Oil and Gas Pipeline Design, Maintenance and Repair

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Part 7: Instrumentation and Pigging

PIGGING OPERATIONS

INTRODUCTION

- Devices that are inserted into and travel throughout the length of a pipeline driven by a product flow.
- Developed to remove deposits which could obstruct or retard flow through a pipeline.
- Today are used during all phases in the life of a pipeline for many different reason

REASONS FOR PIGGING

- Batch or separate dissimilar products
- Displacement purposes
- Internal inspection.

PIG CATEGORIES

- Utility Pigs, which are used to perform functions such as cleaning, separating, or dewatering
- In Line Inspection Tools, which provide information on the condition of the line, as well as the extent and location of any problems.
- Gel Pigs, which are used in conjunction with conventional pigs to optimize pipeline dewatering, cleaning, and drying tasks.

SELECTION CRITERIA

The purpose:

- Type, location, and volume of the substance to be removed or displaced in conventional pigging applications,
- Type of information to be gathered from an intelligent pig run,
- Objectives and goals for the pig run

SELECTION CRITERIA

The line contents

- The contents of the line while pigging,
- Available vs. required driving pressure,
- Velocity of the pig.

SELECTION CRITERIA

Characteristics of the pipeline

- The minimum and maximum internal line sizes,
- Maximum distance pig must travel,
- Minimum bend radius, and bend angles,
- Additional features such as valve types, branch connections, and the elevation profile.

UTILITY PIGS

- **Cleaning Pigs**, to remove solid or semi-solid deposits or debris from the pipeline
- **Sealing Pigs**, used to provide a good seal in order to either sweep liquids from the line, or provide an interface between two dissimilar products within the pipeline.
- Within these two groups, a further subdivision can be made to differentiate among the various types or forms of pigs:
- **Mandrel pigs**, which have a central body tube, or mandrel, and various components which can be assembled onto the mandrel to configure a pig for a specific duty;

UTILITY PIGS

- **Foam pigs**, which are molded from polyurethane foam with various configurations of solid polyurethane strips and/or abrasive materials permanently bonded to them;
- **Solid cast pigs**, which are moulded in one piece, usually from polyurethane, and;
- **Spherical pigs or spheres**, which are of either a solid composition or inflated to their optimum diameter with glycol and/or water.

UTILITY PIGS

Mandrel pigs

Foam pigs

UTILITY PIGS

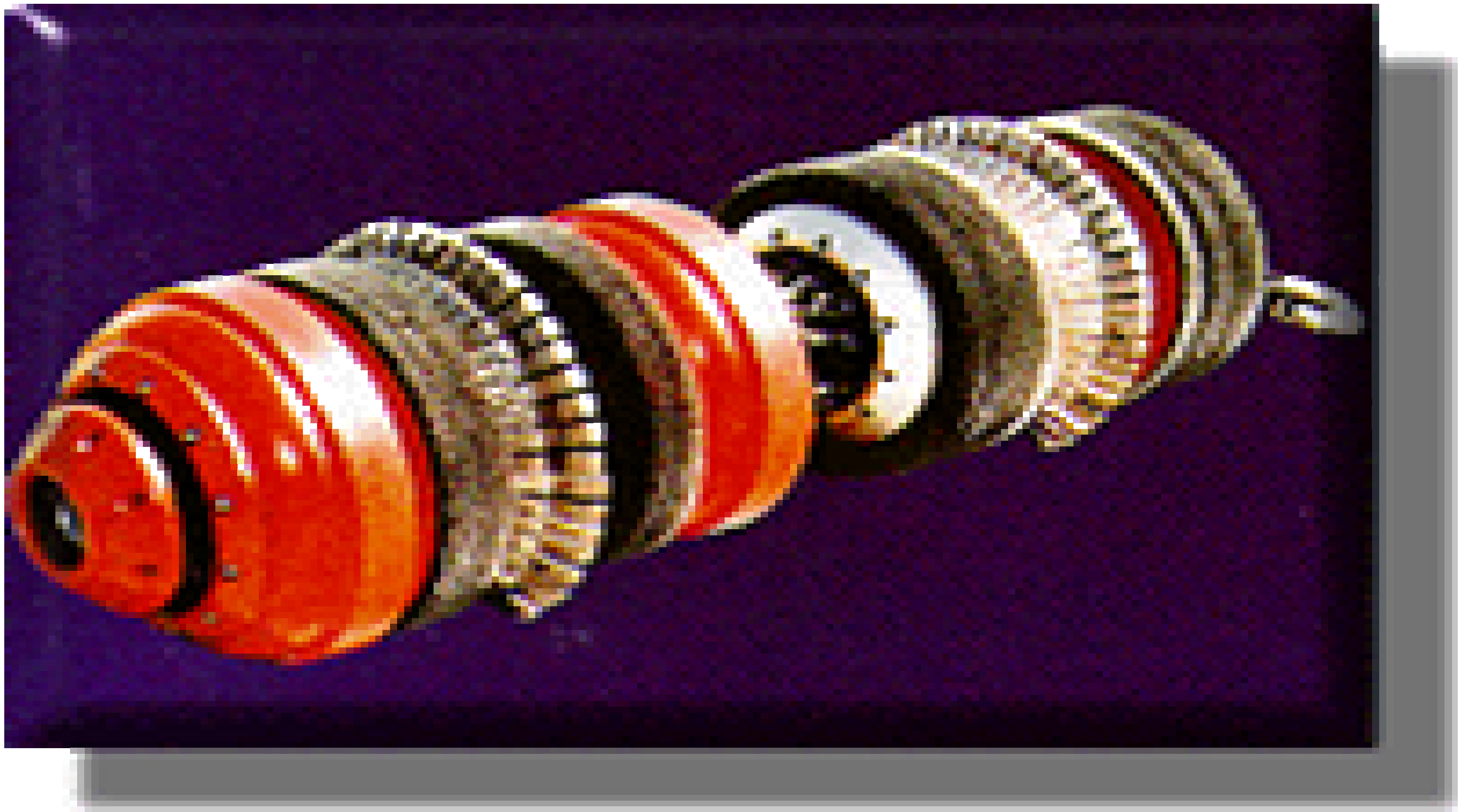
Solid cast pigs

Spherical pigs or spheres

IN LINE INSPECTION TOOLS

- In Line Inspection provides information on the condition of the pipe and/or its contents.
- With few exceptions, the In Line Inspection Tool itself is simply the tool which gathers the data, which is then analyzed by the engineers and technicians to determine and report on the condition of the line.

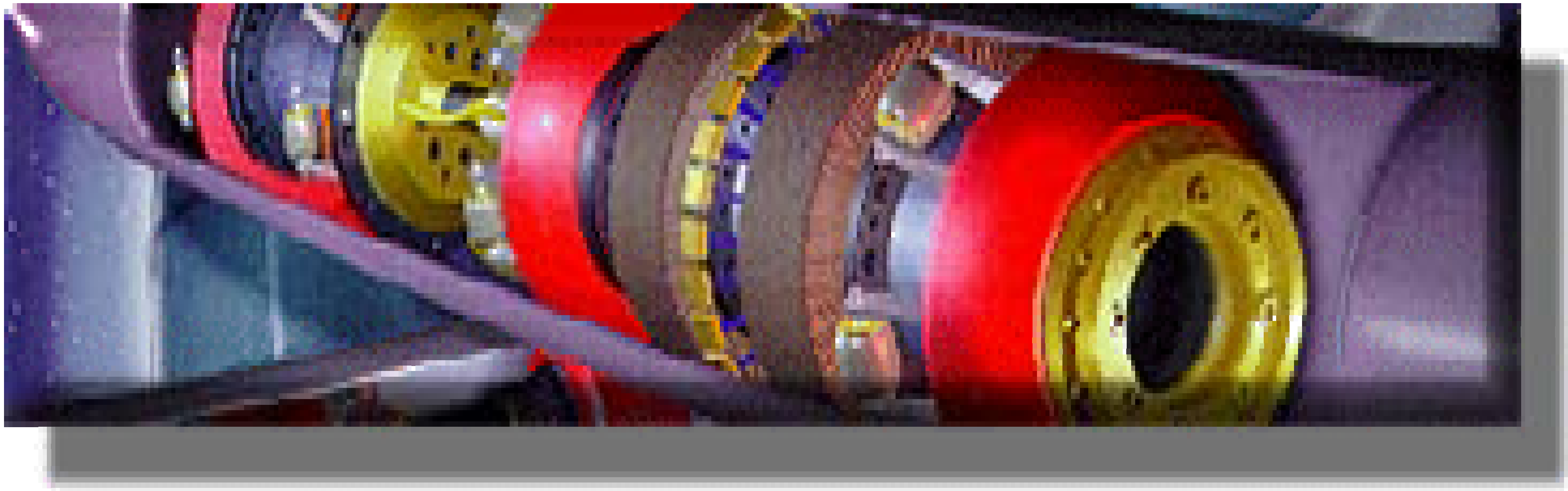
IN LINE INSPECTION TOOLS



INFORMATION FOR IN LINE INSPECTION TOOLS

- Diameter/geometry measurements;
- Curvature monitoring
- Pipeline profile;
- Temperature/pressure recording
- Bend measurement
- Metal-loss/corrosion detection
- Photographic inspection
- Crack detection
- Wax deposition measurement
- Leak detection
- Product sampling
- Mapping.

