THE

PIPELINE PIGGING HANDBOOK

formerly published as "All About Pigging"

THIRD EDITION

A GUIDE to pig selection, operation, maintenance, and services

A REFERENCE for designing pipelines and facilities for utility and intelligent pigging

JIM CORDELL
HERSHEL VANZANT

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THE PIPELINE PIGGING HANDBOOK

THIRD EDITION

Formerly published as
ALL ABOUT PIGGING

A reference handbook for the design of pipelines and facilities for both utility and intelligent ("smart") pigging, and a guide to pig selection, operation, and maintenance as well as pipeline pigging services.

Jim Cordell and **Hershel Vanzant**

CLARION TECHNICAL PUBLISHERS

SCIENTIFIC SURVEYS

The Pipeline Pigging Handbook, Third Edition
Formerly published as *All About Pigging*

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IMPORTANT NOTICE

The purpose of this publication is to inform the reader of general pigging practices in modern pipeline operations. **It is not intended to be an instructional manual, but rather a general guide to pigs and pigging practices.** In general, the practices outlined in this book will be applicable up to a point; but in the final analysis, specific programs will have to be tailored to meet the specific purpose, the line conditions and company operating policies and procedures.

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FOREWORD

This manual is an invaluable source of information for all those involved with pipeline design, construction, operation and maintenance and covers every aspect of pipeline pigging in a logical and easy to use format. It will provide guidance for the design of pipelines and pigging systems, as well as for the selection and operation of all types of pipeline pigs. However, because every pipeline contains certain unique features, this manual is not intended to be, neither must it be considered as, a definitive work on the subject. It is a guide only and independent professional advice must be obtained before making a commitment to any particular course of action.

The Publishers would welcome any suggestions which, in the opinion of the reader, would make future editions of the manual more 'user friendly'.

About the authors:

Jim Cordell has been actively involved with pipeline pigging, maintenance and inspection since the mid 1960's at both practical and managerial levels. He founded On-Stream Systems Ltd. in 1985 to provide completely impartial consulting services on all matters relating to pipeline pigging. In 1990 he founded the Pigging Products & Services Association (PPSA), and served as its Executive Secretary and Technical Adviser for almost a decade. Virtually all of the major pigging related companies throughout the world are now Members of PPSA, the contact details for which will be found in the appendices.

Hershel Vanzant worked 38 years for one of the world's leading pipeline equipment manufacturers. He worked in the Engineering, Research and Management areas of the company. During his years in the Research Department he designed and assisted with the design and testing of pigs and related pigging equipment. He also traveled to many areas of the world to work onsite assisting pipeline operators with their pigging applications. In 1990 he started his consulting services concerning pigging and other pipeline maintenance applications.

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1.0 BACKGROUND

"Pig" is now the most widely accepted term for any device which is inserted into a pipeline and which travels freely through it, driven by the product flow. A pig is in effect a free moving piston. Occasionally other words are used, such as rabbit or mole and in some countries, they may be referred to by their function e.g. scraper, swab, tool, etc.

The term "pig" originated in the United States, but why the word was chosen has never been satisfactorily explained. There are various theories, but the most widely accepted explanation is that the screeching sound made as the early pigs traveled through the pipeline, together with their brushes and their appearance when they emerged covered in crude oil, in many ways resembled the farmyard pig. The suggestion that PIG was an acronym for Pipeline Inspection Gauge is highly unlikely as the term was used long before inspection became a significant factor.

Pigs were originally used exclusively for cleaning a pipeline. There is no documented evidence of when the first pig was run, but it was probably during the early days of crude oil pipelining in America, although it is possible that the water industry could claim to have been first. These early pigs are believed to have been made on site from straw wrapped with barbed wire. Other stories tell of the earliest 'pigs' being simply bundles of rags. These it is said were replaced by bundles of leather because this was not only stronger, but would swell when it was wetted and so gave a good seal in the pipe. Further details of the history of pigging will be found in Section 14.

Early purpose built mechanical pigs were made without any consideration of possible damage to the pipeline and comprised hardened steel scraper blades, steel spur wheels and leather driving cups. They earned the name of "Go-Devil" and such pigs are still occasionally used today to clean short pipes which are carrying a high percentage of soft solids in suspension, as may be the case for example in china clay quarries. Even here however, there are more modern pigs which could generally perform the tasks significantly better.

Today there are over 350 pigs of all types, a large number of specialist services and several thousand related products. Selection of the correct ones and the design of an optimum pigging system will depend upon a great many, often seemingly unimportant factors.

There are at present no recognized national or international standards for the design, construction or operation of pigs or pigging systems. But there are industry "norms" which have resulted from long experience and which, if they are understood and followed, will contribute to trouble-free operation.

These norms and some of the experiences have been the subject of various papers but these documents are not always readily accessible and are far from comprehensive. This manual is intended to resolve many of these problems.

The terms and phrases used in this manual are those normally used in the pipeline pigging industry. For those who are not entirely familiar with this, it is strongly recommended that reference be made to the definitions included in the Appendices before referring to the main sections.

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2.0 THE PURPOSE OF PIGGING

2.1 WHY PIG A PIPELINE?

It is generally agreed that a pipeline should be pigged, but the reasons for doing so are not always fully appreciated. This may result in improper pigging programs and/or the use of the wrong type of pig and this could have an adverse effect on the pipeline's operating and maintenance costs. It is therefore important to clearly define the reasons at the very beginning and the following will provide some guidance in this respect.

2.1.1 SAFEGUARDING ASSETS & OPTIMIZING EFFICIENCY

Many operators only resort to pigging when a problem becomes apparent and they have no other choice. Often, this is too late. The damage has been done and a multi-million dollar investment is put at risk.

Use of the correct type of pig and a proper pigging program will help to maintain the integrity and optimum efficiency of the pipeline; safeguarding both the environment and the assets of the pipeline owner.

A pipeline is arguably the most efficient method yet devised for transporting fluids - whether gases or liquids. Its relative efficiency though, depends upon two fundamental requirements:

1. It must operate continuously.

2. The required throughput must be obtained with the least capital investment and the lowest operating costs.

Most pipelines are designed and constructed on these principles. Even so, the capital and operating costs are often very high, particularly for large diameter, long distance transport pipelines.

While many pipelines are constructed for purely financial reasons (they are simply the cheapest means of transporting a certain volume of fluid between certain points), others are built for strategic (often military), political, or international trading purposes.

Whatever the reason, it is certain that the decision to build a major pipeline has been taken at a very high (often the highest) level and that the decision is based on the two fundamental considerations mentioned above.

What is not always appreciated is that such decisions presuppose that these two fundamental requirements can be maintained during the life of the pipeline. It is not sufficient to simply design and construct the pipeline on the basis of continuous operation and optimum efficiency, it must be kept that way.

Pigs play a major role in both obtaining and maintaining the 'two fundamentals':

1. They help to maintain continuous operation by:
   - removing any substance which might damage the pipeline process systems
   - helping to prevent the formation of corrosion cells
   - providing timely information of any developing problems
   - providing data on any perceived problems to enable informed decisions to be made
   - providing an alternative to shutting down for statutory periodic testing.

2. They help to obtain and maintain maximum efficiency by:
   - removing any debris or foreign matter in the line
   - removing any deposits, either liquid or solid, which might otherwise build up and restrict the flow
   - by monitoring the operating and/or physical conditions of the line.

In short, pipeline pigs help to ensure that the pipeline is constructed properly - and that it stays that way.

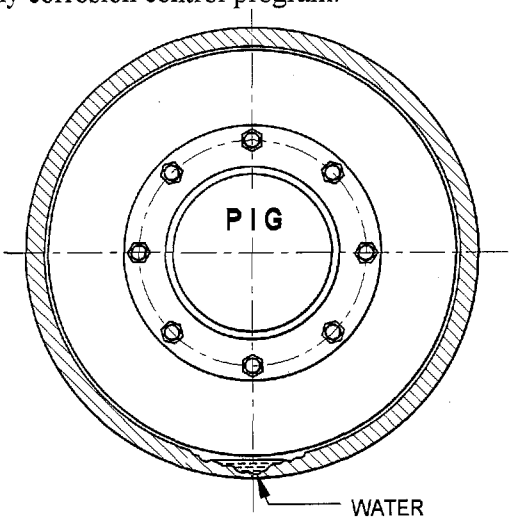
However, it must be remembered that the level of the contribution made to both the efficiency of the pipeline and to its protection will depend upon the pigging program and the effectiveness of the pigs which are used. Under any given set of circumstances there will be significant variations in the performance of different types of pig and even between different makes of the same type. However, the use of virtually any pig will be better than none at all.

Some elementary calculations will prove the point. Consider a simple short, straight section of a 12" (300 mm) water line. If the inside diameter is reduced by only 5% (15 mm) by a **SMOOTH** deposit, the loss of throughput at a given pressure would be over 10%. To bring the throughput back to its original level would require the pressure to be increased by almost 30%. However, if as is more likely, the deposit was uneven, the resulting turbulent flow may cause an effective reduction of 15%. In this case, throughput could be reduced by some 35%, while the pressure to overcome these losses would need to be increased by more than 140%.

Admittedly, this example is based on theoretical calculations but similarly dramatic effects have been noted in practice. Typical of these is the study made by Bern, Withers and Cairn of British Petroleum on the Forties pipeline [paper EUR 206 - European Offshore Petroleum Conference] which showed that friction increased by 4.2% per day if the line was not pigged.

Perhaps one of the most common and yet costly mistakes is to rely totally on corrosion monitoring and automatic corrosion control systems to decide when to run a pig. The reliability of any monitoring system depends upon where the probes, coupons and/or sampling points are located - and this is difficult, if not impossible to achieve on subsea lines or to determine accurately on land lines, particularly on those which have any significant gradients.

Once corrosion, particularly pitting or channel corrosion has occurred, it is unlikely that a pig will be able to remove the water which will accumulate in these recesses. It is therefore advisable to include batch inhibition (running a slug of inhibitor between two pigs) as part of any corrosion control program.



Effect of Channel Corrosion

2.1.2 REGULATIONS, SAFETY & THE ENVIRONMENT

Towards the end of 2002 the United States introduced the *Pipeline Safety Improvement Act.* This act requires all US oil and gas pipeline operators to develop an *Integrity Management Plan.* The timing of the implementation of the Plan will depend upon

the pipeline itself and the relative risks involved due to its location.

Inspection of each pipeline will be a fundamental part of any such Plan. It is understood that in general terms, the Act requires every pipeline to be inspected within ten years, but all 'problematic' pipelines must be inspected within the first five years. After the initial ten year period, all oil and gas pipelines must be inspected every seven years.

However, as already stated, the actual requirements will vary depending upon the individual circumstances and operators must develop their Intregrity Management Plan in close consultation with their own legal advisers and the Authorities – typically the Office of Pipeline Safety (OPS).

Elsewhere, there are no known regulations, but in many countries, licenses to construct and operate pipelines are dependent upon them being designed for In Line Inspection.

2.1.3 PRACTICAL NEEDS

The earliest pigs were used simply to remove any large deposits of wax or dirt in order to maintain a flow through the pipeline. Today, pigging is required during each phase in the life of a pipeline - for many different reasons, typically:

During construction

i) Removing construction debris from the line.
ii) Acceptance testing (water filling, dewatering, etc.)
iii) Commissioning

During operation

i) Pipe wall cleaning
ii) Condensate removal
iii) Product separation (batching)
iv) Applying inhibitors

For inspection

i) To check for physical damage (geometry)
ii) To detect corrosion, laminations or cracking
iii) Leak detection
iv) Sampling
v) Line cover and spanning (subsea)

For general maintenance and repair

i) Corrosion inhibition
ii) Pre-inspection cleaning
iii) Decommissioning
iv) Isolation
v) Recommissioning

During renovation/rehabilitation

i) Gel pigging
ii) Applying in situ coatings
iii) Chemical cleaning
iv) Scale removal
v) Cleaning for product conversion

Decommissioning

i) Product removal
ii) Pipe wall cleaning
iii) Inspecting/testing
iv) Inerting

When considering any of the above applications, it should be remembered that each pipeline is different. They have different diameters, lengths, contents, geometry, operating pressures and temperatures, materials, wall thickness, locations, etc. They are also built by different contractors and have different owners, each of whom may have different philosophies and operating procedures. They will also have to be constructed and operated in accordance with different Codes and comply with requirements of different Authorities. Pig selection and the pigging program must therefore be tailored to suit the particular need as well as the characteristics of the individual pipeline and its operation.

2.2 PIGGING DURING PIPELINE CONSTRUCTION

2.2.1 GENERAL

Pigging during construction is frequently performed on sections of pipeline that are shorter than the entire pipeline, often using compressed air as the means of propulsion.

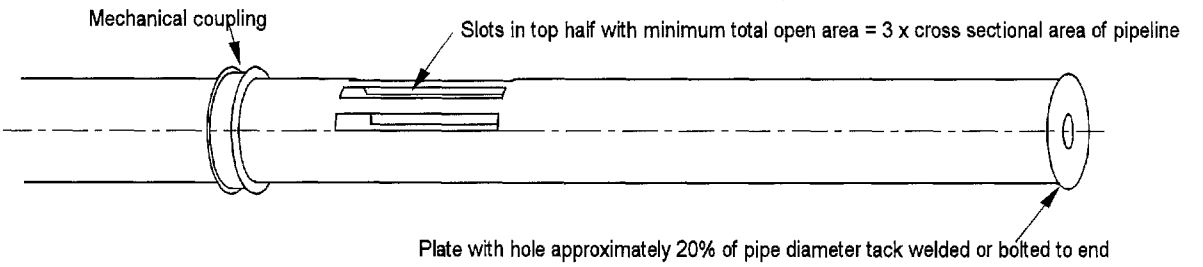
Pigs perform best if they are run at a near constant speed, therefore it is necessary to provide some means of speed control other than a constant input. If this control is not provided the pig may stop at a minor obstruction and the pressure behind the pig will increase until the pig moves. The pig then moves at a faster pace until equilibrium is reached and the pig again moves at a constant speed. This is often referred to as a 'speed excursion'.

One means of providing better control is to close the downstream end of the pipe section, pressurize the entire section and then, by releasing pressure downstream as air is inserted upstream, it will be easier to maintain a constant differential pressure and therefore a near constant pig speed.

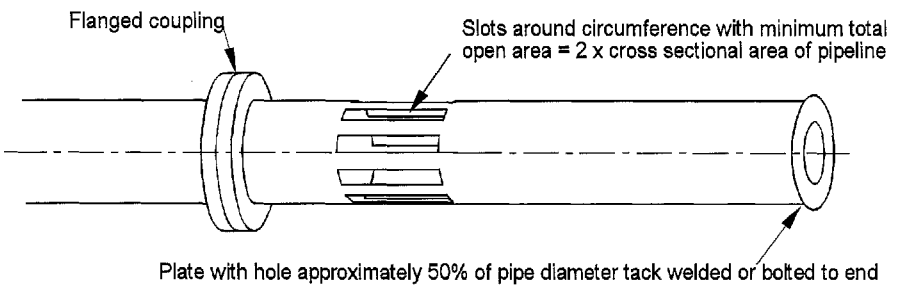
It must be remembered that the differential pressure required to keep a pig moving may be only 10% of that required to start it moving. Excessive and uncontrolled speed of a pig creates the potential for injury or damage during the pigging operation.

It is always necessary to provide some means of restraining the pig at the receiving end of the pipe while releasing the pressure ahead of the pig. If the restraining device is not provided, the pig can become a projectile propelled by the compressed air behind the pig, similar to the action of an air rifle.

The catching devices can be as simple as a field made pig catcher or as sophisticated as a manufactured pig receiving trap. Often the receiving end of the pipeline is closed with a weld cap equipped with piping for controlling the release of the product and therefore the pig's speed. Many contractors will build temporary pig launching and receiving devices that are reused during the construction of the pipeline.



Typical Pig Catcher when Driving with Air



Typical Pig Catcher when Driving with Water

2.2.2 CLEANING

Pigging is an integral part of pipeline construction. Usually, the first application is when the contractor runs a cleaning pig to clean short sections of pipe to remove dirt and other construction debris that may be inside the pipe as the pipeline is being assembled. Apart from removing sand, stones, welding rods, rags, and other debris which will invariably be left inside the pipe, this procedure has been known to remove lunch buckets, construction skids, wild animals and other items which might be around the construction site.

As with many procedures on a pipeline, any steps that can be carried out before the pipeline is sealed will usually be easier than working with a closed system. A clean pipeline is required before a successful survey can be accomplished using either a gauging pig or an instrumented pig to ensure that the pipe has been laid properly.

The type of pig used will depend on various factors associated with the pipeline such as its diameter and length, the topography, whether it is onshore or offshore, sandy, rocky, etc. However, the arduous duty of a contractors cleaning pig usually requires it to be very strong and unless the line is internally coated it will usually be equipped with wire brushes. Even so, several pig runs may be necessary to remove all the debris.

Offshore, things are very different. Because offshore operations are much more costly, several steps may be combined. In spite of sometimes very strict specifications on cleanliness during construction, some debris will still accumulate.

Subsea pipelines are generally laid in very long sections which are capped and laid down on the sea bed. The ends are then tied in at some later stage. The "lay-down head" used at each end of the section on these lines is similar to the test end on a land line and is basically a very long pig trap. It may have to hold a large number of pigs, sometimes of different types, which need to be launched and received separately. To do this requires a manifold comprising numerous connections and very complex pigging procedures. These operations are therefore normally sub-contracted to a competent pigging service company.

2.3 ACCEPTANCE TESTING

2.3.1 GAUGING

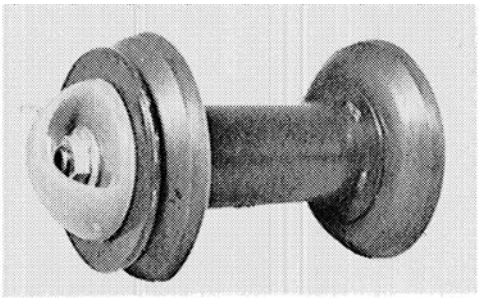
Pigging with a gauging pig during the construction process can be one of the most important inspection tools available to verify the pipeline is laid as specified. Since a pipeline is designed to deliver a certain throughput based on a minimum diameter, it is therefore necessary to be sure that the minimum diameter is not lost during the laying process.

The oldest means of gauging this minimum diameter is by installing a plate on a pig. The diameter of the plate varies somewhat between pipeline companies but usually is between 90% and 95% of the pipe's normal inside diameter. This allows for some of the oval shape the pipe may have in the unpressurized condition as well as for any ovality caused by field bends.

In the early days of pipelining the gauging plates were made of steel and when gas welding was used the plates may have had hard surfacing applied to the outside diameter to shear welding icicles that intruded into the pipeline at the weld joint.

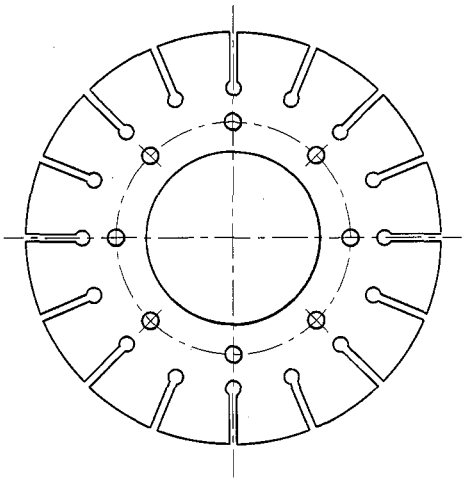
They also needed some device attached to the pig to make a noise so that the pig could be followed by walking to identify where it

stopped if an obstruction was encountered. The noise maker might have been a dragging chain, or various types and shapes of rollers, gears or sprockets. This was a means for finding areas where the pipe had been damaged by material left in the bottom of the ditch or by material back-filled onto the pipe.



Gauging Pig *Courtesy: T.D. Williamson, Inc.*

When steel gauging flanges were used they were almost always placed on the front of the pig so that the flange would push any construction debris out of the pipeline, or the pig would stop if it encountered an obstruction. Most modern gauging flanges are made of aluminum so that contact with the pipe will not damage inside surfaces. The aluminum gauging plates are usually installed between the pig seals so that the gauging plate will be protected from any damage other than that caused by a reduction in diameter within the pipeline. If the aluminum plate traverses the pipe section without damage, it is evidence that the pipe does not have any reductions of concern. Some aluminum gauging plates are made of a soft aluminum to reduce spring back and some are cut into segments to help identify the shape of any restriction. It may be important to know whether the pipe is reduced in diameter in an oval shape or if the reduction is over a small area as may occur due to a dent caused by some external object. If the gauging plate is damaged, then it becomes necessary to find the obstruction and make a repair. These obstructions may have been located by the pipeline walkers following the pig, if for example at some point they noticed a hesitation in the pig speed.



Typical Slotted Aluminum Gauging Flange

Once the obstructions have been removed it is then necessary to rerun the gauging pig to verify that all pipe diameter reductions have been removed from that section of the pipeline.

If the gauging flange is undamaged on the first run, this can be an economical means of inspection of the pipeline and it is a common means of gauging the pipe in the smaller sizes. It may also be used in larger size pipelines provided the wall thickness is sufficient for the pipe to stay in a near round shape while unpressurized, but after the pipe is covered.

When the pipeline is subsea the procedures for running and tracking a gauging pig must be modified. The pig may need to be bi-directional in case it contacts an obstruction that it cannot pass. It could then be pumped back to the point of origin. The location of such an obstruction may be estimated by monitoring the gas or liquid injected into the pipeline to propel the gauging pig. Electronic tracking devices may also be used.

However, whether a pipeline is onshore or offshore, using a gauging pig can be an extended operation if an obstruction is found. A bent gauging plate will indicate the worst reduction in the pipe but will not indicate how many similar or smaller reductions have been

passed. The fault or faults must be repaired before the pigging run can be continued.

It must also be remembered that the gauging plate is deformed by contact with the pipe wall, so with the modern high tensile steel pipeline, it is desirable to have an alternate gauging system. This alternate is the instrumented pig designed to measure the inside diameter of the pipeline and identify the location of any non-conformity. These are known as 'geometry' or 'caliper' pigs. Some of these pigs can give a profile of the non-conformity to help with the decision making about corrective action.

Most geometry pigs can survey a pipeline without making any metallic contact with the pipe wall. The resulting report can be used to locate and make all the repairs needed. It is then rerun to provide a final report for the acceptance decision as well as a permanent record of the 'as laid' condition.

Unlike the gauging pig the geometry pig is designed to pass restrictions in the pipe without damage to the pig or the pipeline. Therefore it is necessary to clean the line first or the geometry pig may pass over any debris in the pipeline and record it as a reduction in diameter. Under careful control, these pigs can be driven through the line with compressed air but their accuracy may be affected by irregular speeds, so they are best run in a liquid. Unless there is an immediate problem to resolve, they are therefore often run during dewatering of the pipeline following hydrostatic testing and then periodically during the operational life of the pipeline.

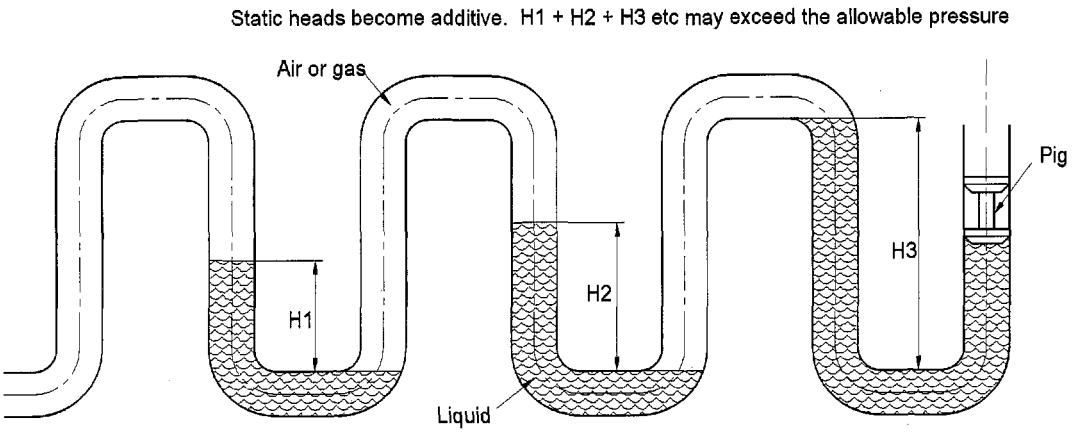
2.3.2 HYDROSTATIC TESTING

After the pipeline section has been accepted as laid in good condition, it then becomes necessary to pressure test for leaks and to ensure it can be safely operated at the design pressure. The pressure test is almost universally a hydrostatic test with water and the pig again becomes an essential tool.

A pig is inserted in the pipe and the water fill is used to pump the pig forward and expel the air from the line. There are a number of reasons for having to ensure all the air is removed. One is to avoid pressure variations due to vapor locks and another is for safety in the event of failure since compressed air contains much more energy than water when under pressure. It is therefore essential to use a pig, otherwise it would be impossible to eliminate air from the higher elevations.

It is important to control the movement of the pig during the water fill. The forward movement will usually be controlled by the input of the water but a regulating air vent valve may also be installed at the receiver to enable the movement of the pig(s) to be controlled by the operator at the receiving end.

However when the pig starts a descent at an elevation change the weight of the water behind it may cause it to move faster than the water input. This can create a partial vacuum behind the pig, causing air to be sucked backwards into the liquid column. This creates a break in the line fill and eliminates the siphon effect, leaving the air at a high point. When there are significant variations in the elevation of the line, this causes the static heads of these now separate columns of liquid to become additive. The pressure then required to drive the pig may exceed the safe working pressure of the pipeline and perhaps the capacity of the available pressure pumps.



Sketch showing effects of liquid with gas pockets in pipeline

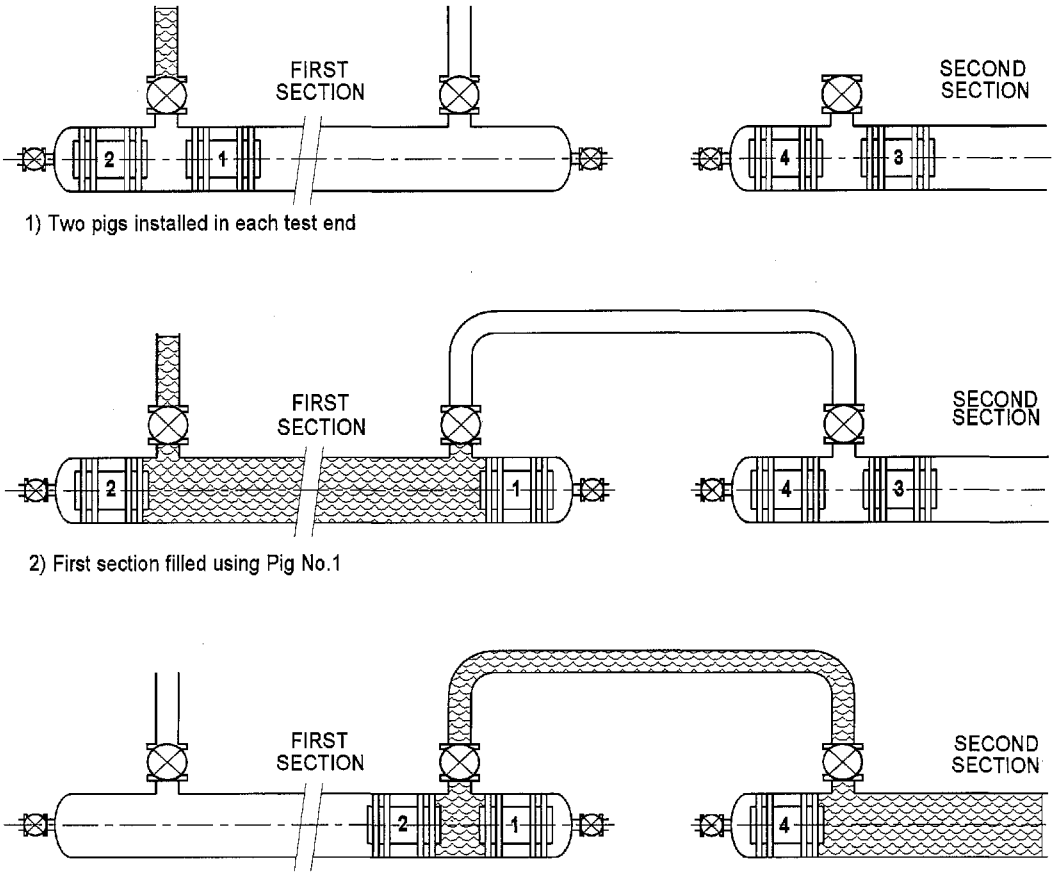
When this happens, it is usually necessary to install a vent at the high point to eliminate the air. The sections of the pipeline to be hydrostatically tested are therefore usually selected according to the elevation changes within the section.

There can be many reasons why it is not desirable to fill the entire pipeline for hydrotesting. The availability of a sufficient volume of test water being just one. In this event, the test water can be moved from one section to another as each section is hydrotested. This is done by pre-installing pigs in each section of the pipeline before welding on the test ends. Manifold piping is installed at each end of the test sections to allow the water to be transferred from one section to the next.

Typically, two pigs are installed in the test end and the first one is launched and pumped to the other end to complete the line fill of the first section. They both remain in the pipe during the pressure test.

After the first section is tested, compressed air (typically) is used behind the second pig to transfer the line fill to the next section for hydrostatic test, simultaneously driving the first of the two pigs pre-installed in that section to complete the line fill of the second section. This is repeated until the entire line has been tested.

If the water must be returned to the watershed from which it came, the pigging process is reversed to return the water back through each section until it arrives at its original source. When this process is used the pigs must be bi-directional so that they are effective in each direction. However, in most other situations almost any pig designed for dewatering, batching or swabbing should be acceptable, except perhaps a foam pig. These pigs might be a sphere, mandrel pig or one piece batching type pig. Foam pigs are made of intercellular materials which allow fluids to permeate through them and so are not normally suitable for line fill prior to hydrostatic testing. Reference should be made to later sections in this manual for guidance in selecting the most suitable pig.



Method of moving hydrostatic test water from one section to another

2.4 PRE-COMMISSIONING

After the acceptance testing is complete there are usually a number of other things which must be done before the pipeline can be brought into operation, or 'commissioned'. This stage is generally referred to as 'pre-commissioning'.

One thing which invariably needs to be done is to remove the test water. To determine what else needs to be done it is first necessary to know the details of the product(s) to be transported. For example, some products cannot tolerate water and therefore the pipeline must be made very dry before being filled.

Some products may be very susceptible to debris so the pipeline must first be thoroughly cleaned. If the new pipe is not internally coated, there may be rust and scale adhering to the pipe wall and even internally coated pipelines may have a coating of construction dust to be removed and it may require many pig runs to remove all the dirt. In some circumstances it may be acceptable to make these pig runs after the pipeline has been filled with product. However it will then usually be necessary to provide a means for filtering or placing the product in storage to allow the dirt to settle in order to have a clean marketable product.

Cleaning is generally relatively straight forward, but dewatering and drying require more careful consideration.

2.4.1 DEWATERING

Once the hydrostatic test is completed the water inside the pipe is removed by a series of pigs normally pushed through the pipeline by compressed air. The type of dewatering pig(s) used will be determined by such things as the length, diameter and configuration of the pipeline and the air compressor(s) should be capable of running the dewatering pig(s) at a speed of at least one mile per hour (1.6 kph) under these conditions.

The outlet end should be fitted with a valve to enable the pipeline to be completely shut off or to be throttled to regulate the rate of discharge to safe levels. Sudden surges may also be expected to occur as the pig approaches the receiving end if some compressed air has bypassed the pig. It should be noted that pigging with compressed air, or any other compressible fluid can be highly dangerous and should only be carried out by fully qualified personnel.

Once the dewatering pig(s) have been received it is common practice to run a series of foam pigs to swab up any residual water. However, if the product to be transported in the pipeline requires that all residual water must be removed (e.g. natural gas) then after dewatering, the line must be dried.

2.4.2 DRYING

Typical methods of drying a pipeline include blowing dry air through the line, usually in conjunction with foam pigs, the use of nitrogen, or to employ a technique known as 'vacuum drying'.

The dry air and foam pig method is used mainly for onshore pipelines. The first step is to run low density polyurethane foam pigs with compressed air dried typically to a -90° F (-68° C) atmospheric dew point temperature. The pigs soak up the residual water while the dry air also absorbs water and carries it out of the pipeline.

This process is continued until the pigs are received dry. On long pipelines, this may require several hundred runs.

The next step is generally to remove any rust and mill scale and any debris that may have settled out of the hydrostatic test water. This is typically achieved by running foam pigs equipped with fine steel wire brushes on a continuous basis until they are received without any material packed into the bristles.

If it is necessary to remove all loose material including the very fine dust which may remain, then more plain foam pigs may be run. Again, they would be run continuously until they are received in some previously specified condition or until some dew point has been attained.

Vacuum drying is particularly useful for offshore pipelines. It works on the principle that the boiling point of water is determined by the pressure. Reducing the line to below atmospheric pressure causes the residual water to boil. The water is then removed from the line in the form of steam. This drying process continues until some predetermined dew point value is reached. This method is invariably long and relatively expensive, but generally can be relied upon to achieve excellent results.

2.5 COMMISSIONING

'Commissioning' is the stage when the completed pipeline is filled with the product and brought to the point where it is ready for operation. Because of the complexity, it is

almost always entrusted to a qualified pigging service company.

Commissioning will almost always involve the use of pigs and may often require 'slugs' of other substances such as methanol, glycol, diesel, etc., to be pumped through ahead of the product. Slugs, if used, are contained between two or more pigs and are usually designed to avoid product contamination as, particularly with hydrocarbons, there may otherwise be a risk of explosion or perhaps serious blockages due to hydrate formation.

The technique finally used to commission the pipeline will almost always be determined by the product(s) to be transported.

2.5.1 WATER PIPELINES

Water pipelines are one of the few cases where there may be no need to dewater after the hydrostatic test. Indeed the line fill for hydrostatic testing may also serve to commission the line as the test water may in fact become the product of the pipeline.

If the pipeline is to transport potable water, then the test water will normally require special treatment before being used as the line fill, and especially so if that water is then to be used for consumption.

In most countries there are strict regulations covering the procedures to be used for potable water pipelines as well as laws governing the quality of the water coming from the pipeline.

2.5.2 PRODUCTS PIPELINES

The method used to commission a products pipeline in particular will depend upon the type of product to be transported.

It is conceivable that for some products, large quantities of residual water would not present a problem. In this case it may be possible to combine the commissioning with the dewatering phase and simply pump the product in behind the dewatering pig to commission the line.

However, the vast majority of long distance products pipelines carry refined products so it is usually necessary to ensure that there is very little water remaining in the line prior to commissioning. Again, the procedure used for commissioning will depend upon the product, but as there will invariably be air left in the line, then for the more volatile products, the pigs must be able to separate the air from the product. There must also be a method of separating the air from any other substance in the line which could create a hazard when exposed to air.

This may require running several pigs, perhaps in a 'train' with say methanol or other water absorbing chemicals in 'slugs' between the pigs and perhaps with slugs of an inert gas such as nitrogen interspersed between each different liquid or gas.

2.5.3 NATURAL GAS PIPELINES

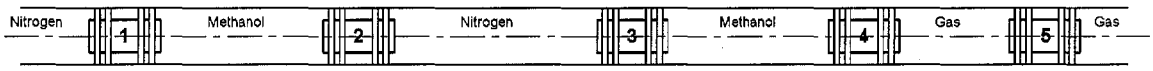
If the pipeline product is to be natural gas, it again becomes necessary to ensure that the moisture content level within the pipeline is at a very low level primarily to prevent the formation of hydrates.

