured as a receiver.



Many In-Line Inspection, or “ILI” tools, are typically constructed of several modules joined together. When these and similar “extra-long” ILI tools are to be used, the launcher barrel should be at least 1D longer than the overall length of the longest pig.

Except for the length, all other dimensions will be the same as for utility pigs.

Piggability

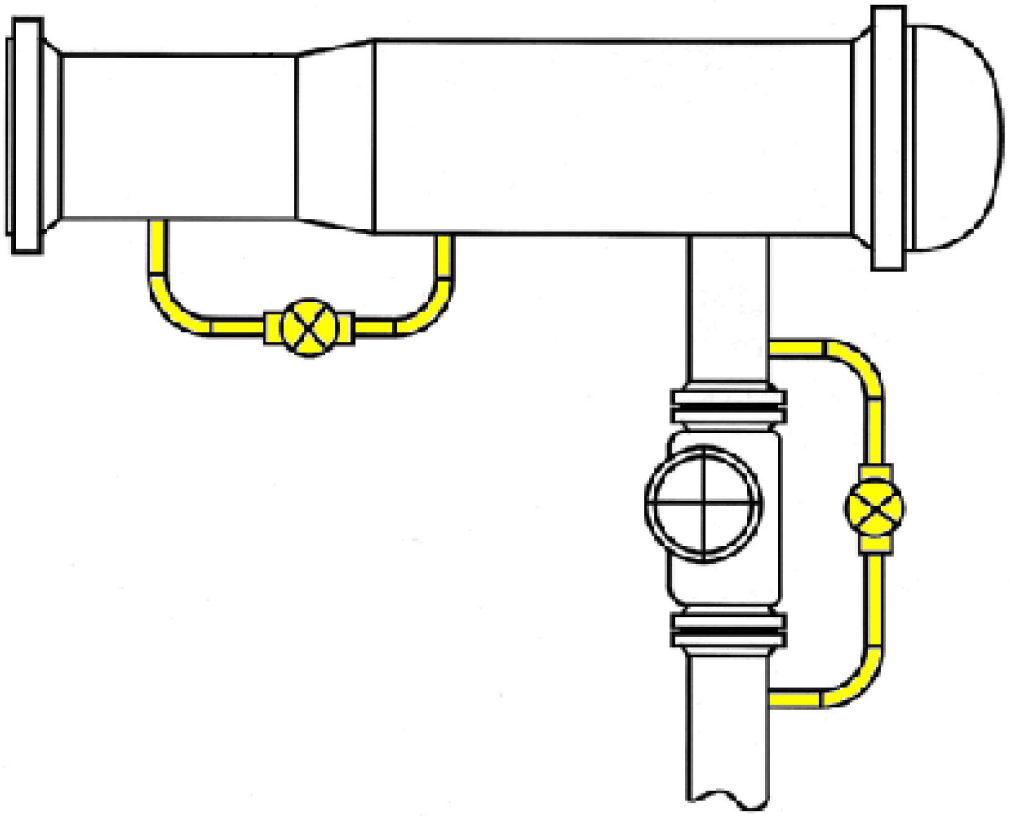
Launcher & Receivers

Spheres

Spheres have a single line of seal and therefore must be treated differently than pigs that will have at least two and often four or more seals per pig.

Since spheres are the same dimension in all directions, they are not self-guiding and will try to follow the flow within the pipeline even through smaller pipe sizes

Launcher / Receiver: Equalization Lines

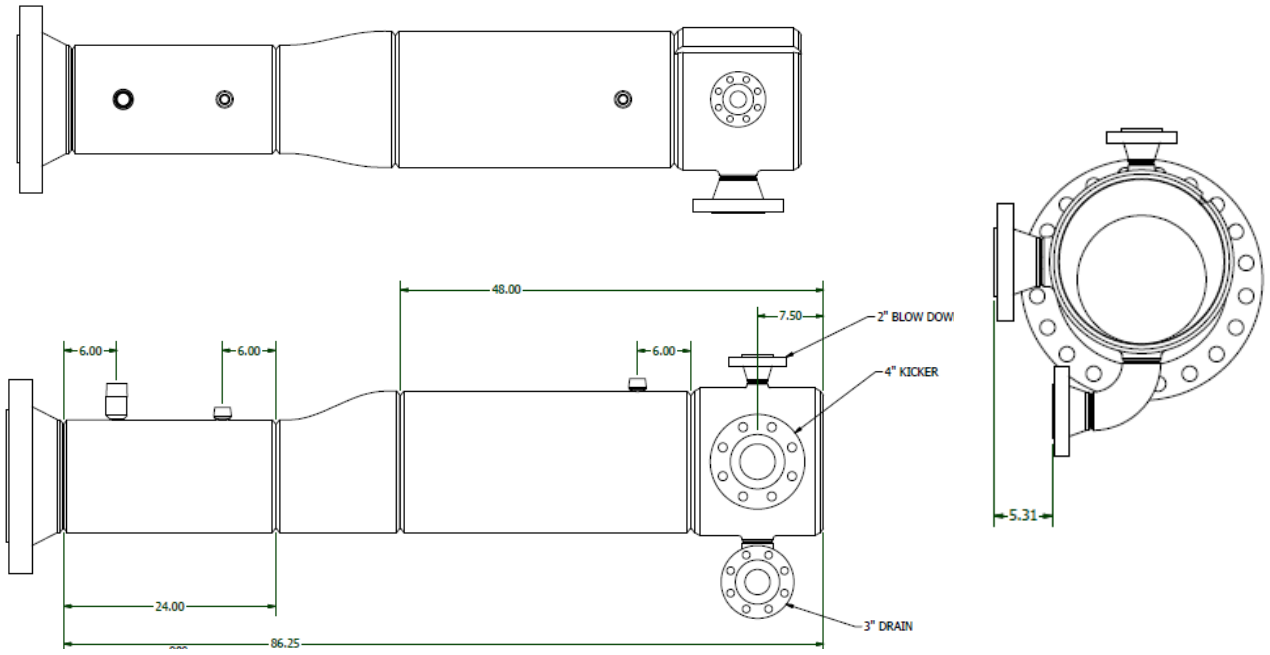


Launcher / Receiver

Design

Extrusions

- No reinforcement pads required on branch outlets
- Eliminates tees and girth welds on the outlets during field installation
- ID is bored to the ID of the nominal pipe



Launcher / Receiver

Design

Closures

Pressure-containing component used to close off the interior of a pipeline or vessel







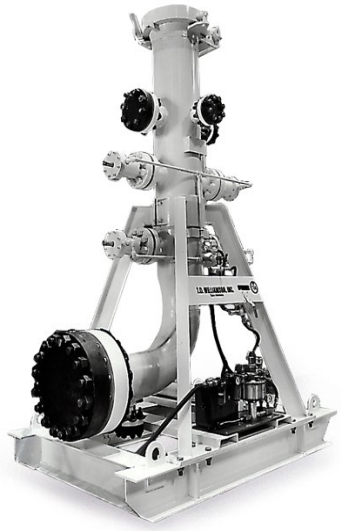


AUCSC

Appalachian Underground Corrosion Short Course

Launcher & Receiver Types

Pigging Systems



Launcher & Receiver Types:
Temporary Launcher & Receivers

Temporary launchers are sometimes used for the following purposes:

- Clean Short Pipeline Segments such as HCAs
- Perform Hydrostatic Pressure Tests
- Decommissioning of Pipeline from Service
- Economic Purposes – Rent instead of Purchase
- Specialty Pigging Operations such as Blow Through Cleaning and Inspection
- Proving Pigging Operations
- New Construction Cleaning & Inspections
- Off-line Pigging Operations

Launcher & Receiver Types:
Specialty Pigging - Tethering

AUCSC
Appalachian Underground Corrosion Short Course

Automated Pigging Systems

"A method and system for staging multiple pigs and launching a single pig with a fully-automated or semi-automated operations."