ULTRASONIC INSPECTION TOOLS



GEL PIGS

- Gel pigs are a series of gelled liquid systems which have been developed for use in pipeline operations, either during initial commissioning, or as a part of a continuing maintenance program.
- Most pipeline gels are water-based, but a range of chemicals, solvents, and even acids can be gelled.
- Some chemicals can be gelled as the bulk liquid and others only diluted in a carrier.
- Gelled diesel used as a carrier of corrosion inhibitor in gas lines.

TYPES OF GEL

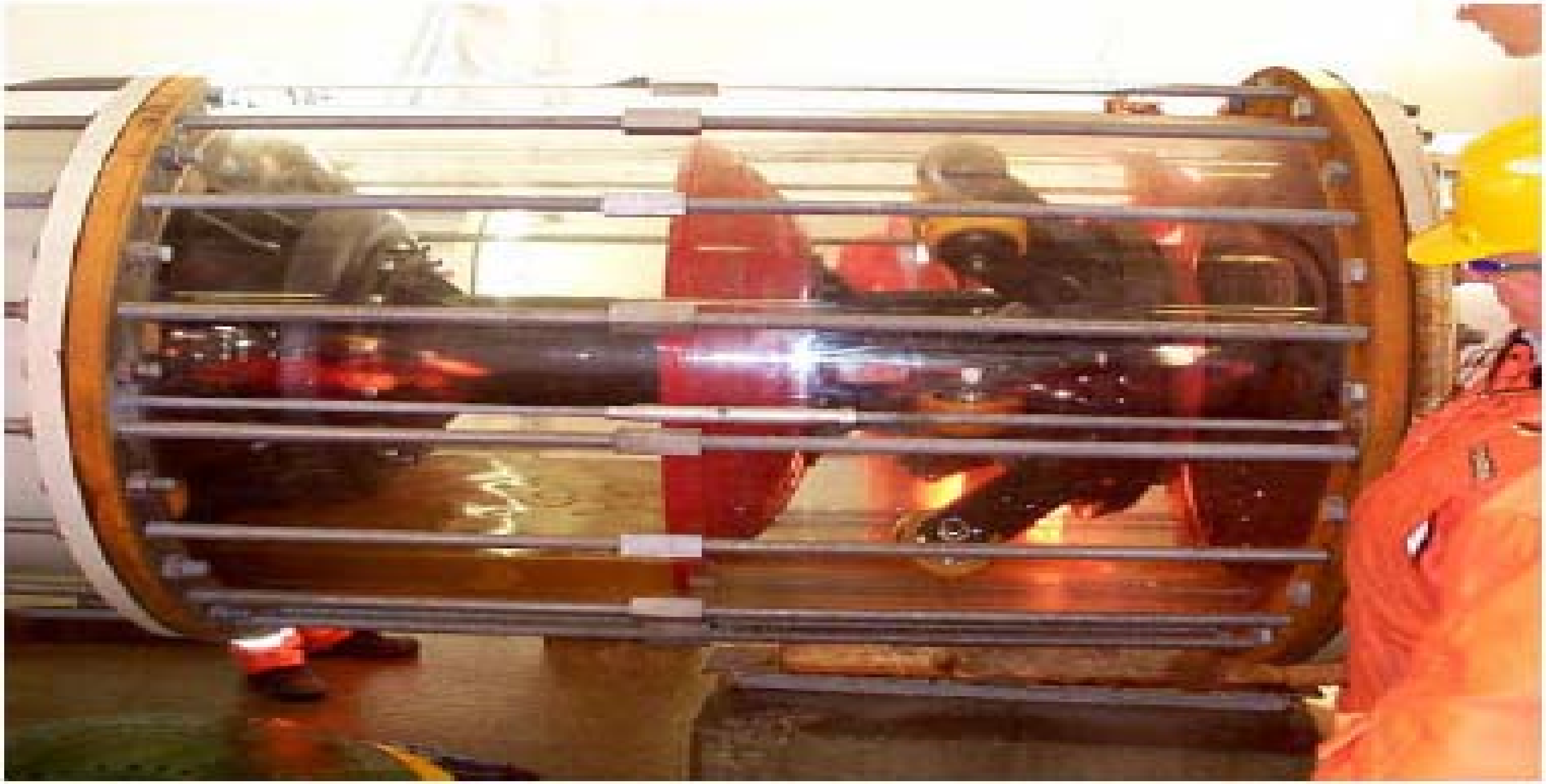
- Batching, or separator gel
- Debris pickup gel
- Hydrocarbon gel
- Dehydrating gel

PRINCIPLE APPLICATION OF GEL PIGS

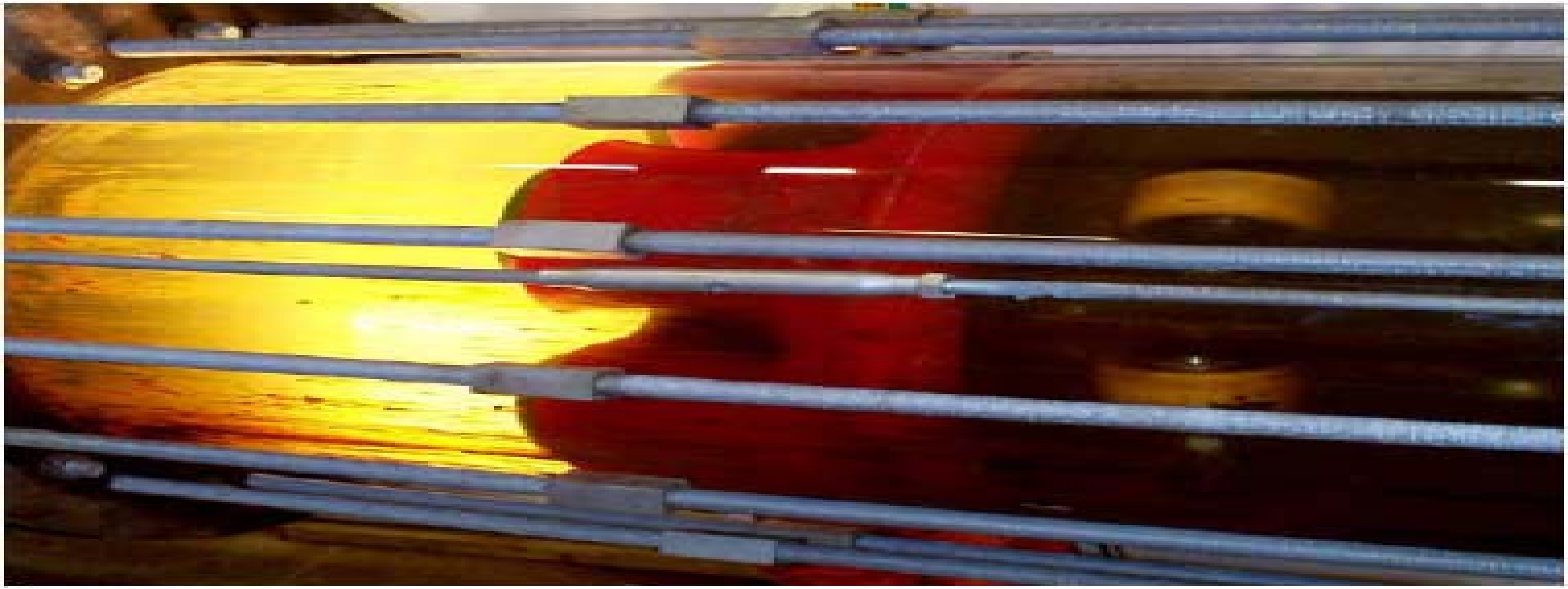
- Product separation
- Debris removal
- Line filling/hydro testing
- Dewatering and drying
- Condensate removal from gas lines
- Inhibitor and biocide lay down
- Special chemical treatment
- Removal of stuck pigs