Hydrates are similar to crushed ice and form under certain conditions of pressure and temperature. They usually require either the application of heat or of a chemical such as methanol to disperse them. They can easily block a pipeline and once this occurs, methanol cannot be pumped down to disperse them and the application of heat is often impractical, especially on subsea pipelines. So once formed they are very difficult to remove.

It is therefore common to adopt a technique for commissioning natural gas pipelines similar to that described for transporting the more volatile products mentioned above.

A typical procedure adopted by a major gas company when commissioning long distance gas transmission lines is to inject nitrogen equivalent to 10% of the volume of the pipeline at atmospheric pressure then insert the first pig. A slug of methanol is then injected equivalent to 7.5D gallons (US) per mile of pipeline (17.6D liters per kilometer) where D = the inside diameter of the pipe in inches, followed by pig No. 2. Next, nitrogen equivalent to a minimum of 0.5 miles (0.8 km) of line when compressed to commissioning pressure is injected and then pig No. 3. A second slug containing the same volume of methanol as the first one is then injected followed by pig No. 4. That normally completes the 'train' but a fifth pig may be run if it is considered necessary to remove any excess methanol.

For exceptionally long lines, particularly those offshore, the procedures may vary widely. Sometimes the methanol is injected in the form of a gel to provide a better seal as well as some lubrication and so minimize the risk of pig failure due to wear.



Typical Pig Train for Commissioning a Gas Pipeline

Commissioning a gas pipeline need not always be so complex. Under certain circumstances it may be possible to fill a pipeline with a gas while displacing the air in the line, without the use of pigs. However, in this case it will be necessary to monitor the downstream end of the line until a satisfactory product is received. This means that a lot of gas will have gone through the pipeline that is not suitable for use and is therefore wasted.

2.5.4 CRUDE OIL PIPELINES

The commissioning of crude oil pipelines may be similar to that used for many products pipelines. However, since many crude oils contain some water, separators are normally installed as standard equipment at the destination point. In this event, it is usually not necessary to dry the pipeline after the line has been dewatered.

2.5.5 OTHER PIPELINES

The commissioning procedures for some products require very special consideration. They may vary according to the material of the pipeline, the product to be carried, governing codes and even the internal company policies. For example; a hydrogen or helium pipeline may require leak testing in addition to the hydrostatic test because of the molecular size of the product. Hydrogen will also require very careful handling. LPG is another special case.

Therefore, it is the product, more than anything else, that will determine the procedures to be adopted. The aim is to commission the line safely and to transport the product thereafter in such a way as to meet the specifications required.

Having previously proven the integrity of the line by way of a pressure test, unless the product is toxic, the safety aspects during commissioning usually revolve around preventing fire or an explosion. So, as most combustible products need air in which to burn and a spark or compression to ignite the resulting mixture it is these two aspects which generally command most attention.

The air can usually be eliminated by using pig trains in conjunction with slugs of other liquids or gases and it is often vitally important to eliminate flammable mixtures of product and air since the sources of ignition are not so easy

to eliminate. Compression is of course inherent in pigging but it must also be remembered that the metallic body of a pig might contact the pipe wall or the pig may pick up a stone or piece of metallic debris which could create a spark.

Unless the product and the pipeline is very straightforward, it is strongly recommended that the commissioning of any pipeline be entrusted to a qualified pigging service company.

2.6 BASE LINE SURVEYS

When the pipeline has been filled with the product and the line is at or near operating pressure, it is a good time to carry out an in line inspection using a geometry pig. This will provide a base line for comparison with all future surveys. The base line survey can help identify changes in the pipeline such as settling within the ditch or loss of support due to erosion (i.e. 'spanning') in subsea lines, which can expose the pipe to points of localized loading that could result in damage to the bottom of the pipe or buckling.

The base line survey can also be used for comparison and to locate damage that may have been caused by third parties operating over the pipeline but which did not create enough damage to cause a rupture at that time. They can provide vital evidence in the event of litigation and in any event they provide important data for monitoring the condition of the pipeline throughout the rest of its operating life.

When the pipeline is new and known to be in good condition, it also an ideal time to run other instrumented pigs to provide a base line survey for comparison with future runs. These surveys may include a metal loss (corrosion) pig and, if the pipeline has river crossings, is in earthquake areas, in areas of permafrost or in any other potentially unstable location, it would be a good time to run a profile survey. Then future runs can be compared with the base survey for indications of movement and possible damage to the pipeline.

2.7 OPERATIONAL PIGGING

2.7.1 WATER PIPELINES

Water pipelines may need pigging to increase efficiency of the flow through the pipeline. The flow area may be restricted by either of two main conditions. There may be a soft sediment in the bottom of the pipeline consisting of solids that settled from the water stream or there may be a chemical deposit on the pipe wall, usually calcium based, which may be on the entire inside circumference. This chemical deposit may vary from being soft and therefore easily removed, to being rock hard and so requiring an entirely different and highly aggressive cleaning process to remove it.

Some of the soft sediment may be removed by simply increasing the flow rate by perhaps opening fire hydrants. Pigs are a better way to remove this sediment but many water pipelines do not have a provision for installing and removing pigs. Pigging services are available that can install foam pigs at or near fire hydrants and remove them at another hydrant further downstream. Most other pig designs are not adaptable to this type of pigging operation.

By contrast, the hard chemical deposit requires a different type of pigging program for its removal. This deposit may be several inches (centimeters) thick and therefore the effective

inside diameter of the pipeline is much smaller than the inside diameter of the pipe. Whenever possible, this pigging is done onstream (i.e. while the pipeline is in operation) so it is critical that the flow is not blocked. In this case the first step is to get some type of a pig through the pipeline and then with repeated pigging runs increase the size and aggressiveness of the pig until the pipe is clean or acceptably improved. This procedure is often referred to as 'progressive pigging'.

To remove heavy, hard deposits in a water pipeline it is desirable to have pig traps for the installation and removal of the pigs since several pigging runs will be required. To help determine the severity of the deposit the first pig through can be a foam pig which will distort and pass obstructions that other types of pigs might not pass. The general procedure is to run a pig and monitor the amount of material received at the receiving trap. It is assumed that the maximum and minimum inside diameters are not known at this point so it is necessary to use a pig that will traverse the pipeline, and then to make gradual changes in the type and size of the pig as the cleaning process continues. The same pig or type of pig should be run as long at it is producing results as monitored at the downstream trap.

When a particular type and size of pig has ceased being effective, the next pig might be a larger foam pig or it may be time to use a mandrel type of pig. This could be a batching pig with flexible seals that would conform to the inside of the pipeline. Another choice could be to use a cleaning pig that is designed for dual sizes and therefore has the flexibility to pass the various inside diameters.

The first run with the mandrel cleaning pig should be made without cleaning elements to reduce the possibility of too much material being scraped from the pipe wall and creating a blockage. This pig should continue to be run until it ceases being effective as monitored at the downstream trap.

The next step would be to add all or perhaps only some of the cleaning elements to the pig and run again. Blade type cleaning devices will usually be more effective for the removal of the deposit than brushes. Brushes may be filled with the removed deposit and become ineffective while blades are self cleaning. Both elastomer and metallic blades are offered and the hardness of the deposit will determine which will be the most effective. When the dual size cleaning pig has become ineffective, the next step would be to run a pig designed for that particular pipe size. Only monitoring of the specific pipe conditions will determine whether blades or brushes will be most effective for the final cleaning.

After the pipeline is cleaned, it is important that a regularly scheduled cleaning program be conducted to prevent a recurrence of the problem that has just been resolved.

2.7.2 PRODUCTS PIPELINES

2.7.2.1 CLEANING

Products pipelines need cleaning to remove fine solids that may have settled from the product as it traversed the pipeline. Also, some foreign material such as water may have separated from the product and be collected at low points in the pipeline. This water may reduce the efficiency of the pipeline but it may also cause corrosion at the point where it is collected, so it is important that it be removed. Any pig that seals in the pipe can be used to remove the water from the pipeline. A better pig for cleaning a products pipeline would be a pig with cleaning devices attached, and usually these would be brushes. These cleaning pigs may vary from a simple foam pig with strips of fine wire brushes bonded to the outside of its body to a purpose built cleaning pig designed for that specific size of pipe which can be fitted with various cleaning devices so they can be replaced as the components wear. Pigs should be selected for the specific application, such as the product and the type of cleaning needed, as

well as taking into account the length and the other parameters of the pipeline.

2.7.2.2 PRODUCT SEPARATION

Pigs can be used between product batches to reduce the interface (the mixture of the two products being pumped) through the pipeline. These pigs can be referred to as batching pigs, swabs, foam pigs or spheres. Most batching pigs designed for this purpose will have four sealing elements. However, the number of seals can vary from one (sphere) to as many as six.

Some factors that must be considered when using pigs for batch separation are whether the interface must pass intermediate pump stations, whether the control systems are capable of placing the pig exactly at the interface and whether the control system can divide the stream exactly at the interface. Tests have shown that properly placed batching pigs can reduce the size of the interface, however a misplaced pig can actually create a greater interface.

2.7.3 NATURAL GAS PIPELINES

2.7.3.1 CLEANING

Natural gas pipelines sometimes need cleaning to remove dust particles that are often produced with the natural gas. This dust along with oil that may come from the compressors may create an internal coating that will reduce the efficiency of the gas flow.

The type of cleaning pig will be determined by the internal coating of the pipe. If the pipeline is internally coated, the cleaning pig should not be equipped with cleaning devices that could damage or remove the coating. When the pipe is internally coated the pig should be fitted with elastomer cleaning devices such as polyurethane blades to avoid damage to the coating. These elastomer blades clean the internal coating and with repeated runs also help to polish the surface.

If the pipeline is bare pipe, the cleaning pig may be equipped with brushes which will clean the inside of the pipe and with repeated runs will burnish the inside of the pipe wall and create a smoother surface, increasing the flow efficiency.

Some natural gas wells produce a pyrophoric dust. This will ignite spontaneously when exposed to air. However, in most cases, provided procedures are in place to damp the dust down prior to opening the receiving trap, this phenomena, although disconcerting, rarely causes any major problems.

Most natural gas transmission pipelines transmit gas that has been dried and therefore water is seldom a problem and condensate will only drop out under unusual conditions, typically a major drop of pressure.

2.7.3.2 SWABBING

Natural gas from the producing wells to the first processing plant will probably contain liquids. These liquids are referred to as NGL (Natural Gas Liquids) and may contain natural gasoline, butane, propane and other gases or liquids. Occasionally water may be also be in the gas stream. These liquids must be removed from the gas pipeline and the NGL is therefore collected and processed for its own content. The water must also be removed to reduce contamination of the natural gas and possible corrosion damage to the pipe.

Liquids rarely threaten to block a line because as they settle out in the low spots and reduce the effective bore, this restriction causes the gas flow to increase locally and pick up the liquid once more. This situation is not acceptable however, because the turbulence will cause an increase in the pressure drop, thus reducing throughput, and the constant pick-up and drop-out at the same point could conceivably give rise to problems of erosion.

Some natural gas wells produce considerable NGL and as the gas is produced and cools, in

the winter especially, more NGL condenses from the gas and drops out into the pipeline. When a particular section of line becomes saturated, the liquids will be carried over to the next section, and so on until it arrives at the terminal. This is often unexpected, and could be in very large slugs. The slug catchers are sized to be able to handle the maximum likely volume and many of them are very large indeed. Even so, the slug which arrives, sometimes exceeds their capacity, and when it does, the liquids get into the processing plant and invariably cause both damage and a shutdown. These liquids need to be removed under controlled conditions. This is called 'swabbing' and it is performed using batching pigs, swabs, foam pigs or spheres. Spheres are commonly used for this purpose as pigging must be carried out on a regular basis and spheres are easier to launch and receive automatically. Some wells produce such quantities of NGL that it is necessary to run a sphere every few hours and therefore automation is essential.

There are several theories about the best size of the sphere for the removal of the condensate from the natural gas. One of the factors that affects this is the frequency of the pigging run. When a pig is run every few hours, wear becomes more of a factor than is the removal of absolutely all of the liquid.

For batch separation or meter proving, the sphere may be pressurized to size it just slightly larger than the pipe inside diameter to give a good seal. When pigging for condensate removal however, it is common to size the sphere to equal the pipe inside diameter which will allow the sphere to roll and minimize the wear.

At one time spheres were produced with the outside diameter slightly smaller than the inside diameter of the pipeline. These spheres were hollow and had a hole in them to keep the pressure equalized inside and outside of the sphere and so they were not filled with liquid and were much easier to handle. The theory was that when spheres were run every few hours by automatic launchers, it was not necessary to remove all liquids with every pig run provided the majority of the condensate was removed. There is always a higher pressure behind a pig (or it would not move) and this reduces the leakage from front to back.

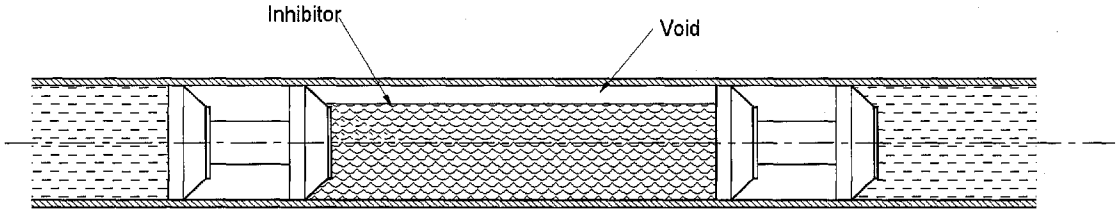
Pipeline Dehydrators Inc. produces a 'Sypho-pig' with a hose that lies on the bottom of the pipe so that if there is any liquid immediately behind the pig the higher pressure at this point will force the liquid from behind through the hose to the front of the pig.

2.7.3.3 BATCH INHIBITION

Corrosion inhibitors are often added to the pipeline while it is in service but recent corrosion problems, particularly in Canada and the North Sea areas are pointing to the need for more effective inhibition to be carried out. In addition to the usual injection systems, pigs are now under development which actually spray the inhibitor onto the internal surfaces of the pipe wall while the pipeline remains in operation. See Section 6.

Running a batch of inhibitor between two pigs is theoretically one way to be sure that the whole of the internal surface of a pipeline is wetted, but there is no way of guaranteeing this - especially at the top center, or twelve o'clock position.

A pipe wall which has only partly been wetted by inhibitor may cause 'preferential corrosion'. This is a phenomena where the metal loss which would have occurred over the entire pipe surface is then concentrated on the small area which has not been wetted, thus making the situation worse, rather than better. It is arguable whether preferential corrosion is yet fully understood but it almost certainly this which has caused batch inhibition to be only rarely used.



Potential Problem with Batch Inhibition

2.7.4 CRUDE OIL PIPELINES

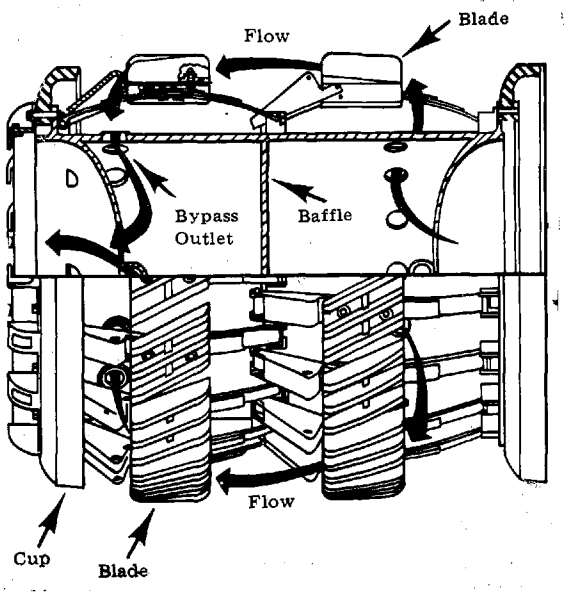
2.7.4.1 CLEANING

Crude Oil pipelines may need pigging to remove wax accumulations on the inside pipe wall but equally, if not more importantly, to remove any water. Water is often produced with crude oil and being of a higher specific gravity it will, if left, collect in the bottom of the pipe and cause pitting or channel corrosion. Regular pigging to remove the water is therefore essential because once this type of corrosion has formed, the pig seals will be unable to get into these crevices to sweep the water out and the corrosion rates will increase very rapidly. Corrosion inhibitors will mitigate the problem but they are generally less reliable and more expensive than establishing a regular pigging program.

If pigs are not used to remove the surface debris such as dirt, sand, wax, corrosion products etc., then water will collect under it and it will prevent the inhibitors from properly treating the active corrosion area. The same situation will arise if there are bacterial corrosion problems caused, for example, by SRB's (Sulfate Reducing Bacteria).

For dewaxing, any type of pig will remove some of the wax, but unless the right type of cleaning pig is used, a lot of it will be left behind and simply smeared on the inside of the pipe wall. Elastomer blades work well for the removal of the wax from the inside surface and are self cleaning.

Most cleaning pigs have a means for product bypass through the pig. The provision for bypass may result in as much as 5% of the total product flow passing through the pig. When removing wax, the maximum acceptable bypass should be used. Many cleaning pigs have the bypass designed such that flow must enter the back of the pig, pass by the cleaning devices and then exit through the front of the pig.



Bypass Path Through Pig Body *Courtesy: T.D. Williamson, Inc.*

This bypass also lets the pig slip slightly in the stream so that the wax that has been removed can be floated away in the faster flowing stream in front of the pig rather than be pushed into a solid mass. This will also avoid the potentially serious problems which could occur if the wax arrives as a solid plug at the receiving trap.

One of the authors witnessed a batching type pig being run in a 150 mile long crude oil line that was recognized for its heavy wax content. No bypass was provided through the pig and when it was received, the pig trap was full of wax that had to be removed with shovels before

the pig could enter the trap. Even so, without changing any of the pumping parameters, the pipeline transported eleven percent more crude oil the day after this pig was run.

2.7.4.2 BATCHING

Crude oil pipelines may run batches when crude oil is not all derived from the same source and the batches may have different destinations or require different refining processes. Crude oil pipelines also may run batches of fuel to be used at intermediate pump stations on the pipeline. The interface mixing of the batches can be reduced by the use of batching pigs located at the interface.

The batching pigs must be placed at the interface of the two products to be effective. If there are intermediate pump stations, provision must be made for the pigs and the batch to pass the station without creating additional mixing of the two products.

2.7.5 PLANT PIPING SYSTEMS

2.7.5.1 CLEANING

Pigging plant piping is similar to any other pigging operation, but some aspects need to be monitored in the plant that normally are not a consideration in a cross-country pipeline. In plant piping systems it is necessary to be sure that the elastomers on the pigs are compatible with the product in the pipeline.

Plant piping often contains factory produced elbows which excludes many pig designs. Most manufacturers produce pigs that will traverse long radius elbows (one and one-half pipe diameter as radius), some may traverse short radius elbows (one pipe diameter radius). It is imperative that the plant piping be carefully surveyed to be sure the correct pig is acquired for the intended purpose.

Many plant pipelines are relatively small and pigs may not be available with spring loaded cleaning elements similar to the larger pigs. These smaller cleaning pigs may use wheel type brushes that must be replaced as they wear.

The cleaning procedures when using pigs, may also involve the use of cleaning or sterilizing fluids and this too will need careful consideration in both the design and operation of the overall system.

2.7.5.2 SWABBING, SEPARATING, BATCHING

Swabbing, separating and batching are similar operations to those carried out on pipelines and are usually performed in a similar manner, although the reasons for the operation may differ.

A plant piping system may be used for many different products and the line fill has to be removed before each change of use. It is for this reason that in industrial or plant pigging, the operation is often referred to as 'clearing' rather than the pipeliner's terminology of swabbing, separating or batching. However, pigs may also be used in these systems to separate different products being transferred in the same pipeline in which case the term 'batching' would be more appropriate.

In some plants, the pipelines are loading lines and the direction of flow is reversed as applications change and the pipeline may be left filled with a non-contaminating product between changes in applications. Some pipelines may be used to transfer products whose specifications will deteriorate if left in the pipeline and therefore the product must be displaced between applications.

Food processing plants use batching pigs to remove product from the pipeline prior to cleaning. This may be required when the pipeline is being converted to another product, between runs of the same product or when the pipeline is to be shut down for some reason. The foods may be such that they would not

meet specifications if allowed to remain in the pipeline for a period of time or the product may be of such a nature that it would solidify if left in the pipeline; chocolate being a typical example.

Pig manufactures can provide pigs for virtually any purpose. They may require seals that are suitable for food products and the components may be made for easier cleaning. Pigs are used in milk, chocolate, dough and other process food plants, for paints, pharmaceuticals, indeed for almost every mass production system which uses piping to transport its products.

Further information on industrial pigging systems will be found in Section 11.

2.8 IN LINE INSPECTION (ILI)

For many years the only method of monitoring what was happening to the inside of the pipeline was by inspection when it was opened for any reason. Research was being carried out in the early 1950's and perhaps before to find ways to inspect a pipeline for changes from the original condition that might indicate weaknesses and possibly potential failures.

Some of the early attempts were to try to monitor the cathodic protection with in-line pigs, to detect dents or other obstructions by recording the changes in the differential pressure required to propel the pig, and to detect liquid in gas lines by recording the temperature changes as the pig traversed the pipeline.

Leak location was attempted by detecting the lost product on the outside of the pipeline using a pig as well as several different means for listening to the noise of the leak.

Research was also carried out to try to measure the temperature accurately over the length of the pipeline to determine what actual total volume of product was required to fill the line.

The state of the art at that time was using mechanical pressure gauges, mercury thermometers, and distance was usually based on time. Needless to say all of this changed when electronics became small, reliable, and had low power consumption.

Instrumented pigs (often called Smart Pigs) are now available to caliper the interior diameter of a pipeline, indicate the shape of any non-conformity at or near a diameter change, measure the radius and the degree of pipe bends, measure the wall thickness with the ability to measure corrosion pits by approximate depth and size and identify whether the pit is inside or outside of the pipe. They can detect loose coating on the outside of a pipeline, detect cracks in the early stage of forming and detect and locate leaks. In fact, there are now over 30 different tools available, and special instrumented pigs can often be developed at relatively short notice to meet individual requirements.

The currently available In Line Inspection (ILI) tools are discussed in more detail in Section 8.0.

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3.0 PIPELINE DESIGN FOR PIGGING

The ideal pipeline for pigging would:

- be perfectly straight from end to end
- have a constant inside diameter with no weld penetration
- be perfectly round
- have an inside surface which was polished or epoxy coated
- have no offtakes (outlets)
- contain no valves or any other devices
- be pumping a light, refined oil at a speed of about 3 feet per sec. (1 meter per sec.)

Few if any of these criteria can be met so it is necessary to establish some acceptable tolerances, but in doing so, it is necessary to consider whether there are any special circumstances and in particular, whether instrument pigs will need to be run.

The requirements will vary throughout the world but in most countries it is usual for all new pipelines intended for the transportation of hydrocarbons to have to be designed and equipped to accommodate instrument pigs. In some countries it is also a requirement that certain existing pipeline systems will have to be modified to accommodate them as well. As there are over 30 types of "instrument pig" this needs further clarification.

Section 8 covers this in more detail, but the most common need is for metal loss (or corrosion) detection and measurement. These types of pigs are also the largest and the heaviest, so the pigging systems should be designed to accommodate these.

Sphere systems also require special consideration and the requirements for these will be found in a separate section of this manual.

3.1 PIPELINE DIMENSIONS

3.1.1 LENGTH

The distance between pig traps is a variable that must be determined for each specific pipeline. One factor is the expected wear of the pigs and the pipeline product is a major consideration. For example, wear on the pigs will be greater in a gas pipeline than in a crude oil pipeline. Another aspect is the compatibility of the pipeline product and the elastomer components. The internal surface of the pipe is also important. An epoxy lined steel pipeline will create less wear than would say a bare or a concrete lined pipeline.

Often, the length of pipeline between pig traps is determined by factors other than pigging, such as the location of pump stations or compressor stations.

Although there cannot be a firm answer that will be suitable for all conditions, the following is not uncommon:

gas pipelines, pig traps 100 miles (160 kilometers) apart
refined products pipelines, 150 miles (240 kilometers) apart
crude oil pipelines, 200 miles (320 kilometers) apart

There are cases where conditions are carefully monitored and controlled, where the pig traps are significantly further apart. The Zeepipe natural gas system has approximately 500 miles (800 kilometers) between pig traps and there is a crude oil pipeline in the United States that has approximately 600 miles (960 kilometers) between pig traps.

3.1.2 DIAMETER and WALL THICKNESS

One of the largest, if not *the* largest cost of a pipeline is the cost of the pipe. The design through-put is used to determine the pipe diameter and pipe wall thickness, but this must be balanced against the pumping or compressor costs. The smallest pipe that will deliver the design through-put may not be the most economical, perhaps because of the excessive friction loss through the pipe or, if high pressures are used to develop the through-put, the increased pumping or compressor costs may justify the use of larger diameter pipe.

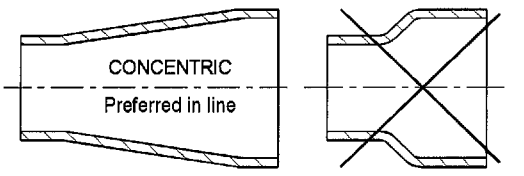
Since the cross-sectional area of the pipe increases faster than its circumference, higher through-put efficiency is feasible as the pipe increases in diameter.

Consideration must also be given to the wall thickness in comparison to the pipe diameter since large diameter, thin wall pipe may be suitable for the operating conditions but may be difficult to install because of the handling of thin wall pipe. The wall thickness may also vary because of external conditions such as the population density near the pipeline right-of-way, highway crossings, railway crossings or other regulations that must be considered. As long as the wall thickness is such that the inside pipe diameter is within the tolerances allowed by the suppliers of pigs, the varying wall thicknesses should not be a problem.

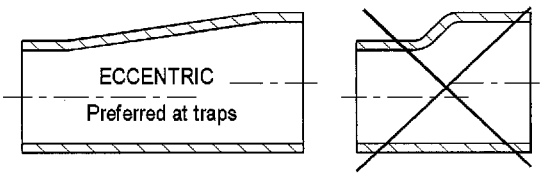
Most pipelines are laid with pipe that is of a constant outside diameter and the inside diameter varies as the wall thickness changes. It is possible to order pipe with a constant inside diameter and varying outside diameter. This is ideal from the pigging point of view but consideration must be given to the need for special equipment during construction such as line-up clamps and the need to be specific in the future if any fittings are purchased for attaching to the outside of the pipeline.

3.1.3 DUAL DIAMETER PIPELINES

Pipelines that have input along their length may need to be smaller near the upstream end and increase in diameter as the through-put increases. From a pigging standpoint, there should be pig traps at each change in pipe size but where this is impractical, reducers can be used. The reducers must have a gradual transition, ideally having a slope of 1:5 (approximately a 22° included angle) or less, from one line size to the other. Some forged reducers have very abrupt transitions and these are unacceptable. 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. Eccentric reducers are ideal on pig traps (provided there is no internal tray or basket) as the pig trap barrel is oversize and the center line of the pig when it is in the trap is almost on the same center line as the pipe.



Concentric Reducers



Eccentric Reducers

Cleaning pigs are readily available that will traverse the dual size when the change is not more than one or two pipe sizes. In some cases special cleaning pigs have been designed to traverse pipes that change in size by three or more sizes but generally, the greater the difference in pipe sizes, the less effective the pigs will be.

Most instrument pigs do not have the ability to traverse dual size pipelines and remain functional in both sizes of the pipeline. However, most instrument pigs will traverse pipes with different wall thicknesses and perform their function effectively.

In some cases with substantial differences in wall thickness such as the splash area on the risers of sub-sea pipelines, special consideration must be made by the pig supplier or the pigging contractor to be able to traverse the heaviest wall thickness and still be effective in the rest of the pipeline.

3.2 PIPELINE MATERIALS

3.2.1 BASE MATERIALS

Most pipelines are of steel, however they are also made of cast iron, wrought iron, asbestos cement, reinforced concrete, plastic, and other materials selected specifically for their compatibility with the product to be carried. For example, some products may require the pipeline material to be of stainless steel and the operating conditions of another may need the physical properties of a chromium-molybdenum steel. Sometimes the optimum solution is to combine different materials so that the pipeline is made of one material, generally for cost or strength reasons, and then coated or lined with another.

Many existing cross country pipelines are of carbon steel with yield strengths of 40,000 to 50,000 lbs/sq.in.. As pipelines got larger in diameter and pressures increased, pipeline companies changed the material to steels of higher yield strengths in order to minimize the wall thickness and therefore the tons of steel required for the pipe. As the yield strength increased it became desirable to use other alloying elements, resulting in steels having 'carbon equivalents' instead of the high carbon content. This was to achieve certain desirable physical properties that are not available with high carbon steels of equal yield strength. This is especially necessary for pipelines operating under low temperature conditions.

3.2.2 LININGS

Pipelines are lined to help protect them from the effects of the product and often to provide an internal surface that will create less flow resistance.

Natural gas pipelines are usually internally lined with paint like materials. These linings are often epoxy based, but they may be of other materials. The linings are usually applied at the factory or at a special site that is a long distance from the pipeline right-of-way. In these cases the lining may be damaged slightly at the weld joint during construction but this is a small percentage of the overall internal area of the pipeline. There are companies that will internally coat the pipeline after it has been laid but the line must be taken out of service for this operation to be carried out.

Metal cleaning elements should not be used in internally lined pipelines. Internally lined pipe is normally cleaned by pigs equipped with elastomer blades or in some cases just the discs or sealing elements of the pig will be sufficient.

3.2.3 COATINGS

Pipelines are externally coated to protect them from corrosion caused by the soil and other materials of the back fill. For many years the prime coating material was hot-applied tar. Various materials were used with the tar to retain it in position while it tar hardened. This was usually covered with a paper wrap to

protect the tar until it was safely laid in the ditch. A similar coating of bitumen was also used by some pipeline companies. These coatings were often applied over the ditch, after welding but before lowering into the ditch.

Another coating material used when the pipe is coated after welding but before being laid in the ditch is made of plastic. This comes in rolls and is spiral wrapped on the pipe. Small pipelines can be wrapped with manually operated machines but larger pipes are coated using powered wrapping machines.

Epoxy based materials are often also used for coatings. These too are applied either at the factory or at a site that is some distance from the pipeline right-of-way.

The preparation of the external surface of the pipe and the application of the coating must be carried out under carefully controlled conditions to ensure maximum pipe protection. Coating failure can cause localized external corrosion so the integrity of the coating is critical to the life and even to the continued safe operation of the pipeline. All coatings are therefore carefully checked for damage or voids (called holidays) just before the pipe is laid into the ditch and any faults must be repaired.

3.3 BENDS

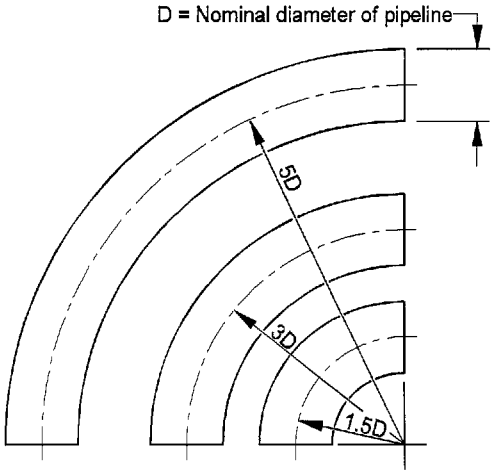
3.3.1 FORGED BENDS

Bends with a relatively short radius must be factory made and are generally forged to a number of different standard radii. The radius of a bend is measured to its center line.

The smallest radius normally used is a one "D" bend, (known as a short radius elbow) that is, the radius of the bend to the center line of the pipe is the same as the nominal diameter of the pipe. Other common sizes of bends are 1½D (known as a long radius elbow) and 3D. For example, bends for 12" pipe would be 12" radius for the one D bend, 18" radius for the 1½D bend and 36" radius for the 3D bend.

Forged bends are available with 90 degree, 45 degree and sometimes 22½ degree included angles. The bends can be cut for angles other than the standard sizes. In general bends of other radii would be available only as a special order and special tooling would be required to produce them.

It is common practice for forged bends to have an increased wall thickness, with the additional material added on the inside diameter. This should be avoided. If extra material is required, it should be added to the outside diameter.



Dimensions of common factory bends

Short radius (one D) bends should not be used in pipelines if pigs are to be run. Long radius elbows (1 1/2 D) are, with a few exceptions, really only suited for spheres. Pigs can be designed to pass long radius elbows but they are generally less effective than those that require a longer radius bend.

For pigging, bends should have a minimum radius as follows:

10D for pipelines 4" and smaller
5D for 6" through 12" lines
3D for pipelines larger than 12".

Ideally, bends should not be installed adjacent to one another. At least three diameters of straight pipe should be installed between any two bends.

When purchasing pigs or pigging services for pipelines it is necessary to notify the supplier of the dimensions of the bends so that a pig can be supplied that will traverse them. The dimensions needed are the radius, and the inside diameter. The included angle should also be given as, for example, some pigs might traverse a bend of 15 degrees but would not pass a bend of the same radius of 90 degrees.

3.3.2 FIELD BENDS

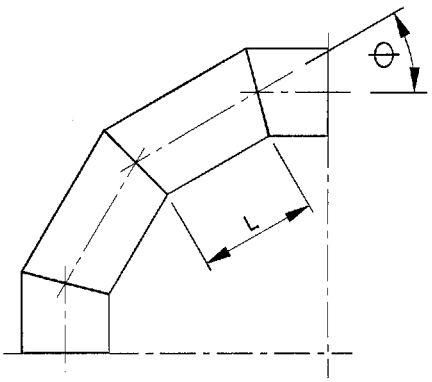
When laying a pipeline the pipe must be bent to the contour of the land through which it is passing. Bending machines are usually part of the equipment which is on site during the laying.

Field bends are often referred to as 'cold bends' and when they are being formed it is important not to exceed the allowable yield stress of the pipe material. It is this factor which generally dictates the minimum allowable bend radius, and this may sometimes be measured in literally hundreds of diameters.

Sometimes field bends are made without a bending machine. These may not be of a uniform radius and could result in a series of sharper bends which might not be acceptable for pigging. Therefore it is important that field bends be of a uniform radius and do not contain flat spots or any other localized deformation. For pigging, localized deformation should be limited to no more than 2 or 3% of the pipeline diameter.

3.3.3 MITER BENDS

Miter bends are made by cutting the end of the pipe at an angle to achieve a change in direction of the pipe. In general these are to be avoided, however small angles, (not exceeding 3 degrees), may be necessary to achieve proper fit up at the weld joint of mating pipes. A bend made of a series of miter joints is unacceptable in almost all pipelines. Whenever there is a miter bend the pig supplier must be notified of the dimensions to be sure that a suitable pig is provided.



Typical Miter Bend

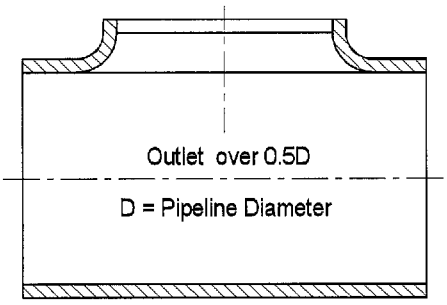
3.4 OFFTAKES

3.4.1 UNBARRED TEES

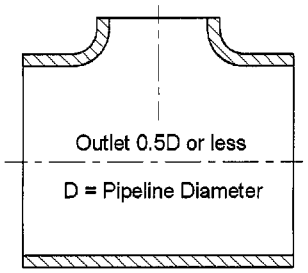
Forged tees are usually used for installing offtakes (outlets) in a pipeline during construction.