Automated pigging systems are typically utilized to address the following issues being experienced in the midstream market segment:

- Wet Gas Lines
- Crude Oil Lines
- Fracking Contamination
- Unpredictable Fluid Production
- Internal Corrosion
- Environmental Exposure

Automated Pigging Systems

Conventional Gas Well Production

- Low Production Rates 0.5 MMCFD – 5 MMCFD
- Water Vapor 7# MCF
- Gas Quality Contract Limitations
- Low-to-Mid Level Pressures
- Processing of High BTU Gas

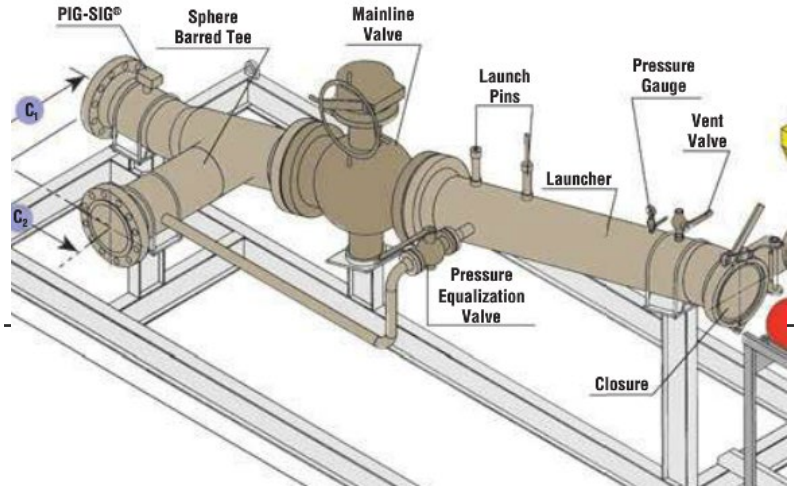
Unconventional Gas Well Production

- High Production Rates 5 MMCFD – 100 MMCFD
- High Water Content – Formation & Frac Water
- E & P Companies have Open Gas Quality Specs
- High Pressure
- Processing of High BTU Gas
- More Susceptible to Corrosion Attack

Types of Automated Pigging Systems

Gravity Feed Automated Pigging Systems

Vertically or angled oriented design where multiple pigs are gravity fed to a downstream launch mechanism. The launch mechanism will typically consist of two insertion pins that are retracted hydraulically or pneumatically to allow the pipeline pig type to be launched. These types of gravity feed systems are primarily utilized for liquid removal with spherical type pigs. The systems are typically controlled with a PLC to program the launch at specified time intervals.



Types of Automated Pigging Systems

Piggable Valve Automated Pigging Systems

Pigging valve with vertical oriented launch barrel where multiple pigs are loaded and gravity fed into the downstream pigging valve. The 3-way pigging valve system is typically actuated with a pneumatic gas supply that can be controlled manually or through a timing device to set the pigging frequency. The pigging system can be utilized for various types of pigging functions with pigs whose total length is equal to the nominal pipe diameter.

Types of Automated Pigging Systems

Horizontal Automated Pigging Systems

Horizontally oriented design where any pig type is loaded into a launch barrel for staging multiple pigs and launching a single pig with a fully-automated, semi-automated, or manually operated pigging system. The pig launch mechanism uses a geared screw jack system that travels the internal length of the oversized launch barrel. The launch drive mechanism can be manually operated, electric motor operated on-demand or programed with a logic driven controller that allows pig launches at a specific time or time interval.

Economic Benefits Of Automated Pigging System

Safety

Safety is not typically associated with economic benefits, however PHMSA's 2010 to present Part 195 hazard liquids accident statistics indicate a total of 1838 reported accidents on pipelines with 58 of those accidents occurring at the pigging system.

Economic Benefits Of Automated Pigging System

Methane Emissions

During pigging operations on natural gas pipelines, traditional launcher and receiver systems are depressurized during the launching and receiving of single pigs' thereby releasing methane emissions. The total volume of methane that is emitted is directly proportional to the line and barrel size and line pressure. The use of an automated pigging system would reduce the methane emission volumes based on the total number of pigs that can be staged and launched.

Economic Benefits Of Automated Pigging System

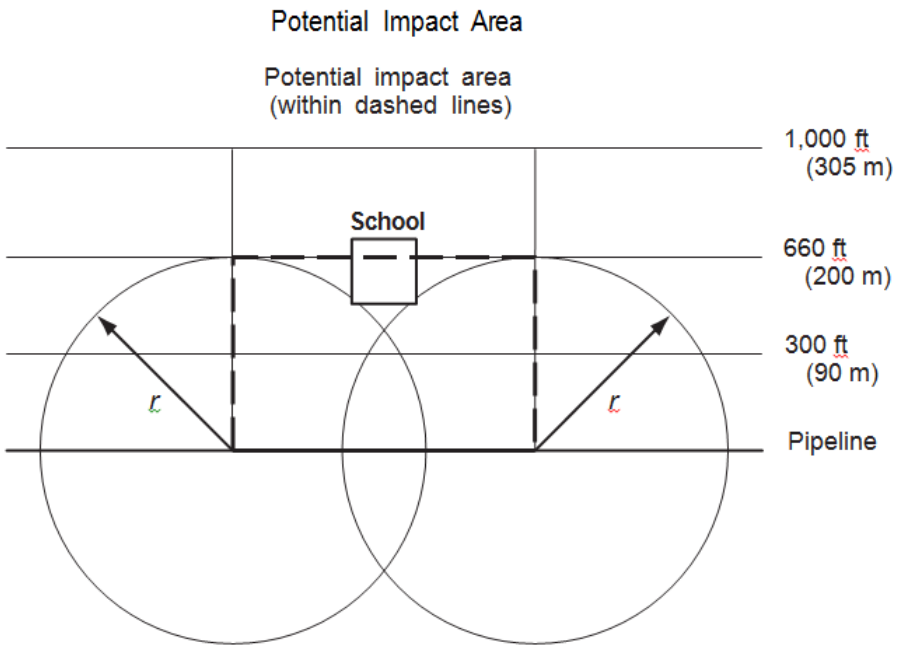
Flow Efficiency

Pressure drops are created by many factors such as surface roughness, fluid density, fluid viscosity, friction factor, debris, and flow type. However, low flow inefficiencies are typically identified through a decrease in throughput. The primary cause of throughput decrease is an internal diameter restriction due to debris such as paraffin, corrosion by-products, frac sand, chlorides, and/or sulfur. It is sometimes possible to overcome the bore diameter restriction by increasing the compressor or pump horsepower outputs.