DUAL DIAMETER PIGS

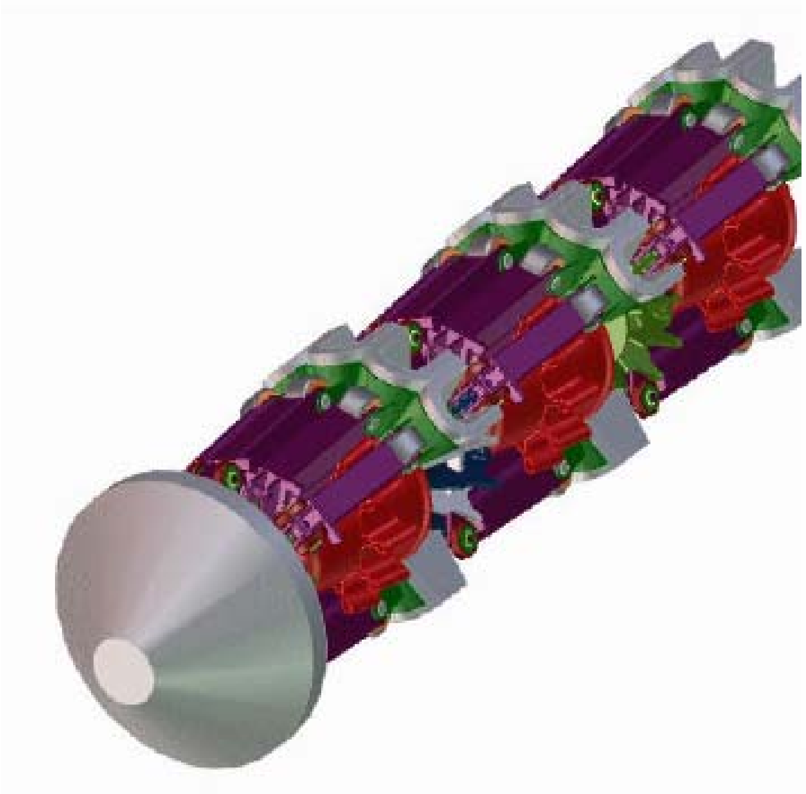
DUAL DIAMETER PIGS

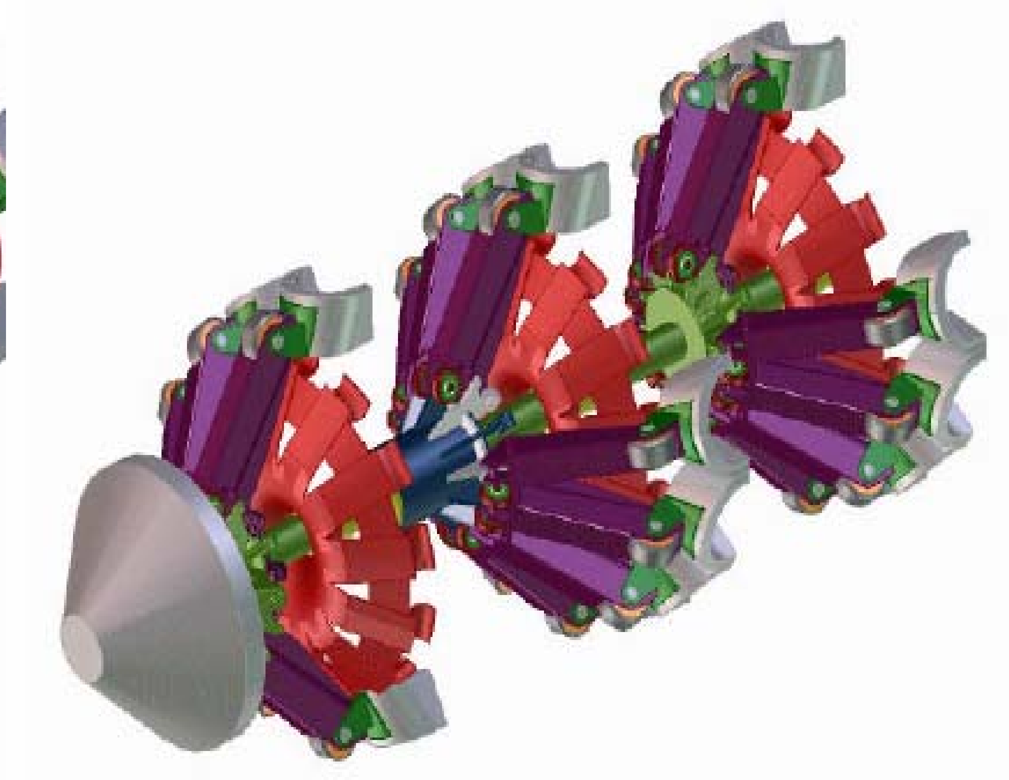


DUAL DIAMETER PIGS



MULTI DIAMETERS PIGS





WHY DO PIG STUCK?

- Pigs plug a pipe and cause a blockage
- Build up of wax in front of a pig causing a wax plug
- Unidirectional bypass leading to a stuck pig with product flowing past to it
- Jack knifing of a dual module pig
- Excessive wear leading to failure of seals and drive
- Mechanical damage
- Failure due to environment material selection
- Others that do not fail in the categories above

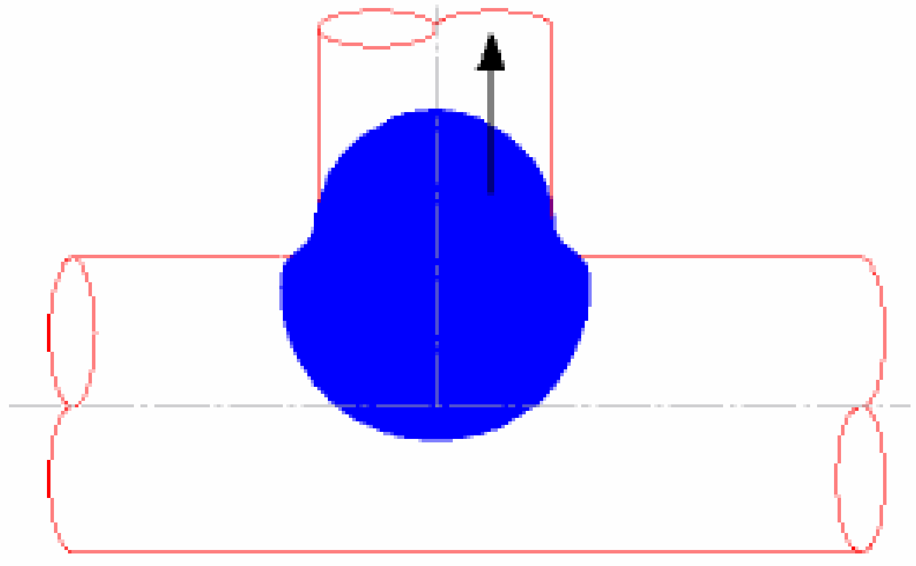
SPHERE JAMMED IN OFF TAKE

Cause

- Due to flow diversion, Flow from branch line

Solution

- Require to provide a bar arrangement in receivers or special flow/sphere tees in the pipeline
- The bearing arrangement should be checked
- In dual diameter line, special bearing arrangement may be necessary



INCORRECT SIZED PIG COMPONENTS

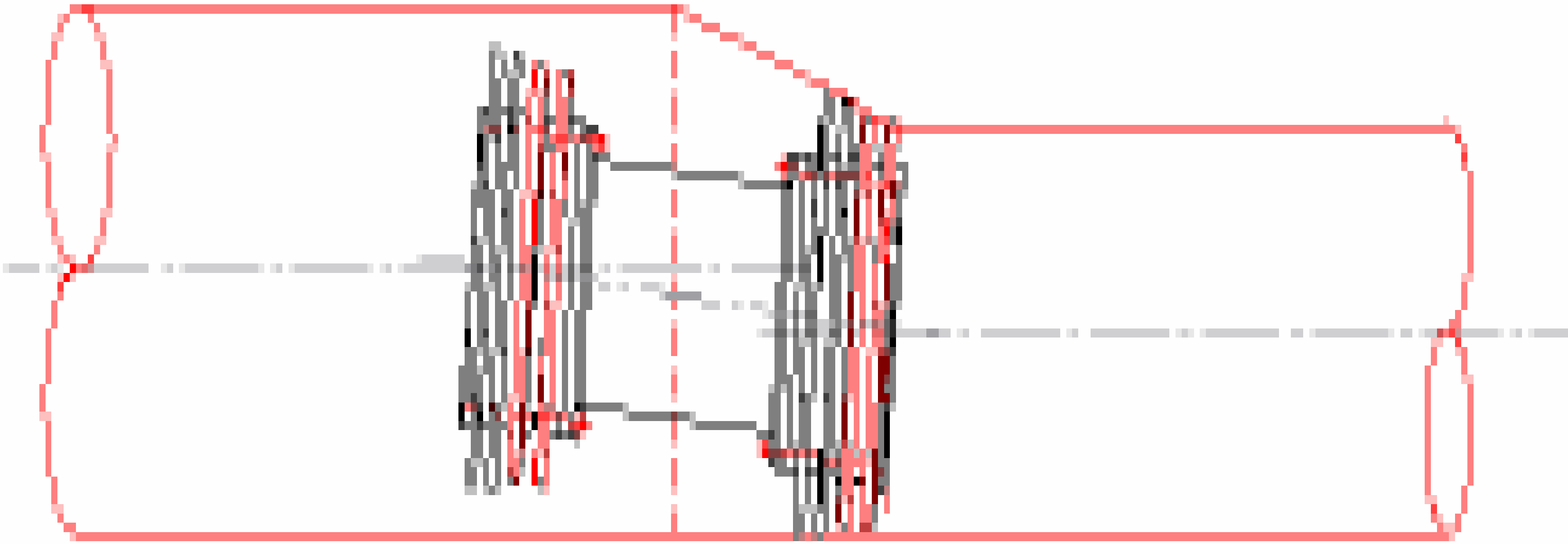
Cause

- Oversized guider can cause pig to misalign and jam in launcher reducer

Solution

- Pig component should be resized to the actual pipeline with an allowance for wear and other such factors
- Guiders need to be sized correctly to 99% of the smallest internal diameter and then seals sized to suit
- Avoid sealing locking on guiders as this may lead to rapid wear and seal damage