Most conventional pigs will safely traverse tees with outlets up to 70% of the nominal line size and most instrument pigs can pass outlets up to 60%. However, it is good practice to install guide bars in all tees with outlets above 50%. This will not only decrease the chance of the

pig getting stuck by "nosing" into the side outlet, but it will help to guide any other attachments such as cleaning brushes or blades, wheels, sensors etc.



Barred Tee



Unbarred Tee

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

When the offtake is made by welding a fitting to the outside of the pipeline and the hole is made by tapping (drilling under pressure), then provided it is at least 6" in diameter, tapping fittings are available which allow guide bars to be installed in the tapped hole. These fittings have a special flange designed to lock the mechanism with the guide bars in position using the machine which was used to make the tap.

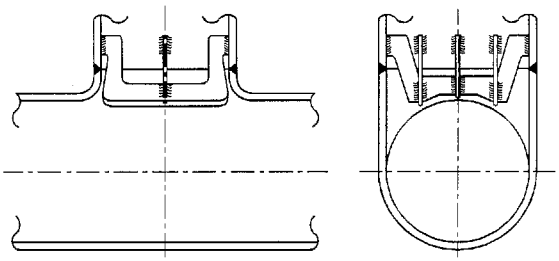
3.4.2 BARRED TEES

As already stated, the tee for any offtake which is more than about 50% of the pipeline size should have bars installed to assist the pig past the opening without damage.

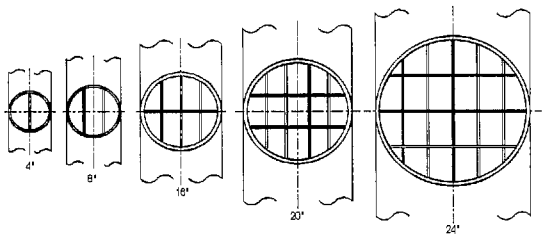
Bars must be of substantial design with full penetration welds (having due regard to any code restrictions applicable to the tee). These bars may be subjected to severe shock loads by pig brushes etc. and cause pigs to jam if they become broken and protrude into the pipeline.

The bars should be installed parallel to the axis of the run (i.e. the line to be pigged) and spaced from about 2" (50 mm) apart for the smallest offtake (e.g. 8" x 4" tees) to about 4" (100 mm) apart for the larger sizes (e.g. 30" x 30" tees). When the outlets are more than 12" in diameter it is advisable to fit a reinforcing bar, or bars, above and at right angles to the guide bars.

As also described above, when the offtake is made by welding a fitting to the pipeline and the opening is made by tapping, the outlet may have bars installed provided the outlet is 6" in diameter or larger. Most tapping fitting manufacturers make fittings that will allow guide bars to be installed across the outlet after the tap has been made.



Typical Method of Installing Bars in Tees

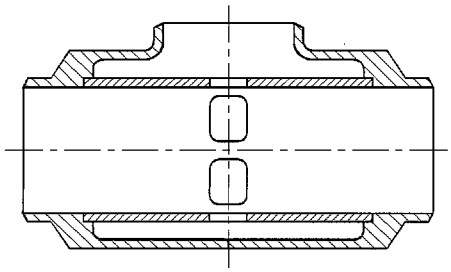


Typical Arrangement of Bars in Tees of Different Branch Sizes

3.4.3 SPHERE or FLOW TEES

A sphere has a single line seal and therefore it will not pass some offtakes that a pig, with its multiple seals, would pass. The single line seal allows the driving fluid to bypass at the offtake and the sphere may stop at that point.

Since spheres are of equal dimensions in all directions, they will follow the flow through an offtake, unfortunately this is true even when the offtake is smaller in diameter than the main pipeline (see 'Anecdotes' towards the end of this book).



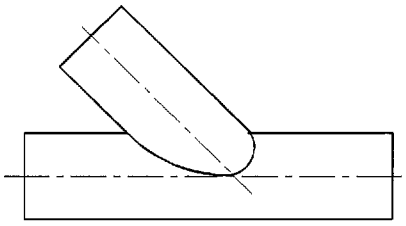
Sphere or Flow Tee

Special fittings have therefore been designed which allow flow out through the offtake, but at the same time, restraining the sphere in the pipeline and making it pass the offtake without stopping. These special fittings may be known as "sphere-tees" or "flow-tees". They are usually of proprietary design, but are all similar to that shown. They prevent the sphere from either entering the side outlet or from simply remaining in the tee while the flow bypasses. To ensure this, the longitudinal dimension of the slots must not exceed one third of the sphere diameter, and preferably be less.

Note that unless the outlet is installed in the 'vertically down' position, sphere tees allow liquids and debris to remain in the annulus, causing potential corrosion problems.

3.4.4 LATERALS

Laterals are offtakes (outlets or inlets) that intersect the pipeline at any angle other than 90 degrees to the pipeline. This results in the opening in the pipeline always being longer than the diameter of the lateral. In order for a pig in the pipeline to pass the lateral it is essential that the span of the seals on the pig be greater than the length of this opening.



Lateral

3.5 WYE JUNCTIONS

Wye junctions are a means of allowing pigs to be run in different pipelines and converge the flow and the pigs into a single pipeline.

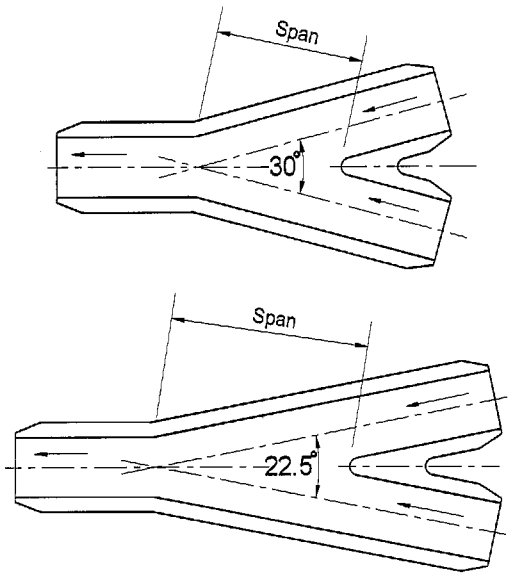
There are a growing number of wye junctions installed. It must be remembered that pigs can only traverse these in one direction: from the laterals into the main line. Thus any possible advantage of utilizing the bi-directional capability of a particular type of pig in these lines is partially, or totally negated.

3.5.1 CONVERGENCE ANGLE

Most wyes installed to date have a 30 degree included convergence angle. At least one is known to have a 22 degree convergence angle and another is 25 degrees.

The shallower angle reduces the impact that the pig makes with the opposite side as it traverses the junction, but it increases the length over which the pig will lose it's seal at that point. This means that the effective length of the pig

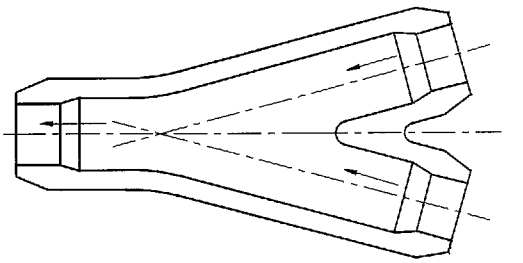
across its seals must be increased and this will generally result in having to use a pig made up of two or more modules.



Typical Wyes

3.5.2 BORES

The bore of the wye is another consideration. Although a wye with a parallel bore will simplify machining, and hence reduce manufacturing costs, the pig will always be subjected to an interference and will need to be "driven" through the wye. This requires that at least one drive cup will need to be in the sealing position at all times. Special extended body or multi-module pigs will therefore be mandatory to traverse this type of wye. Care will need to be taken to ensure that if the pig is a multi-module type, it cannot jack-knife as it enters the "void" immediately downstream of the crotch.



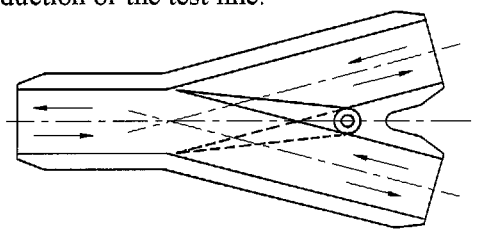
Wye with Oversize Bore (Statoil)

Tests carried out for a major North Sea pipeline resulted in a wye with an enlarged bore section. This allows single, conventional pigs to "float" through even at relatively low fluid velocities.

Other wye trials carried out by HydroTech indicated there may be some merit in slightly restricting the bore immediately before the pig enters the wye in order to build up a back pressure to 'fire' it across this junction. However, such a technique cannot be recommended as tremendous forces and very high speeds could easily result.

3.6 DIVERTERS

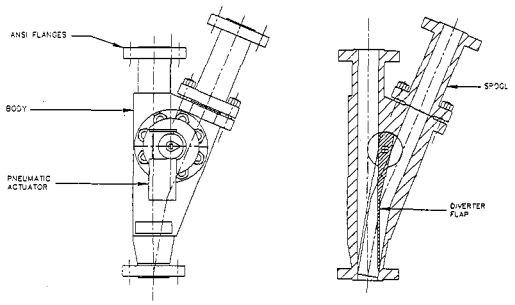
Most pipeline systems are similar to rivers and waterways in that the branches flow into a single main line. Provided the branches and the main line are of the same diameter, pigging such systems is relatively simple as the junctions between different pipelines can be formed using a wye, or converger. However, there is a sometimes a need, particularly in subsea production systems, for the pig to travel down a pipeline and then be diverted into one of two other lines. A typical example would be to launch the pig from a platform, down the water injection line and then return via either the production or the test line.



Principle of Diverter

This requires some mechanism to direct the pig into the desired pipeline. There are number of

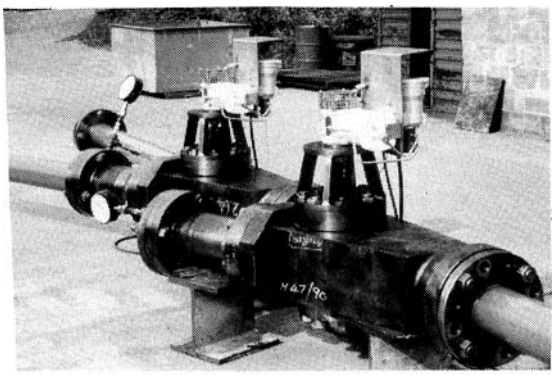
different designs of diverters which will allow this. One diverter which has been patented for industrial pigging systems utilizes magnetic forces to guide the pig into the desired branch. For pipelines however, all except one of the designs involves mounting a gate within what is otherwise a wye type junction. The gate is pivoted at the crotch of the wye and can be swung from one side to the other by an external lever which, for subsea use is fitted with an actuator. In none of these designs is any attempt made to have the gate seal off one pipeline from the other. It acts purely as a pig guide.



Pig Diverter *Courtesy: Cooper Oil Tools*

Typical diverters for low pressure pipeline systems are made by Webb Services Inc. and GD Engineering, while high pressure diverters of this basic design were patented by BP/Seanor a.s. in Norway and Cooper Oil Tools (now Cooper Cameron). The Cooper Oil Tools design is unusual in that one outlet is on the center line of the inlet with the second outlet forming a lateral at 30°. This configuration saves considerable space and limits the number of bends in a system as compared to the use of an equal wye configuration.

Cooper Oil Tools also manufactured the only known diverter which does not utilize a swinging gate. It is designed on the principle of a plug valve but instead of rotating, the plug moves in an axial direction. The plug has two separately bored holes, one above the other, and at differing angles, so that it forms a continuous pipeline from the inlet to one or other of the outlets depending upon the axial position of the plug. In this way, a seal can be created completely isolating the pipeline which is not being pigged. This particular diverter was developed for a complex subsea system, but in most other cases, if it is necessary to isolate a line during pigging, a more simple and versatile solution would probably be to use a swinging gate diverter with conventional valves mounted on each branch.



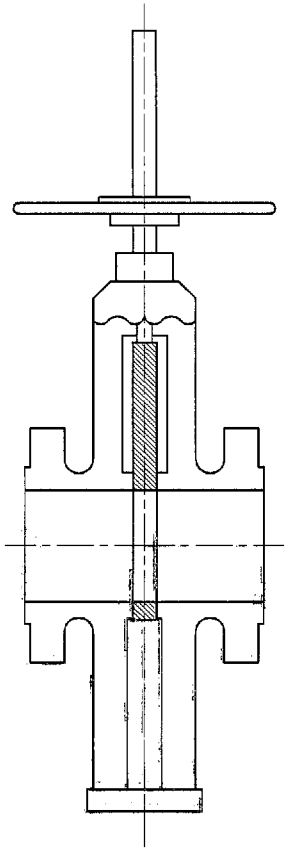
Pig Diverter *Courtesy: Cooper Oil Tools*

3.7 VALVES

3.7.1 IN-LINE BLOCK VALVES

Valves are arguably the biggest single cause of pigging problems. Full bore valves are more or less essential and commonly, these are solid bored (not hollow ball) ball valves. 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.

Certainly, the best block valve from a pigging point of view is one which has a smooth bore with a diameter approximately equal to the bore of the pipeline. This smooth bore is available with most ball and through conduit gate valves.



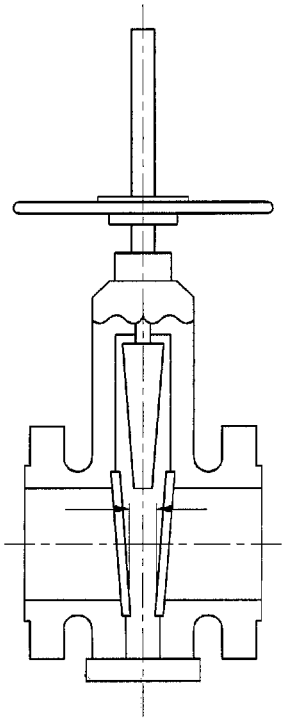
Through Conduit Gate Valve

Utility pigs can be designed to traverse most block valve designs but valves with an undersize bore or those with gaps for the valve gate will limit the types of pig that can be used. If the bore of a valve has a diameter smaller than the pipe inside diameter the pigs may have to be designed specifically for that purpose. Such pigs are usually a compromise between their ability to pass through the valve and their effectiveness.

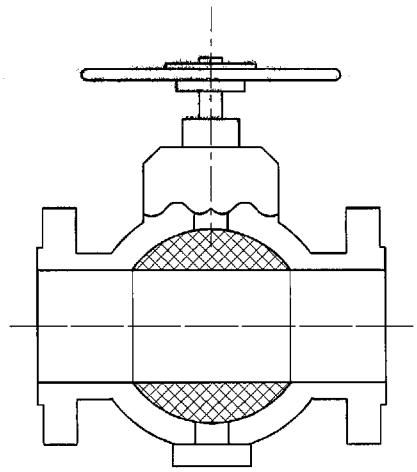
If wedge gate or parallel slide valves are already installed, or for some reason must be used, it is important to know the dimension of the gap between the seat rings to enable the correct pig to be selected.

Valve manufacturers frequently confuse "full bore" with "full flow" so it is essential to specify the actual inside diameter required.

Where, for technical reasons, it is impossible to exactly match the bore of the valve with the bore of the pipeline, then a smooth transition of not more that 1:5 (30 degrees) should be provided.



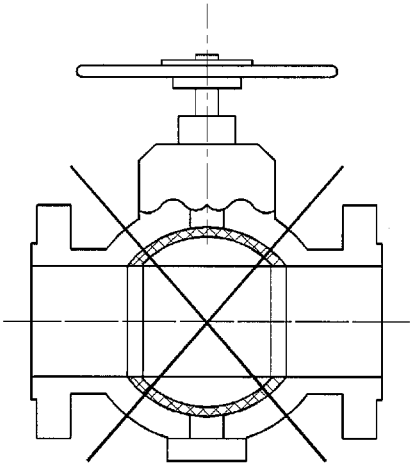
Gate Valve
Wedge Gate (shown) or Parallel Slide



Solid Ball Valve

Each valve should be carefully checked to ensure the stops are correctly set, particularly if the valves are fitted with actuators. If a pig is launched when the main line valves are not in

fact fully open, or if the ball has gone slightly beyond the fully open position, it can cause serious and costly damage to both the pig and the valve. In extreme cases, it could result in a shut-down.

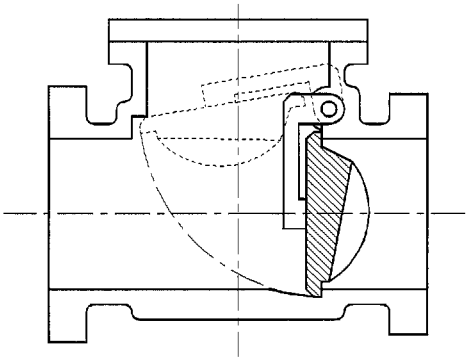


Hollow Ball Valve

Instrument pigs are more limited in the range of variances that can be accepted in the pipeline design generally, including the valves. Butterfly valves and most plug type valves cannot be used in a pipeline to be pigged.

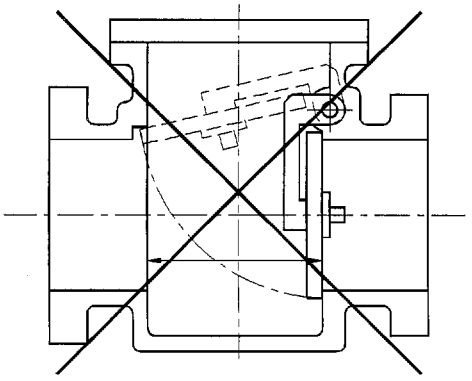
3.7.2 CHECK VALVES

By the nature of their design, check valves (also known as non-return valves) require an area in the valve body that is larger than the pipe inside diameter. This requires the seals on a pig to be spaced such that they span the oversized area. In addition the pig must provide the force required to open the check valve fully for it to pass. To assist the pig passage, some valves have part of the weight of the check valve clapper counterbalanced with weights or springs. Some types of check valve have the pivot point on the side rather than at the top. This means that the opening force will be less than the total weight of the clapper and so make it easier for the pig to push the clapper open.



Check Valve for Pigging

The pig will push the clapper to the fully open position with no noticeable change in pig speed, so the resulting movement is very quick. This means that the clapper needs to have a relatively smooth surface for the pig contact so it can pass with the minimum of difficulty. Some check valves may have fins or guides to assist the pig in opening and these can cause damage to the pig if not properly designed. Sometimes it is necessary to equip the pig with specially designed bumpers at the front and/or at the mid-point to push the clapper open and hold it there during pig passage.

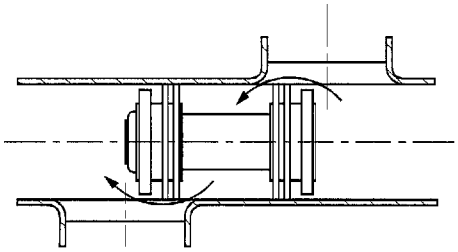


Check Valve Unsuitable for Pigging

Spheres are not suited for dependable passage through check valves as they tend to sit in the bowl and be held there by the weight of the clapper. This not only traps the sphere but negates the purpose of the check valve.

3.8 RELATIVE POSITION OF FEATURES

Frequently, a pipeline is designed with all the individual components suitable for pigging, but with them installed relative to one another such that the completed assembly becomes unsuitable.



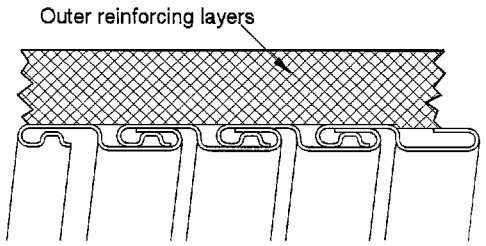
Pig Stalling Between Two Tees

The best example of this is two tees placed such that their outlets are the same distance apart as the seals (or cups) on a pig. The result is that the pig stalls, with the fluid bypassing the seals at the front and back. This same situation can occur with a tee and a bend, a tee and a check valve or many other combinations. Some pigs also have difficulty in passing two bends welded back-to-back.

To avoid these problems and to take account of possible future developments in instrument pigs particularly, it is recommended that a minimum straight length of pipe equivalent to three pipe diameters, be installed between any two components or features. Where this is impractical, or where there is an existing configuration which does not meet this ideal, then it should be checked with the utility and instrument pig supplier(s).

3.9 FLEXIBLES

The main limitation when pigging flexibles compared to pigging conventional rigid steel pipe is in the type of pigs which may be used. This is due entirely to the construction of the internal surface of the flexible. Flexible pipe is usually supplied with one of the two types of internal finish--smooth bore or rough bore.



Typical Structure of "Rough Bore" Flexibles

The smooth bore has a thick internal plastic lining. It is used primarily for chemical and water injection systems. In general it is recommended that smooth bore flexible pipe is not to be pigged.

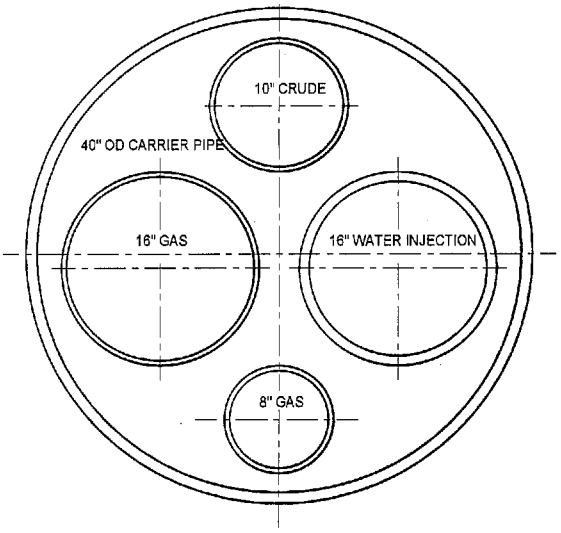
Rough bore pipe is invariably specified when flexibles are required for flow lines, jumpers, flexible risers etc. The internal surface is convoluted interlocking spiral wound stainless steel strip approximately 2 mm thick. As such, it is fairly robust but if it were damaged at any point, it is probable that the spiral would become unwound and completely ruin the pipe possibly with catastrophic results, especially if a pig were to follow after the damage was done.

As far as is known, flexible pipe manufactures have not issued any formal specifications with respect to pigging but they do recommend that metal to metal contact between the pipe wall and the pig be avoided. This effectively rules out the use of wire brush type pigs and the possibility of running MFL (Magnetic Flux Leakage) type instrument pigs through flexible pipelines.

3.10 BUNDLES

The use of pipe bundles is basically an extension of the practice of tying together umbilicals or electrical cables and running them as a single line - except pipe bundles are considerably larger and more complex.

For offshore use especially, this method has major cost advantages over laying pipelines individually. A bundle might comprise a 16" water injection line, an 18" gas and a 12" oil export line and a 6" gas lift line. All of these would be contained within perhaps a 42" carrier pipe and held in their correct relative position by spacers.



Typical Arrangement of Subsea Pipe Bundle

These bundles would normally be assembled onshore and then towed out when completed and fully tested.

Provided there are no significant or rapid changes in their inside diameters, any one of these lines can be pigged much the same as any other pipeline. The main difference becomes apparent when it comes to inspection and maintenance.

The magnetic field of Magnetic Flux Leakage (MFL) ILI inspection tools is affected by the presence of any carbon steel object within a certain distance of the wall of the pipe which is being inspected. This distance will depend upon a number of factors but is usually in the region of 2" (25 mm). This means that even if the spacing is arranged such that the adjacent pipes are set further apart, any bending (sagging) between spacers will need to be considered and the spacers themselves will cause problems if they are made of carbon steel.

Maintenance is clearly an even bigger problem. If one pipe in the bundle leaks it will be extremely difficult to locate it and equally difficult to repair it. This situation would probably lead to a shutdown so it would be prudent to limit the pipes in any one bundle to those serving a common field or process.

3.11 OPERATING CONDITIONS

3.11.1 PRODUCT

The pipeline product must be a consideration when selecting the proper pig for a pipeline.

The product may affect the type of cleaning devices which should be used on a cleaning pig. The product may also determine the materials which must be used for the pig seals or other pig parts. If the product is foodstuff or some types of pharmaceuticals, the product may even determine the design of the whole pig.

In the hydrocarbons field, refined products must be monitored as their composition or the additives may change, even though the same generic name is used for their description. For example gasoline has been a product in pipelines for many years and has been pigged with many types of pigs. However, more

recently, special chemicals have been added to gasoline for environmental purposes and some elastomers that have been used in the past may now may be unsuitable.

If pigs are to be reused, the product will affect that decision too. Foam pigs will absorb the product and will be almost impossible to clean. So if the product is a hydrocarbon or some other inflammable or noxious fluid, then it may be difficult or dangerous to store them and perhaps solid cast or mandrel pigs will have to be used.

3.11.2 PRESSURE

Most utility pigs are molded or fabricated from materials normally considered as solids and therefore are affected very little, if any by pressure. Most foam pigs are open cell and also are not affected by pressure while inflatable spheres should be full of liquid and so are also unaffected.

Instrument pigs however have pressure vessels containing instrumentation and therefore have both static and dynamic seals. These pigs must be designed to withstand the external pressure on the instrument case and all of the seals must be compatible with the pipeline product.

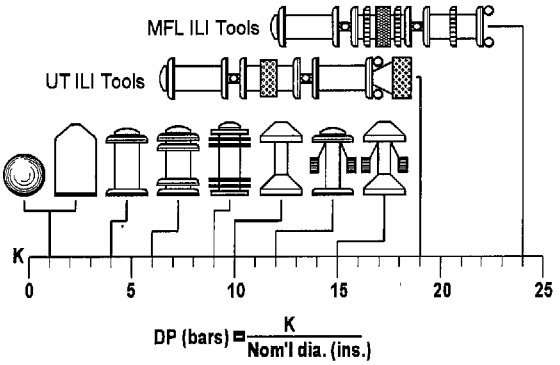
It will be noted that some suppliers show minimum allowable operating pressures in their specifications. This limitation usually applies to gas or compressed air. When a pig is operated in a low pressure gaseous environment it frequently stops when it meets even minor obstructions such as ovality, bends and circumferential welds.

The pressure builds up behind the pig until it is sufficient to overcome the obstruction. It then accelerates almost instantaneously, reaching very high velocities before the energy is dissipated, or it meets another obstruction. These are often referred to as "speed excursions". In one series of trials, velocities in the region of 170 mph (75 m/sec) within a distance of only 250 feet (75 m) were attained. Clearly these can be very dangerous and must be avoided.

A common approach to this problem is to pressurize the whole pipeline and run the pig by venting at the downstream end, maintaining a certain minimum pressure in front of the pig to act as a buffer.

In reality, a specific minimum pressure cannot be stated as both the diameter and condition of the pipeline must be considered. The suppliers will always discuss this aspect during the planning stage for each instrument pig survey.

A rough guide to the differential pressure required to drive various types of pigs is included in the following chart.



Note: In practice these figures will vary widely. This chart is only intended to provide a rough guide

Typical DP Required to Drive a Pig

(Refer to Appendix 13H for a larger chart showing Differential Pressure to drive various types of pigs through a pipeline).

3.11.3 TEMPERATURE

Most pigs use polyurethane seals and the allowable temperature range for this material is generally between 32° F. and 180° F. (0° and 82° C.) Since most pipelines operate at ambient temperatures within this range, this

does not normally create any problems for utility pigs.

However, polyurethane is subject to hydrolysis and should not be used in water or stored in humid conditions at temperatures above about 150° F. (65° C).

If the operating conditions are not within the allowable limits of any particular material, the pigging supplier will normally be able to supply suitable alternates.

Instrument pigs (ILI tools) may have a lower temperature range because of the dynamic seals, electronics and the batteries. It is therefore important to ensure that the pigging service company is aware of the temperature conditions of the pipeline.

3.11.4 FLUID VELOCITY or 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.

The following are considered to be typical speeds for utility pigging and are given as reference only:

Application	Speed mph	Speed m/sec
New Construction	1-5	0.5-2
On-Stream Gas	5-15	2-7
On-Stream Liquids	2-10	1-5

These appear to be reasonable, but care should be taken if operating at the upper end of the range for gas lines. If the gas is dry, speeds of this order (i.e. 5-7 m/sec) are likely to cause frictional heating and consequent breakdown of the polyurethane components. Or, if there are substantial volumes of liquids present, aquaplaning might occur.

Current research has shown that as speed increases, the differential pressure decreases. As it is the differential pressure which forces the seals against the pipe wall to create an effective wiping action, it is reasonable to assume that high velocities will not provide optimum pig performance.

For optimum performance, most instrument pigs (ILI tools) need to be run at strictly controlled speeds. This is due to the limitations imposed by the data acquisition and on board processing systems as well as to the technological limitations of the methods used to acquire the data. In most cases this is in the range of 2-8 mph (1-4 m/sec). Indeed this range has proven to be very effective for utility pigging as well.

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4.0 PIG STATIONS

The following provides details of the basic design concepts and selection criteria for pig stations and the related equipment and components. These requirements will vary depending on the location and/or the type of service. A pig station consists of a device called a pig 'trap' for launching or receiving a pig while the pipeline product passes through or around the pig trap without interruption of flow. Valves must be installed at appropriate locations to allow the flow to be directed for the pigging operation.

Pig stations include the traps and the associated piping, as well as all the valves which are needed to isolate the trap from the operating pipeline. The pig station may be constructed from individual components, such as trap, valves and piping which are assembled on site or as a complete unit, usually skid mounted, to connect directly to the pipeline.

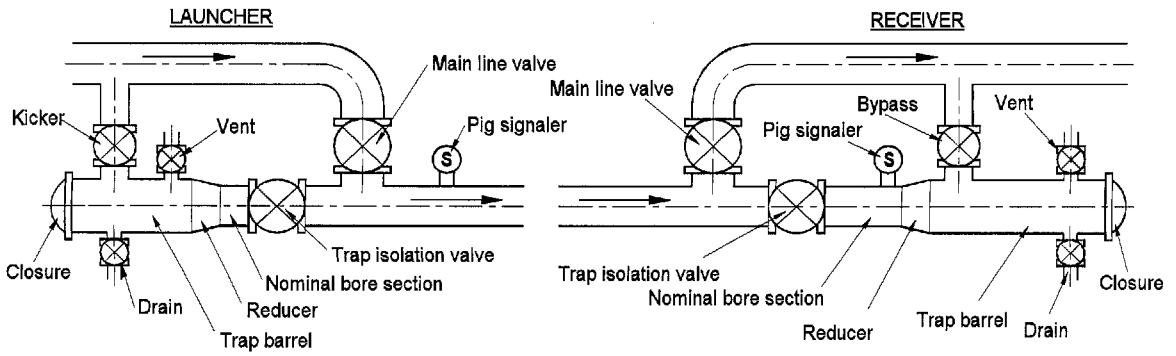
4.1 BASIC CONFIGURATION

Pig traps are for inserting and launching pigs into an operating pipeline and for subsequently receiving and removing them from the pipeline.

The main body of the pig trap, sometimes referred to as the 'barrel', consists of a section of pipe which is larger than the nominal diameter of the pipeline. This section houses the pig and, being oversize, allows the pig to be inserted or removed more easily. The barrel should be 2" over the pipeline size for pipelines in sizes up to 10". For pipelines from 12" up to 26" the barrel diameter should be 4" larger than the pipeline and for pipelines 28" and above, the barrel should be 6" oversize.

A quick opening closure of the same diameter is attached to one end of the barrel and a reducer followed by a section of pipe having the same inside diameter as the pipeline (referred to as the 'nominal bore section'), is attached to the other end.

To simplify handling the larger diameter pigs and to allow them to be positioned correctly the trap may be equipped with a tray or basket which can be rolled in and out. In this event, the oversize diameter of the barrel should be increased by the extra amount necessary to install the tray or basket. Unless a tray or basket is installed, which centers the pig, the reducer between the barrel and the nominal bore should be eccentric with the taper at the top. This will assist in locating the first drive seal in the reducer for launching and give the pig a smooth transition from the trap into the



Basic Configuration and Terminology for Pig Launcher and Receiver

pipeline and from the pipeline, into the trap when the pig is being received. An eccentric reducer will also allow the trap to be more easily used for the occasional sphere run.

The pig trap and all connections must have valves so that the trap can be isolated from the pipeline flow and pressure. Additional piping with the appropriate valves is also required for filling, venting, draining and flushing the pig trap.

4.2 LAUNCHING TRAP DESIGN and DIMENSIONS

Although, as described above, there are many features common to all pig traps, there are certain differences between launchers and receivers and some of these differences will vary depending on the type of pigs that they are required to handle.

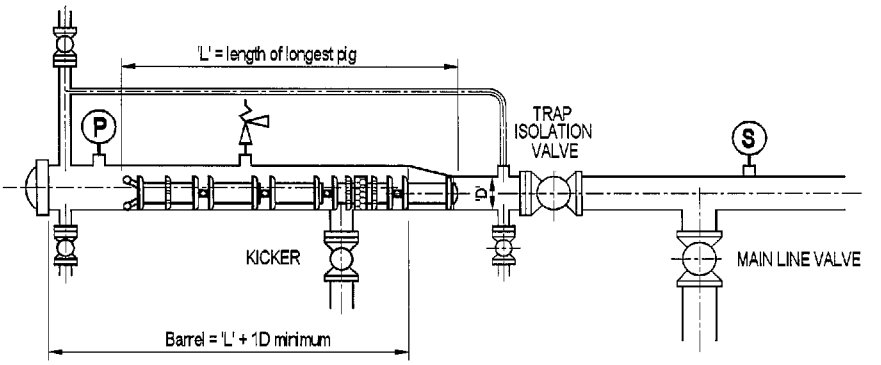
For launchers, the nominal bore section need only be long enough to prevent the nose of the pig touching the valve ball or gate of the trap isolation valve. A length of 1.5D should be adequate. (D equals the nominal diameter of pipeline).

4.2.1 FOR UTILITY PIGS

For utility pigging only, the "rule of thumb" for the length of the launcher barrel is 1.5 times the length of the longest pig. It is often the case that the pigs have not been selected at the time the traps are designed so an alternative "rule of thumb" for the length of the barrel, assuming single module pigs will be used, is 2.5D.

4.2.2 FOR IN LINE INSPECTION TOOLS

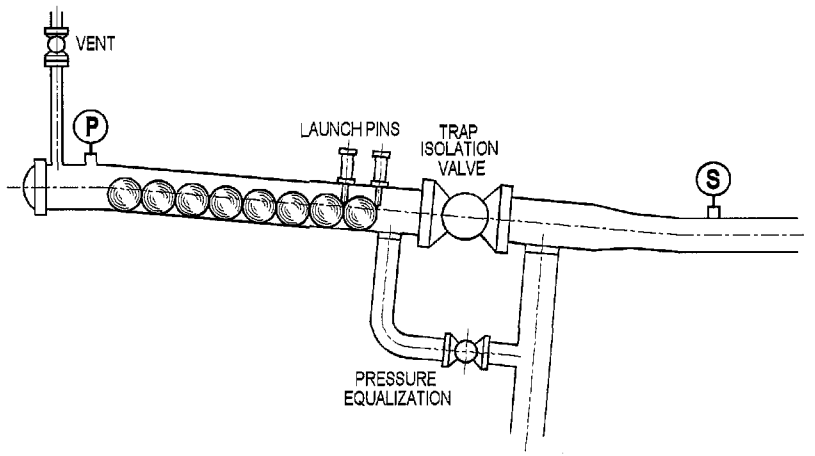
Many In Line Inspection, or "ILI" tools, especially those for detecting metal loss or corrosion, are made of several modules joined together with universal joints. When these and similar "extra-long" ILI tools are to be used, the launcher barrel should be at least 1D longer than the overall length of the longest pig. Except for the length, all other dimensions will be the same as for utility pigs.