ASME B31.8S 3.2 Potential Impact Area

Radius of impact for natural gas is calculated using the formula

$$r = 0.69 \cdot d \sqrt{p}$$



Spill Modeling of Natural Gas Pipelines

- Rupture with immediate ignition. This scenario is modeled using the flame jet model in ARCHIE. Models the aerosol emissions from the pipeline being immediately ignited and the expected length of the flame and the safe separation distance such that protection from the thermal hazards is anticipated.
- Rupture with delayed ignition. This scenario is modeled using the vapor cloud explosion model. ARCHIE reports various levels of damage to structures based on the overpressure created from the explosion shock wave.
- Rupture with no ignition. This scenario is modeled using the toxic vapor cloud model. This model calculates an anticipated downstream distance to where the concentration of the hazardous vapor in the air reaches the user input toxicity threshold level.

Reduction of Spill Volume on Natural Gas Pipelines

SEGMENT START	SEGMENT END	SEGMENT LENGTH (FT)	MAX RUPTURE VOLUME (BBL) – WEEKLY PIGGING	MAX RUPTURE VOLUME (BBL) – DAILY PIGGING	BASELINE HCA LENGTH (FT)	DAILY PIGGING HCA LENGTH (FT)	% HCA REDUCTION
10" LAUNCHER	CHECK VALVE	33,497	660	95	5,098	3,255	36.2%
CHECK VALVE	MLV	15,966	803	115	3,257	1,548	52.5%
MLV	CHECK VALVE	12,200	603	86	5,631	2,798	50.3%
CHECK VALVE	MLV	12,255	553	79	3,280	1,185	63.9%
MLV	CHECK VALVE	6,095	378	54	4,557	2.794	38.7%
CHECK VALVE	10"RECEIVER	5,838	455	65	419	156	62.8%
TOTAL		85,851 (16.26-MILES)	3,452 BARRELS	494 BARRELS	22,242 (4.21-MI)	11,736 (2.22-MI)	47%

10" x 16.26-miles
1000-psi 50-MMCFD 1,500+/- BTU 60° F
2-hour Response Time
NPMS HCA Identification for Hazardous Liquids Pipeline

Pig Selection

- Types of Deposits / Contamination (pig cleaning elements)
  - Wax (hard / soft): self cleaning urethane blades, discs, by-pass
  - Scale: wear-compensating brushes, pit-cleaning brushes, studs
  - Black Powder: discs, brushes
  - Ferrous Debris: brushes, magnets
  - Sand: discs, brushes
  - Liquids: sealing cups and/or discs
  - Microbes: pit-cleaning / wear-compensating brushes, discs

- Fit-for-purpose chemicals should be added to most of the above to enhance effectiveness.

Pig Selection

Type / Purpose	Foam		Sphere	Mandrel					Solid cast	
	Foam Plain	Foam Brush		Plastic Disc	Metal Blades	Plastic Blades	Metal Brush	Magnets	Soild Cast Plain	Soild Cast Brush
Wax Removal				✓		✓				
Soft Dirt Removal		✓		✓		✓	✓			✓
Hard Deposit Removal					✓		✓			
Ferrous Material Removal								✓	✓	
Chemical Cleaning	✓	✓		✓	✓	✓	✓	✓	✓	✓
Batch Treating				✓			✓		✓	✓
Biocide Treating				✓			✓		✓	✓
Liquid Removal	✓		✓	✓				✓	✓	

AUCSC

Appalachian Underground Corrosion Short Course

Select A Pig For Cleaning Applications

The best choice is a pig with discs, conical cups, spring mounted brushes and bypass ports:

- **Discs** are effective at pushing out solids while also providing good support for the pig.
- **Conical cups** provide excellent sealing characteristics, good support and long wear.
- **Spring mounted brushes** provide continuous forceful scraping for removal of rust, scale and other build-ups on the pipe wall.
- **Bypass ports** allow some of the flow to bypass through the pig and helps minimize solids build-up in front of the pig. Also used for slowing the speed of the pig down.

Pig Types

Multi-use pigs equipped with either scraper discs/cups, cups, brushes and or blade cleaning elements.

Brush pig for removing soft, gummy deposits, scraper discs to clean both hard and soft internal deposits and magnet kits to remove ferrous material.

Batching pigs are multi-use pigs designed for batching, displacing and light cleaning. Two and four cups configurations are available.

Bi-Directional Pig

- Outside discs are used as guide/support discs (these discs are made of a harder material).
- Typically disc pigs are used for hydrostatic testing and as displacing pigs.
- Can also be equipped with brushes for cleaning purposes as well.

AUCSC
Appalachian Underground Corrosion Short Course

Cast Urethane Pigs

AUCSC

Appalachian Underground Corrosion Short Course

Spherical Pigs

99% of the time, spheres are used to push liquids out of natural gas gathering lines.

Gravity allows the automated launching and receiving of spheres which makes them very easy to use and very cost effective.

Typically, lines have been designed to handle spheres.

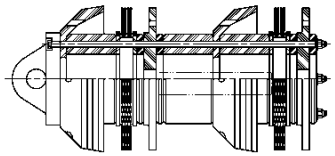
Seamless, one-piece, inflatable.

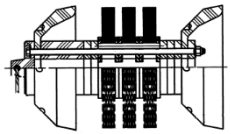
Spheres are filled with liquid and can also be inflated to compensate for wear.

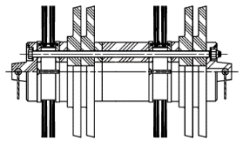
Foam Pigs

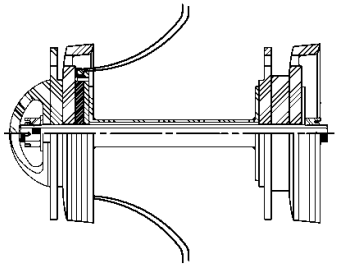
Brush Pig Configurations

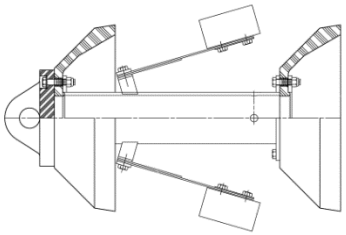
What Type of Brush Should I Use ?