INCORRECT SIZED PIG COMPONENTS



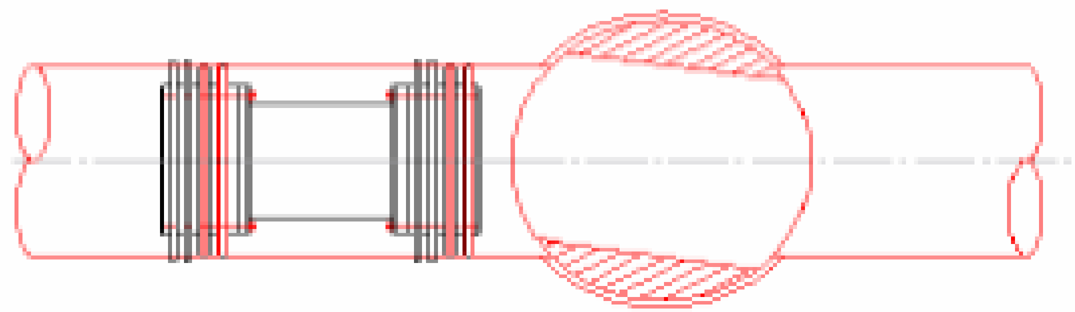
INCORRECT VALVE/VALVE NOT OPEN

Cause

- Use of incorrect valve in line, valves are not fully open
- Happens in smaller diameter line 12 in and smaller

Solution

- Checks in the operating procedures should be in place to check opening the valve
- Pig design should consider this eventually



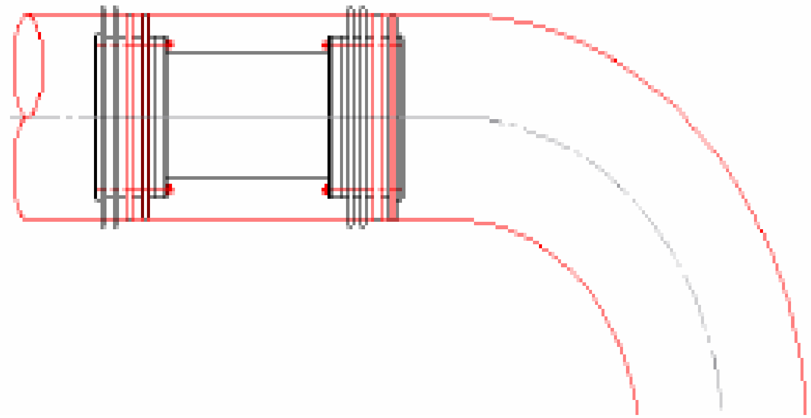
INSUFFICIENT INFORMATION (wrong bend radius)

Cause

- Insufficient information regarding pipeline design, especially older one

Solution

- Pigs must be designed for the line
- Some conservative assumptions must be made and agreed



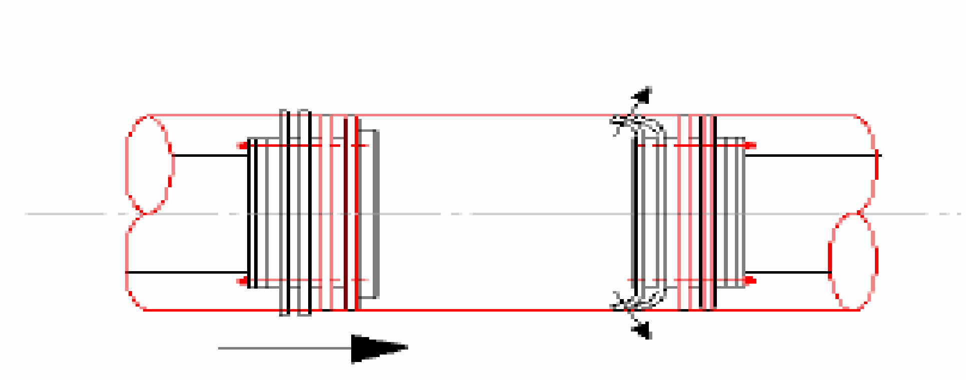
PIG PUSHING ON PIG IN FRONT

Cause

- when one pig pushes into the rear of another pig. It acts on the seals, forcing them harder against the pipe wall

Solution

- Have a bumper noses, both front and rear
- This be provided even if it is not only planned to have one pig in the line



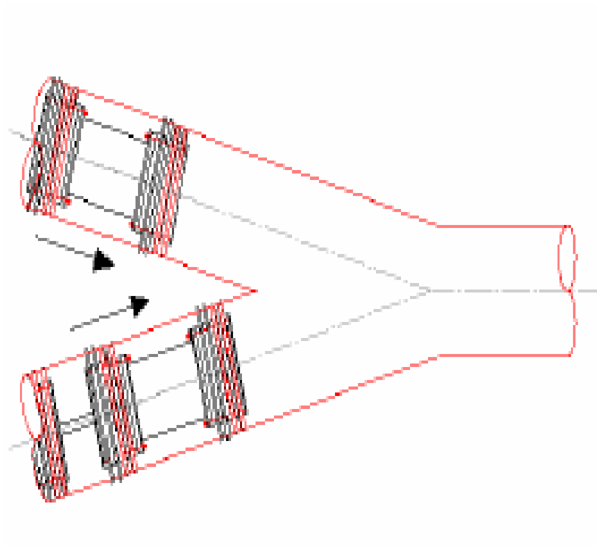
COLLIDING PIGS

Causes

- Possibility of pigs to meet at wyes or tees in complex lines

Solution

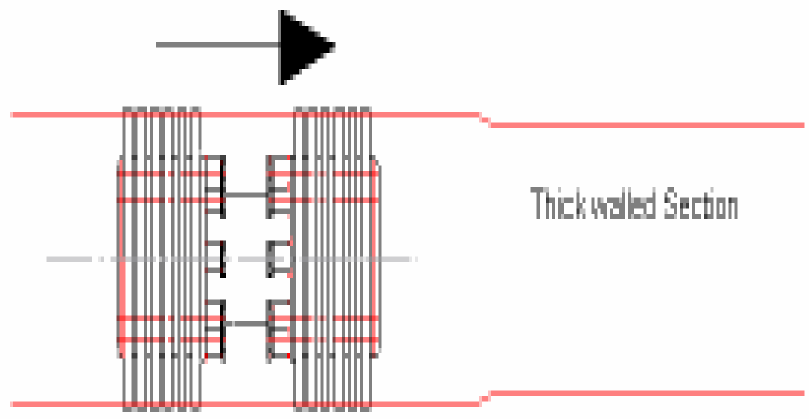
- Good communication and pigging operation procedures
- One pig may be made sacrificial



HIGH FRICTION PIGS

Cause

- Change from thin wall to thick wall pipe, lead to serious damage of the seals



Solution

- All pigs should be designed to deal with all internal diameters of the line and if in doubt, a test performed

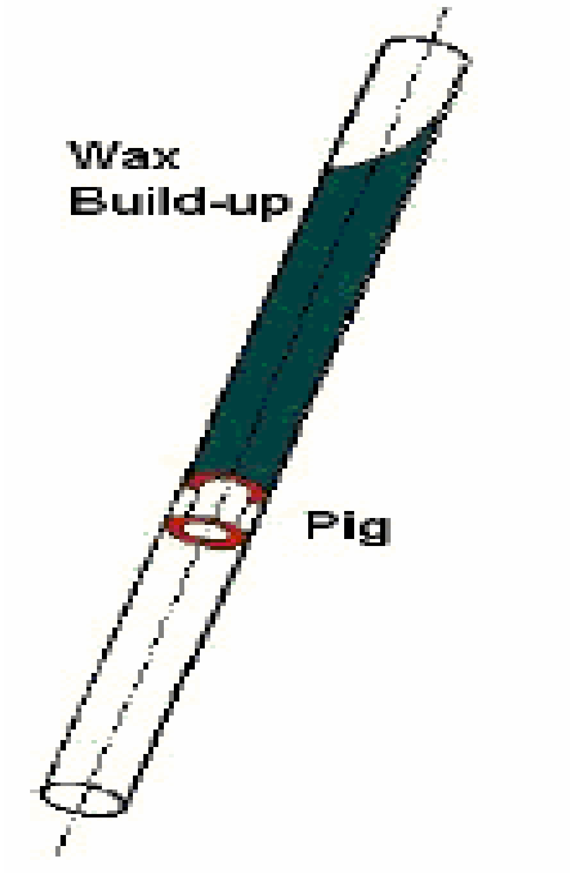
PLUGGING WITH WAX

Cause

- Wax build up in front of pigs

Solution

- Correct selection of pigs and correct bypass rates to allow debris in suspension