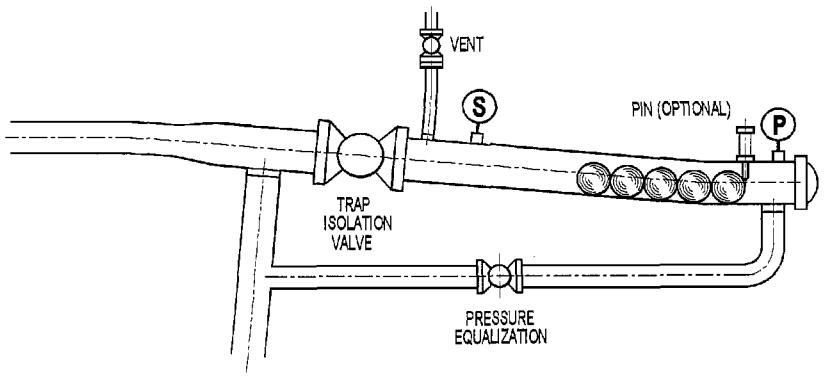
Launcher for In Line Inspection (ILI) Tools

4.2.3 FOR SPHERES

Spheres have a single line of seal and therefore must be treated differently than pigs which 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. When this happens, they will be damaged or destroyed and may damage other equipment installed in the pipeline.



Typical Sphere Launcher



Typical Sphere Receiver

Flow or sphere tees must be fitted to all full size side outlets and reduced size side outlets must have bars to prevent the spheres from entering. The connections into the trap barrel should have bars which extend into the bore enough to prevent the sphere from sealing across the outlet.

Spheres are usually selected because they can be run automatically. To facilitate this, sphere launchers are usually installed at an inclined angle of about 5 degrees with the closure higher than the pipeline so that the spheres will roll into position ready for launching. To enable them to roll into the pipeline, the launching trap may therefore not have any nominal diameter section and be oversize until the sphere actually enters the line.

The length of the launcher is determined by the number of spheres anticipated to be run before the trap is reloaded and this will be influenced by the frequency of the sphere runs and the accessibility of the site at which the trap is installed.

The trap isolation valve for a sphere launcher may sometimes be a special valve that is also designed to launch each sphere automatically. If the trap is not equipped with one of these special valves, then launching pins or similar devices must be used to release one sphere at a time.

4.3 RECEIVING TRAP DESIGN and DIMENSIONS

When receiving, there is a risk of the pig loosing its drive as soon as the front seal enters the reducer. If this occurs the rear of the pig must be clear of the valve to ensure that it can be safely closed. The nominal bore section should therefore be long enough to contain a pig. For single module utility pigs, this should be at least 2D and for ILI tools, at least 1D longer than the longest tool - the dimensions of which must be obtained from the suppliers.

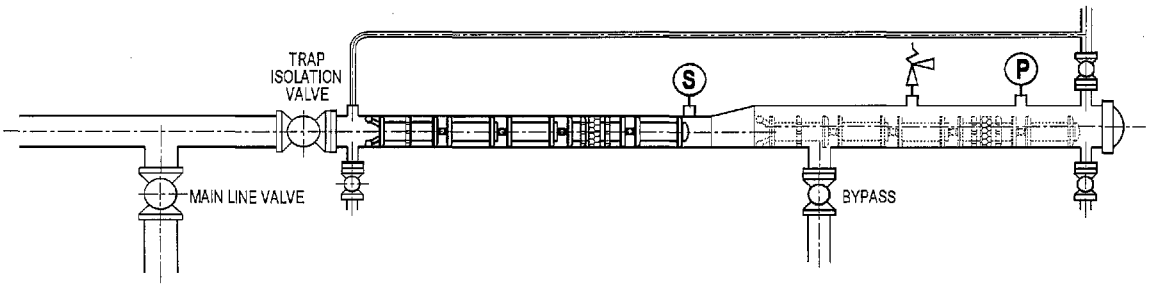
4.3.1 FOR UTILITY PIGS

For utility pigging only, the "rule of thumb" for the length of the receiver barrel is 2.5 times the length of the longest pig. This allows two pigs to be received together should a problem occur which requires a chaser pig to be used. It also allows space for the pig to decelerate under normal conditions. It is often the case that the pigs have not been selected at the time the traps are designed, so an alternative "rule of thumb" for the length of the receiver barrel, assuming single module pigs will be used, is 4.5D.

4.3.2 FOR IN LINE INSPECTION TOOLS

Many ILI tools, especially those for detecting metal loss or corrosion, are made of several modules joined together with universal joints. The receiver barrel should normally be about 2.5D longer than the longest pig to allow for deceleration, however some metal loss pig drives only on the front module, the other modules being towed on wheels. This means that the pig will stop as soon as the front module arrives in the barrel, and it can easily be removed even though the rear module(s) may still be in the nominal bore section. Therefore, for this type of pig the nominal bore also should be longer than the pig to be sure the valve can be closed when the pig stops in the trap.

Other instrument and utility pigs have both their front and rear modules supported on cups and, even though they may be drilled to provides bypass to the front module, the rear cups will still tend to drive whilst they remain



Receiver for In Line Inspection (ILI) Tools

in the nominal bore so forward motion could continue until the last cup reaches the oversized barrel section. Allowance must therefore be made for this or very serious damage could result with a risk of closure failure.

It is therefore essential to have the trap design approved by all the prospective suppliers of ILI surveys.

4.3.3 FOR SPHERES

The design of sphere receivers is very similar to that described above for sphere launchers and reference should be made to that section for guidance with respect to providing bars on all side outlets.

Similarly, sphere receivers are also usually installed at an angle of about 5 degrees, but are

declined such that the closure is lower than the pipeline. This ensures that the spheres will move away from the trap isolation valve when received and roll out of the trap when the closure is opened.

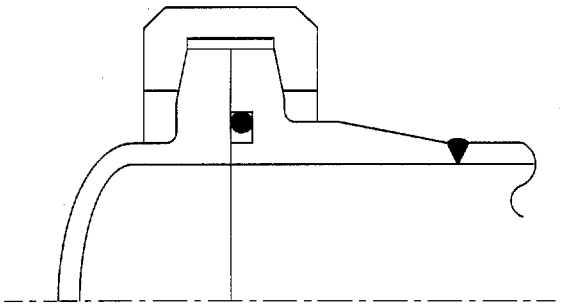
The length of the receiver is determined by the number of spheres anticipated to be run before the trap is unloaded. This may be influenced by the capacity of the launcher as well as the number of launchers the receiver is servicing. It may also be influenced by the frequency of the sphere runs and the accessibility of the site at which the trap is installed.

The trap isolation valve on the receiving trap may be oversize, but if not then it may be any through port valve that offers a continuous surface for the sphere to seal and therefore pass. Spheres will not dependably pass valves which have gaps between the valve seats.

4.4 PIG TRAP CLOSURES

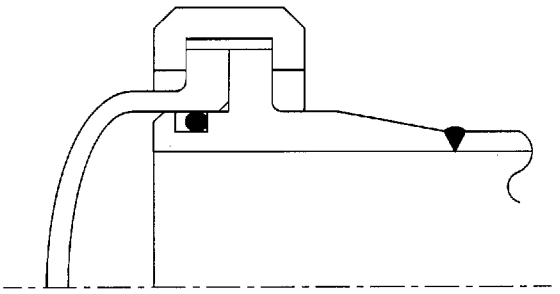
4.4.1 BASIC TYPES

Closures are designed to be easy and relatively quick to operate. Normally they can be operated by one person. A closure may simply be a blind flange bolted to the end of the trap with provision for handling it into or out of position. Other types of closures have various methods of providing a quick means of opening or closing. One design uses a multiple thread so that the closure can be opened or closed with a few rotations of the end cap. Another design uses interlocking lugs that require only a partial rotation to engage or disengage.

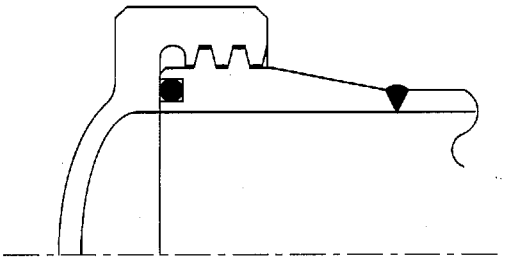


Clamp Ring Closure-Face Seal

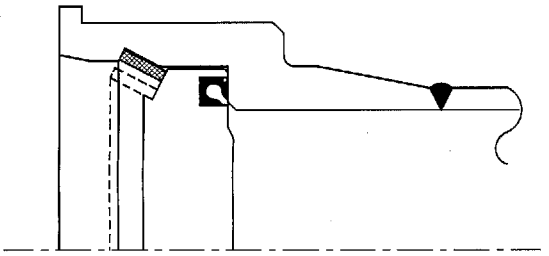
A number of manufacturers use split clamp rings to lock the end cap in position. These split rings are opened and closed in various manners. Some utilize screws at the top and bottom which have right and left hand threads. An alternative design uses lever operated clamp rings which are pivoted at the bottom and have an over-center locking device at the top.



Clamp Ring Closure



Threaded Closure



'Bandlock' Closure
(GD Engineering patent)

All of the closures except the blind flange use o-rings or similar self energizing seals and therefore do not rely on the tightening to cause a seal. However, they all require that the closure door be positioned correctly whenever it is operated. All closures except the smallest sizes therefore have hinges or some other means for supporting the weight of the closure door so that it can be moved into or out of sealing position.

If the closure cannot be installed with the hinge vertical to allow the closure door to open horizontally, it is usually necessary to provide a counterbalance so that the closure can be operated more safely and with reasonable ease.

4.4.2 CLOSURE DESIGN

4.4.2.1 SAFETY

A number of serious accidents have occurred due to closure failure and/or incorrect operating procedures and they are probably the biggest single cause of accidents during pigging. Closures are the subject of stringent code requirements and reference must be made to the relevant documents to ensure compliance.

It is essential that the closure is fitted with a pressure related device that will prevent opening of the closure door when the pig trap is pressurized and that will prevent pressurizing the pig trap if the closure is not closed and in its correct position.

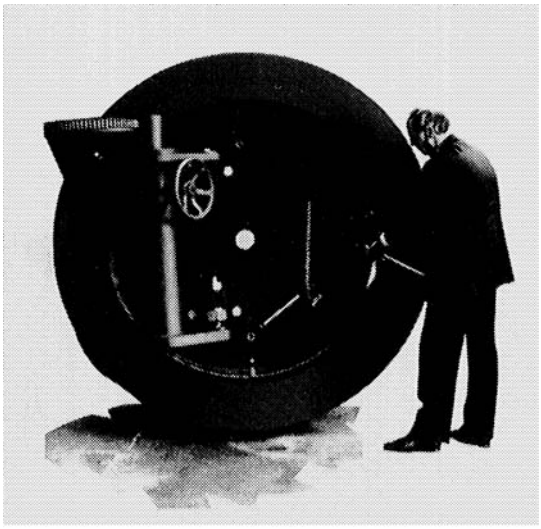
These pressure safety devices are of varied design but most have in common a means of preventing opening of the closure until the safety device has been removed and likewise the safety device cannot be installed unless the closure is locked in the proper position. Most of these safety devices have unique design features to prevent alternate bolts, screws, etc. from being substituted for the safety device.

4.4.2.2 OPERATION

Closures are designed for ease of operation. Before attempting to operate a closure it is essential to ensure that any pressure in the trap is released. All traps should have a pressure gauge to indicate the pressure within the trap. Even when the gauge indicates no pressure, the safety device must be unlocked before the closure can be opened and this will verify the absence of pressure in the trap.

When closing the closure, the safety device cannot be locked in position until the closure is closed completely and correctly, and this will prevent the trap from being pressurized.

Note: Basic procedures covering launching and receiving pigs will be found in section 10.



Large Closure *Courtesy: GD Engineering*

4.4.2.3 PROTECTION

Closures are usually exposed to the elements and the working parts should be adequately protected, as should the materials themselves.

This can be difficult because the hinges, sealing surfaces and other mating parts are precision machined and the traditional coat of paint, unless applied by a skilled worker, may create more problems than it solves.

Stainless steel or more exotic materials cannot normally be used because of their cost and their incompatibility with the surrounding carbon steel components. However, certain parts may be effectively protected with electro, or electroless plating.

The best form of protection is generally a factory applied epoxy resin paint to all exposed surfaces except those requiring subsequent fit-up (such as weld preparations), precision machined surfaces and mating parts. These sensitive areas should be treated individually using proprietary lubricants and protective coatings.

4.4.2.4 SEAL

Closures usually use an o-ring as the sealing means. Some closures use other cross-section designs to assist with the initial seal but almost all of the seals are self energizing once the initial seal has been made.

It is important that the sealing surfaces are always kept clean and extra care should be used when inserting or removing pigs, so that these surfaces are not damaged during the operation.

As part of the standard operating procedures, before closing a closure, the seal and the sealing surfaces of both the closure door and hub should be cleaned and inspected for cuts or other damage and lubricated if appropriate. The trap should not be operated until any damage has been repaired.

4.4.2.5 HINGES

The closure door is usually hinged to allow the door to open for the insertion or removal of the pig. These hinges have adjustments so that the door can be placed in correct alignment for ease of opening and closing. The hinges are usually exposed to the atmosphere and therefore must be protected to prevent corrosion. Any seals, covers or other protective devices on the hinges must be kept in place and maintained in good condition. The hinges usually have a fitting for lubrication and they should be lubricated on a routine basis.

4.4.3 INSTALLATION

The closure is of a larger size than the pipeline because of the oversize of the pig trap barrel. The closure must be installed so that there is adequate space for the closure to be opened completely and allow working space to install or remove pigs.

The closure should be installed with the hinge vertical so that the closure door will open in a horizontal plane and therefore will not require additional equipment or undue force by the operator. This will also avoid the need for any additional fixtures to hold the closure in any particular position.

When the closure is installed on a trap that is not horizontal, such as an automated sphere launcher or on vertical traps, which are sometimes used on offshore platforms, the closure must either be counterbalanced or lifting equipment must be provided for handling.

The method used for opening and closing the closure should be considered during the installation so that it can be operated from a comfortable position and in a safe manner. If the closure cannot be operated from ground level, platforms must be provided with adequate steps and guards.

Provisions must be made at the closure end of the trap to retain any spillage that may occur when it is opened or when the pigs are being removed from the trap. A non-skid surface should be provided in the work area for the operator.

Where closures are used on traps containing hazardous materials, easy access must be provided in case of an emergency.

4.4.4 SELECTION

4.4.4.1 SAFETY

Safety must be a prime consideration in the selection of any equipment to be used on or around a pipeline.

It is assumed that all closures being considered are functional and meet all relevant codes. Therefore safety considerations would be given to the ease of access to all components that must be operated to open or close the closure. These components include, but would not be limited to the safety lock on the closure and the locking device for holding the closure closed.

Except for small traps, the closure will probably not be accessible for operation from ground level and would therefore have to be operated from a platform or similar device located at the trap. A closure that can be operated with the minimum of movement by the operator will normally be safer to operate.

If the closure door does not swing in a horizontal plane, it must be fitted with a means to lock it in the open position to prevent movement while the operator is working in front of the opened trap.

4.4.4.2 OPERABILITY

Whilst ease of opening is an important criteria, speed of opening is generally not (although it is often promoted as such). After ensuring the trap is depressurized and drained down, the basic steps required are simply to release the pressure safety interlock, release the door retaining mechanism and then open the closure door. When closing it, these operations would be reversed with the pressure safety interlock being the last item to be installed to verify that the closure is properly closed.

Closures are never operated unless the trap has been depressurized and that is why the pressure interlock must be removed first to verify the pressure has been released and installed last before pressure can be applied to the trap.

Hinge mounted closure doors can normally be moved by the operator with relative ease, however o-ring and similar type seals that have been in position for a period of time may be difficult to move initially so some assist may be needed to break the seal. Some assist may also be needed when closing it, to position the door properly against the seal.

To minimize the exertion by the operator the design should therefore be reviewed to see if such assists are needed, whether they are supplied and if so, whether they are accessible and easy to use. But it must be remembered that most closures are not operated often. Some may be monthly and many will be at much greater intervals, therefore most of the operations and assists for opening and closing closures are manual. However, particularly on the larger traps, in order to minimize the manual work required, hydraulic, pneumatic or mechanical devices are often provided. These are especially useful when the closure is built with a tray attached for moving pigs into and out of the trap.

4.4.4.3 MAINTAINABILITY

Closures are simple mechanical devices usually with few components, but they restrain very high forces and it is imperative that all of the components are capable of being maintained in good working order.

Some of the components are exposed to the pipeline product and others are exposed to the atmospheric environment. This means that all components are not maintained in the same way.

The seal must be cleaned and checked every time the closure is opened and closed so the seal and the seal surfaces must be easily accessible to ensure that they can be properly maintained and provide an absolute seal at all times.

If the seal is not in its near original physical condition and shape it must be replaced. This means that the seal must be easy to replace and spares must be readily available.

The locking mechanism must be easy to maintain to prevent corrosion and be designed to ensure that it can be reliably closed without having to use additional external force such as levers or hammers to force the locking mechanism into position. A closure will only safely hold its design pressure if the locking mechanism is in its correct position. The mating components must therefore be kept clean and free of rust or other corrosion and should be easy to clean and lubricate.

The safety lock is a critical component of the closure. Not only does it effect the final seal but it should not be able to be installed unless all other components are in their correct position. The safety lock must therefore be easy to clean and its seals easy to inspect and replace if necessary. Like the other components of a closure, the safety lock must never be forced into position.

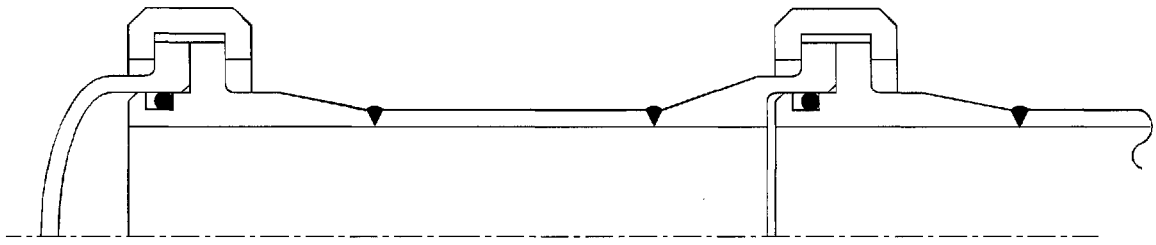
The importance of the safety lock cannot be over emphasized. It is well to remember that the closure is restraining a force equal to the cross-sectional area of the over size portion of the trap times the pressure per square unit. For example, the closure on a 24" trap with a 28" barrel at a pressure of 1000 psi is restraining a force of almost 300 tons.

The hinges are important in that they affect the ease of the closure operation as well as bringing the sealing surfaces into correct alignment. They are exposed to the atmosphere and therefore must have some form of protection. The hinges will incorporate bearings of some sort and these should be protected by seals to keep out any dirt. The bearings will normally have to be lubricated on a regular basis and there should be a means to facilitate this.

Whenever the closure is operated, the alignment should be checked and if it is not correct, there is usually a simple means of making any necessary adjustment.

4.4.4.4 ADAPTABILITY

Consideration should be given to selecting a closure which will allow an extension piece to be fitted to the barrel without modification (e.g. by using the closure seal or locking mechanism to attach the extension). This will allow greater flexibility in the event that there is a change in requirements at some later date.



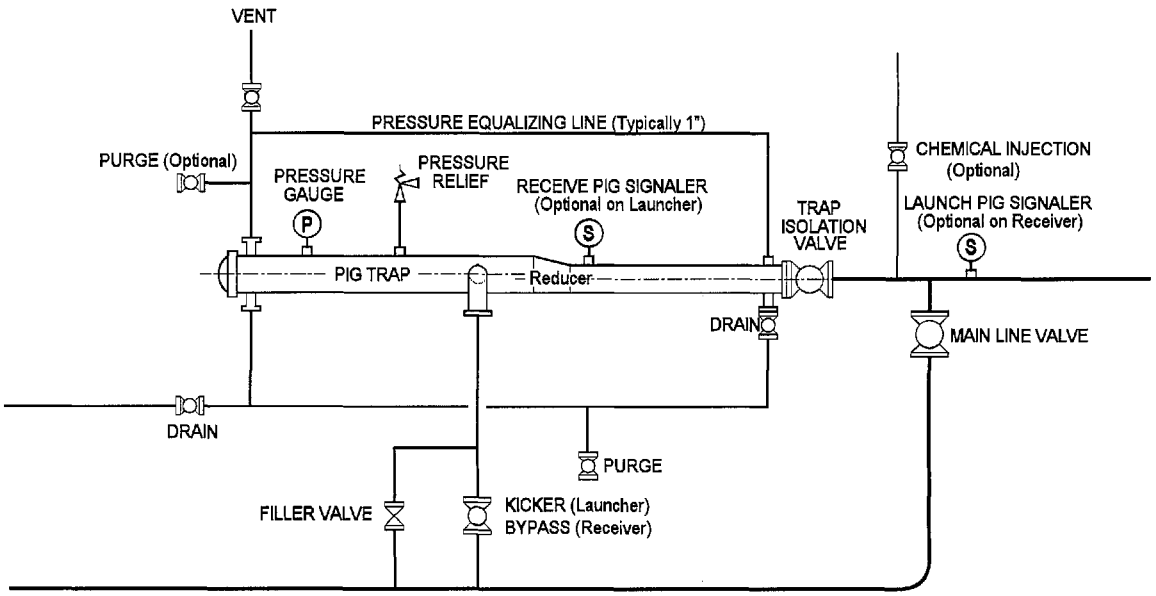
Temporary Trap Extension for ILI Pig, Utilizing Clamp Ring Closures

4.5 PIPEWORK LAYOUT and CONNECTIONS

4.5.1 KICKER AND BYPASS CONNECTIONS

To launch a pig into the pipeline, the trap must have piping to allow flow from the pipeline into the barrel of the trap at a point that is behind the pig. This flow will move the pig into the nominal bore section of the trap, out through the trap isolation valve and on into the pipeline. This piping is often referred to as the kicker line since it "kicks" the pig into the pipeline.

The diameter of the kicker piping may determine the procedure used for launching a pig. When the kicker piping is large enough, all of the pipeline flow can be diverted through the pig trap. This will create adequate differential flow across the pig so that positioning the pig within the trap may not be critical. If the kicker line is small, the pig must be positioned with its front seal snug into or against the transition to the nominal bore section of the trap. This will ensure that the flow through the trap is greater than any leakage past the pig to create sufficient differential pressure to launch the pig. The main line valve can be pinched (partially closed) enough to create a positive flow through the trap. However, care must be exercised to avoid pinching the main line block valve too much and causing an over-pressure alarm or shutdown at the pump station.



Typical Diagram for Launching and Receiving Traps

Similar piping is installed in the barrel of the receiving trap (receiver) providing a path for positive flow through the trap when a pig is to be received. Being in this position, the pipeline flow will continue to drive the pig out of the nominal bore section of the trap and into the oversize barrel. The pig then loses its seal and hence the differential pressure, which brings it to a stop. The flow then continues to go around the pig and exit the trap and it is for this reason that this connection is often referred to as the "bypass".

As with the launcher, the size of the bypass piping will determine the procedures for receiving. When the bypass piping is large enough, the entire pipeline flow can be diverted through the receiver. The pig will come into the trap and stop in the over size barrel section of the trap. This is a more common procedure on

liquid pipelines where the relatively low flow rates are such that the pig can easily stop within the space allowed.

However on many gas pipelines, or where flow rates are higher, procedures may be changed so that the pig can be received at a more controlled speed. One procedure for this method is to open the bypass piping when a pig is expected at the receiver but also leave the main line valve fully open. This will allow the pig to pass the tee just upstream of the trap isolation valve and then stop. The momentum of the pig may carry it into the trap or it may stop just past the tee outlet. In either case, the mainline valve is now pinched (partially closed) to create just enough differential across the pig to move it into the pig trap.

The receiver usually has a signaling device mounted on the nominal bore section to indicate when the pig is fully within the receiver.

The "rule of thumb" for sizing kicker or bypass connections is D/3 for liquid pipelines and 2D/3 for gas pipelines (where "D" is the nominal pipeline diameter). Many traps will have a small equalizing line and valve around the kicker and bypass line valves. This is used as an alternate for filling the trap without the potential for damage to the seats of the main kicker or bypass valves.

On the launcher, there should be a length of at least 2D between the kicker and the reducer, while on the receiver, the distance between the bypass and the reducer should be the minimum possible.

4.5.2 DRAIN POINTS

Drains are required at the lowest point of all traps, whether launchers or receivers. To minimize the chance for spillage and be sure that a drain is not blocked by a seal on the pig, it is good practice to install two drain connections with one in front and one behind the point where the pig may be lying in the trap. This will allow drainage of any and all liquids from the trap. These drains must be connected to piping so that the drained liquid can be disposed safely.

Situations have arisen where the drain line has become plugged at a point some distance from the trap. Drain lines should therefore be made up of "hard piping" (not flexible) designed for the full pressure rating until well clear of the work area.

Drain points, and any other connection located at the bottom, or "6 O'clock" position in the oversized barrel, should be fitted with a raised central bar to prevent the pig cups (or the sphere) from inadvertently sealing them off.

4.5.3 PRESSURE BALANCE

Pig traps must be filled slowly and the pressure within the trap must be equalized with the pipeline pressure before the trap isolation valve is opened. It is necessary to fill the trap slowly and vent any non-product from the trap as it is being filled. It is doubtful that the trap can be filled too slowly but it can certainly be filled too fast.

The trap isolation valve must never be used for filling the trap however, as previously mentioned, the kicker or bypass valve may be used for filling but damage to the seats can result and a small bypass line around these valves is preferred for filling .

If the fill connection is behind the pig, as it would be if the kicker connection were used, fast filling can force the pig against the trap isolation valve and may damage the pig or the valve. If the fill connection is in front of the pig, fast filling may force the pig backwards, out of its launching position in the reducer. This may damage the pig or even the closure and in any event, require the trap to be opened to reposition the pig for launching.

When filling the trap it is necessary to fill both in front and behind the pig and this requires a vent in both of these areas.

Some traps have small piping fitted between one end of the trap and the other to keep the pressure equalized both in front of, and behind the pig while it is in the trap. For maximum safety this piping will not normally have a valve as this could be closed and prevent pressure equalization within the pig trap. If a valve is installed in the equalization piping it must be tagged, that it should normally be in the open position.

If pipeline flow rates are such that the flow through the equalization line will prevent launching the pig, it would be desirable to delay the pig run until higher flow rates are available.

When the trap has been filled and vented and the pressure is equalized with the pipeline pressure, the launching or receiving procedures may be implemented. *(Refer to Section 10)*.

4.5.4 SIGNALERS

It is important that the position of a pig be known when it is being launched or received. This is usually done with a signaling device mounted on the pipeline.

At the launching end of the pipeline, the signaler is mounted downstream of the tee where the main stream joins the pipeline. This not only indicates that the pig has left the launching trap, but that it has also passed the tees and other downstream connections and is actually in the pipeline.

Many pipeline companies will locate a second signaler further downstream to provide a backup signal that the pig has been launched. This second signaler may be close to the edge of the station property or further downstream, sometimes at a distance of up to 1 mile (1.6 kilometers).

At the receiving end of the pipeline, a signaler is needed on the nominal bore section of the trap. This signaler will indicate that the pig is completely within the trap and the trap isolation valve can be closed without risk of damaging the pig. This means that the signaler must be located downstream of the trap isolation valve a distance equal to or greater than the length of the pig being run.

Some pipeline companies locate signalers upstream of the receiver at a point equivalent to the distance the pig will travel in about an hour. This can be a useful additional signal or alarm that the station piping must be set properly for the handling of the dirty product, interface, or simply to allow the pig into the trap.

4.5.5 VENTS or BLOWDOWN CONNECTIONS

A vent must be placed at the highest point of the pig trap. This is to allow release of non-product as the trap is being filled.

The vent is often used to verify that the trap is completely filled but in this event, care must be exercised to avoid spillage or danger to personnel.

The vent can be connected to the drain line or to a flare to allow disposal of most of the interface between the non-product and product, however a valve must be provided so that the operator can verify the status of the filling procedure.

The vent valve must be located to provide for easy access by the operator.

4.5.6 OPTIONAL CONNECTIONS

4.5.6.1 PURGE

The nature of the product or the location of the trap may make it necessary to purge the product vapors from the trap before it can be safely opened. For example, this might be caused by the product containing Hydrogen

Sulfide which is very toxic, even in small amounts. There are many other similar products.

The trap may need purging because it is located in a confined area where even a small amount of vapor could create a hazard. Whatever the reason, permanent purge piping may be connected to the trap for this purpose.

The trap may be purged with an inert gas or other appropriate fluid.

Whether the purge would pass through the trap to a drain or to a flare will depend on the purge fluid being used.

4.5.6.2 INJECTION POINT

In some pigging applications, it is desirable to run two pigs with some product other than the pipeline product between them. If the trap is equipped so that multiple pigs can be loaded and then launched one at a time, injection piping can allow this product to be injected without requiring the trap to be opened and additional pigs installed. The use of injection piping gives better control when such applications are undertaken.

4.5.6.3 VALVE BYPASSES

Most pipeline valves contain soft seats such as PTFE and these are not suited for throttling without damage. Therefore, as already discussed for the kicker and bypass piping, when a small flow is required and such a valve must be opened with differential pressure across it, piping with a valve should be provided to allow the flow and pressure to equalize.

4.5.6.4 INSTRUMENTATION CONNECTIONS

Quite apart from the need to be able to isolate a gauge or sample point on site, almost all pipeline functions and conditions are measured and monitored at locations that are remote from the point where the measurements are being taken. This remote site may be in the pump station or in the pipeline control room located perhaps hundreds of miles (kilometers) away.

In addition to monitoring the position of the valves (open or closed) at the pig traps, instruments will be used to monitor the pressure within the traps, so instrument connections will need to be provided on the traps and at various places within the pig station.

Instrument connections must be of such a design and located so that they cannot be damaged or blocked by any of the pigging or other activities.

4.6 AUTOMATIC PIG LAUNCHING AND RECEIVING

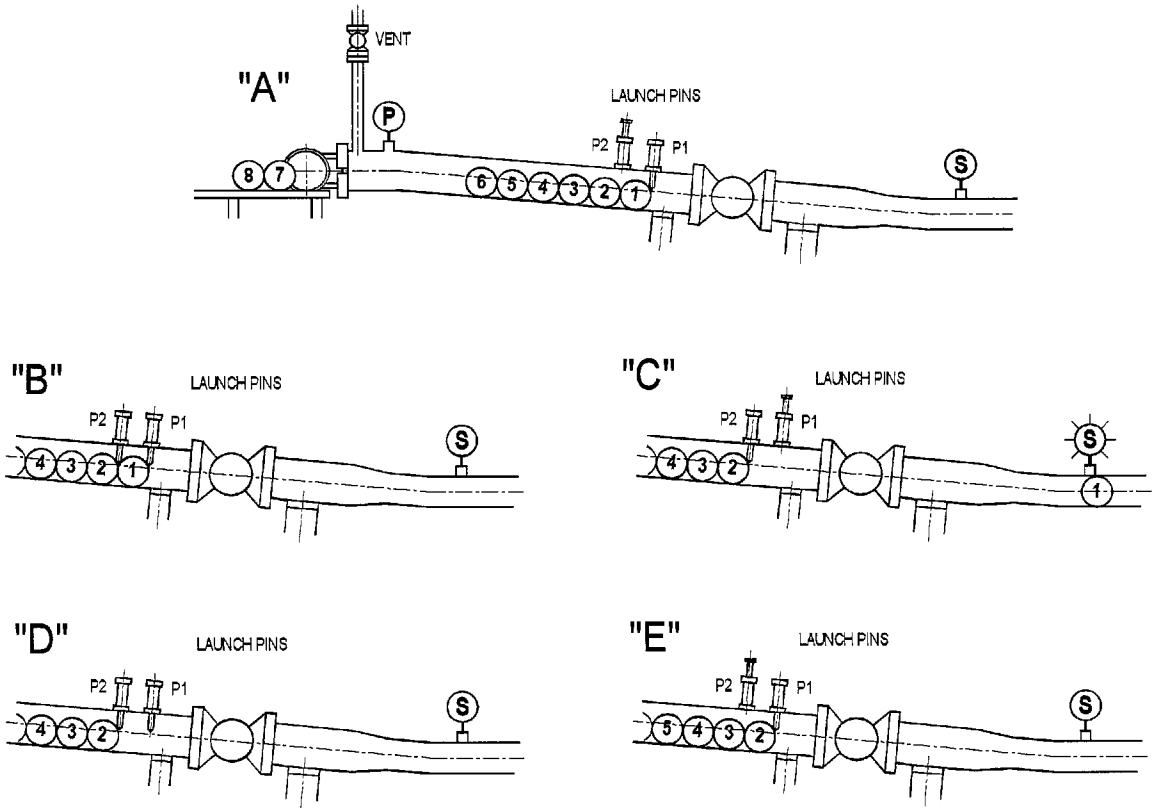
When a pipeline system has to be pigged frequently, the time, and hence the cost, of launching and receiving individual pigs becomes prohibitive. Typical examples are gas gathering or wet gas pipeline systems where there is a continuous dropout of condensate which must be kept under control by frequent pigging.

Where a large number of pigs are run on a regular basis, the efficiency of each pig is generally not critical. It is more important for the pigs to have a shape which enables them to be handled easily and it is for this reason that virtually all automatic pigging systems utilize spheres. Although the sphere is one of the least efficient pigs (having only one sealing surface) it will remove most of the unwanted fluids in a pipeline and the fact that it will roll freely, makes it ideal for use in automatic pigging systems.

By installing the launching and receiving traps at a slight angle to the horizontal (normally about 5°) several spheres (as many as 12 is not uncommon) can be loaded into the launching trap and can be launched into the pipeline by releasing them one at a time.

The most common method of releasing spheres individually is to install two 'pins', spaced one sphere diameter apart at the pipeline end of the launching trap. Each pin is essentially a hydraulic cylinder, the ram of which protrudes into the pig trap and prevents a sphere from passing it until it is retracted.

When loading the spheres, the downstream pin is extended and the spheres are simply rolled into the trap such that the first sphere comes to rest against the launch pin and this in turn holds back the remainder. When the upstream pin is also extended, the first sphere is trapped between the two pins. This sphere can then be launched by retracting the downstream pin. Once the signaler indicates that the first sphere has entered the pipeline, the downstream pin is again extended, the upstream pin is then lifted to allow the spheres to roll forward, bringing the second sphere into position against the downstream pin and await its turn to be launched by repeating this sequence.



Sphere Launch Pin Sequence

STEP	ACTIVITY	PIN 'P1'	PIN 'P2'
"A"	Loading	Extended	Retracted
"B"	Ready to launch	Extended	Extended
"C"	Launch	Retracted	Extended
"D"	Re-setting	Extended	Extended
"E"	Repeat cycle	Extended	Retracted

A similar arrangement is usually also installed at the receiving trap, but at the closure end to allow controlled unloading of the spheres.

These systems are very effective, but spheres are 'sized' by inflating them with a liquid (usually glycol and water) and in the larger sizes they become extremely heavy. A 40" sphere for example, may weigh over half a ton, so the shock load on the pin as a sphere rolls into position can be extremely high. This problem is compounded in traps designed to hold a large number of spheres and there is a possibility that the launch pin will become distorted and may even be physically bent. This can cause leakage around the seals of the pin and in extreme cases, may make it impossible to operate.