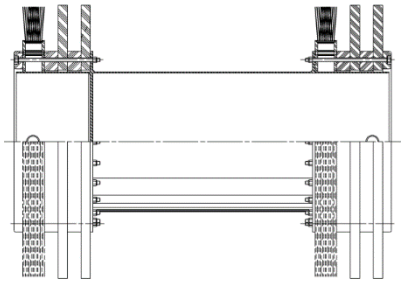


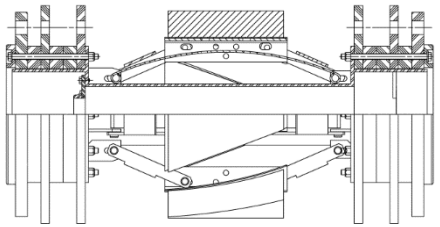












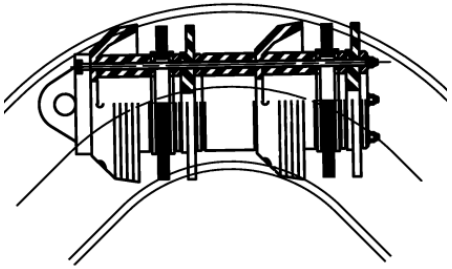
AUCSC

Appalachian Underground Corrosion Short Course

Circular Brushes

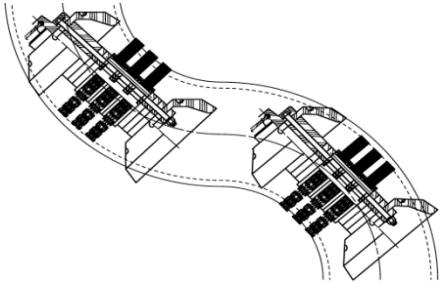
Advantages

- Bi-Directional
- Come in all sizes
- Can be stacked in dense cleaning packs
- Provide good centering guide in the pipeline



Disadvantages

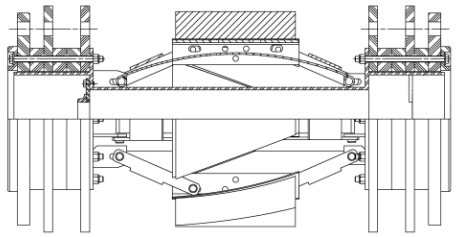
- Not effective in cleaning deep pits
- Not effective in pipelines with multiple ID's
- Can be Damaged in tight bends and pipe ID anomalies



Pad Type Brushes

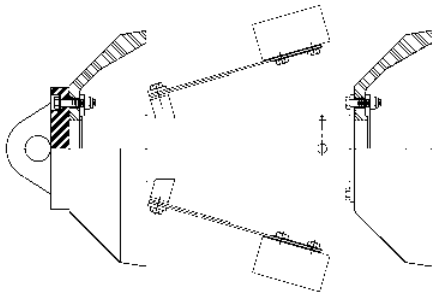
Advantages

- Pads are wear-compensated & can conform to bends
- Effective in multi-diameter pipelines
- “Buggy spring” mounted pads are Bi-Directional
- Can articulate thru pipeline anomalies



Disadvantages

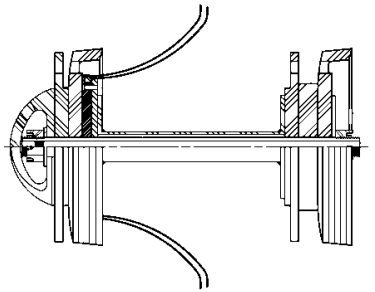
- Size restrictions
- Not effective in cleaning deep pits
- Lever mounted pads are not Bi-Directional



Pit Cleaning Brushes

Advantages

- Wear compensated and conform to bends & anomalies
- Effective cleaning in deep pits
- Effective in multi-diameter lines
- Self cleaning



Disadvantages

- Not Bi-Directional
- Size Restrictions
- Expensive

AUCSC

Appalachian Underground Corrosion Short Course

Pit Cleaning Brushes

Advantages

- Wear compensated and conform to bends & anomalies
- Effective cleaning in deep pits
- Excellent for low pressure and flow systems

Disadvantages

- Not Bi-Directional
- Requires Trailing Pig

AUCSC
Appalachian Underground Corrosion Short Course

Pig Type Options

Special features that can be added to pigs:

Blades for Wax Removal

Wear-Compensating Brushes

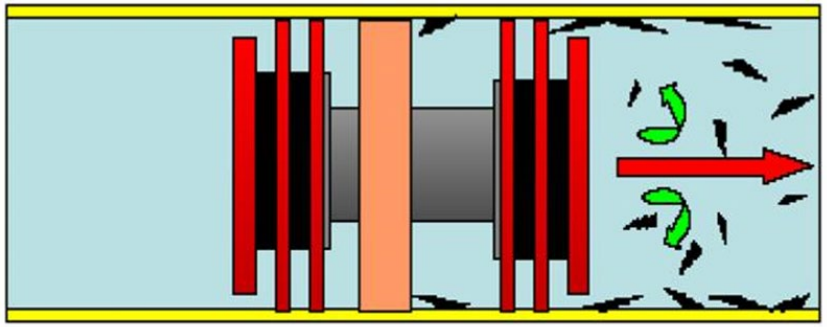
Studded Pig

AUCSC
Appalachian Underground Corrosion Short Course

Pig Type Options

Bypass Pigging

- Can be used to slow pigs to optimum speed
- Prevents debris pile up in front of the pig (riding over it)
- Suspends debris ahead of the pig in the faster flow
- Bypass in cups or discs jets / dislodges debris
- Continuously clears debris from the cleaning elements on the pig



Pig Type Options

Bypass Pigging

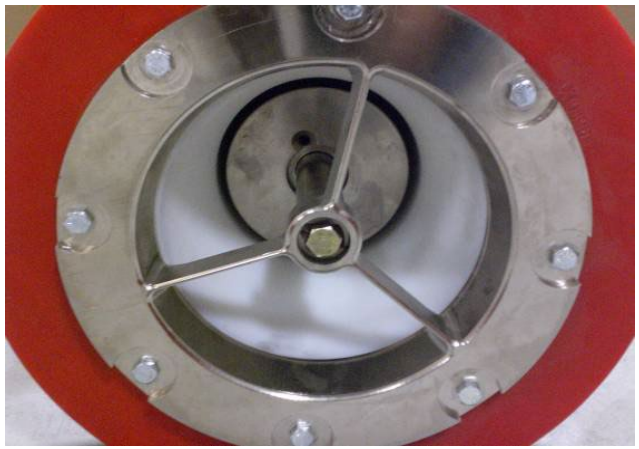
Bypass may be used to slow the pig in high velocity pipelines, but:

- Cannot slow the pig significantly without risk of stalling
- Amount of bypass should be developed gradually by experimentation / timing of runs
- Too much bypass may cause the pig NOT to launch (limited kicker size) – may need to increase flow to kicker line
- May need to push a stalled pig with a foam pig or pig with lesser bypass
- May be more effective in higher pressure pipelines (reduces speed excursions)
- Pigs may run faster near the end of long lines due to cup / disc wear (resulting in less friction/drag)
- Bypass through a cleaning pig will result in a longer slug of contaminated / dirty product than a pig without bypass, so you must have adequate provisions for collecting this larger debris field.