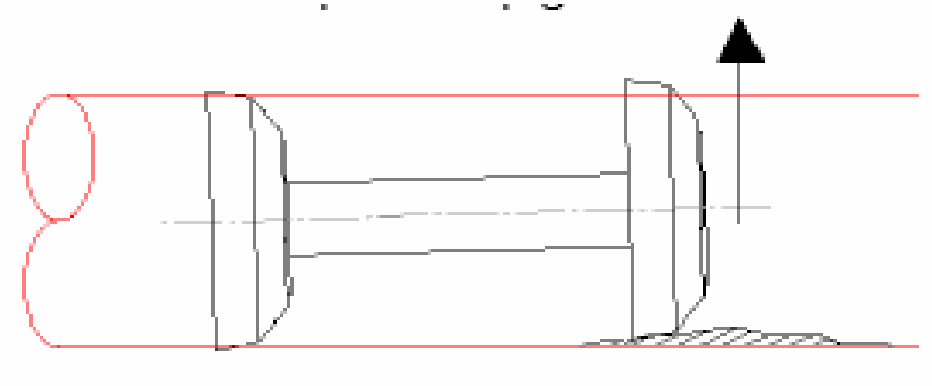
DEPRIS IN THE LINE

Cause

- Depris such as sand lift the pig up and cause rapid wear

Solution

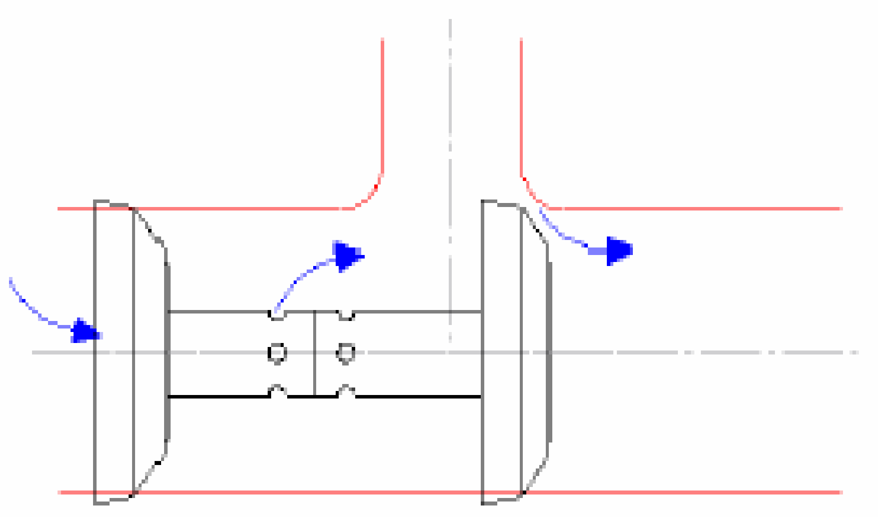
- Provide strong and sufficient bypass to the pig



FLOW AROUND THE PIG

Cause

- Pipeline features such as branches and offtakes, wyes etc. which can lead to a stalled pig if the bypass system is incorrect



Solution

- Consider the position of the offtakes

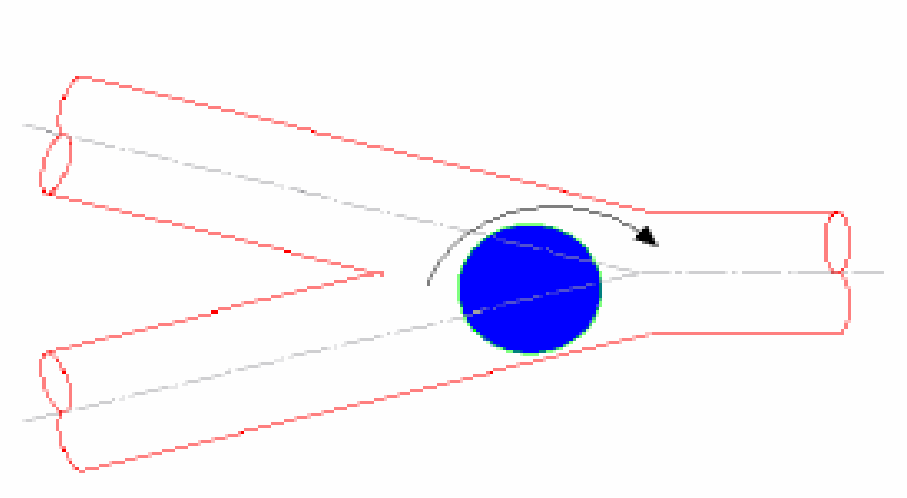
INSUFFICIENT SEALING LENGTH

Cause

- Components such as wyes and tees

Solution

- A dual pig should be used to span the component



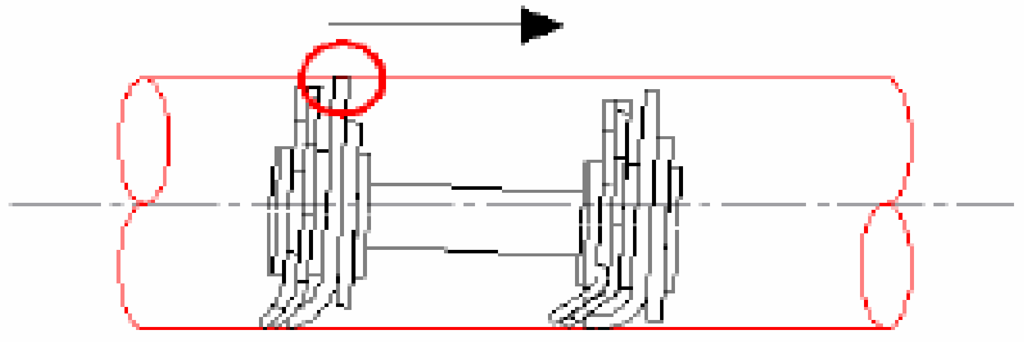
NOSE DOWN

Cause

- It happens the large diameter line

Solution

- Modern support techniques should be employed and seals sized appropriately



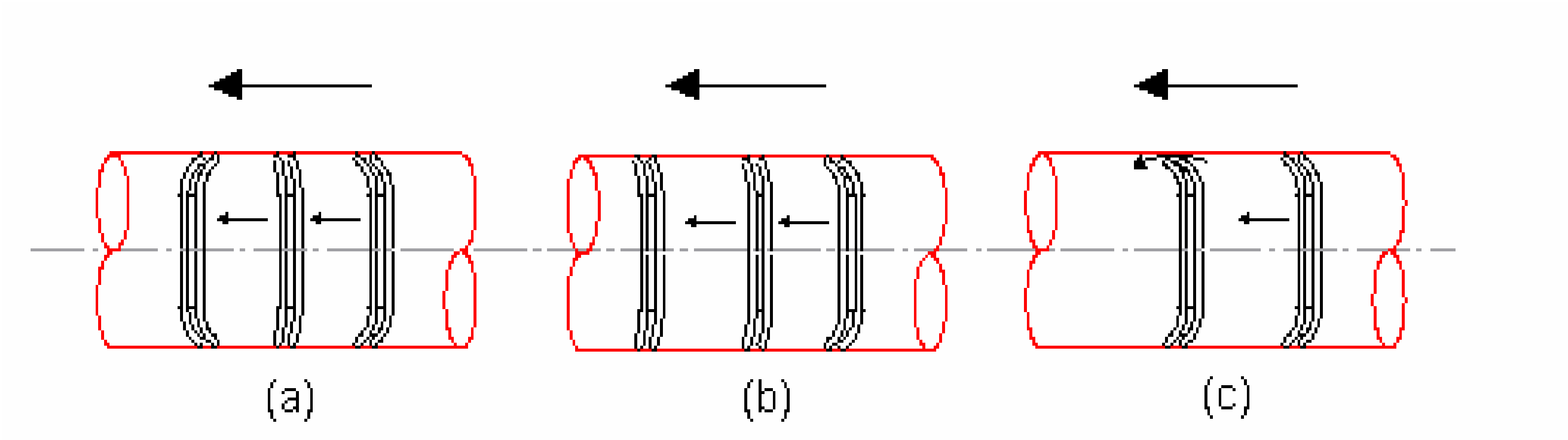
REVERSAL

Cause

- Reversing the flow of the line which causes interaction between pipe seal and pipe wall