To overcome this problem one manufacturer, GD Engineering, has developed a 'flap' release mechanism. The flaps are designed to absorb very high loads and contain shear pins to cater for any extreme forces which may occur. They are installed in pairs in the same relative position as the pins would normally be, but they are operated by a single hydraulic (or pneumatic) cylinder. This actuates an external twin cam mechanism, making it impossible for the flaps to get out of sequence. The single cylinder also simplifies the fluid power system, so it is ideal for use at remote unmanned locations, especially offshore. The flaps can be manually locked in the 'up' position to enable cup-type pigs or ILI tools to be launched and received.

Another system uses a special ball valve that has a cavity within the valve ball capable of holding one sphere. When the valve is rotated 180 degrees to launch a sphere the design of the ball prevents additional spheres from moving into the launch position until the valve has returned to its initial position. Then the next sphere rolls into position ready for launch.

4.7 PIG HANDLING

4.7.1 HANDLING AREA

Space must be provided around the trap area so that the closure can be opened while allowing adequate space for the operators to maneuver safely. The handling area must also provide space for the pig or pigs to be installed in, or removed from the trap.

Larger traps may have trays attached to the closure so that when it is opened and retracted, the tray will be accessible for installing or removing pigs. The tray will be approximately the length of the barrel of the pig trap.

The area must be designed so that any fluids dripping from pigs that have been removed from the pipeline will be safely contained. The work area should be such that any spillage will be drained to a sump for safe disposal. This area may be covered with grating to provide a safe walkway for the operators.

The handling area around the trap must be treated the same as any other work area and escape routes must be available in the case of an emergency.

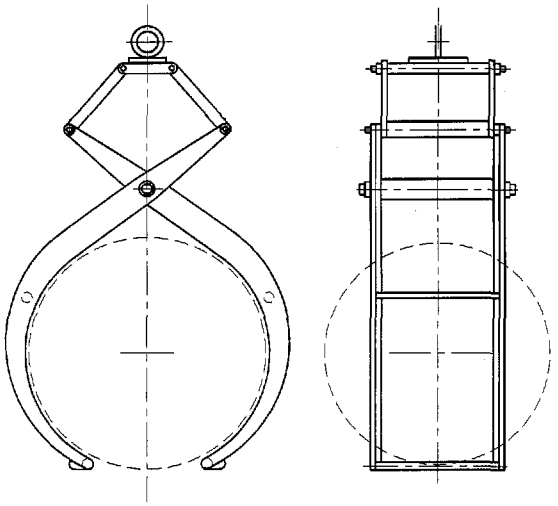
4.7.2 LIFTING EQUIPMENT

Many pigs are too heavy for manual lifting. In addition, pigs that have been removed from the pipeline may be covered with debris cleaned from the pipeline as well as with the pipeline product. As a result the pigs can often be heavy, dirty, slippery and dangerous to handle manually.

Handling equipment must be provided for lifting the pigs from or onto the vehicle that will transport them. Lifting equipment will also be

used when loading the pigs into, or removing them from the trap. This may require the handling equipment to be moveable to handle the pigs anywhere within the area of the trap. Jib type cranes are often used for this purpose.

If spheres are to be handled, special lifting devices must be provided to attach to the sphere. Smaller spheres can be lifted using a suction cup device, but since the spheres are filled with liquid, a sphere may be heavier than a pig for the same pipeline. As already stated, a 40" sphere for example, may weigh over half a ton (500 kg) and this might best be handled using lifting tongs.



Sphere Lifting Tongs

4.7.3 ACCESS

Most pigs larger than 12" size will be too heavy for handling manually and handling equipment will be needed. Therefore, access must be provided to the trap area for a vehicle to deliver or pick up the pigs. All ILI tools, with a few exceptions, will be of such weight and size that they will need to be delivered to within range of the lifting equipment at the pig trap. All traps, whether launching or receiving will require approximately the same provisions for access, handling and work areas. When other piping must be crossed for access to the pig trap, stairs and platforms or pipe bridges must be provided for a safe crossing.

4.7.4 Safety

Many pipelines contain a product that is flammable and therefore care must be exercised to avoid a fire or explosion whenever any operation is being performed.

In hazardous situations, traps should be earthed to avoid the risk of static electrical discharge and precautions must be taken to prevent sparks and other sources of ignition.

The products may also be toxic and therefore the atmosphere must be monitored to ensure the safety of the personnel in the area.

Certain residues in the trap can vaporize when the pressure is reduced to atmospheric, or they may ignite spontaneously when exposed to atmosphere.

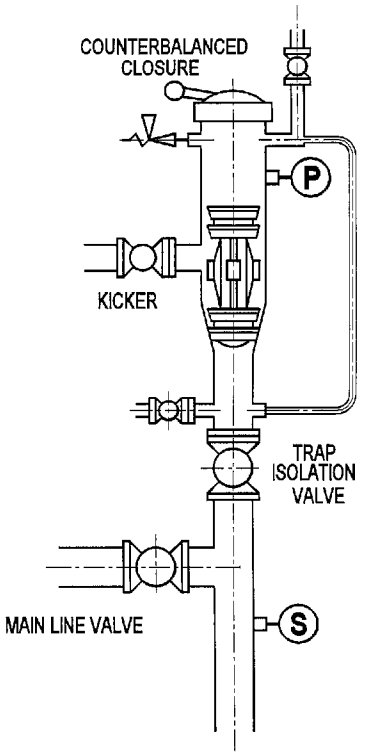
The residue in the trap may be from a sour product, that is, it contains Hydrogen Sulfide. Hydrogen Sulfide is very toxic and if it is discovered in any quantity, fresh air breathing equipment must be used unless the environment is monitored and proved to be safe.

4.8 OFFSHORE--TOPSIDES

Pig stations for offshore use on platforms will conform to most of the same dimensions and conditions as those used on shore. Some changes will be made because of the confined space on the offshore platform. For this reason, it is not uncommon to have the closure facing out to sea. This eliminates the need to provide handling space within the confines of the platform, and with suitable temporary structures in place, it can make loading and

provides an additional level of safety in the (unlikely) event that a pig should arrive at too high a velocity and perhaps damage the closure door.

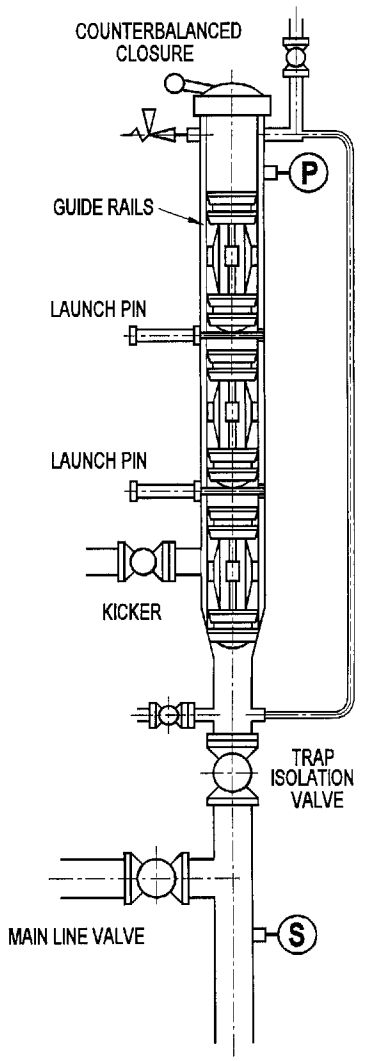
Another space saving method is to mount the traps in a vertical position. This makes handling of the pigs and spheres more difficult, and often complicates things for Magnetic Flux Leakage (MFL) ILI tools. The powerful magnets on these tools tend to 'grab' the wall of the trap as they enter and they cannot be pushed in because of the universal joints between the modules. To overcome this, MFL ILI tools may be first installed in a non-magnetic stainless steel sleeve which is lowered into the trap with the pig and then slid back out either after the launch or once the pig is in position.



Vertical Pig Launcher

In spite of the problems they create, vertical traps can provide a practical solution to space saving at both launching and receiving stations where floor area is at a premium on the platform. They can be used to dispatch pigs individually using a ladder system with an internal guide frame. Spheres are normally released individually through a lower flap mechanism only.

Receiving pigs in a vertical trap with the pig traveling upwards was at first thought to be a problem but by using purpose designed and approved internal reception baskets and or simple ledges which act like a sprag, it can and is performed very successfully.



Vertical Multiple Pig Launcher
(May also be designed for ILI Tool)

However, most offshore pig stations are launchers with the receiver being at some onshore location. This allows the debris and the dirty pig to be handled onshore so provisions are not generally required on the

the dirty pig to be handled onshore so provisions are not generally required on the platform for this function. If pig receivers are located on the platform, the same provisions must be provided as mentioned above for onshore applications.

Another difference between pigging at offshore locations, compared to onshore, is that subsea pipelines are generally constructed with a thicker wall than normally used onshore. Therefore the pig or sphere will have to be sized to suit. In addition, for safety reasons, the part of the pipeline between the platform and the sea bed, called the "riser", will generally have a still thicker wall. This therefore requires a pig that will have to traverse a smaller diameter at the start of its run, down the riser, than it will encounter during most of the rest of the pigging run.

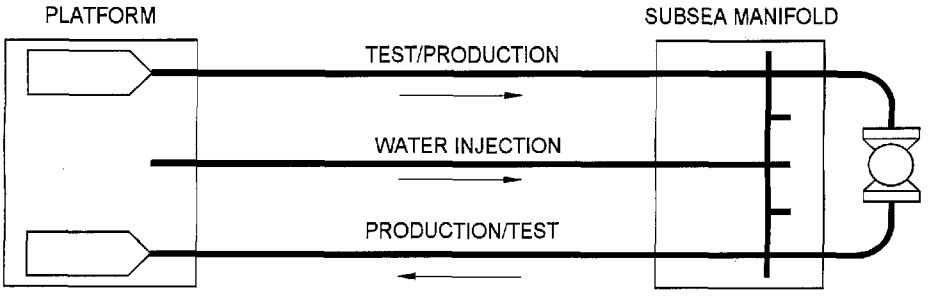
If it is received on a platform, it will also have to traverse a similar smaller diameter section at the end of its run too. This increases the differential pressure (DP) and if it is propelled by gas or air and is pushing a column of liquid ahead of it the DP will increase still further. As the liquid is discharged at platform level, the DP due to static head may fall off rapidly and cause the pig to progressively accelerate. There are no known instances where this has caused serious problems, but it needs to be taken into account when developing procedures for this type of situation.

Weight saving is another thing which must be considered on an offshore platform. Even a small pig trap complete with all its connecting valves and pipework will have a significant total weight and larger ones will weigh several tons. As a result, a great deal of work has been done to minimize the number of traps on a platform.

One innovative development was known as the "Multisize Pipeline Pigging Facility" (MPPF). It was funded by Shell UK Exploration with support from the UK Department of Energy.

The basic concept was to have one pair of pig trap barrels mounted on rails that could be moved to connect to and provide launching and or receiving facilities for almost any number or size of pipelines. The end of each pipeline was fitted with a closure and a transition piece to reduce down from the trap to the pipeline size. The closures were TDW clamp ring types where the door can be swung completely clear. The trap barrel could then be moved into position and the closure clamp ring was then used to lock the barrel into position for either launching or receiving. The barrel was fitted with a cassette to suit the particular pipeline. As far as is known, this system was never put into service but the full scale test facility worked successfully with 6", 12" and 20" utility and ILI tools.

The development of marginal fields is also resulting in some new approaches to space and weight saving on platforms. Subsea processing is still some way off so the produced fluids from the subsea satellite developments are generally transported to the nearest fixed platform or to a floating production facility through a flow line system.



Conventional Looped System

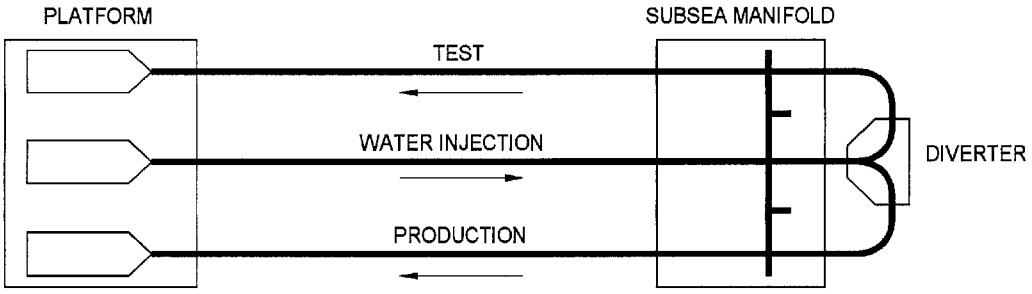
On most subsea production systems the wells feed into a header on a manifold which is tied back to the platform by three flowlines: production, test and water injection.

Pigging these flowlines may involve the installation of a subsea launcher, but the trend is more towards using a pigging loop to enable 'round trip' pigging from the platform.

This allows a pig to be launched from the platform, travel down one line, then cross over via a 'pigging loop' to return back along one of the other lines. As the water injection line rarely needs pigging, it may be sufficient to pig down the test line, through the loop then back along the production line.

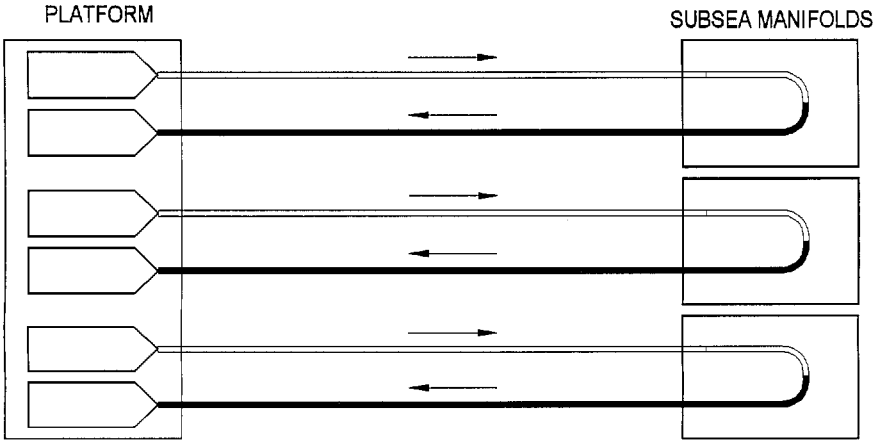
If only the production or the test line needs to be pigged, not both, then the water injection line can be used to send the pig down to the manifold to return along whichever line needs to be pigged.

If all three flowlines need pigging, then it is probable that the water injection line would still be used to send the pig down, but a subsea diverter would have to be installed at the manifold to direct the pig into whichever other line had been selected. Alternatively, the production and test lines could be looped and the water injection line pigged separately, by being designed to be 'open ended' so allowing the pig to exit at the manifold and be recovered by a Remote Operating Vehicle (ROV), a type of 'unmanned submarine'.



System Using Water Injection Line and Diverter

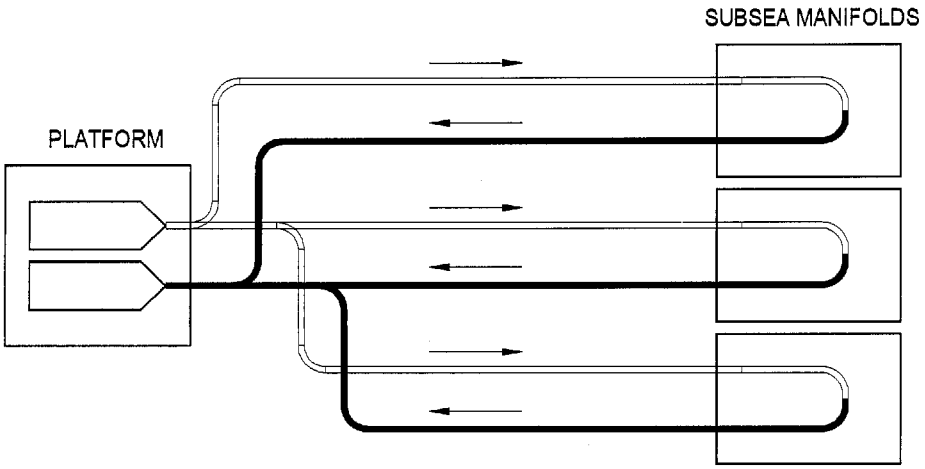
The flowlines normally terminate on the platform with conventional pig traps, but on some platforms, the number of flowlines becomes excessive and both weight and space for traps becomes a problem.



Conventional Looped System

The "Multisize Pipeline Pigging Facility" (MPPF) has already been described and might provide a solution, but most of these flowlines are 12" diameter or less, and many are the same size. The latter case presents another solution to the problem which has been used successfully.

A single launcher and a receiver are installed together with a series of wyes and diverters, all on the platform. In this way, flowlines of common sizes all share the same traps. The valving is complicated, but the space and weight savings can be significant.



System Using Wyes and Diverters

4.9 OFFSHORE--SUBSEA

Provision for a subsea launcher and pigging from there to a platform or to shore is generally only adopted for the larger pipe diameters and longer distances, where the economics cannot justify a parallel line which would allow a pig to be 'looped'.

Subsea launch traps are not intended for routine operational pigging and they are generally stored onshore. Few such systems have yet actually been used to launch a pig, except as part of the commissioning procedure. In fact, most subsea pig launches to date have been from temporary traps or laydown heads and have been carried out by contractors during construction, repair or maintenance.

A subsea receiver is very rarely, if ever used for operational or inspection pigging. Temporary subsea receivers may occasionally be used during the construction phase, when the line contents can be disposed of into the sea.

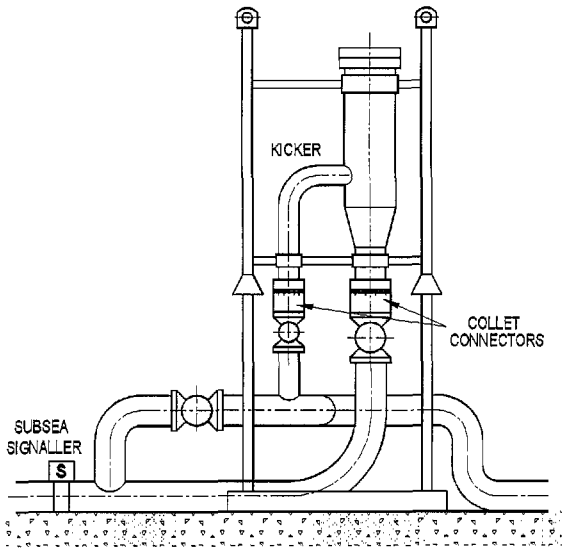
Because subsea pig stations are used only for very special situations, they are generally designed for a specific purpose and require specialized procedures for their operation. Some will be designed to be operated by divers while others may be operated remotely.

There are some similarities between subsea and conventional onshore pig traps but to minimize the subsea work requirement the overall design may be very different.

To minimize the number of deployments, each of which is very costly, most subsea traps are designed to be 'multi-shot'. That is, they are designed to contain a number of pigs, often loaded in a cartridge, each of which can be launched individually. Often, it would also be capable of handling an intelligent pig, although

this would almost always require a separate deployment.

Normally, the pigs are loaded into the trap barrel onshore. The assembly is then shipped out and installed as a unit at the launch point. This usually involves removing a special cap at the manifold and then lowering the trap, using guideposts for accurate positioning, and then locking it in place with some type of 'quick connection'. These connectors may be similar to that used on a closure or they may be hydraulic or remote operated collet connectors. Often the operation requires diver intervention. It is therefore costly and very weather dependent.



Schematic Layout of Subsea Launch Trap

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5.0 UTILITY PIGS

5.1 DESCRIPTIONS

Utility pigs can be divided into two groups:

a) "Cleaning pigs" - for removing accumulated solids or debris.

b) "Sealing pigs" - for removing accumulated liquids, separating dissimilar fluids, filling, dewatering, etc.

Cleaning pigs are often referred to as "scrapers", while sealing pigs may be called "batching" or sometimes "swabbing" pigs.

The type of pig used for cleaning a pipeline will depend largely upon the nature of the material which is to be removed. As there is an almost infinite number of different sediments, deposits and other substances which can cause reduced throughput, there is similarly a very large number of different types or configurations of pig which might be used to combat these problems. Often a single configuration of pig may not be the optimum for even one pipeline, let alone all pipelines.

Similarly, the final type and configuration of a sealing pig will depend upon its purpose. Typical applications of sealing pigs include:

- Removal of condensates/liquids from gas lines
- Separation of dissimilar fluids in multi-product lines
- Line filling prior to pressure testing
- Dewatering after pressure testing
- Commissioning (separating slugs of methanol, nitrogen, etc.)
- In situ internal coating
- Product removal prior to shutdown

To cater for all the different requirements, cleaning and sealing pigs are provided in four different forms:

1) *Mandrel pigs*: which are assembled from a number of component parts and for which spare parts are available. Mandrel pigs are available in most sizes.

2) *Foam pigs*: which are molded from polyurethane foam with various configurations of solid polyurethane strips and/or wire bristles, studs, etc., permanently bonded to them. Foam pigs are available in most sizes.

3) *Solid cast pigs*: which are molded in one piece - usually from polyurethane. These pigs are normally only available in the smaller sizes.

4) *Spheres*: normally filled with water/glycol, these pigs can be inflated to the optimum diameter. Spheres are available in most sizes.

It should be noted that most standard pigs can only traverse the line in one direction, however "bi-di" pigs are capable of traveling in either direction (i.e. bi-directional). Multi-diameter (or "double-diameter") pigs can traverse a pipeline which has more than one nominal diameter (normally only one or two line sizes different).

5.1.1 MANDREL CLEANING PIGS

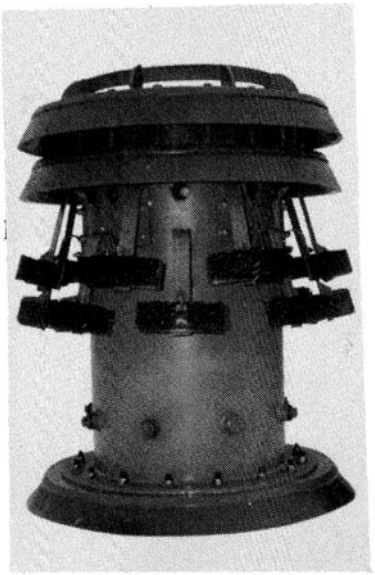
Mandrel pigs are made up of a number of component parts which are mounted on a body tube so that they may be replaced or re-configured as the need arises.

The main components are the pig body, the seals (cups), which may be either cup shaped or discs to provide the drive, and the cleaning elements which provide the means to scrape or wipe the pipe wall. The cleaning elements may

be mounted on springs and the individual components are often separated by spacers.

With careful design, a relatively small number of standard components can be assembled in different ways in order to build pigs suitable for different types of pipeline.

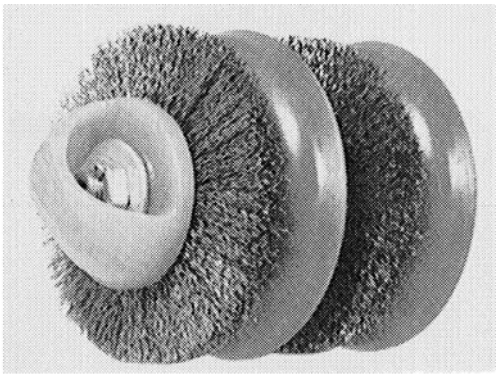
Mandrel cleaning pigs in particular are configured in many different ways. Variations include, the number of seals, the seal spacing, the overall length, and the type and spacing of the cleaning elements.



Cleaning Pig equipped with brushes *Courtesy: Pipeline Engineering*

The conditions of the pipeline are the determining factor for many of these variations. The radius of the bends will determine the overall length of the pig, as well as the location of the seals and cleaning elements. The shorter the radius of the bend the shorter the pig must be in order to traverse the bend. The shorter radius bends and therefore shorter pigs may mean that there can only be one row of cleaning elements on the pig, and that the seals must be placed at each end.

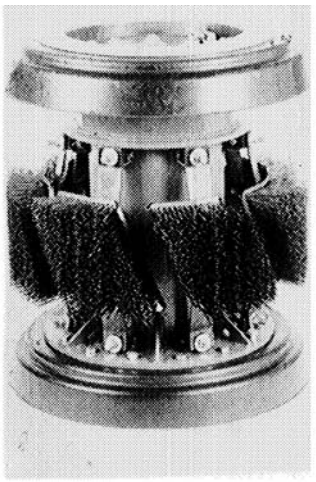
In general, pigs 6" and larger have spring mounted cleaning elements which will keep the cleaning element in contact with the pipe wall as the element wears.



Small Cleaning Pig *Courtesy: T.D. Williamson, Inc.*

Pigs smaller than 6" generally use wheel type cleaning elements and therefore do not have a means for wear compensation.

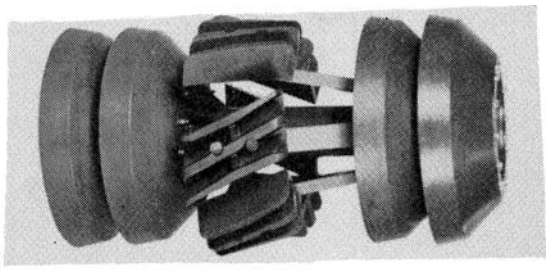
In order to get complete coverage of the inside pipe wall the cleaning elements are shaped and mounted so that some parts of the cleaning element will overlap to give cleaning contact for the entire circumference.



Cleaning Pig *Courtesy: Pipeline Dehydrators Inc.*

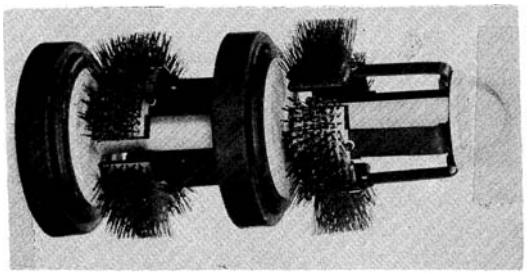
If there are check valves in the pipeline, this will also determine some of the design factors for the pig. The pig must be long enough and the seals so placed that it will span the gap caused by the bowl of the check valve to ensure that at least one seal will be in sealing position at all times. Some pigs have seals at or near the middle to help support the pig as it traverses the check valve.

When the pig is not restricted in length, there will usually be two rows of cleaning elements, as large as possible, and so mounted that the cleaning elements in one row are positioned to cover the spaces between the cleaning elements in the other row. Therefore the entire pipe wall will be contacted by a cleaning element as large as practical for the size of the pig.



Cleaning Pig *Courtesy: T.D. Williamson, Inc.*

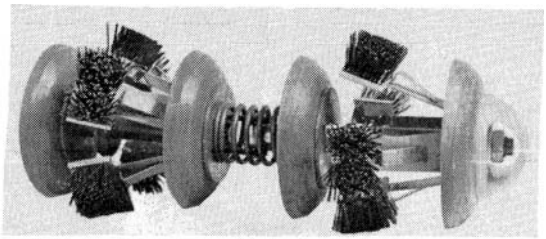
A pig supplier will often have a variety of parts that can be assembled in different configurations to meet the conditions of the pipeline. For example a pig for traversing a check valve could have seals on each end and have two rows of cleaning elements between the seals. Alternatively, these parts may be assembled with a seal in the middle and at the rear to allow the pig to traverse a bend, and a row of cleaning elements in front of each seal to provide a similar cleaning capability.



Cleaning Pig *Courtesy: Pipeline Dehydrators, Inc.*

If the pipeline contains valves that do not have a continuous bore, such as a wedge gate valve or similar, seals are spaced on the pig so that the pig is supported and the front seal cannot drop into the gap in the valve. This can be done by placing a seal near the middle of the pig or two seals may be placed near the front with the spacing adequate to span the valve gap.

When the pipeline contains side outlets, the pig must have its seals spaced such that they will span the opening of the outlet. This means that sometimes a pig must be short to traverse the bends in the pipeline but also needs to be long to span a side outlet, a check valve or some other type of non continuous pipe wall. This situation can be resolved by using two short pigs coupled together with a universal joint or by using a flexible body. In this way, the pig will be able to traverse all of the conditions in the pipeline.



Cleaning Pig with Universal Joint *Courtesy: T.D. Williamson, Inc.*

5.1.2 MANDREL SEALING PIGS

Mandrel sealing pigs are similar to cleaning pigs - but without the cleaning elements. They also come in various configurations to meet the conditions of a particular pipeline.

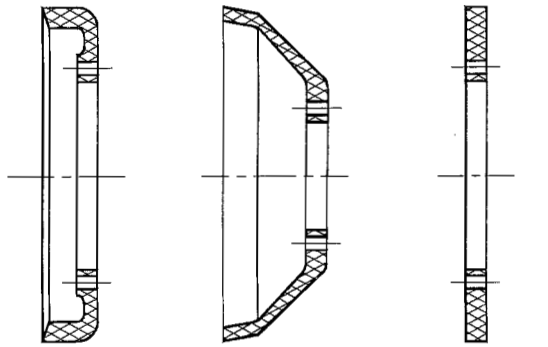
Many of the factors that affect the design of cleaning pigs also affect sealing pigs but the spacing of the seals is more critical than it is on a cleaning pig. For a cleaning pig, it is only necessary to obtain a seal which creates enough differential pressure to move it. In fact, for cleaning, some leakage or 'bypass' at the point where the seal contacts the pipe wall can be beneficial, but the purpose of a sealing pig is to effect a seal and this determines both the type and spacing of the seals.

A sealing pig will have multiple seals, ranging from two to six, and sometime more.

Seals fall roughly into the three types:

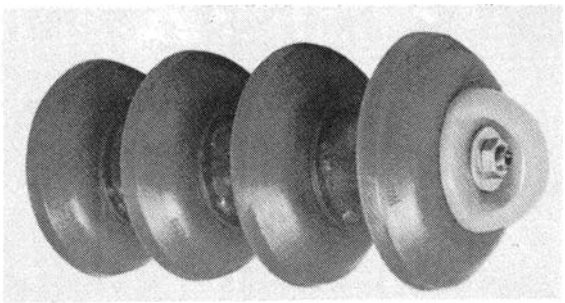
1) The "Cup" seal, which was the earliest type and was derived from the hydraulic piston seals.
2) The "Conical" seal which had its origins in the early ILI tools.
3) The "Disc" seal which originated with the bi-directional pig.

These are discussed later in more detail in Section 5.2.



Typical Pig Seals

For the pipeline with short bends that requires a short pig, the seals may have to be close together. For the longer pig the seals may be equally spaced over the length of the pig or they may be grouped near each end.



Small Sealing Pig *Courtesy: T.D. Williamson, Inc.*

When the pipeline size gets larger, a pig that will traverse the bends may also be long enough to traverse check valves and side outlets, so one pig may meet the conditions for several applications.

5.1.3 FOAM PIGS

As with so many other products, the principle advantages of using plastic materials for pipeline pigs were apparent before the materials themselves were really sufficiently developed. Low cost price, zero maintenance and reduced risk of 'sticking', encouraged many operators to use them for purposes for which they were not suitable. As a result, some of the early foam pigs gained a questionable reputation, which in most cases was undeserved.

Today, the technology has developed to a point where foam materials have a very high tear and wear resistance. Most manufacturers now include some foam pigs in their range, but those who specialize in these products may carry over 30 different standard types.

Foam pigs are widely used in the pipeline industry, especially for rehabilitation work. They are also particularly useful when developing a pigging program for a line which has not been regularly pigged and which may contain some unexpected problems.

Foam pigs are made of open cell polyurethane foam. The open cell structure is required so that the pig does not compress when it is subjected to pipeline pressure.

Foam pigs are light weight and easy to handle, however when removed from a liquid pipeline the open cell foam will be full of the product and therefore may require special handling.

Foam pigs may be a simple cylindrical shape with a flat front and rear. However the rear face is usually covered with a thin polyurethane coating to block a flow path through the open cell foam.

The density of the foam used normally ranges from around two pounds per cubic foot (32 kg per cubic meter) to eight pounds per cubic foot (128 kg per cubic meter) depending on the

8 lbs/cu. ft. density

SBD (Scarlet Bare Durofoam)
Heavy Wiping & Dewatering

SSS (Scarlet Single Spiral)
Heavy Wiping

SCC (Scarlet Criss-Cross)
Heavy Cleaning & Dewatering

SCC-WB (Scarlet Criss-Cross Wire Brush)
Heavy Scraping

SCC-SC (Scarlet Criss-Cross Silicon Carbide)
Heavy Scraping

SCC-T (Scarlet Criss-Cross Turning)
Heavy Cleaning & Dewatering

SCC-WB-T (Scarlet Criss-Cross Wire Brush Turning) Heavy Scraping

SCC-SC-T (Scarlet Criss-Cross Silicon Carbide Turning) Heavy Scraping

2 lbs/cu. ft. density

YBS (Yellow Bare Swab)
Drying

YBS-B (Yellow Bare Swab Bullet)
Drying

YCC (Yellow Criss-Cross)
Light Cleaning

YCC-SC (Yellow Criss-Cross Silicon Carbide)
Light Scraping

YCC-T (Yellow Criss-Cross Turning)
Light Cleaning

YCC-SC-T (Yellow Criss-Cross Silicon Carbide Turning) Light Scraping

5 lbs/cu. ft. density

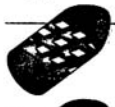
RBS (Red Bare Squeegee)
Regular Wiping & Dewatering

RSS (Red Single Spiral)
Regular Wiping

RCC (Red Criss-Cross)
Regular Cleaning & Dewatering

RCC-WB (Red Criss-Cross Wire Brush)
Regular Scraping

RCC-SC (Red Criss-Cross Silicon Carbide)
Regular Scraping

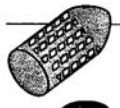


RCC-T (Red Criss-Cross Turning)
Regular Cleaning & Dewatering

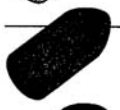
RCC-WB-T (Red Criss-Cross Wire Brush Turning) Regular Scraping

RCC-SC-T (Red Criss-Cross Silicon Carbide Turning) Regular Scraping

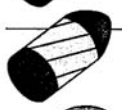
Special Applications



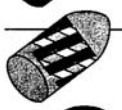
Unicast
Batching & Purging



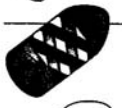
Maxi-Brush Heavy Wire
Maximum Scraping



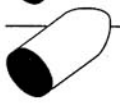
Maxi-Brush Light Wire
Maximum Scraping



Gray Hard Scale
Industrial Scraping



BCC-PB (Blue Criss-Cross Plastic Brush)
Non-Abrasive Brushing



KRG
Drying For Polyethylene Pipe

Various Types of Foam Pigs

Courtesy: Girard Industries

purpose. In general the higher the density the greater the wear life and performance

Foam pigs are often molded to provide a cone or dome shape on the front and perhaps a concave surface at the rear.

Plain foam pigs are generally used as sealing pigs and they may have a thin polyurethane coating on the outside surface to increase service life. Being of cylindrical shape they contact the wall over their entire length and this reduces the unit loading. But to seal well, a pig must maintain good tight contact with the pipe wall so to achieve this, criss-cross or spiral strips of solid polyurethane are bonded to the outside. These expand outwards when the pig is 'squashed' by the differential pressure which it generates. These strips also provide a greater degree of both wear and tear resistance as well as some compensation for wear.

Foam pigs to be used for cleaning are provided with various outside coatings. The coating may cover the entire surface that will contact the pipe wall or it may be in strips running from front to back in a spiral shape or in rings around the body. These coatings may also have abrasive materials imbedded in them such as grit or carborundum. Fine wire strip brushes or hardened steel pins may also be bonded to the surface during manufacture. These are usually installed over the length of the pig in a spiral to give complete coverage of the pipe wall.