Pig Type Options

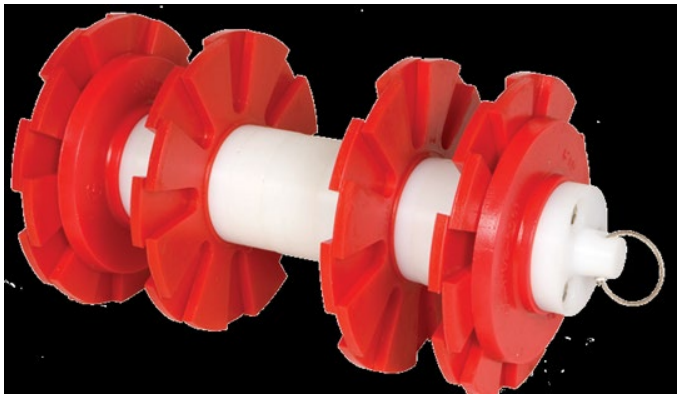
Speed Control

- Oscillating Bypass Valve
  - A passive system functioning solely on differential pressure & inertia
  - When fully opened, maximum bypass (speed reduction) is provided
  - As pig experiences increase in differential (driving) pressure, valve begins to close limiting bypass to less than 5% when fully closed
  - Increase in differential pressure could be due to debris, bends and heavier wall thickness.



Pig Type Options

Dual Diameter Pigs



Pig Type Options

Dummy Tools

Pipeline Pigging

Pipelines are pigged to perform four (4) different functions

- Cleaning
- Batching
- Displacement
- Inspection

Pigging during Construction

During pipeline construction it is not uncommon that a certain amount of debris will find its way into the pipeline. This debris must be removed prior to commissioning the pipeline and it is normally removed by pigs that the contractor will run after construction with compressed air.

Pigging during Construction

Once the debris is removed from the pipeline it is not uncommon to run the following tools;

Gauging Pig

Caliper Tool

Geometry Tool

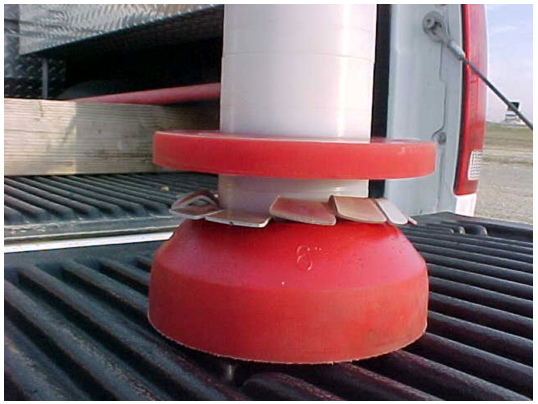
These tools are run to determine if there are any abnormalities in the pipeline such as reductions and out of round conditions.

Pigging during Construction

Gauging Pig

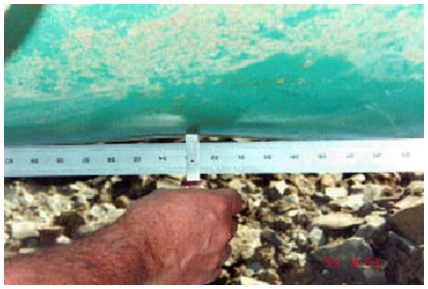
A gauge plate pig is used to determine if ID restrictions exist.

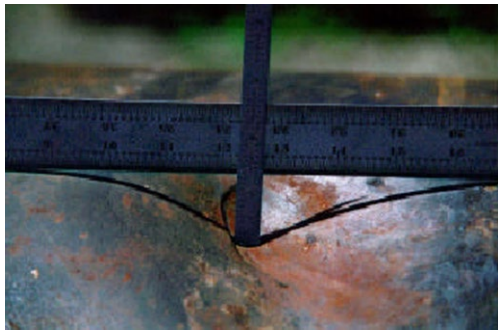
It does not tell you where or when the plates were bent



Pigging during Construction

Detectable Pipe Features





- Bends
- Valves
- Wall thickness changes
- Tees
- Taps
- Girth Welds

- Dents
- Ovalities
- Other
- Misalignments
- Mitre Bends
- Wrinkles/Buckles

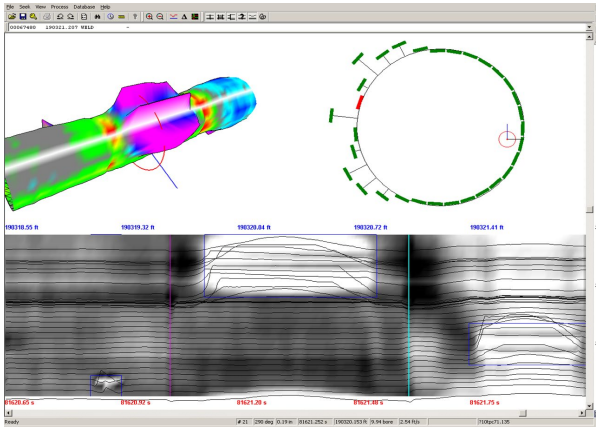
Pigging during Construction

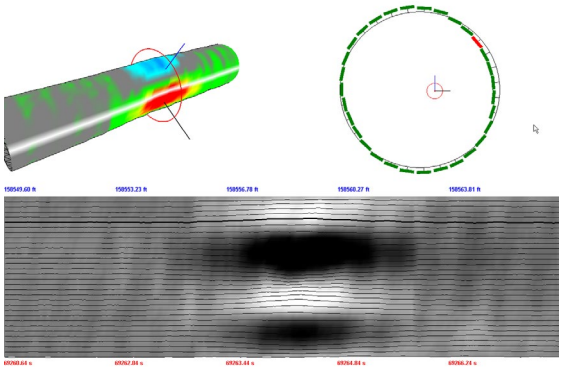
Types of Geometry Pigs

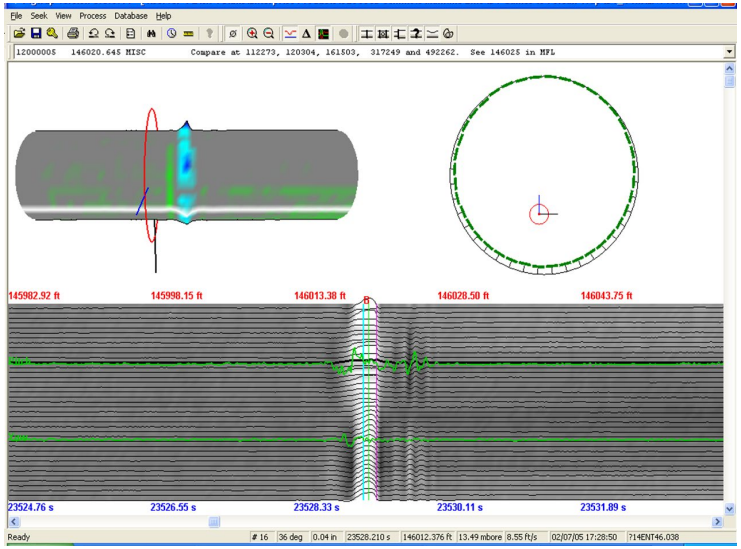
Movement is detected in mechanical “arms” oriented at the rear cup as tool traverses the pipeline