Solution

- Consider the interference of pig component such as seals and guide discs in reversing pigs



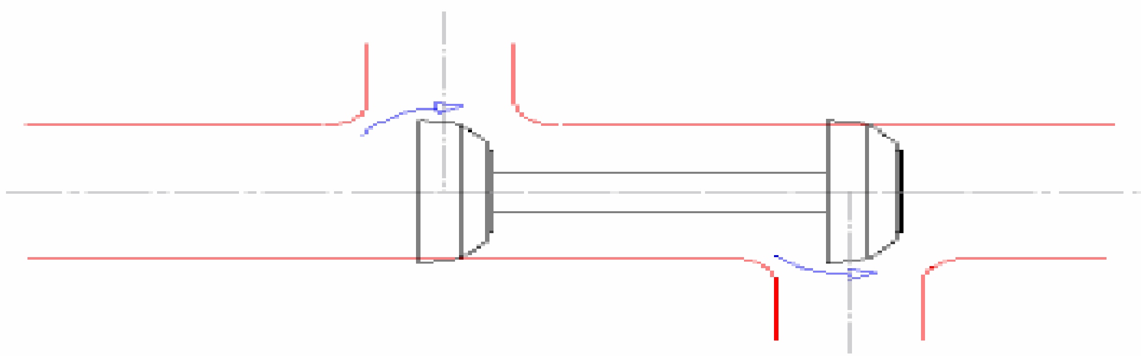
PROXIMITY OF COMPONENTS

Cause

- Too close line components which makes a risk of bypass as the sealing is incorrect

Solution

- The configuration of the pig must be considered and sufficient length between line components should be allowed



BUCKLING OF SEALS

Cause

- Buckling of sealing disks

Solution

- Appropriate selection of the seal geometry and flange selection

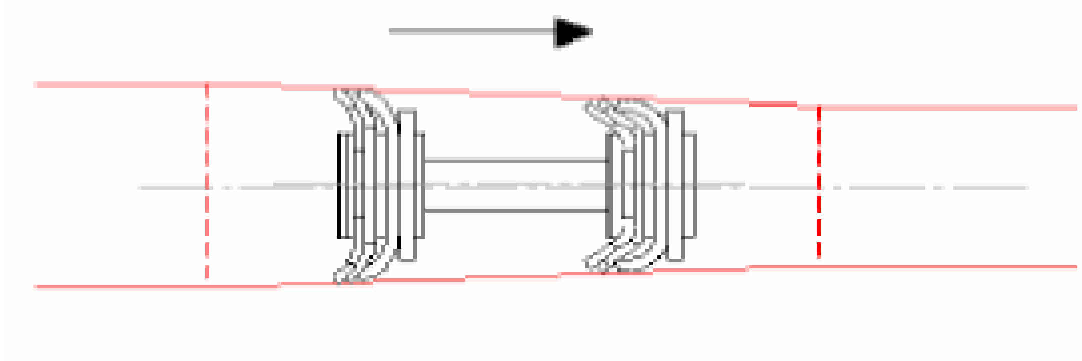
REDUCER LENGTH

Cause

- When the diameter of the pipe is reduced from a large diameter to a smaller diameter

Solution

- The reducer length should be as long as possible with inspection pigging compared with utility pigging where it should be as short as possible



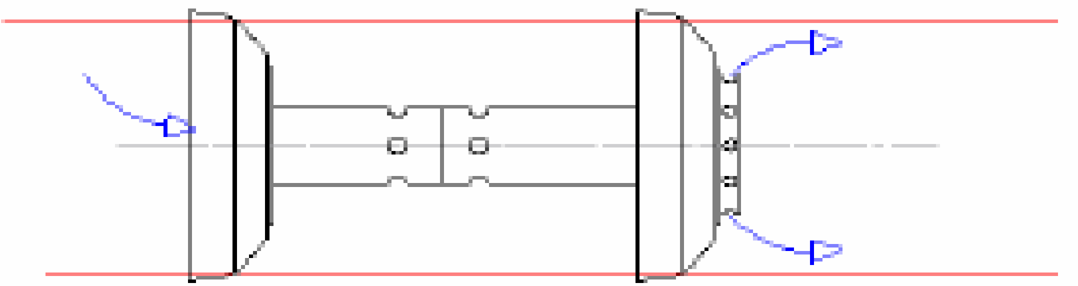
BYPASS WITH REDUCTION IN FLOW

Cause

- When a standard bypass pig is in a pipeline an d there is a sudden reduction in fluid flow

Solution

- Perform the the necessary calculations to allow the correct bypass to be selected



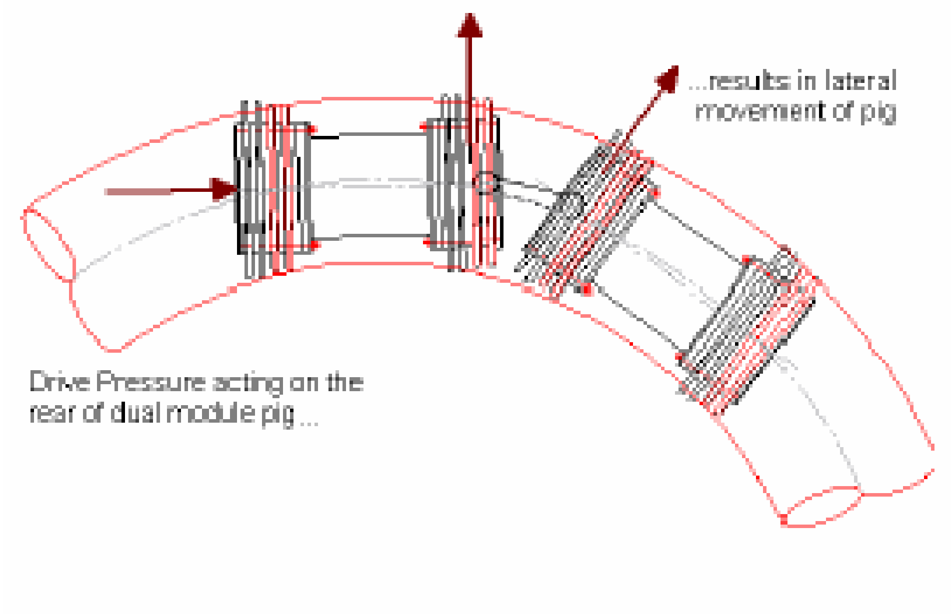
DRIVING DUAL MODULE PIG ON REAR

Cause

- Bends makes the pigs tend to move laterally, results in seal flapping

Solution

- Pressure should be transferred to the front module via bypass ports on the rear
- This allows the rear module to be towed



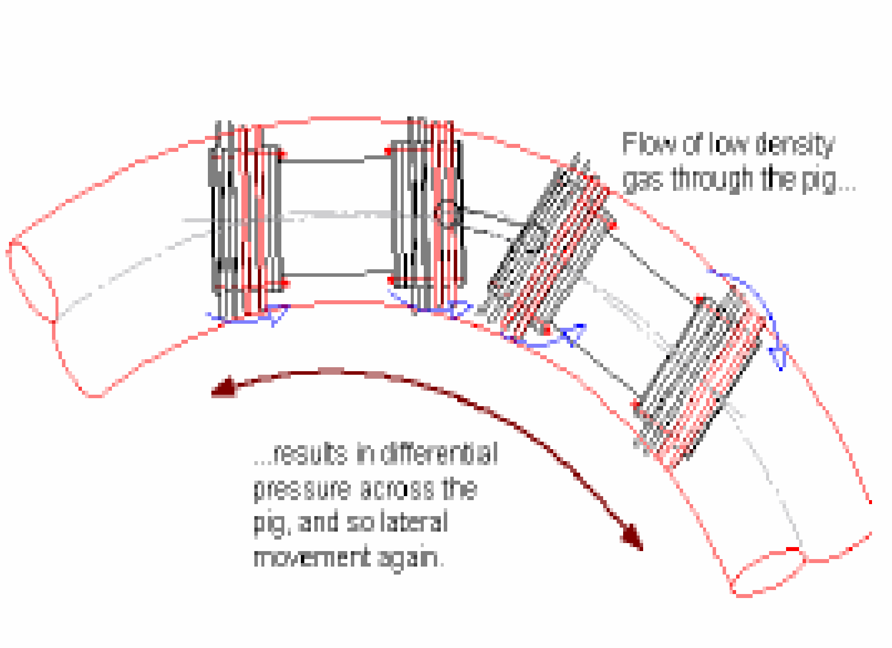
DUAL MODULE PIG WITH LEAKAGE

Cause

- Low density gas leaks through a dual module pig, differential pressure is set up across the pig and lateral movement can result