Foam pigs are not made to be rebuilt and when worn beyond acceptable use, they are discarded.

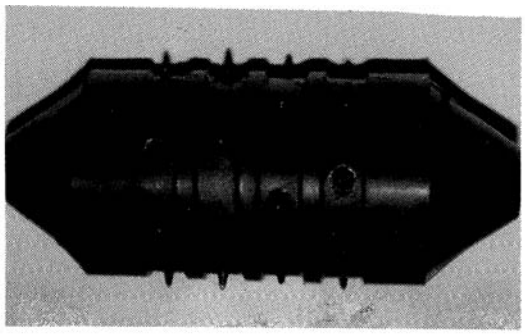
The advantages of foam pigs are:

- they are usually the least expensive pig available
- they are expendable
- they are very flexible and will not normally become stuck where a hard body pig might
- they are easier to insert into a pipeline without pig traps.

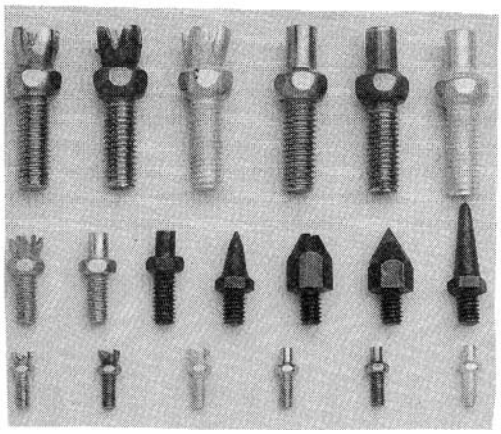
The disadvantages are:

- they are not as effective as most other types of cleaning pig
- their service life is much shorter than that of most other pigs
- because of the open cell material, the used foam pig will be full of the pipeline product and will require special consideration for storage or disposal.

Although many foam pig manufacturers can supply similar pigs, two in particular specialize in making foam pigs for very arduous duties. Decoking Descaling Technology Inc. (DDT) and PEC Corporation have developed pigs with a very dense foam into which are molded threaded steel inserts. Various types of hardened steel pins can be screwed into these inserts, the type used being determined by the material which is to be removed from the pipe wall.



DDT Foam Pig with Pins *Courtesy: Decoking Descaling Technology Inc.*



Various Pin Shapes for DDT Pig *Courtesy: Decoking Descaling Technology Inc.*

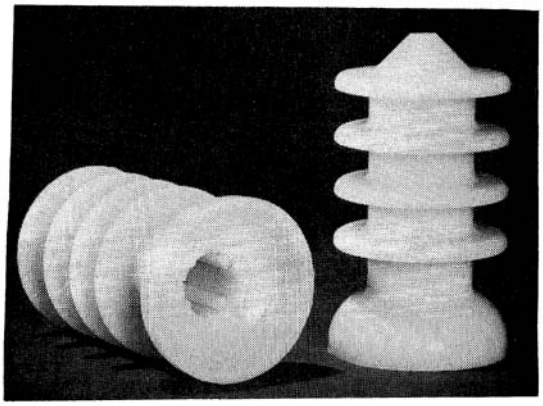
DDT can supply these pigs in both cylindrical and spherical shapes. These pigs are commonly used for removing heavy scale and coke and, under these conditions, they are much less likely to get stuck than a more conventional mandrel pig because they are inherently flexible.

5.1.4 SOLID CAST PIGS

Solid cast pigs are usually made of polyurethane and most are made as sealing pigs. The solid cast pig was developed to produce a pig that would give results similar to a mandrel pig but since it was purchased for a specific use there was no need or desire to purchase a pig that could be rebuilt and would last for years.

Many pipeline companies use contract maintenance and it was found by them, as well as many operators, that the labor cost of assembling and replacing parts on small pigs is relatively high. A 2" diameter pig may take as long to assemble as a 6" or 8" size; in fact, the point at which it is cheaper to replace the whole pig rather than a single component is generally around the 12" size.

The cost of transporting pigs back to the launching points is another factor which often justifies the use of solid cast pigs

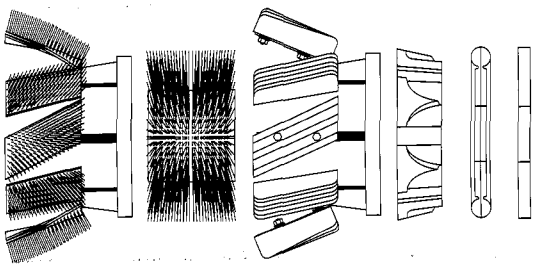


Cast one piece Sealing pig *Courtesy: Coulter Services, Inc.*

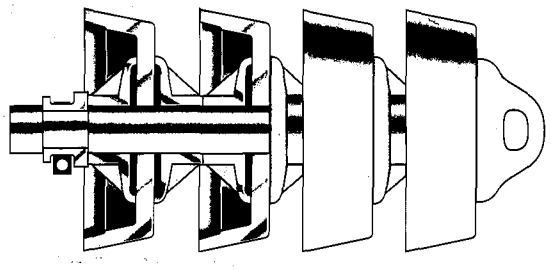
Solid cast sealing pigs are very common in the smaller sizes. Most small diameter lines are not very long and the pigs are not very heavy, so wear is not usually a problem. By making the pigs a little oversize the wear compensation is usually adequate and in any event, replacement costs are minimal. These types of pig are particularly useful in process plant systems.

Some companies now produce these pigs in much larger sizes and some types are available in standard sizes up to 36".

For cleaning, the pig may be molded with integral discs. Cleaning elements can also be supplied to attach to some solid cast pigs to provide a disposable cleaning pig.



Cleaning Elements for Solid Cast Pigs *Courtesy: S.U.N. Engineering, Inc.*



All Urethane Pig *Courtesy: S.U.N. Engineering Inc.*

Some suppliers offer what appear to be solid cast pigs since almost all of the components are made of cast polyurethane. These pigs have polyurethane seals and spacers. They may have cup type seals as well as discs and, like mandrel pigs, they can be assembled in many different configurations. The discs perform as a seal and because of their stiffness, they also act as a cleaning device. These pigs were originally developed to meet the needs of pipeline companies who were concerned that a

metal component might contact the inside surface of the pipeline and cause damage.

5.1.5 SPHERES

Spheres are almost exclusively used as sealing pigs however, there are a limited number of spherical pigs designed for removing solids.

Particular attention must be paid to the design of the pipeline to ensure that the sphere is guided past any voids or obstructions and can maintain its seal at all times. Even barred tees can cause a sphere to stall, so specially designed 'flow tees' must be installed in all pipelines where spheres are to be run.

In spite of their relative inefficiency, spheres are very versatile. They can negotiate very short radius bends, and they roll freely. This means they can travel along a lateral, drop through a tee into a larger diameter line, and then be pushed into the trap by another pig or sphere sized to suit the main line. This versatility helps to solve the problems of pigging pipelines with complex configurations such as gas gathering systems.

Their shape makes them ideal for use in automatic systems and this is the main reason why they are widely used for removing condensates. In many gas gathering lines for example, natural gas liquids will condense in the pipeline due to pressure or temperature changes because of the lower ambient conditions above ground. The volume of liquids dropping out may be such that a pig must be run every few hours to control the condensate levels and it is in this situation that spheres are particularly useful.

When the diameter of the pipelines in a gathering system increase in size as they approach the destination, spheres are ideal. As the smallest sphere comes to a pipeline size change, it can activate a pig signaler that starts a procedure to launch a sphere in the larger size pipeline. The smaller sphere will roll on into the larger pipeline where the larger size sphere will then push it to the receiving trap.

This method is being used very successfully and the train of spheres at the receiving end may contain spheres of four or five sizes. These are then sorted and transported back to be inserted into their original traps to repeat the process.

Spheres are made in a number of different elastomers. The material used is generally determined by the product in the pipeline.

The most common material is polyurethane which, even though it is relatively expensive, has better abrasion and tear resistance than most other elastomers. It also has excellent resistance to swelling in hydrocarbons. However, it does have a limited temperature range and will degrade quite rapidly when in contact with hot water or in high humidity.

Other materials used for spheres include neoprene and nitrile rubbers and although these generally have less resistance to swelling and abrasion, they do have generally higher temperature ranges. Maloney Technical Products Inc., one of the major manufacturers of spheres, gives the following:

Polyurethane: -25°F (-32°C) to 170°F (76°C)
Neoprene: -15°F (-17°C) to 280°F (138°C)
Nitrile: 30°F (-1°C) to 300°F (149°C).

Filling and Sizing a Sphere *Courtesy: T.D. Williamson, Inc.*

Spheres over about 3" are made hollow with inserts for filling and venting. They are filled with a liquid, usually a water and glycol mixture. This allows the sphere to be inflated to match the pipe inside diameter or to be slightly oversize so it can be changed in size to compensate for wear and/or pipe wall thickness.

Spheres are not usually inflated to an outside diameter more than about one percent over the inside diameter of the pipeline. Increased inflation to try to improve the seal will increase the wear and may cause the sphere to wear in a flat pattern. This will prevent it from rotating and so prevent it from wearing evenly. Uneven wear will also create thin places in the sphere wall and cause weakness and accelerated wear at those points.

At least two companies provide spheres for cleaning a pipeline. One is made by Knapp Polly Pig Inc. and is a foam sphere with fine wire brushes bonded to its external surface. The other is made by Decoking Descaling Technology Inc. This has hardened steel pins which are screwed into inserts molded into the sphere's surface and was described earlier.

Two other companies (T D Williamson Inc. and GD Engineering) patented a cleaning sphere. Both were based on the principle of a polyhedron and had tufted brushes fitted into recesses. However, neither of these is now being marketed.

5.2 PIG DESIGN

The basic design of a utility pipeline pig is very simple. It has to be, because it may have to travel hundreds of miles under very arduous conditions and yet remain efficient throughout. Experience has shown that the more complicated such a tool is, the more likely it is to fail - and failure within a pipeline cannot be tolerated.

The features incorporated into the design of a pig are therefore usually based on experience and are generally not immediately apparent.

Originally, pig bodies were built by the pipeline companies and available materials were used. This meant that many were made from pipe and the flanges were made from heavy steel plate. It became evident that this weight was increasing wear on the seals and the cleaning elements without serving any useful purpose. Now most pig bodies have been designed to be as light as possible and still be as strong as needed for the purpose.

Some pigs were built with hollow bodies so that they literally floated in the pipeline product and in effect had zero weight, but the advantage of this over a simple light weight body did not justify the additional cost.

To some extent the weight of a pig also determines its ultimate performance. It is important that, as far as is possible, the axis of the pig is on the same axis as the pipe, i.e. the pig is concentric to the pipe. However, as the pig, even when traveling in a fluid, has a mass, perfect concentricity can never be obtained. The center-line of the pig will always be slightly below the center-line of the pipe. This results in a slight overturning moment and tends to push the nose of the pig downwards. This is why, on most pigs, the wear will usually be greatest at the 6 o'clock position on the front seal.

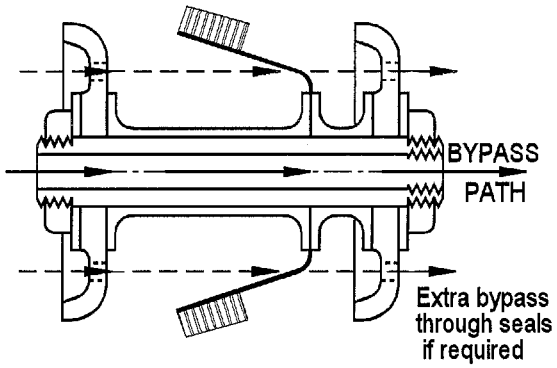
The question of weight, and many other factors must be taken into account when designing any pig, but the following analysis of the design of mandrel pigs, with their many component parts, covers most aspects.

5.2.1 PIG BODY

The body must have sufficient strength to resist the loads imposed upon it. These loads include the opposing forces which occur when the pig is equipped with spring loaded brushes, the bending moments applied when negotiating tight bends, the 'g' forces when traversing bends at high speeds, and the more obvious forces created by removing and perhaps pushing large volumes of dirt and debris.

The dictionary definition of the word 'mandrel' is: "an axle or spindle which is inserted into a hole in a workpiece to support it during machining", so it is easy to see how the term 'mandrel pig' originated.

The body for mandrel type pigs in sizes up to 14" is generally made from steel tubing. Tubing is used to provide a simple way to bypass the pipeline product through the pig. The reason for bypassing is described later.



Typical Bypass Through Small Diameter Mandrel Pig

The tubing may be threaded on one or both ends so that components can be slid onto the tubing and then clamped firmly into position. The tubing is usually also threaded internally at one end so that it can be plugged to stop the bypass when not wanted.

The body for mandrel type pigs 16" and larger is usually in the form of a steel cylinder equipped with flanges for bolting on the seals.

The cleaning elements and springs are usually attached directly to the cylinder body.

Bypass ports may be installed in the front of the cylindrical pig body or they may be provided around its circumference. The total cross sectional area of the bypass ports is usually equivalent to about 5 percent of the cross sectional area of the pipeline. Each port is provided with a plug so that the amount of bypass can be controlled. Bypass is discussed later in more detail.

The front, or "nose" of the pig is also important. The designer must take into account the possibility of the pig meeting an obstruction in the pipe. The shape and/or the material of the nose should therefore be designed to not only minimize damage to the pig but more importantly, to prevent damage to the pipe. Indeed, the whole pig should be designed, as far as possible, to avoid contact between any metal components and the inside surface of the pipeline.

The body should also be fitted with strong lifting attachments These are essential, but often neglected features. The most important of these is in the nose of the pig so that it may be easily removed from the trap, after completion of the run. There may be considerable dirt and debris in the trap and the pig must be dragged out so the attachment provided must be robust and preferably fitted within the body of the pig, to prevent damage to itself and any obstruction which it may otherwise encounter.

5.2.2 CUPS and SEALS

5.2.2.1 MATERIALS

The cup and seal materials are now almost exclusively polyurethane, but care must be taken to ensure the correct grade is used. Whatever the grade, quality control at all stages of manufacture is also a critical requirement. The days of mixing the components in a bucket are, or should be, over!

Polyurethane is made up of various combinations of polyols and isocyanates from which a vast range of hardnesses and properties can be obtained. Most pig seals fall within a hardness range of 60 to 85 Shore 'A'.

The two types of polyol used for pig seals are polyether and polyester. Polyethers have a good resistance to water (which at elevated temperatures will break down a polyurethane material), while polyesters have a better resistance to hydrocarbons and have generally higher physical properties.

There are also two types of isocyanate: methyl diphenyl di-isocyanate (MDI) and toluene di-isocyanate (TDI).

The most commonly used combination for pig cups and seals is Polyester/MDI. When carefully formulated and processed by properly equipped and qualified manufacturers, this will provide good performance under most circumstances, at modest cost.

However, there are a growing number of situations requiring even better performance. Subsea production systems for example, cannot afford inefficient pigs and least of all, pig failure. In these same areas, fluid temperatures are increasing and dual diameter systems are now commonplace. 500 mile (800 km) long pipelines now need to be pigged in a single run. Pigs generating and maintaining a high differential pressure are required for critical maintenance purposes. All of these situations require what has become known as "high performance polyurethane". This extra-high performance generally requires a Polyester/TDI combination. This material is very difficult to process, and may require special breathing apparatus for the operatives. It also generally has a curing cycle extending to several days. As a result it is more expensive, but the performance is outstanding.

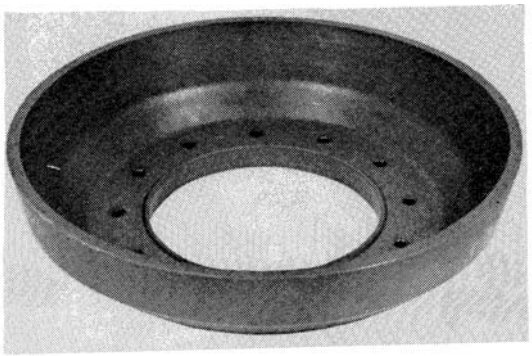
Most of the reputable manufacturers of polyurethane pig cups and seals now publish detailed material specifications and purchasers would be well advised to insist upon this. Where conditions are critical, many will also provide test pieces from each batch. At least one (Pipeline Engineering) now produces three distinct grades of their "Omnithane" material, to cover most needs. These are referred to as Standard, Super and Hyper Omnithane. Even so, special grades are still sometimes required.

5.2.2.2 DESIGN

Early experience showed, not surprisingly, that shapes that pushed hard against the pipe wall would wear the fastest. The thick, oversize discs used on some of the early pigs were not very flexible and wore much faster than a flexible seal.

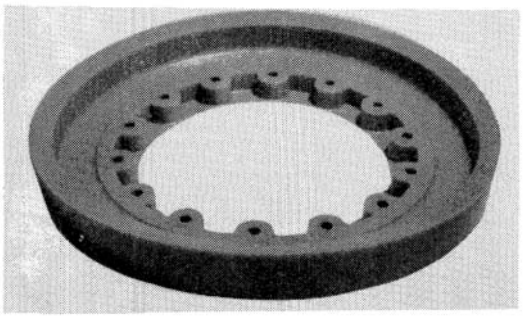
Some development work resulted in shapes which used the differential pressure across the seal to keep it in contact with the pipe wall. This worked, but as the seal became worn, the seal was easier to push against the pipe wall and the rate of wear progressively increased.

Some experimental shapes were such that the differential pressure pushing the sealing area against the pipe wall was such that the seal lips locked on to the pipe wall. The differential pressure on the other parts then caused the pig to literally pass through the front seal, tearing it from the body. There must therefore be a balance between the stiffness of the seal and its flexibility to conform to the pipe wall, and the conical cup is a good example of this.



Conical Seal *Courtesy: T.D. Williamson, Inc.*

The most widely used shape was, and perhaps still is, that of a 'cup' which is basically a disc with a lip around the circumference similar in shape to the old hydraulic piston seals. Until fairly recently, this shape was used on almost all pigs and it was for this reason that they became known as 'pig cups'.



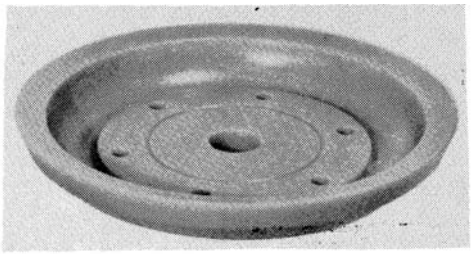
Heavy Duty Cup Seal *Courtesy: T.D. Williamson, Inc.*

However, the use of polyurethane materials has made it possible to use simple oversize discs equally effectively and multi-diameter pigs often utilize flaps or 'petals'. It has therefore become necessary to use the term 'seals' rather than 'cups' when referring in general to these flexible components which provide drive to the pig.

Materials have played a major part in helping to overcome the wear problem, but whatever material or design is used, wear will always occur, so some form of wear compensation must be incorporated in the design. This is still usually achieved by using the differential pressure to expand the seal into contact with the pipe wall, but skillful design is necessary to limit the radial force which is created.

Pig seals continue to evolve in shape as new materials become available and as pig designs change but, as already mentioned, seal configurations now fall roughly into three types:

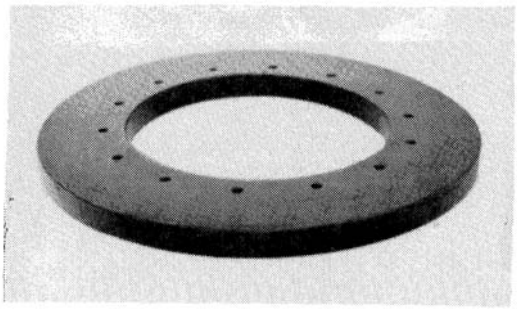
1) The "Cup" seal, which was the earliest type and was derived from the hydraulic piston seals.
2) The "Conical" seal which had its origins in the early ILI tools.
3) The "Disc" seal which originated with the bi-directional pig.



Cup Seal *Courtesy: T.D. Williamson, Inc.*

The early bi-directional pigs utilized four (or more) solid discs which were made oversize. Often, these discs were made of natural or synthetic (neoprene or nitrile) rubber. Wear rates were extremely high; in many cases giving less than 50 miles. But as they were generally used for filling and dewatering short sections of newly constructed line they were adequate.

The modern "Bi-Di" pig has overcome these problems. It uses two different types of disc. One type, the sealer, is thin and soft and made 5-10% larger than the inside diameter of the line to provide a good seal with plenty of wear compensation. The other, the guider, is thicker and much harder and is machined to the actual inside diameter. The guiders carry the weight of the pig and provide a simple yet very effective cleaning element. This type of pig can therefore be used for cleaning and for sealing.



Disc Seal *Courtesy: T.D. Williamson, Inc.*

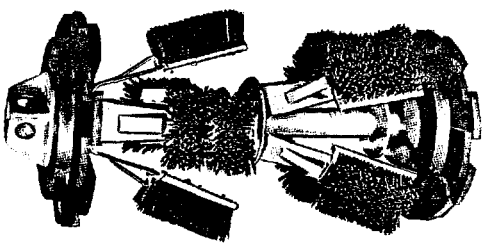
Occasionally the combination of the pipe inside diameter, the differential pressure, the seal shape and the material will be such that wear will stabilize and additional runs will not create

much additional wear. Unfortunately, this cannot be designed as a repeatable feature for all conditions and care needs to be taken in selecting the best seal for the pig and the pipeline.

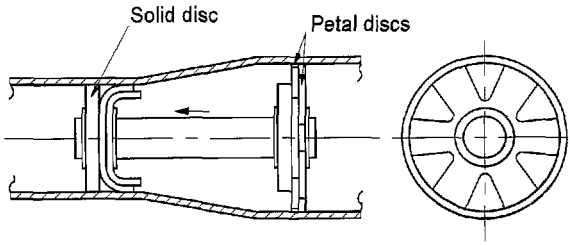
Of the three types mentioned, the cup seal is usually the least expensive. Conical seals are very effective in thin-wall pipe as they compensate very well for any out-of-roundness. The new Bi-Di pigs are very effective for both sealing and cleaning provided there is no severe out-of-roundness. However, there are often many other factors to consider and the suppliers should be asked to provide guidance in this respect.

If the pig is required to effect a good seal as it might be for example when commissioning a gas pipeline it is important to ensure not only that the best shape is used, but that it is also fitted properly. There is usually significant leakage through the seal flange fixing holes and other parts of the pig body, so fiber washers and silicon sealant should be used to block all potential leak paths.

As previously mentioned, seals are also available in shapes other than cups or discs to suit specific purposes. Pigs to be run in dual or multi-diameter (more than one size) pipelines require seals that will work in both sizes. This is often accomplished with a disc for the smaller pipeline and overlapping slotted discs (sometimes referred to as 'flaps' or 'petal discs') that will fold in the small pipeline and assume their original shape in the larger pipeline to give a seal.



Dual-Diameter Pig *Courtesy: T.D. Williamson, Inc.*



Dual Diameter Pig in Two Pipe Sizes

Seals of this type are not recommended for a sealing type pig for dual size pipelines. Where it is important to maintain a good seal, it has usually been necessary to install pig traps at the point where the line changes diameter, and treat each section as a separate pipeline. However, such pigs have been used because the junction of the pipelines was at a remote location with difficult access in bad weather and the convenience justified the compromise of results.

With the introduction of high performance polyurethane, there are now some situations where an effective dual diameter sealing pig can be used. With the correct combination of seal material, outside diameter and thickness, it is possible to make a single disc which will seal effectively in two pipe sizes. However, the most common design philosophy is to use separate sealing discs for each line size, mounted on the same body. On long pipelines, this will only be possible when the pig is traveling from the larger diameter into the smaller diameter. The concept is that when the pig is in the larger diameter, the smaller discs are not touching the pipe wall and when it enters the smaller diameter these discs take over while the larger discs are collapsed. From this point onwards, the large discs perform no useful function and afterwards, may well be too badly worn to be used again - but by then they will have done their job.

This approach was considered feasible only for changes in diameter of one or two pipe sizes and generally for smaller diameter lines. The problem in designing a dual diameter sealing pig of this type is keeping it centered while it is in the larger diameter section. Provided the

weight of the pig is not excessive, this can be achieved by fitting harder, thicker, slotted discs.

In the 1990's, it was realized that big savings could be made if pigs could be designed to work efficiently in very long pipelines. As a result, wheeled supports, were fitted and this technique was later used to center large dual and multi-diameter pigs, allowing for changes in diameter of over six pipe sizes.

The development of these pigs required a lot of research and testing and specialist companies such as Pipeline Research Ltd. have amassed a great deal of technical data and know-how, enabling pigs of this type to be designed with predictable performance characteristics.

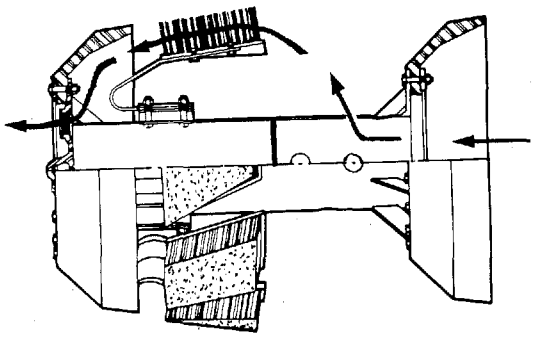
5.2.3 BYPASS

"Bypass" is often essential for an efficient cleaning operation. By utilizing the differential pressure across the pig, a fluid flow path is deliberately created through it, from the back to the front. This results in turbulence ahead of the pig, greatly assisting the cleaning process. The volume of fluid flowing through the bypass will depend upon the differential pressure, so care should be exercised when deciding on the amount of bypass to be used, particularly in low-flow conditions. If there is a tight spot perhaps due to a change in wall thickness, then high differentials could occur. Although it is unlikely, this could increase the flow through the bypass ports to a point where the pig remains stationary and in effect becomes "stuck".

Bypass is not normally used with a sealing pig. Since the purpose of the pig is to seal, there would be little reason for the bypass. However, at least one operator uses bypass when pigging to control condensates and is of the opinion that the gas flow through the pig 'aerates' the liquids in front and helps to prevent the build up of solid liquid slugs which the pig may begin to ride over.

The bypass should be open in a cleaning pig to allow the pig to slip back behind the debris that it may have scraped from the pipe wall. The purpose is to keep the debris flowing with the stream and not accumulate in front of, and be pushed along by the pig.

When pigs are made with a cylinder type body the bypass may be routed so that the fluid enters the cylinder from the rear and emerges through the circumference near the center of the pig body. It then passes over and around the cleaning elements to remove material the elements have scraped from the pipe wall, and then exits through the front of the pig.



Pig Design with Bypass *Courtesy: T.D. Williamson, Inc.*

It can be seen that a bypass of this type means that there is no differential across the rear seal so the pig is driven by the front seal. There is evidence to suggest that all pigs should be run by driving only on the front seal, the other seals being used to support the weight of the pig and to keep it aligned in the center of the pipeline.

Many instrumented pigs are run with a bypass purposely made through the rear seals so that they are propelled only by the front seal. Tests have shown that a pig will stay centered within the pipeline better when it is being 'pulled' than when it is being 'pushed'.

Pigs have been produced with special bypass nozzles, often positioned to give a jetting action to the debris that may accumulate at some point on the pig. This has been used successfully to

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supposedly to impart a rotation to the pig, but there is little evidence that this was significantly better than the simple bypass.

5.2.4 CLEANING ELEMENTS

Cleaning elements are available in many different shapes and materials. In the early days of pigging the cleaning elements were wheel type brushes. When the diameter became so large that wheel brushes were not available, strip brushes were used and bent into circular form.

Wheel type brushes have the advantage that they can be used on small pigs, but the disadvantage is that as they wear, they lose their effectiveness. During the 1940's springs were added to press the cleaning element against the pipe wall to compensate for the wear which occurred during the life of the element.

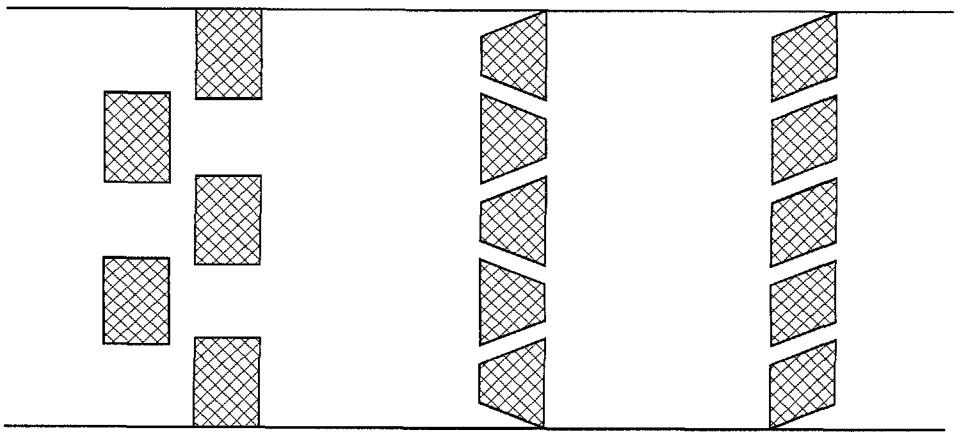
Some of the early cleaning elements were made of steel and fabricated in the shape of a plow blade. There are still some specialist pigs which use this type of element today. They are effective on very hard deposits within the pipeline but it is not desirable to have steel components contacting the inside pipe wall of most modern pipelines.

Among the early cleaning elements were hardened star wheels like those used on grinding stone dressers. These could be mounted to give near uniform contact of the pipe wall and the rolling action was used to break loose thin hard internal deposits. These cleaning devices have now being replaced by brushes and polyurethane cleaning elements.

Brushes are made in different shapes to be compatible with the design of the pig. When the pig has two rows of cleaning elements they are often rectangular in shape since one row can be mounted such that it will clean any section of the pipeline not covered by the other row.

When the pig can have only one row of cleaning elements, then their shape must be such that they can still provide complete coverage of the pipe wall. This may be done using elements of a triangular shape, mounted with their apex alternatively at the front and back. Another method is to make them in a trapezoidal shape so that the front of one element overlaps the rear of the adjacent element.

Brushes are a common type of cleaning element and are generally made of hardened steel and wire and strip to give good wear resistance. Brushes can also be made of materials such as stainless steels and plastics.



Arrangement of Cleaning Elements for Full Pipe Covering

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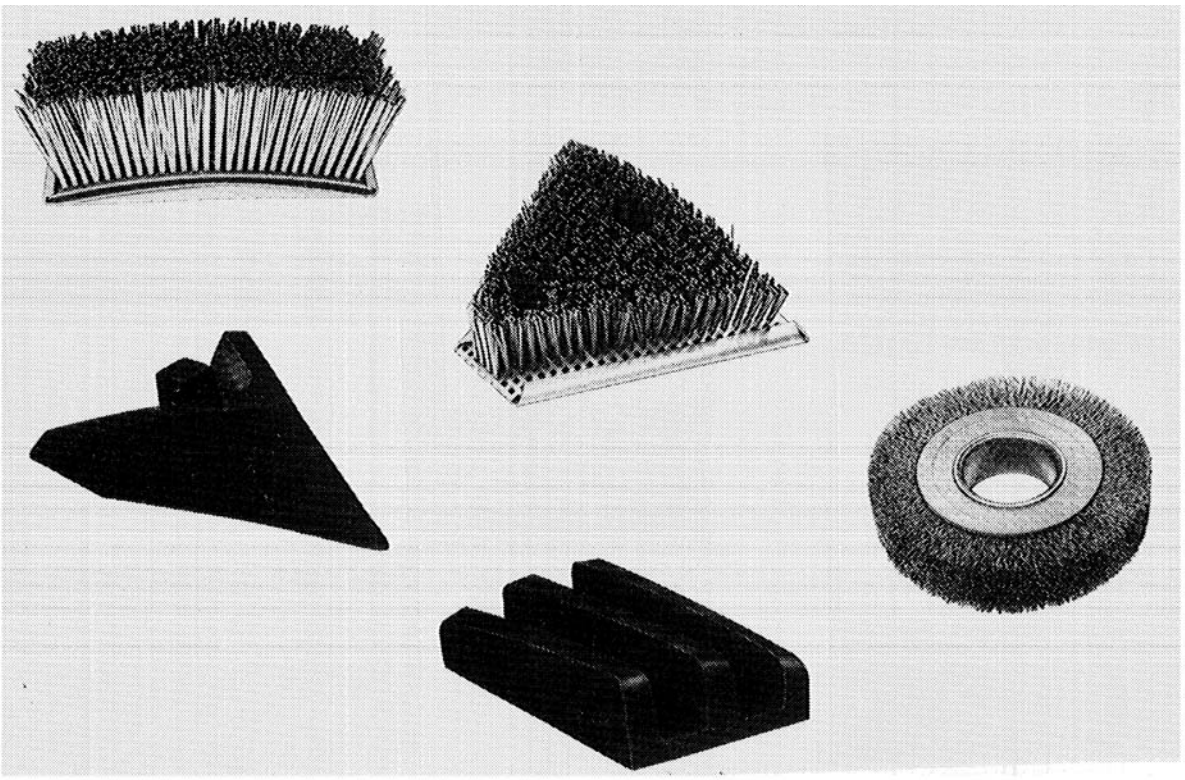


Various Types and Material for Cleaning Elements Used on Pigs *Courtesy: InPipe Products*

Polyurethane cleaning elements are often used to clean internally coated pipelines since they will not damage the coating. They are also used to clean pipelines that have wax or other soft deposits.

Polyurethane elements are molded in the form of a series of blades. This makes them self cleaning as they remove the deposit from the pipe wall. This is an advantage over a brush where the deposit may be trapped within the bristles and then it becomes almost ineffective.

Discs may be used as a combination of sealing and cleaning elements to remove soft deposits on the pipe wall.

When pipelines run pigs regularly as part of a routine maintenance program it is usually not necessary to use a cleaning element designed for severe service. This regular cleaning schedule will help keep the pipeline clean and efficient.

When starting a pigging schedule several pigging runs will be necessary to achieve the maximum efficiency. The first run may give

the most dramatic results but improvements will be noted with each additional run and good records are necessary to determine when maximum efficiency has been achieved, and how often pigs should then be run to maintain this efficiency.

There have been experiments, and there are a small number of pigs available, which have cleaning devices molded into the sealing edge of the seals on the pig. There have been claims that this is very effective, but there is no known hard evidence that these are significantly better than the separately mounted cleaning elements that have been more widely used to date. However, with the need to develop more effective pigs for pre-inspection cleaning, research into this, and other methods is known to be continuing.

5.3 PIG SELECTION

5.3.1 THE SELECTION PROCESS

5.3.1.1 SETTING THE OBJECTIVE

As with any logical selection process, the first requirement is to establish the objective. Unfortunately, pigging is still not an exact science so objective setting will continue to present some difficulties. Nevertheless, it is still necessary to establish the objective as precisely as possible. It is not sufficient to simply define it as "cleaning", "swabbing", "batching", "dewatering", or whatever.

In setting the objective, the questions to be answered must include the following. *(For ease of reference, these are summarized towards the end of this section):*

a) What is the substance to be removed (or displaced)?

If it is a liquid, then a swabbing pig may be considered. If a solid, then a cleaning pig is needed. If the solid is hard, then brushes may be necessary - or if soft, then blades might be better.

b) Where is the substance radially longitudinally (if known)?