Hi – Resolution Geometry

Pigging during Construction



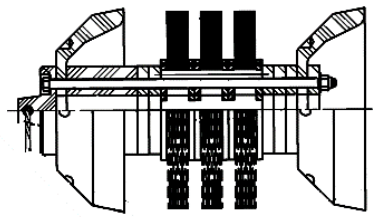


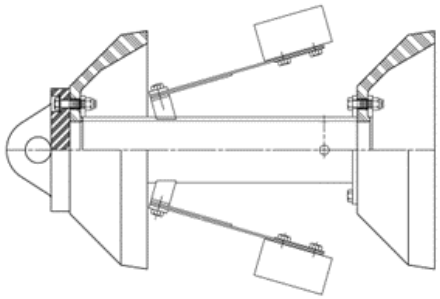


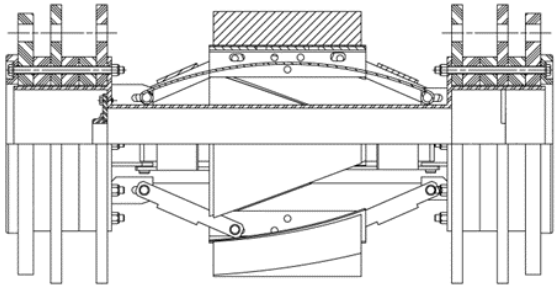
Pigging during Construction

Cleaning

Providing the pipeline is free of any major abnormalities the contractor will then use some aggressive wire brush pigs to remove any rust, scale, weld slag, etc., to clean the line prior to hydrostatic pressure testing.







AUCSC

Appalachian Underground Corrosion Short Course

Pigging for Hydrostatic Testing

Displacement of Air

During the hydrostatic testing process batching pigs are used to displace the air from the pipeline during the fill-water process. The batching pig is placed into the pipeline first and then moved through the pipeline by the fill-water process to displace any air in the pipeline.

AUCSC

Appalachian Underground Corrosion Short Course

Pigging for Hydrostatic Testing

Drying

Once the pipeline has been hydro-tested the contractor will dewater the pipeline using a series of pigs pushed through the pipeline with dry compressed air. After the water has been displaced the pipeline normally needs to be dried. This is accomplished by blowing dry air or nitrogen through the pipeline in conjunction with running numerous foam pigs.

Post Hydrostatic Treatment

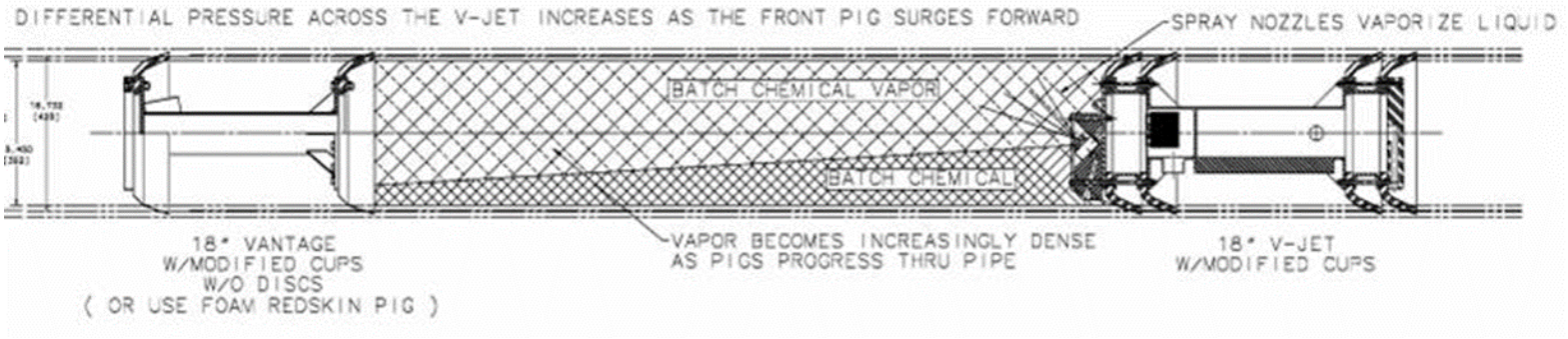
Biocide / Corrosion Inhibitor Treatment

Prior to commissioning pipeline – it is recommended to batch treat the pipeline with a specially formulated biocide with surface-active properties to film the pipe surface and control microorganisms that may exist in residual hydro water or may be dormant on the pipe wall. The biocide that is typically used includes a water-soluble filming corrosion inhibitor for longer-term metal protection.

ChampionX recommends batching in neat form between two pigs based on surface area. The batching application will consist of a lead and filming pig.

Post Hydrostatic Treatment

Biocide / Corrosion Inhibitor Treatment Methods



AUCSC

Appalachian Underground Corrosion Short Course

Cleaning

Cleaning a pipeline during operation is a maintenance procedure that needs to be performed on a regular predetermined frequency using pigs adequately designed for the proper cleaning application.