Solution

- Use better support for the pig and correct sizing of the seals



WEAR

Cause

- Abrasion cause wear due to large distance

Solution

- Determine the maximum piggable distance depending on: pig velocity, fluid type, pig differential pressure, pipeline nominal diameter, pipe surface type

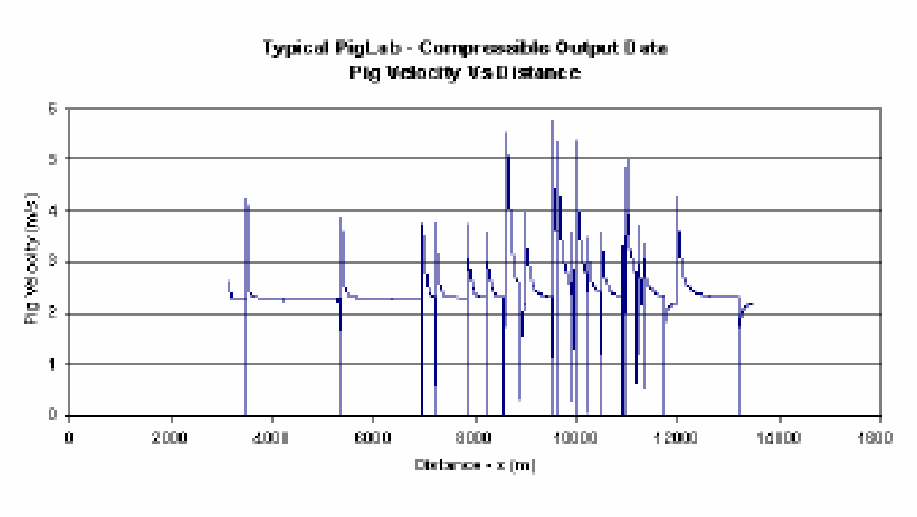
VELOCITY EXCURSIONS

Cause

- Large acceleration and velocities due to the compressibility of the system

Solution

- Take into consideration during pig selection



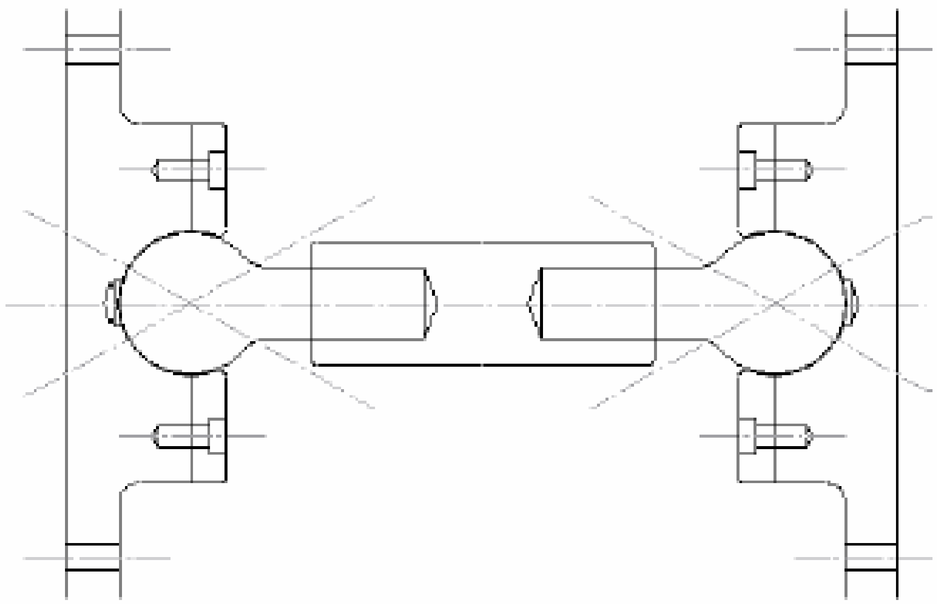
COUPLING DAMAGE

Cause

- In dual module pig, compression and tension on coupling between module

Solution

- Strong coupling selection
- Joint must be capable of opening to the correct angle to allow the pig to negotiate the line features



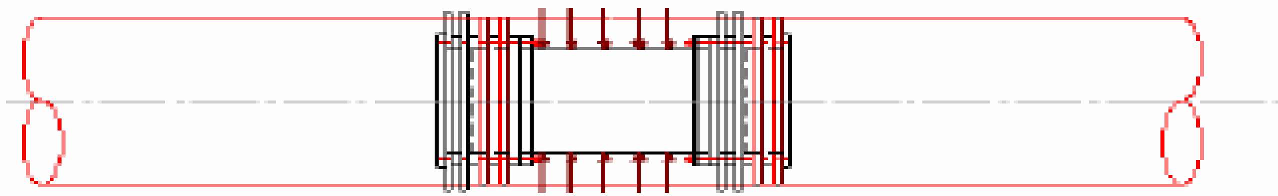
TRAPPED CAVITIES

Cause

- Cavities in pig cause collapse under high pipeline pressure or during testing

Solution

- Balance all cavities
- If cavity is required, it should be designed as an externally pressurized container and subject to qualification



External, pipeline pressure acting on a trapped cavity

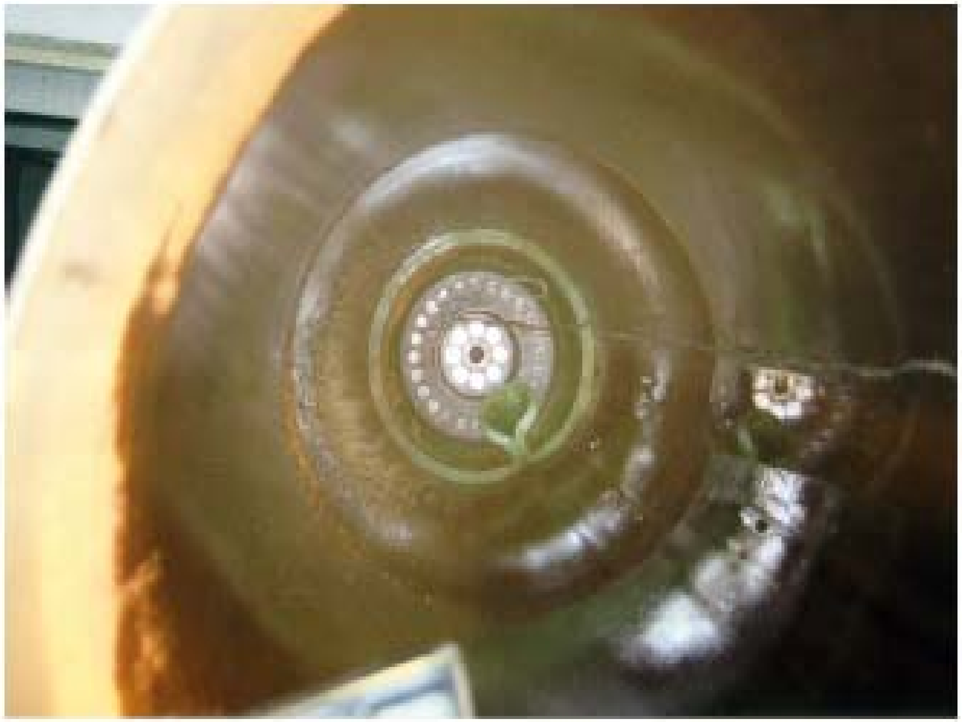
TEARING SEALS OUT OF BOLTHOLES

Cause

- Highly oversized sealing discs

Solution

- Oversize needs to be carefully selected and the bolting arrangement such that the discs is properly clamped to the pig



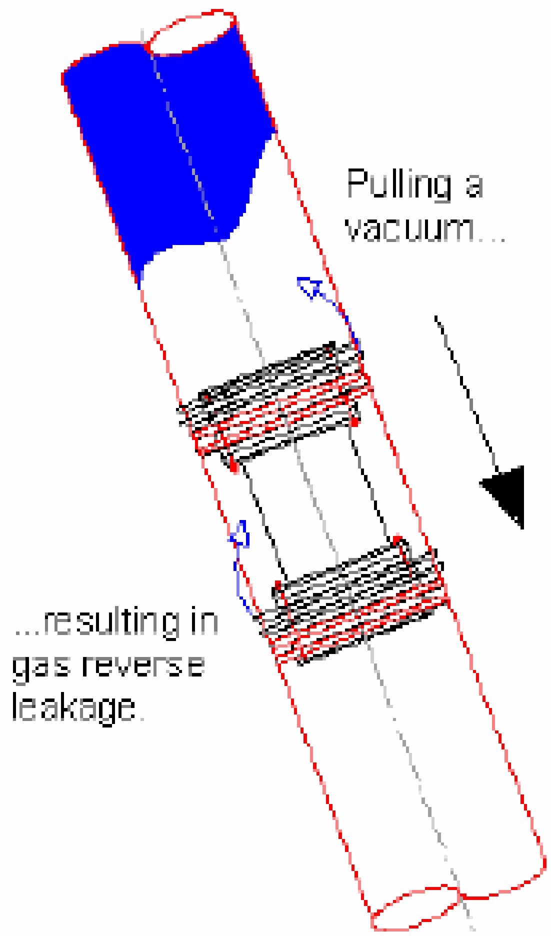
PIGS IN FREE FALL

Cause

- Steep sections such as risers, lead to high velocity

Solution

- Slow the pig down



ENVIRONMENTAL ISSUES

Cause

- Line temperature (degradation of the seal materials, expansion of metallic parts
- Line pressure (Cavities, explosion, decompression)
- Line contents (incompatibility with the seal materials)
- Immersion time