Although solids and, in hydrocarbon pipelines, water, tend to accumulate in the bottom of the line, this is not always the main problem area. The answer to this question is also sometimes helpful in deciding whether to track a pig and if so, where to concentrate the tracking activities - and it will help to answer the next question:

c) What is the estimated volume to be removed?

Clearly, arrangements will have to be made to handle the substance, either by removing it from the line altogether, or passing it through the process systems. Either way, the facilities must be able to handle the volumes expected. If the volume is likely to exceed that which can be handled, or which might block the line, a pig must be selected which will only partially clean the line.

d) Does the substance removed present any hazards?

Some substances are not only harmful if inhaled or touched, but may react when in contact with air or water. Some debris and scale is radioactive and even if, as is often the case, it has a very short half-life, appropriate handling procedures need to be established. A professional analysis is therefore required and if there are any potential dangers, adequate precautions must be taken.

The resulting objective might then read:

"To improve the throughput of the 24" (600 mm), 30 mile (48 km) crude line by at least 8% by removing the accumulation of an estimated 60 cu yd. (46 cu m) of radioactive scale from the lower quadrant of the first 10 mile (16 km) section".

This is far from an ideally stated objective, and it will often be impossible to be even as precise as this, but the closer the objective can be defined, the easier it will be to make the optimum pig selection and to develop the best procedures.

Having defined the objective, it is then necessary to look first at the operational conditions and then at the pigs.

5.3.1.2 OPERATIONAL CONDITIONS

a) What are the contents of the line WHILE PIGGING?

No doubt the contents under normal operating conditions will have been made known when discussing the purpose of pigging. There are differences when pigging refined products as compared to crude oil, but there are very significant differences if the comparison is between a gas and a liquid.

b) What is the driving pressure available?

Clearly it is important to ensure there is sufficient pressure available to drive the pig. However, it will also be useful for contingency planning to know the maximum differential available so that alternative procedures can be devised in the event of problems.

c) What is the velocity while pigging?

The answer to this question is critical for an ILI tool but is equally important for utility pigs. The "stop-start" situation encountered when pigging low pressure gas lines should always be avoided but even in high pressure gas, or liquid lines, speed has a major effect on pig performance.

d) What is the temperature profile?

In crude lines particularly, this will determine where the wax deposition begins and therefore at what point the pig will begin to remove the deposits. This in turn will then provide some guidance with respect to the volumes expected. In gas lines too, the temperature may affect liquid drop out and so could, in conjunction with the line profile, provide a better indication of what to expect.

5.3.1.3 THE PIPELINE

Typical of the questions which must be answered about the pipeline itself are:

a) What is the pipe material and is it lined (and if so with what)?

This will obviously be one of the first questions asked prior to an ILI survey, but it can be important for utility pigging also. The internal surface will affect the type of cleaning element selected. Some materials will crack or flake if abraded too strongly. In some combinations of product and age, mill-scale may be inadvertently removed and this has caused serious, unexpected problems.

b) What is the minimum and maximum inside diameter?

The nominal diameter is usually not sufficient. Some heavy wall pipe may have an internal diameter equivalent to that of a standard weight pipe one size smaller. It is the ID which determines the diameter of the pig NOT the nominal pipe size. Be sure to check the ID of the bends and tees.

c) What is the pipeline elevation profile?

This can prove especially helpful in selecting tracking locations as well as likely trouble

spots. It will also act as a double check on whether the available pressure is adequate.

Liquids will lie in the low spots, but they will also run away from the high spots, possibly creating negative pressures and very high pig speeds. This is especially critical for ILI tools, which often need very closely controlled speeds.

d) What is the maximum distance the pig must travel in one run?

Again, this is critical for ILI tools, but will also determine such things as cup configuration and numbers of cups or whether wheels are required (for wear considerations) on utility pigs.

e) What is the MINIMUM bend radius in the line?

This is usually expressed in pipe diameters and is measured to the pipe center-line. 3D is the minimum desirable, but many pigs can negotiate 1.5D, subject to line conditions. Miter bends should be avoided at all costs but if they do exist, they must be measured carefully as it is probable that a pig would need to be "tailor-made" for this situation.

f) What is the angle of the bend(s)?

Most bends are 45° or 90° but field bends may be of any angle and some bends may actually exceed 90°.

g) What is the relative position of the features?

Ideally there should be at least one pig length between any two features (e.g. a bend and a tee, two bends, two tees, etc.). However, as the pig has yet to be selected, the distance between the features should be noted. Bends welded back-to-back should be particularly noted, especially with respect to their relative directions.

h) What is the inside diameter of each offtake (tee or outlet)?

This is important so as to ensure the pig does not "nose up" into the branch and become stuck, or hold up as it tries to travel past the tee.

i) Are any of the offtakes barred - if so which, and what are the spacing of the bars?

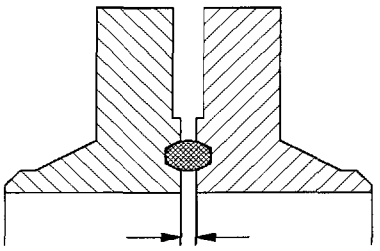
Clearly, barred openings present less of a hazard and increase the options for pigging. When running spheres it is essential to fit special 'sphere' or 'flow' tees. This will avoid the possibility of them holding up by "by-passing".

j) What type/make/model of valves are installed?

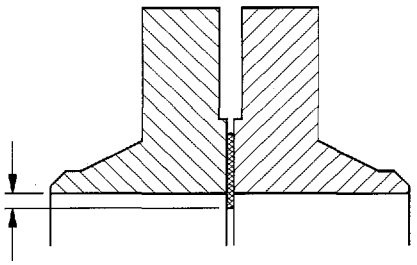
Full bore ball valves usually present no problems but gate valves and check valves might. In particular, any gap due to the seat rings or any recess in the check valve bowl must be carefully considered as it is at these points that the pig may lose its seal (or drive) or become stuck.

k) Are there any other features which might be relevant?

Typical of these are whether there are probes in the line which must be removed prior to the run; whether the pig signalers are uni-directional (and if so, are they in the right direction!) and do they work; which types of gasket are used on the flanged joints (RTJ's leave a circumferential gap which can trap certain brush-type pigs, while RF joints can have a gasket located eccentrically which could cause a problem); what traps/closures are installed; trap dimensions, etc.



Ring Type Joint



Flat Face Gasket
(Fitted Incorrectly)

5.3.1.4 SELECTING THE PIG

It is not surprising that with development extending over a period of more than 100 years and an ever-increasing list of things for which they are used, there are now about 300 different types of pig on offer.

However, as previously mentioned, utility pigs can be broken down into two groups:

1) Cleaning pigs and
2) Sealing pigs

Each of these two groups are provided in four different forms:

a) Mandrel pigs
b) Foam pigs
c) Solid cast pigs
d) Spheres

Having established the objective, the group will be obvious. Then, by considering the particular advantages and disadvantages of each in relation to the features of the pipeline and the operational conditions, the form of pig to be used should also become apparent. The following summary of the questions to be answered to enable a pig to be selected is provided for ease of reference:

SETTING THE OBJECTIVE

a) What is the substance to be removed (or displaced)?

b) Where is the substance radially - longitudinally (if known)?

c) What is the estimated volume to be removed?

d) Does the substance removed present any hazards?

OPERATIONAL CONDITIONS

a) What are the contents of the line WHILE PIGGING?

b) What is the driving pressure available?

c) What is the velocity while pigging?

d) What is the temperature profile?

THE PIPELINE

a) What is the pipe material and is it lined (and if so with what)?

b) What is the minimum and maximum inside diameter?

c) What is the pipeline elevation profile?

d) What is the maximum distance the pig must travel in one run?

e) What is the MINIMUM bend radius in the line?

f) What is the angle of the bend(s)?

g) What is the relative position of the features?

h) What is the inside diameter of each offtake (tee)?

i) Are any of the offtakes barred - if so which and what are the spacing of the bars?

j) What type/make/model of valves are installed?

k) Are there any other features which might be relevant?

From this point on, selection of the precise type of pig is essentially a process of elimination. For example:

If there is one or more 1.5D bends, then all pigs requiring 3D or more minimum radius are automatically rejected.

If there are two tees in close proximity it may be necessary to consider an exceptionally long pig - or install additional cups or discs.

A combination of short radii (usually implying a short pig) and two tees close together (usually implying a long pig) may lead to the need for a flexible bodied or articulated pig which, although more expensive, will resolve the problem.

Once a number of potential types have been selected, then each feature and condition in the pipeline should again be reviewed considering each pig in turn and then selecting the pig which:

i) Will travel through the line without risk and,

ii) Will provide optimum performance.

Note that the cost of the pig has not been considered. Pigs are highly competitive and are generally sensibly priced. Pigs should be selected on the basis of PERFORMANCE - always.

It is well to remember that the supplier can also carry out the selection process, but they too will need to have the full details. Indeed, even if the selection process is carried out by the user, it is still important to get the supplier to approve it or to provide their recommendations.

5.3.2 PIG SELECTION FOR CONSTRUCTION

See Page 5-22

5.3.3 PIG SELECTION FOR MAINTENANCE

See page 5-23

5.3.4 PIG SELECTION FOR SURVEYS

See page 5-24

5.3.2 Types of pigs used during pipeline construction

Pigging Purpose	foam plain	foam brush	plastic disc	sphere	metal brush	plastic blades	seals only	gauging pig	caliper pig	bend detector	corrosion detector	crack detector	leak detector	pipeline mapping
Initial cleaning	X	X	X	---	X	X	---	X	---	---	---	---	---	---
Additional cleaning	---	X	X	---	X	X	---	---	---	---	---	---	---	---
Hydrostatic water fill	X	---	---	X	---	---	X	---	---	---	---	---	---	---
Hydrostatic dewatering	X	---	---	X	---	---	X	---	---	---	---	---	---	---
Quality verification	---	---	---	---	---	---	---	X	X	---	---	---	---	---
Line fill with product	X	---	---	X	---	---	X	---	---	---	---	---	---	---
Baseline surveys	---	---	---	---	---	---	---	---	X	X	X	X	---	X

The above pig selection indicates applications where the pigs may be suitable. The pipeline length, pipe diameter, pipeline product, and many other factors must be considered when selecting the correct pig. This chart does not imply that all pigs that may be used for an application are of equal capability or that they will give equal results.

5.3.3 Types of pigs used for pipeline maintenance

Pigging Purpose	foam plain	foam brush	plastic disc	sphere	metal blades	plastic blades	metal brush	seals only
Wax removal	---	---	X	---	---	X	---	---
Soft dirt removal - Internally lined	---	---	X	---	---	X	---	---
Soft dirt removal - Non-lined pipe	---	X	X	---	---	X	X	---
Hard deposit removal	---	---	---	---	X	X	X	---
Liquid removal	X	---	X	X	---	---	---	X

The above pig selection indicates applications where the pigs may be suitable. The pipeline length, pipe diameter, pipeline product, and many other factors must be considered when selecting the correct pig. This chart does not imply that all pigs that may be used for an application are of equal capability or that they will give equal results.

5.3.4 Types of Pigs used in preparing for, and during ILI

Pigging Purpose	foam plain	foam brush	plastic disc	metal brush	plastic blades	seals only	magnet pig	caliper pig	bend locator	metal loss tool	crack detector	leak detector	survey pig
Pre-cleaning	X	X	X	X	X	X	X	---	---	---	---	---	---
Proving	---	---	---	---	---	---	---	X	X	dummy	---	---	---
Geometry survey	---	---	---	---	---	---	---	X	X	---	---	---	---
Corrosion survey	---	---	---	---	---	---	X	X	X	X	---	---	---
Crack survey	---	---	---	---	---	---	X	X	X	---	X	---	---
Leak survey	---	---	---	---	---	X	---	---	---	---	---	X	---
Mapping	---	---	---	---	---	---	---	---	---	---	---	---	X

The above pig selection indicates applications where the pigs may be suitable. The pipeline length, pipe diameter, pipeline product, and many other factors must be considered when selecting the correct pig. This chart does not imply that all pigs that may be used for an application are of equal capability or that they will give equal results.

5.4 PIG MAINTENANCE and STORAGE

The following applies only to rigid bodied pigs with metal bodies and (usually) polyurethane cleaning and sealing elements. It is intended to provide guidance when no formal procedures or other recommendations are available.

Approval for the use of any or all of these guidelines, and for appropriate safety measures, must be obtained from an authorized person before they are adopted.

All pigs should be allocated a unique reference number to be used to record all runs and the maintenance and service work carried out on each.

See Section 10 for further information on pig maintenance and Section 13A for recommended maintenance records.

5.4.1 CLEANING

If the pig is heavily caked in wax, remove excess by scraping. Steam cleaning is acceptable for metal components, but the polyurethane components should not be exposed to temperatures above 180° F. (82° C.) for extended periods, particularly in the presence of water. A solvent such as diesel fuel or kerosene may be used, or a suitable proprietary product such as T.D. Williamson's "Automated Solvent Free Pig Cleaner" may be used.

5.4.2 MAINTENANCE

5.4.2.1 DISASSEMBLE and INSPECT

Once clean, the pig should be carefully inspected for damage, particularly the elastomer parts. Failure of urethane components frequently occurs at or near the flange mounting holes which may be caused by over tightening. This is not visible without removing the mounting flange and it is recommended that this be done after each run. Flexing of the urethane components after removal will normally identify tears or cracking.

5.4.2.2 CUPS and SEALS

Each seal should be given a unique number using a permanent marker pen. To prevent it being erased, this number should be applied to some point which will not be exposed after assembly (e.g. under a mounting flange). The position of a seal should be identified by numbering from the front of the pig, the front cup being Number 1, the second Number 2 etc.

Drive seals should be changed if there is significant damage or if the radial distance from the centerline of the pig to the circumference of the seal at any point is equal to, or less than half the inside diameter of the pipeline. A good way to check the wear is to measure the circumference to determine the diameter. This can be done using a special diameter tape. Alternatively, any standard tape can be used to measure the circumference and the measurement is then divided by 3.14 to determine the diameter

Front seals usually receive the greatest wear during the pig run. If the front seals are within the above limits but expected wear creates concern about a successful run, they may be replaced by new seals and then used in a position behind the front seal. If there is any doubt about whether the seal should be reused, it should not be used.

The harder scraper discs mounted at the front and the rear of bi-directional pigs are designed to be equal to or slightly less than the line inside diameter. These are unlikely to need changing unless they have worn down to 5% or more below the original size. Some bi-directional pigs use seals composed of the harder discs used on either side of a softer sealing disc. The

softer disc of this design should always be larger than the pipe inside diameter at the beginning of the pig run.

When reassembling the seals and other elastomer components which are not fitted with ferrules (i.e. metal spacers which are molded into the component), do not over tighten the bolts. Excessive "squeeze" will distort the contours of the component and cause premature failure. **It is important that the recommendations of the manufacturer be obtained and followed.**

5.4.2.3 CLEANING ELEMENTS

Scraper blades or brushes (if used) are subjected to heavy wear and should be renewed frequently. They rely on their flexibility to perform effectively. Apart from the obvious need to prevent their attachment bolts from contacting the pipe wall, they should not be used after the bristles or blades have worn down to within approximately 60% of their original length. If the pig runs are long the cleaning elements may need replacing before reaching the 60% wear.

5.4.2.4 BODY, SPRINGS and OTHER METAL COMPONENTS

Metal components should be visually inspected, and if there is evidence of any damage (i.e. dents or "bruising"), it is advisable to check all welds with dye penetrant. Springs are also subject to fatigue and must always be regularly checked for cracks with dye penetrant, as should the welds attaching the cup, seal, and disc flanges to the pig body.

Metal components should be painted and touched up whenever bare metal is exposed.

5.4.3 STORAGE

5.4.3.1 PIGS

Pigs should be stored either in cradles which support the body or at least on their ends. Polyurethane, in line with most elastomers will take a permanent set if subjected to a constant load at one point, so pigs should never be left lying on the cups or seals.

5.4.3.2 METAL COMPONENTS and SPARES

Metal components parts must be protected against corrosion while in storage.

5.4.3.3 ELASTOMER COMPONENTS and SPARES

Cups, seals and discs should be stored in short stacks taking care that the lips are supported all around and concentric with each other.

Polyurethane in particular is subject to hydrolysis. Excessive temperature and humidity causes deterioration of the material. A darkening color will sometimes indicate a breakdown in the material and a simple check can be made by attempting to force a sharp object into the material. The amount of penetration will be minimal with a good material. Flexing of the urethane may show cracking as the parts start to deteriorate. If in doubt, the hardness should be checked against the manufactures specifications. Storage life can be extended for polyurethane components by sealing within dark plastic bags and storing away from direct heat.

Large quantities of polyurethane parts should not be kept in stock. Reordering on a regular basis and a strict system of first-in and first-out should eliminate potential problems due to material failures.

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6.0 PIGS FOR MAINTENANCE or REPAIR

As the pipeline industry has grown and developed, so too have the products and services designed to meet the needs. When a problem has recurred, many of the special pigs which were originally designed to resolve a specific problem, have become almost standard.

If a pipeline is to operate efficiently, it must operate continuously, so a lot of work has gone into the development of systems for maintenance and repair and pigs have played a vital role in this field.

Some of these, such as soluble pigs, are relatively simple and were developed over a short period of time. Others, like the plugging pigs, have created major challenges and in spite of being invented several decades ago, are still in the course of further development.

The descriptions of the pigs which follow are in no particular order of importance.

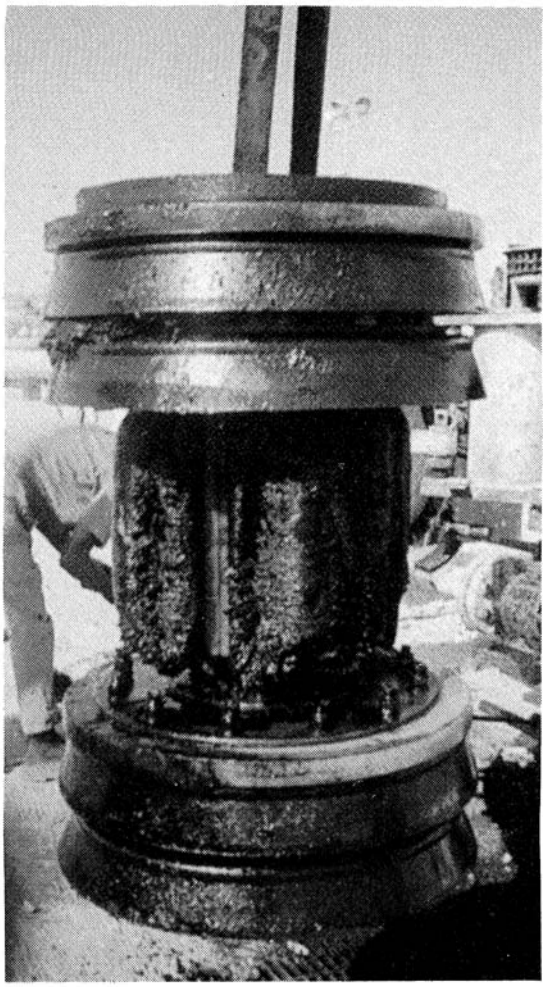
6.1 MAGNETIC (FERROUS DEBRIS) PIGS

The presence of ferrous debris, such as welding rods, metallic dust and steel shot does not generally present a major problem in an operational pipeline, but it is essential that such debris is removed if ILI (in line inspection) is to take place.

Ferrous debris may cause serious damage and can result in false readings by ILI tools. Although normal cleaning pigs will remove much of this ferrous debris, for thorough cleaning a specialized pig is needed. Many pig manufacturers can provide simple magnetic-cleaning pigs, but if there is a particularly high volume of ferrous debris to be removed, multiple runs may be necessary. In one instance for example, 43 separate pigging runs were necessary. In these situations, a specialist pig would have reduced the number of runs considerably.

For good inspection results, it is important to remove as much foreign material from the pipeline as possible so a pre in-line inspection program usually requires the pipeline to be thoroughly cleaned prior to running the ILI tool.

After removing as much as possible with conventional cleaning pigs, it is common to find



Magnetic Cleaning Pig

considerable amounts of fine ferrous dust and debris remaining that the cleaning pig did not retrieve. As a result, pigs have been produced that have powerful permanent magnets attached to them, generally located so they are in close proximity to the pipe wall.

These specialist magnetic cleaning pigs are the result of a long development program which has determined not only the best type of magnet, but also the method of mounting them and the optimum orientation to provide maximum efficiency and performance.

It is also common for these pigs to consist of two, or even three modules, to collect the maximum amount of debris per run.

Magnetic pigs often recover many pounds (kilograms) of debris including mill scale, welding rods, brush bristles and similar material. It is worth remembering that because the volume of debris cannot be predicted until cleaning actually begins, pre in-line inspection cleaning programs should take place well in advance of any form of on-line inspection operation. This will allow time for re-runs if necessary.

6.2 PLUGGING or ISOLATION PIGS

6.2.1 HISTORY & DEVELOPMENT

Plugging pigs were on many pipeline operators "wish lists" for a very long time. Being able to plug a pipeline at any point and at any time without the need for external intervention clearly has enormous advantages for onshore, and even more so for offshore pipelines.

A plugging pig was developed over 40 years ago by T.D. Williamson, Inc. and a pipeline company. About the same time, T.D. Williamson, Inc. developed and patented the Stopple® Plugging Machine.

The Stopple Plugging Machine is a device which is used for pipeline maintenance and repair work. It is temporarily mounted externally on a pre-installed and tapped tee, then inserted into the pipeline to plug it. After the repair work has been done it can be removed for reuse elsewhere.

The Stopple had several advantages over the plugging pig and therefore the plugging pig was seldom used. By using two Stopples and installing temporary bypass piping around them, full pipeline operation could continue around the isolated section, whereas with the plugging pig the line had to be shut down.

The plugging pig had to be pumped into position from one end of the pipeline to the point to be plugged. This was a major disadvantage if the isolation was needed to repair a leak.

The plugging pig would not pass significant reductions in diameter such as may be caused by damage due to third party activities or partially closed valves. In addition the early plugging pig could not be used at full pipeline operating pressure, whereas the Stopple Plugging Machine generally could.

Later, in 1960, another plugging pig was developed and patented by Bill Morrison of Tulsa, Oklahoma. It was designed for use on land pipelines. The basic principle was to weld small nipples on the pipe at predetermined points and then to insert pins through the nipples into the pipeline to catch the pig. The nipples were installed so that two pigs could be stopped at the upstream plugging site. A small bypass was installed externally around the plugging location. Once both pigs were in place, the upstream pig was expanded into sealing position and the downstream pig was released. An inert product (usually nitrogen) was then used to pump the downstream plugging pig to the downstream plugging site

where it was stopped by the previously installed pins.

Several companies have since owned and operated this plugging pig service. One of those is IPSCO.

Later still, with the growth of the offshore industry; it became apparent that the subsea installation and maintenance of the special fittings needed for isolations using Stopple type equipment were extremely expensive. There was clearly a need to look at other types of plugging device.

A typical application for a subsea plugging device would be for the installation of Emergency Shut-Down valves without either contaminating the pipeline or the surrounding environment. Other uses involving the repair, maintenance or modification of a pipeline can be readily appreciated.

6.2.2 DESIGN CONSIDERATIONS

In its most basic form a plugging pig comprises a body on which are mounted two flexible discs each slightly larger than the inside diameter of the pipeline in order to obtain a seal. It therefore follows that, if such a device could be stopped and held in position at a certain point along the pipeline, then it would be an ideal means of isolating sections of the line for modification, maintenance or repairs.

As with most things that are simple in principal it is extremely difficult in practice. The plugging pig must be capable of traveling through a pipeline to a predetermined point, be remotely actuated in order to create a seal then subsequently be deactivated so that it may either continue its journey or be reverse pumped back to its starting point.

Tethered tools have been used for some time where the isolation point is near one end of a pipeline. Because the distance is short, the tool can be moved into the pipeline to isolate that end of the line then retrieved back to the launching site. This allows all control to be external to the pipeline via an umbilical.

However, remotely operated plugging pigs have now been developed. Arguably, the most difficult part of this has been the development of effective through pipe-wall communication systems, which generally requires the use of Extremely Low Frequency (ELF). Those offering this service include Plugging Services International AS (using PSI SmartPlug). Oil States HydroTech Division (HydroPlug) and KH Tecnomarine.

6.2.2.1 PIPELINE DIAMETER

Among the aspects which must be considered when designing an instrumented pig of any sort is the pipeline diameter. The pig will inevitably carry some form of mechanism or instrumentation. The smaller the pipeline diameter becomes the more difficult it is to design a mechanism which will fit into the space available. This problem can often be alleviated by adding further modules, effectively making the pig longer. However, there will probably be a limitation on the number of modules possible; dictated by the length of the launching and receiving facilities at each end of the pipeline.

A plugging pig must also be capable of traversing any changes in the nominal inside diameter of the line so consideration must be given to potential restrictions such as ovality, weld penetration, dents, buckles and flat spots. In general these latter considerations mean that the pig must be designed to pass a reduction of at least 5% and preferably 10% of the nominal inside diameter; a fact frequently overlooked by the designers of many of the tools which have been patented for this purpose - some of which are almost bizarre!

6.2.2.2 WORKING PRESSURE

For most instrumented pigs, it is generally accepted that, with the exception of weight, the

larger the pig the easier it is to design. However, with plugging pigs that is not necessarily so. A plugging pig, by definition, must resist the pressure within the pipeline by gripping the walls. The surface area available for gripping per unit length of line, is in direct proportion to the pipeline diameter. However, the load imposed upon the pig by line pressure is proportional to the square of the pipeline diameter. It therefore follows that plugging pigs are likely to experience design problems at both ends of the pipeline size range.

6.2.2.3 PIPE WALL THICKNESS

Plugging pigs resist pipeline pressure by gripping the pipe wall. Pressure activated gripping devices, such as slips (which are used on various types of pipe plugs) can be forced so hard against the pipe wall as to cause permanent deformation and damage, and in extreme cases, it may result in it being impossible to release the grip.

Clearly the wall thickness is another factor that must be taken into consideration when designing and/or utilizing any type of plugging pig.

6.2.2.4 PIPE WALL CONDITION

Corrosion, pitting or other highly localized corrosion is unlikely to give problems for a plugging pig. However, general corrosion could conceivably cause an eccentricity within the pipe and in serious cases could affect the wall thickness calculations.

6.2.2.5 WELD BEADS

The effect of circumferential weld beads on the free passage of the tool must be taken into account. Subject to the design of the plugging pig, it may also be undesirable to attempt to lock and seal a plugging pig at a circumferential weld bead.

Longitudinal weld beads are unlikely to present problems but must not be forgotten when considering any particular design. For example, a longitudinal weld bead may create a leak path past certain types of circumferential seals.

6.2.2.6 PIPE CONTENT

Clearly the device must be compatible with the product in the pipeline, but care must also be taken to ensure that any product used within the plugging pig or as part of the plugging system, is also compatible with both the line content and the pipe.

Other, perhaps less obvious things to consider are the likely presence of foreign or related substances such as sand, water, wax, rust and other debris.

6.2.2.7 CONTROL SYSTEMS

In addition to the factors mentioned above, there are a number of aspects concerning the control of the tool, most of which present serious difficulties. These include the need to be able to bring the tool to a halt at a precise location, to be able to track it whilst traveling through the line and to locate it when stationary (this may require two distinctly different types of equipment). It will need a double block and bleed sealing facility and a backup locking mechanism (e.g. a sprag) would also seem to be desirable. Some means of ensuring that the tool releases properly would also be necessary and the life of any on board power source (if there is one) would clearly be important

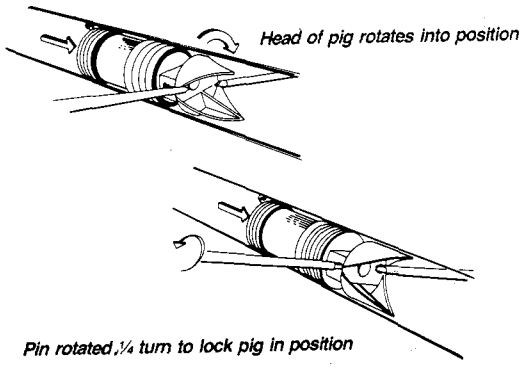
6.2.3 PLUGGING PIGS

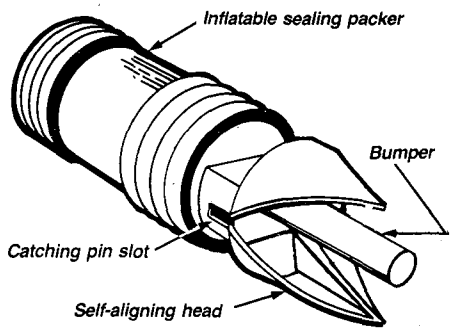
6.2.3.1 IPSCO PLUGGING PIG

This device is one of the earliest plugging pigs and has already been described.

It is understood that IPSCO have carried out a number of jobs but in most cases there was no significant advantage over doing a conventional hot tap and plugging operation, which IPSCO

also perform as a service on a regular basis. It is also thought to be capable of negotiating a 3D bend and the design has undergone some further development by incorporating a built in bypass to enable the pig to be run smoothly and slowly into locking position. Once in position, the internal bypass is closed.





Plugging Pig *Courtesy: IPSCO (UK) Ltd.*

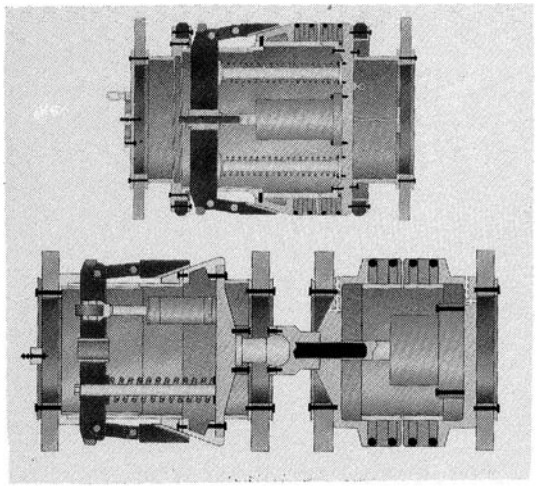
6.2.3.2 HYDROTECH 'HYDROPLUG'

The basic HydroPlug appears to have been first patented in 1982 by Adkins et al of Hughes Undersea Coupling Inc. This original patent carried the title "Pipeline Pigging Plug". A patent issued in 1983 to the same people and company was entitled "Pressure Energized Pipeline Plug". It is this second patent which is the basis of the present design of the HydroPlug.

In its original form, the HydroPlug relies on an umbilical passing through a seal unit mounted on the pig trap and this version has amassed a good track record; being used several times for the repair, maintenance or installation of subsea valves.

Subsequent development resulted in what was referred to as the "Triple Module Design". This is a completely self contained unit, without umbilicals. It can be pigged into position and actuated using a 'through pipe wall' remotely controlled operating system.

6.2.3.3 KH TECNOMARINE PLUGGING PIG



Plugging Pig *Courtesy:KH Tecnomarine*

KH Tecnomarine manufacture a wide range of plugs and joint testing equipment. One of the more recent introductions is a remote controlled plugging pig which was developed from the company's well tried and tested umbilical operated tool. The original tethered version was developed to the point where it had a remote disconnect system, so that in the event it was necessary to pig the tool back, the umbilical could be disconnected and removed prior to that operation. However, it was recognized that a fully remotely operated version was highly desirable and a great deal of work went into its development.

Although these plugging pigs are bi-directional, they are designed to seal in one direction only. They also often have to operate at extremely

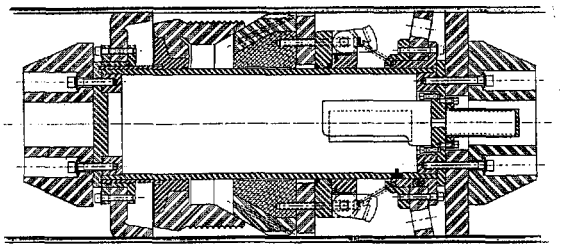
high pressures, so they are generally of very heavy construction. The question of wear and support when pigging over long distances is another area therefore which has had to be addressed.

Over the past few years, the company have carried out a significant amount of further development work in perfecting the through wall communications and isolation procedures.

There seems little doubt that tools of this type provide unique opportunities for subsea pipeline maintenance.

6.2.3.4 ITAS 'PAPlug'

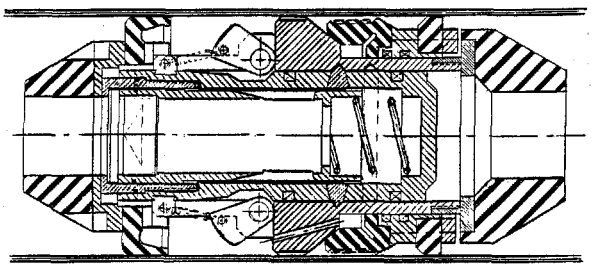
ITAS are based in Norawy and the PAPlug is one of the more recent introductions.



Downstream PAPlug *Courtesy: Pipeline Products & Services Inc.*

Announced in 1994, the PAPlug was patented by Pipeline Products and Services Inc. of Canada. It is probably unique in that it does not rely on any external actuating device. It is a simple, purely mechanical, self contained unit which can be used to temporarily isolate a section of pipeline during construction, maintenance or repair. The design utilizes available internal pressure and flow in the pipeline to activate the locking, release and sealing mechanism of the pig. It functions as a 'one way clutch', traveling in one direction, but locking when forced to travel in the opposite direction. When the PAPlug is locked, the line pressure activates the seal by pushing it onto an expanding cone. Reapplying pressure to drive it forward automatically releases it.

The locking mechanism is based on the moving strut principle. The struts are fitted with aluminum grippers to prevent damage to the pipe wall and are spaced to provide an evenly distributed load. When used as a pair to isolate a section of pipeline with pressure, two different pigs are required. A downstream pig and an upstream pig. The pigs are activated and locked in place by reverse movement and differential pressure. Specific procedures are given for the movement into place, locking, unlocking and moving to another site or to the receiving trap.



UpStream PAPlug *Courtesy: Pipeline Products & Services Inc.*

As with many other high pressure pipe plugs, the maximum allowable operating pressure is determined by the pipe diameter, wall thickness and material. However PLP provide these calculations as part of the service.

Interestingly, although it was originally designed as a 'free swimming' pig, further development has resulted in a tethered version which is primarily for the isolation of risers. This path is the opposite of most development programs in this area.

6.2.3.5 PLUGGING SPECIALISTS INTERNATIONAL 'SmartPlug'

Plugging Specialists International AS (PSI) launched their range of remotely operated plugging pigs in 1998. They are similar to other remote plugging pigs in that they use ELF as their communication system.

The company now offer sizes from 10" to 40" 'off the shelf' and the tools can be leased to isolate pipelines anywhere in the world. The plugs are type-approved by Det Norske Veritas (DnV) and carry a DnV Product Certificate.

6.3 HYPERBARIC SPHERES

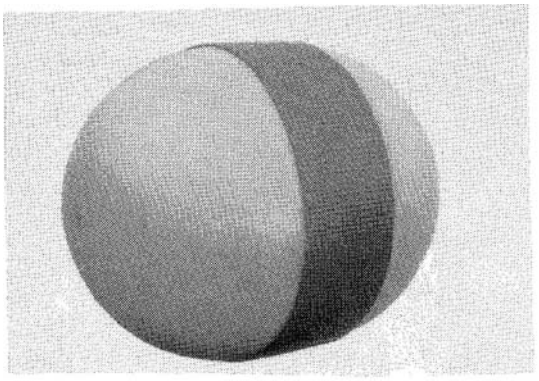
Hyperbaric welding is commonly used to join (tie-in) or repair subsea pipelines in situ. A 'habitat' is first positioned around the weld area and the water is then expelled by pumping in helium or a mixture of oxygen and helium. The welding and NDT processes can then be performed while working in a dry environment.