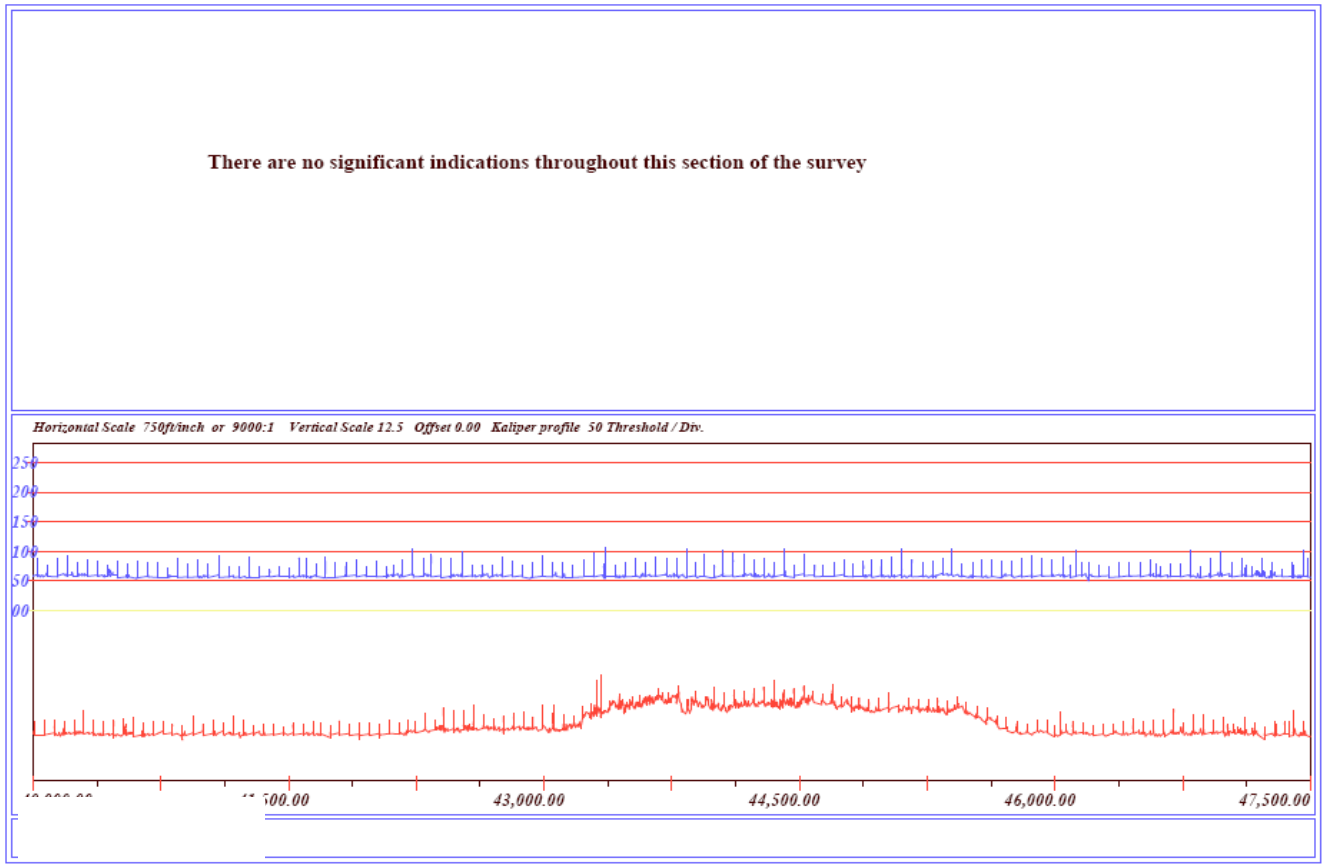
In pipelines that have low flow conditions it is more prevalent to see an increase in the accumulation of free water in the bottom of the pipeline, even in crude oil lines. In low flow conditions you need a mechanical means (pigs) to remove both the solids and liquids that collect in the bottom of the pipeline to help prevent the process of internal corrosion.

Online Pigging: Mechanical & Chemical Enhanced

Offline Pigging: Pig can be propelled with water, air, nitrogen or wire-line equipment.

Measurement of Debris Fields

Caliper Pig



AUCSC

Appalachian Underground Corrosion Short Course

Operational Pigging

Advantages of Cleaning w/Surfactants

Chemically enhanced line cleaning produces:

- Project total time lengths are compressed
  (results in cost saving in most cases)
- Solids in suspension move through the line easier
- Dry Iron Sulfide is flammable (pyrophoric) in presence of oxygen.
- Performance and effectiveness of cleaning process can be measured by determining % solids to total liquid volume, magnet saturation of ferrous by-products, and through composition sampling.

Operational Pigging

Magnetic Cleaning Pig for Ferrous Materials

Debris such as welding rods, bolts, tools, ferrous corrosion by-products, etc., is very difficult to remove with conventional pigs as the pigs typically push these objects for some distance and then ride over them.

Run #1	320 welding rods and four steel plates removed
Run #2	165 welding rods and five steel plates removed
Run #3	50 welding rods and one steel plate removed
Run #4	12 welding rods and zero steel plates removed

AUCSC

Appalachian Underground Corrosion Short Course

Operational Pigging

Batching with Inhibitors

Introducing a column of liquid between pigs for the purposes of applying Inhibitor and/or biocides can be an effective method to apply these products.

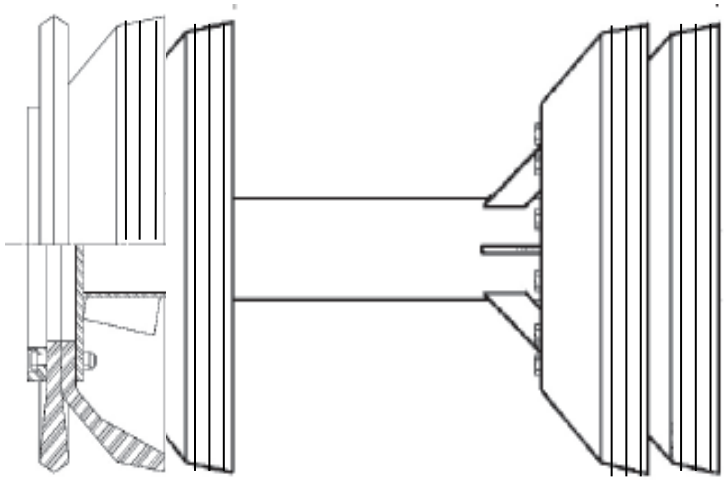
- The pipeline must be clean for the inhibitor to be effective
- The inhibitor must contact the pipe to be effective
- The inhibitor application must be effective
- The quantity of inhibitor must be calculated for 100% coverage

Operational Pigging

Batching with Inhibitors

Special features of the front pig(s)

- Front pig should have higher drag (delta-P) than rear pig – addition of disc(s) and/or use of harder sealing elements
- Pig should have a disc and 2 cups on the front and 2 cups on the rear – all multi-lip sealing cups
- Pig may have no bypass through the rear section



Operational Pigging

Batching with Inhibitors

Special features of the Rear pig(s)

- Rear pig should have lower contact pressure with the pipe wall than front pig – this can be done by the use of softer (and/or fewer) sealing elements
  - Results in lower drag to ensure that it doesn't tend to fall behind
  - Doesn't tend to wipe the inhibitor completely off the pipe wall
- Two cups in front and two cups in rear