Solution

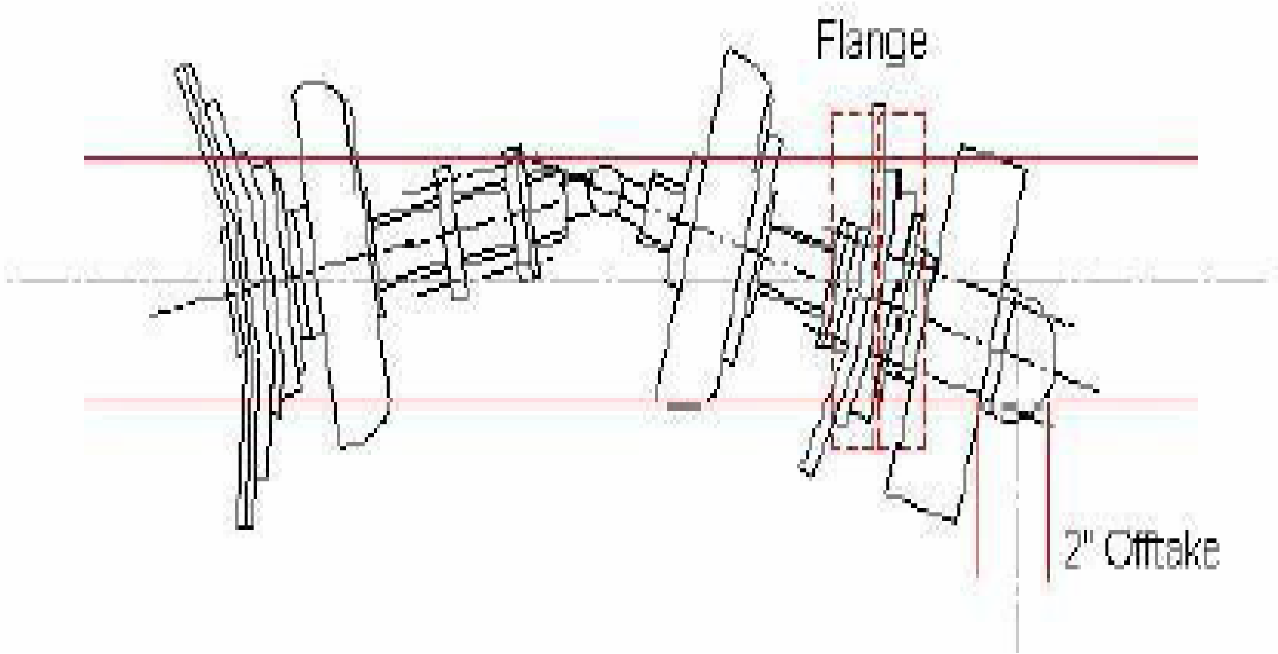
- Check such aspects with pig suppliers

UNUSUAL DAMAGE TO 10” X 16” PIG DURING TESTING

- As an example of the need to “Expect the Unexpected”, the following photograph shows a 10” x 16” pig stuck in the straight 10” line at a flange and offtake

UNUSUAL DAMAGE TO 10” X 16” PIG DURING TESTING

UNUSUAL DAMAGE TO 10" X 16" PIG DURING TESTING

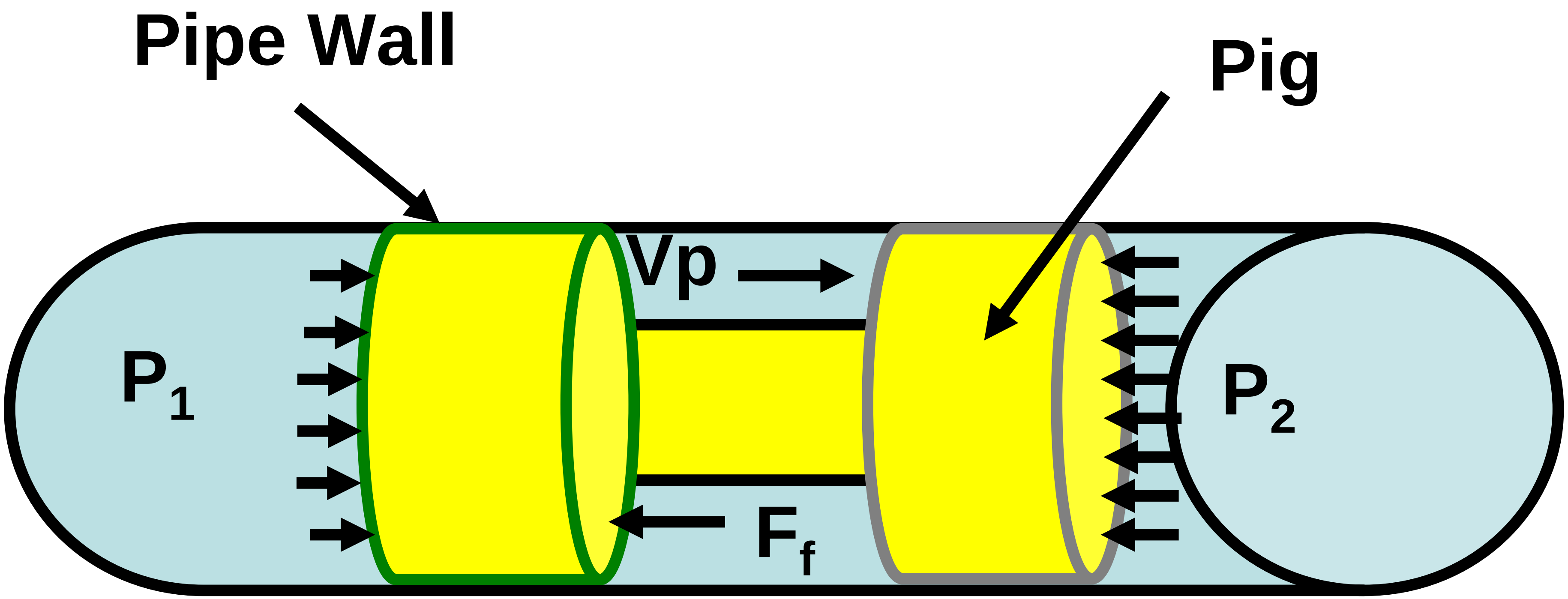


PIG MOTION ANALYSIS

- A pig moves through the pipe at constant velocity V_p
- Due to large contact friction between the pig and the pipe, Vp is smaller than the mean flow velocity V
- The flow creates a drag force F_D on the pig

$$F_D = \frac{1}{2} C_D A \rho \left(V - V_p\right)^2$$

PIG MOTION ANALYSIS



PIG MOTION ANALYSIS (Cont.)

- The drag force is equal in magnitude but opposite direction of the contact friction force

$$F_D = F_f = \eta N$$

$$V_p = V - V_d \quad Where \quad V_d = \sqrt{\frac{2\eta N}{C_D \rho A}}$$

- The equation shows that the pig velocity is smaller than fluid velocity by V_d

PIG MOTION ANALYSIS (Cont.)

$$C_D = \frac{4k_d^4}{\left(1 - k_d^2\right)^2} \qquad k_d = D_d / D$$

- The leakage ratio is given by:
- Leakage = 1-Vp/V
- Where
- C_D = Drag coefficient
- A = Area
- P = Fluid density
- η = Contact friction coefficient
- N = Angular speed, rpm
- k_d = Diameter ratio of the disk

Example

- A pig with two end disks having an effective disk diameter of D_d=0.98 D is used in a 10 in steel pipe for cleaning the pipe interior. The fluid is water flowing at 6 fps. The pig being squeezed into the pipe exerted a total normal force of 400 lb on the pipe wall and the contact friction coefficient between the pig and the pipe is o.6. Find the velocity of the pig and the percentage of the leakage flow

Solution

- **Given**
  - $\eta = 0.6$
  - $N = 400$ lb
  - $\rho = 1.94$ slug/ft^3
  - $V = 6$ fps
  - $A = 0.545$ ft^2
  - $k_d = 0.98$
- Required
  - V_p, Leakage
- **Solution**
  - $C_D = 2353$
  - $V_d = 0.439$
  - $V_p = 5.56$ fps
  - Leakage = 1 –(5.56/6)

    = 0.073