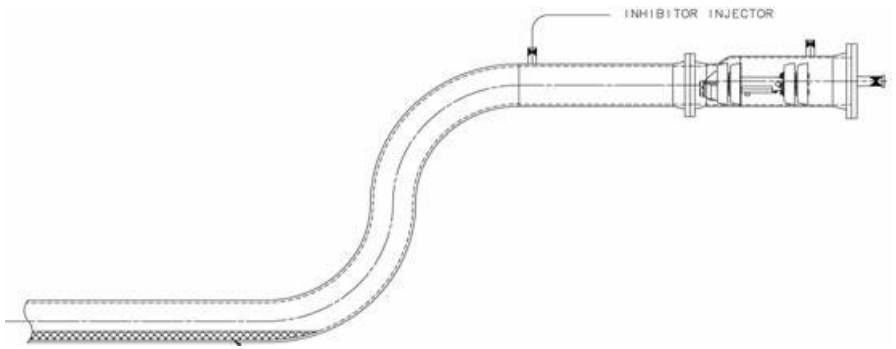
Operational Pigging

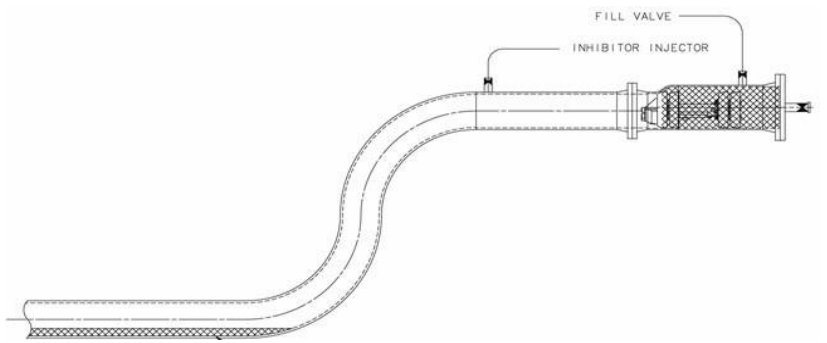
Batching with Inhibitors – Jet Pig

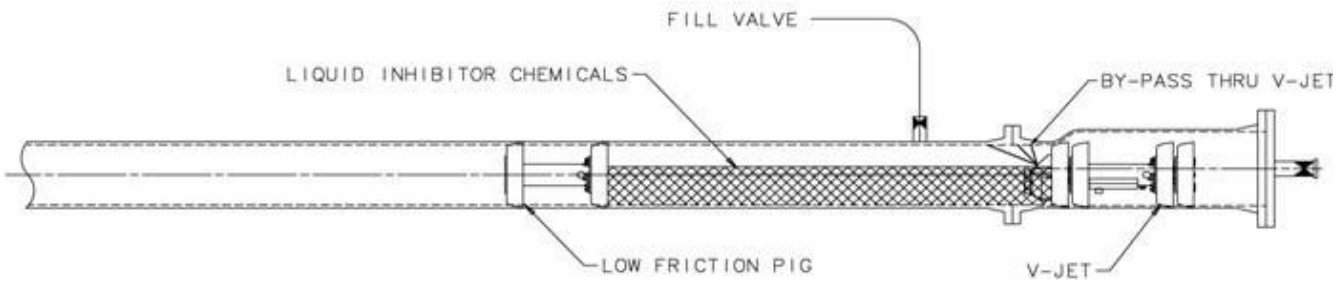
- Bypass flow and differential pressure.
- There are no moving parts or pressure vessels to fill and charge
- Allows bypass flow through its body and spray head
- Bypass flow acts as the accelerant to transfer and vaporize fluid
- Creates low pressure / suction lifting liquids off the bottom of the pipe
- Front inlet ports draw pooled inhibitor-containing liquid - spraying to top
- A counterweight system insures proper orientation of the spray head

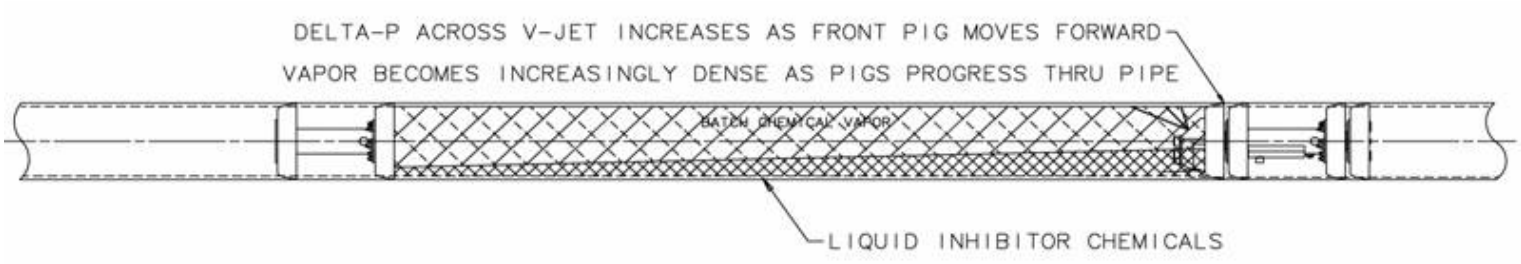
Operational Pigging

Batching with Inhibitors – Jet Pig









Operational Pigging

Inspection

MFL Tools are the best & most expensive cleaning pigs available. Sensor “Lift Off” will reduce the intensity of the magnetic signal and will affect data quality.

Operational Pigging

Special Purpose / Progressive

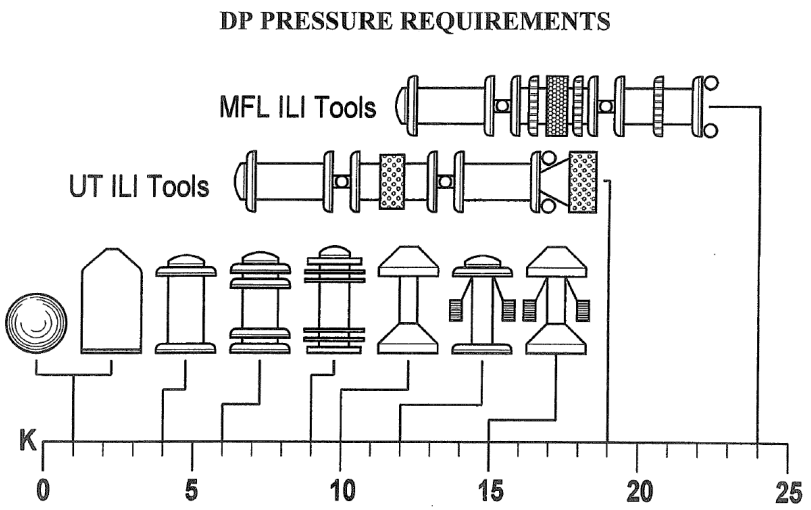
The more unknowns that exist in a pipeline segment, the less intrusive the initial pig run should be - start with a less aggressive pigs and progress to more aggressive pig based on the monitored results. An example of a progressive pigging program may consist of the following:

- Foam Pig
- Foam Pig with Bristles
- Steel bodied Mandrel Pig With Brushes
- Steel bodied Mandrel Pig with Aggressive Brushes
- Gauging Pig
- Dummy Pig w/ Magnets
- Geometry Pig

Pigging

Differential Pressure

Typical Differential Pressure (DP) Required to Drive a Pig	
DP (bars) =	$\frac{\text{K (type of pig)}}{\text{Nominal Diameter (inches)}}$
K (Types of Pigs)	
Sphere and Foam Pig =	1
2 Cup Pig =	4
4 Cup Pig =	7
Disc Pig =	9
Cup Brush Pig =	12
Disc Brush Pig =	15
UT ILI Tool =	19
MFL ILI Tool =	24



Appalachian Underground Corrosion Short Course

Pressure

Typical Differential Pressure (DP) Required to Drive a Pig	
DP (bars) =	$\frac{\text{K (type of pig)}}{\text{Nominal Diameter (inches)}}$
Example: 10-inch Disc Brush Pig (K Factor = 15)	
DP (bars) =	$\frac{15}{10 \text{ inch}}$
1.5 bars x 14.5 psi =	21.75 DP psi

DIFFICULT TO PIG PIPELINES

QUESTIONS

David Wint

David.wint@championx.com

CHAMPIONX

AUCSC

Appalachian Underground Corrosion Short Course