Hyperbaric spheres are used to plug the open ends of the pipe and are thus an important element in this type of work. They are installed by divers who must insert, position and inflate the spheres in each of the pipes to be joined.

Hyperbaric spheres are normally manufactured to order and may be fitted with removable handles to assist the diver in positioning them. Typically, they are constructed from three layers of polyurethane: a core, an intermediate layer to provide strength, and a softer outer layer, usually with a 'waffle' pattern to provide an optimum seal. An internal tie-rod is also built-in which limits the longitudinal expansion during inflation and so increases the force exerted by the sphere on the pipe wall to ensure a tight seal.

When the tie-in has been completed, the hyperbaric spheres are pumped out through the pipeline by pigging in the usual way. Typically hyperbaric spheres will retain a differential pressure of between 15 and 45 psi (1 and 3 bar) depending on diameter and will require about 60 to 90 psi (4 to 6 bar) to pig from the pipeline.

In harsh conditions or moderately deep water it is usual to install two hyperbaric spheres in each pipe end but in shallower more moderate environments one will generally suffice.



Hyperbaric Sphere *Courtesy: Inpipe Products Ltd.*

6.4 HIGH DP AND SECONDARY BARRIER PIGS

6.4.1 HIGH DP PIGS

There are many instances when a subsea pipeline can be shut down and depressurized to allow maintenance or repair work to be carried out. However, emptying the line, flooding it and then subsequently dewatering and recommissioning it (which may involve drying) would be too costly.

One way of achieving this is to place a slug of water (or some other fluid) trapped between two or more pigs into the area where the work is to be carried out and then balance the pressure in the line with the static head pressure caused by the depth of water. This allows the line to be cut without contaminating the pipeline or polluting the sea. Once the work is complete, the line is re-pressurized and the pig train is pumped out.

In principle this is simple and the pigs should only be required to create a seal and not have to resist any pressure. However, in practice, temperature and tidal changes can and do result in pressure fluctuations so it is essential that the pigs are capable of resisting at least modest pressures.

As one solution to the problem, a number of companies have developed pigs which require a very high differential pressure (DP) to move them and they have become known generically as 'High DP' pigs. These are not to be confused with plugging pigs.

High DP pigs are basically bi-directional mandrel pigs with discs of different diameters and hardnesses stacked closely together. When forced into the pipeline, the elastomer discs, which are usually made of high performance polyurethane, are compressed creating very high pipe wall friction and hence requiring a high differential pressure to move the pig.

The pipeline diameter is a potential problem for deploying High DP pigs and clearly wear is a major concern, especially if the pigs must be pumped long distances into position. Another critical aspect is leakage through the pig body. Preventing this at relatively high DP's generally requires all the disc bolt fixing holes to be sealed either with fiber washers or by using

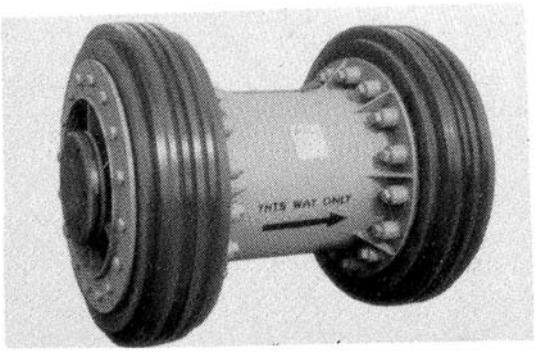
6.4.1.1 BJ PROCESS & PIPELINE SERVICES

One company that did a lot of the early development work on High DP pigs were McKenna & Sullivan. This company has since become part of BJ Process & Pipeline Services.

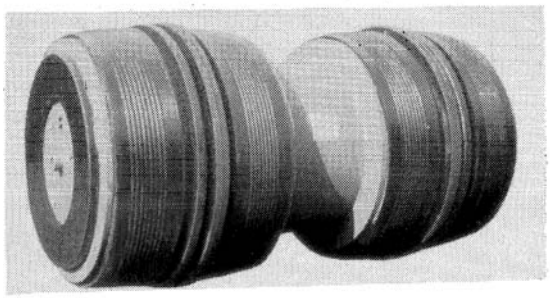
BJ Process & Pipeline Services are understood to have developed a method of calculating the DP required to move a given pig, or conversely, being able to design a High DP pig with predictable DP capabilities.

6.4.1.2 INTERNATIONAL PIPELINE PRODUCTS

International Pipeline Products are another company which have been actively involved with High DP pigs. So much so, that they now include them as part of their standard product range.



High DP Pig *Courtesy: International Pipeline Products Ltd.*



Piggable Plug *Courtesy: Internationsl Pipeline Products*

6.4.1.3 ACURITE 'ARC' SPHERE

The problem of the pipeline internal configuration and the wear rates on High DP pigs was addressed in an unusual way by now defunct company called Acurite, under contract to Shell. They developed a remotely activated. sphere known as the Acurite Remotely Activated, or ARC sphere.

Externally it resembled any other sphere but molded into it was an electronics package, a through sphere and pipe wall communications system, and a series of nitrogen bottles for inflating the sphere once it was in position.

A train comprising four of these spheres was used to isolate the 30" Leman to Bacton gas pipeline. A cup-type pig was subsequently developed along similar lines and is known as the ARC pig.

6.5 SOLUBLE PIGS

As the name suggests, soluble pigs are designed to dissolve in the pipeline product after a predetermined period of time. This makes them particularly useful for cleaning lines containing relatively warm fluids which may affect the material properties of the more conventional pigs. It may also eliminate the need to install receiving facilities in situations where only very infrequent pigging is required. They are also quite inexpensive.

One of the leading suppliers of soluble pigs is Select Industries Inc. who make two basic types. One type is oil-soluble and is intended for use in oil systems. These contain micro-crystalline wax, paraffin inhibitor and pour point depressant. The other type is water-soluble (for use in water systems) and contains a water-soluble surfactant and corrosion inhibitor. Both types can be supplied in either solid spherical or cylindrical shapes.

The inclusion of inhibitors in the oil soluble type is intended to reduce the subsequent rate of wax deposition while the pour point depressant reduces the viscosity of the oil that comes into contact with the pig, to improve flow characteristics at lower temperatures.

The rate at which soluble pigs dissolve is a function of fluid temperature, flow rate, friction, and the particular characteristics of the product in the line. The melting point for Select Industries standard oil soluble pigs is about 145° F. (63° C), but they can also supply special formulations with melt points in the range of 125° to 180° F. (52° to 82° C). It should be noted that even when the fluid temperature is below the melting point of the pig, it will eventually dissolve, provided there is some fluid flowing past it.

The procedures required for pigging a pipeline with soluble pigs are similar to those required for other types, such as foam pigs. The number of pig runs required to clean a line will be determined by the volume of dirt or debris to be removed, the length of the line, fluid temperature etc. Select Industries report that field experience has shown that short lines of 500 feet (150 meters) or less usually require 1 to 5 pigs and lines over about 500 feet (150 meters) usually require 5 to 10 pigs, sometimes more.

Although sticking a soluble pig is uncommon, where there are heavy deposits to be removed, or where the internal configuration is unknown it is still best to run smaller size pigs first, then progressively increase the size to ensure safe passage. It is always good practice to record the volume of the fluid behind a pig so that its position can be calculated should it become stuck. If it is safe to do so, then applying heat to the pipe can melt and so 'remove' a soluble pig. The capability to reverse the flow by pumping from the opposite end of the line is also a major advantage in helping to remove any type of stuck pig.

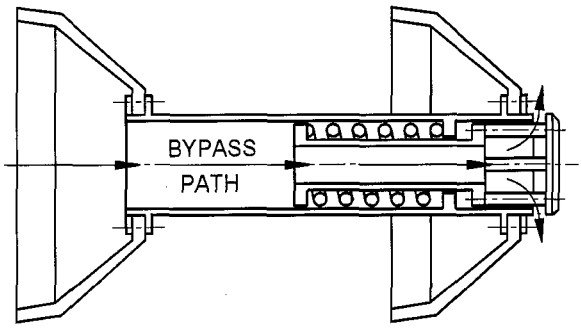
6.6 OTHER SPECIALIST PIGS

While the majority of operational pipelines can be successfully pigged using standard proprietary products, there are many occasions where a specialist pig is required and there are some companies that specialize in this type of "one off" product rather than having a range of standard pigs.

The following is typical of some of the specialist pigs which have been developed, most of which are now owned and operated by PII Pipeline Solutions.

6.6.1 PRESSURE BY-PASS PIG

The front of the 'pressure by-pass pig' is fitted with what is effectively a pressure relief valve, having a diameter of around 40% of the internal bore of the pipeline, and set to open at a pre-chosen differential pressure.



Pressure Bypass Pig
(Bypass opens at pre-set pressure)

If, during a proving or cleaning run, the pig builds up a large accumulation or slug of debris ahead of it, the differential pressure will rise as the pig begins to work harder in order to push the debris. Once the pre-set differential pressure is reached, the by-pass valve opens and the debris is jetted or from the front of the pig. This causes the differential pressure to drop, which then closes the by-pass valve again. In a particularly dirty pipeline, this sequence may take place many hundreds of times during a single run.

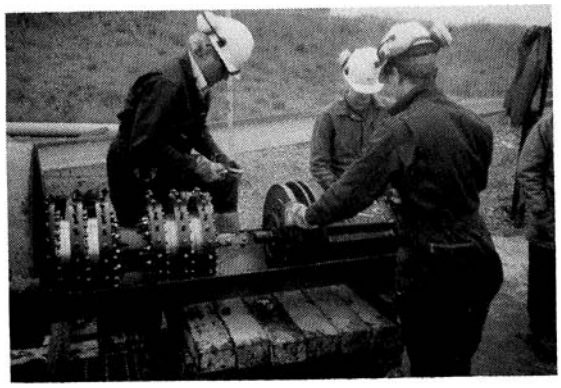
This feature also makes it highly unlikely that the pressure by-pass pig can ever totally block the pipeline, since the by-pass allows a continuous flow, giving time for the problem to be investigated and rectified.

6.6.2 PIN-WHEEL PIG

The pin-wheel pig was designed specifically to remove very hard wax and scale.

The cleaning assemblies consist of a number of heavy duty polyurethane discs which have an outside diameter significantly less than the inside diameter of the pipeline. Protruding radially from the circumferential edge of each disc are a number of steel pins with hardened tips which are radiused to prevent damage to the pipe wall. The diameter across any two opposite pins is greater than the inside diameter of the pipeline so that when the pig is traveling through the line, the pins are bent back at a slight angle. This both assists in the cleaning action and also compensates for any wear.

None of the wax or scale removed from the pipe wall will actually be pushed forward by the pig itself. This will be left behind in the line for removal by another type of specialist pig as part of the overall program.

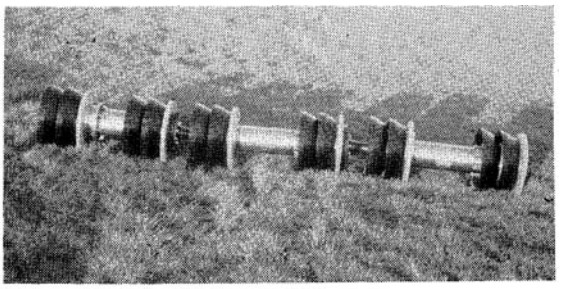


Pin Wheel Pig *Courtesy: PII Pipeline Solutions*

The number and the hardness of the pin-wheel discs is variable and, together with the fact that the pins are removable allows the 'aggressivity' to be tailored to suit the circumstances.

6.6.3 SHUNTING PIG

The shunting pig is basically a three-module articulated pig which has been specifically developed for the removal of stuck or lost pigs from pipelines. Experience has shown that if a pig does become stuck or lost in the pipeline, there is little point in running a second pig of similar or identical design to push out the first pig, since this pig is also likely to fail for the same reasons and simply add to the problem.



Shunting Pig *Courtesy: PII Pipeline Solutions*

What often happens to a pig which is required to push a stuck or lost pig is that the additional effort to remove it causes the second pig to become damaged itself. Using a three module articulated pig, the first module will probably become damaged to a considerable extent as it pushes the debris ahead of it, but drive will be maintained because of the second and third modules which never come into contact with the debris being pushed.

In principle it is simple, but much attention is paid to the design of a shunting pig. The weight can be critical and metal-to-metal contact between the shunting pig and the debris is avoided by fitting a hard polyurethane bumper to the front of the first module. The shunting pig is also equipped with permanent magnets for tracking purposes, together with a battery operated electromagnetic transmitter for positive location when stationary.

6.6.4 SPRAY PIG

The application of corrosion inhibitors to pipelines is normally achieved by injection or by periodically running a batch of inhibitor through the line in between two pigs. However, neither of these methods will guarantee full coverage of the internal surfaces and if this is not achieved, then in extreme cases, 'preferential' corrosion can occur. In layman's terms, this means that the metal loss that would have occurred over the whole surface will be concentrated in those areas not protected by inhibitors - a situation which is worse than it would have been without using inhibitors at all.

The problem of inhibiting long, large diameter wet gas lines is particularly acute and BG Kershaw were given a contract to develop a pig which carried a tank full of inhibitor through the pipeline and literally sprayed it onto the surface. The rear of the pig is equipped with nozzles and the inhibitor is pressurized using nitrogen. For long lines, where the pig cannot carry sufficient inhibitor to cover the line in a single run, multiple runs are used, each run covering a particular section.

A 36" Spray Pig has been used successfully a number of times but it is not known whether there are plans for any further development.

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7.0 GEL PIGS and PIGGING

Gel pigs evolved originally from a downhole oil field environment. Hydraulic fracturing of downhole reservoir rock requires high viscosity fluids. Most pipeline gels are water based but a range of chemicals, solvents and even acids can be gelled. Gelled pigs for pipeline use are now available in a wide range of formulations.

Gel pigs offer numerous advantages. They can be inserted through a 2" opening, they can perform in lines of varying diameters, pass line restrictions, intrusions, or probes, maintain a seal over long distances and move large amounts of solid debris. The following outlines the main types.

7.1 FLUID GELS

Much of the information contained in this section has been obtained from papers presented by HydroChem Industrial Services Inc. and the authors would like to acknowledge this fact.

7.1.1 SEALING and SEPARATION GELS

Batching or separator, gelled pigs are prepared by gelling fresh or sea water with a cross linked polymer. Such gels will flow around objects or shear through restrictions and then reform into a single mass. Since the gel is water-dispersible there is some degradation by line fill or displacement water.

For disposal the gel can be discharged into the open sea. If necessary a chemical breaker can be injected into the gel as it leaves the pipeline causing the gel structure to be destroyed. The gels are biodegradable and therefore have little environmental impact. They are approved for marine discharge by several countries.

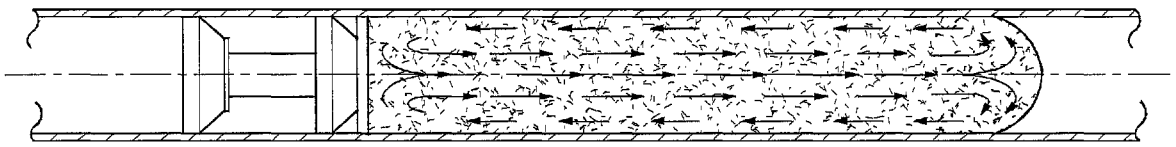
Batching gels can be used alone, if displaced by liquids, or in conjunction with a mechanical pig if displaced by or displacing a gas. Batching gels are usually run in a 200 to 2,000 foot (67 to 679 meters) slug, depending on the pipeline diameter and length. In a wet pipeline differential pressure for displacement will be similar to that of the line fill. A dry pipeline will require higher displacement pressures and should be provided for when planning gel pigging.

7.1.2 DEBRIS PICK-UP and CLEANING GELS

All types of gelled pigs can pick-up and transport loose debris, but with variable efficiencies and loading levels. Debris pick-up gelly pigs are prepared from fresh or sea water. The gel has a high yield strength which helps ensure that debris remains suspended even if the gel is static for long periods. The viscosity and yield point increase as the debris-loading increases. Debris pick up gels must be run in conjunction with a mechanical pig following the slug. The slug should be displaced at 1 to 3 feet per second (0.3 to 1 meter per second) to ensure that the gel moves as a plug.

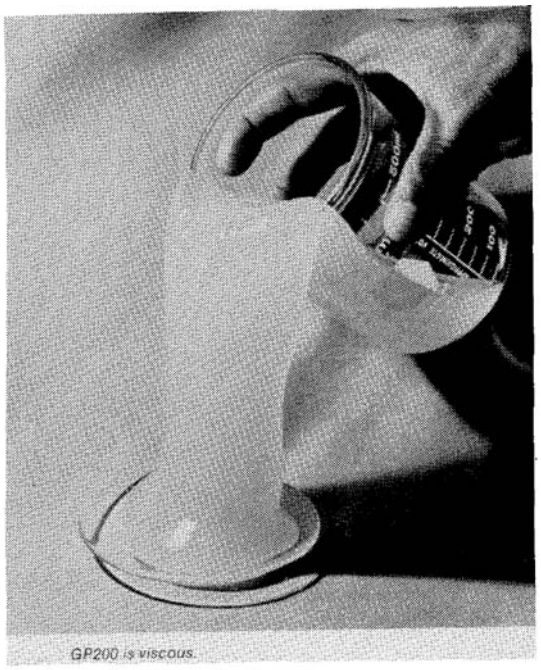
During displacement, the gel in the annular zone is removed from the pipe wall by the mechanical pig and flows forward into the core of the slug, generating a "tractor action"

The gel is very adhesive to either previously loose or newly pig loosened debris. The debris is picked up, entrained and carried forward into the core of the slug. This way debris will not accumulate in front of the pig but is distributed throughout the gel slug.



Tractor Type Motion of Debris Pick-up Gel

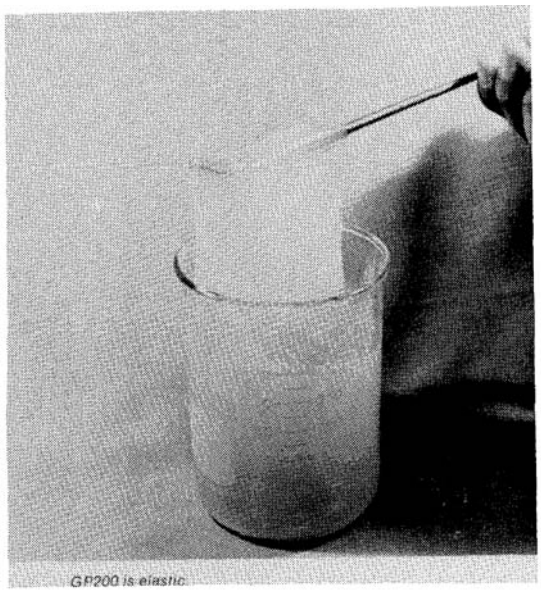
Since the debris pick-up gel is readily water dispersible, it must be protected at each end by batching gels to prevent dilution from the displacement water. The batching gels and the debris pick-up gels are very different and do not intermix in the pipeline. At the front of the slug the two gels may be in contact, however, at the rear a mechanical pig must be used to prevent the tractor type action from carrying the batching gel into the debris pick-up gel.



Typical Gel Property *Courtesy: HydroChem Industrial Services*

The design parameters for a cleaning train have considerable latitude for operational contingencies. A debris-carrying gel slug designed for the expected amount of debris will tolerate 100% dilution by water without dropout of solids.

When discharged into the sea the debris pick-up gel disperses very quickly. The additives to the water to make the gel are biodegradable with no adverse environmental impact. Several countries have approved direct marine discharge. For inland pipelines approved landfills have been used for gel disposal.



Typical Gel Property *Courtesy: HydroChem Industrial Services*

7.1.3 CARRIER and INHIBITOR GELS

Hydrocarbons such as diesel or kerosene may be gelled and will have the same sealing efficiency as batching-gel pigs. These gelled pigs are very effective in flushing accumulated or unpiggable water and debris from oil lines or removing condensate from gas lines.

The gels can be loaded with corrosion inhibitors and in this form have proven effective for simultaneously removing unwanted liquids and applying corrosion inhibitor.

After the hydrostatic test, alcohol and other drying agents such as methanol may be gelled and used in a pig train during pipeline

dewatering and drying. This will reduce the number of pigs and/or pig runs required.

In a typical drying-train sequence, the lead slug is a regular water based batching gel pig, whose purpose is to push out most of the free water in the line. Using this gel as the lead slug, prevents large amounts of water entering the gelled drying slug.

A gelled hydrocarbon with corrosion inhibitor may be used as a third slug after the drying slug so that the pipeline is dewatered, dried and inhibited with one train of gelled and mechanical pigs.

7.2 PRE-CAST GEL PIGS

The fluid gels previously described usually require a considerable amount of equipment to be mobilized and this cannot always be justified. One option might be to use a pre-cast gel pig. This is made of a highly viscous, generally water soluble gel which is precast in a steel mold where it remains during transportation to site. It is then pushed out of the mold directly into the pig launcher.

The pig has a degree of compressibility which allows it to be pumped through different diameters, but as with most gels, it is susceptible to gas breakthrough. However, this ability to break up is perhaps its major advantage in that if it meets an obstruction, blockage of the line is unlikely and it is also possible to discharge it through small diameter outlets.

Pre-cast gel pigs are normally available from the same suppliers as fluid gel pigs.

7.3 SPECIAL GEL 'PIGS'

7.3.1 PLUGGING GELS

There have been a number of research projects designed to develop safe and reliable tools and methods to isolate sections of subsea pipelines using gels, typically:

1. The insertion of a gel slug trapped between two pigs/spheres, which can be halted at a predetermined point and then frozen to create a solid plug.

2. A pig which carries a reservoir of gel which can be stopped at a predetermined point, where-upon the gel is released into a annulus and frozen into position.

3 A highly viscous gel which on its own or as a slug trapped between two pigs can withstand a relatively high differential pressure.

It is believed that none of these methods has actually yet been used in service and the status of their development is unknown.

7.3.2 'GELBLOK' VALVE SEALANT

'GELBLOK' was developed by HydroChem Industrial Services. It is a water based, biodegradable, non-regulated and non hazardous product which was specifically designed to seal leaking valves during routine pipeline pressure testing.

The basic method is to inject GELBLOK through 2" hot tapped connections which are made adjacent to the valves prior to the pressure test. The gel is capable of sealing

relatively large gaps. In tests, a 0.156" (4 mm) orifice was sealed against a pressure of 2,000 psig (138 bar) and in a 36" test with a simulated crescent shaped leak which was 0.125" (3.2 mm) to 0.25" (6.4 mm) wide by 3" (75 mm) to 4" (100 mm) long, held more than 800 psig (55 bar).

After the pressure test the bulk of the gel is normally recovered through the tapped holes, while the residue is removed with the test water.

7.3.3 FOAMED FLUIDS

To date, foamed fluids are believed to have been used only for dewatering, and on very few occasions. Foamed fluids were used successfully in the UK Sector of the North Sea to dewater the gas lift line from Tartan 'A' to Highlander. This piping system has a number of different, and widely varying inside diameters, from small choke lines of 0.25" (6.4 mm) through 2" (50 mm) crossovers, and a 4" (100 mm) flexible jumper up to the main 8" (200 mm) line with an ID of 7.625" (193.7 mm).

It was essential to dewater this system to prevent the formation of hydrates. Obviously rigid body or foam pigs could not be used and the more common form of gel pig proved unsuitable due to break down caused by probes being in the line and the problems of gas break-through. The result was that some 15% of the system still contained water.

The foamed fluid technique was devised by Nowsco to remove the remaining free fluids. High-expansion aqueous foam is injected into the line. The foam has a high surfactant concentration and sweeps the fluids ahead of it. Any fluids which fall back into the main body of the foam are either entrained and carried out or left in the line. The remaining fluids contain surfactant absorbed from the foam which causes them to be refoamed by the displacement gas under turbulent conditions and so be carried from the line.

Any residual aqueous foam is then displaced from the system by methanol foam, the concentration of which is sufficient to reduce the hydrate point of the remaining water/methanol mixture.

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8.0 IN-LINE INSPECTION PIGGING

8.1 GENERAL

In-line inspection (ILI) services utilize an 'intelligent pig' or 'ILI tool' to provide information about the pipeline or its contents. Most tools will measure and record both the magnitude and the position of the anomalies or features that they are designed to detect. These inspection services are often referred to outside the USA as "on line inspection"; meaning that the line will be inspected while it is in service (or on-stream). The ILI tool is used to gather the data which is then analyzed, normally by the suppliers' engineers and technicians, to determine and report on the condition of the line.

ILI really began in 1965 when Tuboscope introduced their 'Linalog' metal loss tool. This was soon followed by T D Williamson's 'Kaliper pig' for geometry measurement. Today there is a very wide range of tools in use by the many different companies that provide instrumented pigging services.

These ILI services now provide the information required for the majority of inspection and trouble shooting needs. The two most common are: 'Metal loss' (which includes corrosion) and 'Geometry' measurement (which includes physical damage).

Other services which are available include:

- Crack detection
- Mapping or profile monitoring
- Leak detection
- Bend measurement
- Video camera inspection
- Product sampling
- Wax deposition measurement
- Line cover and spanning

In some cases, the tools can be combined to provide data on two or more of these areas of interest in a single pig run.

Many years of research and many millions of dollars have been spent in the development of these tools and detailed information about them remains confidential. In addition, with the rapid advances in technology, the specifications and capabilities of each tool are constantly being up-graded so if specific information is needed, it should be obtained directly from the suppliers, the contact details for whom are listed in the Appendices.

The following is not, and cannot be definitive, but it will provide useful information and guidance on many of the services currently available.

8.2 METAL LOSS SERVICES

8.2.1 GENERAL

The early attempts at finding corrosion were by using pigs which recorded the temperature and pressure inside the pipeline. The reasoning behind this was that the pressure and in particular the temperature, often determined the point at which water drop-out would begin and therefore the point at which corrosion would occur. T.D. Williamson Inc. were one of the pioneers of this approach and they built a number of prototype pigs to record both the temperature and pressure in the line. Many tests were conducted by them during the late 1950's and early 1960's.

The main problem with temperature recording in the early days was the very slow response time of the sensors and when recording pressure, the pig itself caused local differences

which presented some major problems. Modern temperature and pressure sensors have resolved these early problems. At least one company (Copipe) produced a dedicated Temperature Profiling Pig and some instrumented pigs are fitted with temperature and pressure recording facilities as an almost incidental part of their main task. Product Sampling Pigs are a typical example.

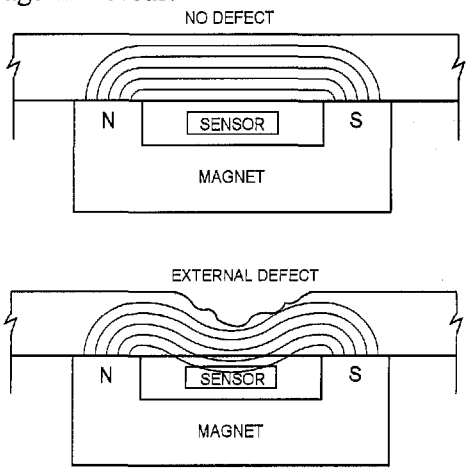
Metal loss and cracking are generally agreed to be the areas of most concern and it is estimated that over one billion dollars has been spent to date on ILI research and development into metal loss alone.

At present, there are three basic technologies which are used for metal loss surveys: magnetic flux leakage, ultrasonics and eddy currents. These are discussed below.

8.2.2 TECHNOLOGIES

8.2.2.1 MAGNETIC FLUX LEAKAGE (MFL)

Perhaps the simplest explanation of the way in which MFL, ILI tools operate is by comparing it to the well known horseshoe shaped magnet. To retain its power, the magnet is fitted with a 'keeper'. This is simply a metal bar which carries the flux from one pole to the other. If the cross sectional area of the keeper at any point is insufficient to contain the flux, then leakage will occur.



Similarly the MFL tools are fitted with two rings of magnets, spaced apart and with opposing poles to induce a flux into the pipe wall, which in effect becomes the 'keeper'. Sensors are mounted between the poles to detect any flux leakage which occurs due to thinning of the wall, or 'metal loss'.

Clearly it is important to saturate the pipe wall so that any metal loss will cause flux leakage. This requires very powerful and often very large magnets, held in close contact with the pipe wall. This has proven to be a limiting factor with respect to the use of MFL in heavy wall pipe as well as problems due to the available space in developing smaller size tools. The maximum wall thickness of MFL tools will vary with the line diameter and speed but for most standard tools it is generally in the region of 1" (25 mm). However, current development work is significantly increasing this and some of the latest tools can inspect large diameter pipelines with wall thicknesses up to 1.5" (38 mm).

The magnetic field travels in what has been described as a 'cloud' which follows the tool and gets weaker as the tool moves away. It is this effect which limits the maximum speed, usually to around 13 ft/sec (4 m/sec). For thicker pipe walls, the speed may need to be reduced considerably to allow time for the flux to saturate the wall and many tools are now fitted with speed control systems.

The early MFL tools suffered particularly from the lack of suitably powerful magnets. To deal with this problem Tuboscope, who introduced the first commercial ILI tool, installed electromagnets. It is understood that they still prefer this method as it enables the flux density to be adjusted to suit the wall thickness and the running speed. Most other MFL tools have since resorted to permanent magnets and it is here that some significant developments have taken place.

British Gas (now PII Pipeline Solutions), who developed the first of what is now generally

referred to as the 'second generation' of ILI tools commented in a technical paper that one of the greatest benefits during the latter stages of their development program came from the improvements in magnetic materials. For example, Neodymium-Iron-Boron magnets have ten times the strength in energy per unit volume, than the Alcomax magnets used in the early 1970's. The use of brushes to maintain better and closer contact with the pipe wall has also greatly improved the efficiency.

Most MFL sensors are based upon the 'Hall-effect' where any flux leakage generates a small electrical signal. In the early ILI tools, the sensors were mounted on a few large and heavy 'sledges' equally spaced around the circumference. Although this resulted in a loss of contact with the pipe wall under various dynamic and geometric conditions it was felt that they needed to be robust to withstand pipeline operations. This particularly affected inspection in the girth weld area and on tight bends.

It was another mechanical development which contributed significantly to the dramatic improvements in the new tools. The new design philosophy was that if the sensors were mounted on very small, light sledges, they would be more easily deflected if they did meet an obstruction and actually be less likely to sustain damage. Equally importantly, they would maintain contact right up to the point of the obstruction and would more rapidly regain contact afterwards. This change, coupled with other methods of improving the sensor ring mounting has led to it often being possible to detect metal loss in the weld itself.

Another innovation in the new tools was to mount a second sensor ring at the rear. This is primarily to determine whether the metal loss is internal or external. The first, or primary ring detects all metal loss. The second ring detects any residual flux loss, which at this point, can only be caused by internal metal loss. Using this principle, it is understood that some tools can actually measure the wall thickness, although how this is achieved remains confidential.

PII once described the rate of data gathering as being equivalent to reading the Bible every six seconds. Today, that would be considered far too slow! Recent developments in the electronics industry, driven by the demands of such things as personal computers (PC's) and digital cameras, are increasing processor speeds by about 40% each year and data storage capacity is increasing even faster. But even though a considerable amount of data can now be processed on board the ILI tool, there is still a vast amount to be analyzed after a run which may take a very long time.

The accurate identification, sizing and location of defects is a fundamental requirement and involves a lot of high powered computer processing. Each signal received from the sensors has a characteristic pattern which must be identified as a particular feature which may, or may not be metal loss. This analysis may also involve comparing the signals recorded, with a library of signals from known defects. Not surprisingly, the final report may take many weeks to prepare.

The report is also vitally important. It must be presented to the client in an understandable and usable format and the latest developments here center around its presentation on diskette or on compact disk (CD) for use on a desk-top PC. Probably the most immediate use for the report is to use the defect size to determine the maximum allowable operating pressure (MAOP). The calculations for this have generally been based on ANSI/ASME B.31-G. However, as more knowledge and experience has been gained it has been shown that a detailed 'Fitness for Purpose Assessment' can significantly reduce the number of repairs actually required.

With growing competition among the inspection companies it has become increasingly difficult for operators to determine which service they ought to use. Unfortunately, the terms 'second

generation', 'advanced' and 'high resolution' have never been defined. This resulted in almost all suppliers claiming that their tools are 'high resolution', even when using the older-type tools.

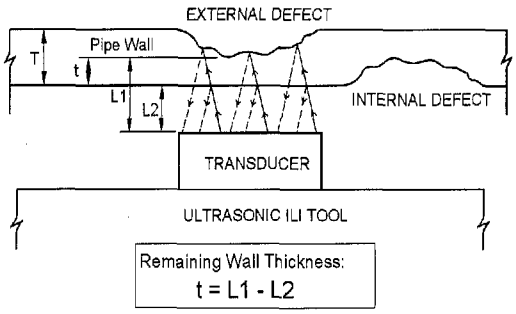
It is doubtful whether any supplier could claim to have a 'second generation' tool if it is not fitted with light-weight sensor rings, or if it does not use either electro-magnets or the latest rare-earth permanent magnets. But the claim to have a 'high resolution' tool is less difficult to justify. In fact, whether or not a tool is 'high resolution' depends entirely upon the size of defect to be reported. If the defect is large enough, any tool could claim to be high resolution. It is best therefore to ignore all the descriptive jargon. The only way to select the correct inspection service for any pipeline is to clearly define the needs in terms of minimum defect type and size, and include it in the contract. Whichever supplier can provide the required level of reporting should be included in the bid list, regardless of what they call their tool!

8.2.2.2 ULTRASONICS (UT)

The principle of ultrasonic inspection is well known. A transducer emits a pulse of ultrasonic sound which travels at a known speed. The gap between the transducer and the inside pipe wall is referred to as the 'stand-off' distance. On entering the pipe wall (the 'front wall') there is an echo, and another echo as the pulse reflects off the back wall. The time taken for these echoes to return provides a virtual direct reading of the wall thickness.

Unlike the MFL tools which have a maximum allowable wall thickness, the UT tools have a minimum. This too will vary depending on the particular tool or circumstances, but is generally in the region of 0.2" (5 mm).

The transducers are 'fired' individually in a predetermined pattern to give 100% coverage of the pipe wall at a given pig speed, usually about 3 ft/sec (1 m/sec). Any increase in speed will simply decrease the coverage. It is understood that there is some development work in progress to automatically relate the firing rate to the pig speed.



Although the principle is very simple, UT tools also have some drawbacks. The first, and arguably the most important, is that they cannot normally be used to inspect gas pipelines as the sound will only travel through a homogeneous liquid. The word "homogeneous" is almost as important as the word "liquid" in this context as such things as gas bubbles and wax flocculation can affect the results.

Another important point for the UT, ILI tool designer to keep in mind is that the transducers must be maintained square to the surface of the pipe wall to within a very few degrees or the echo will be missed. This poses particular problems on bends and through dents and other similar features which may deflect the signal.

Another potential problem is that normally, UT, ILI tools will only record the first two echoes received. The pulse is emitted by the transducer in the form of a cone, thus if there is a small corrosion pit for example, it is possible to have two (or more) front wall echoes (the first from the front wall and the second from the pit) before the back wall echo returns. These could be interpreted as a front and back wall echo respectively and so produce a 'wall thickness' equal to the depth of the pit! Incorrect interpretation is often referred to as a 'false call'.

Continuous development has meant that many of these problems have been partially or even completely overcome. It will be noted that the stand-off distance is one of the most important factors. If the transducer is close to the front wall, the problems associated with homogeneity will be lessened. It reduces the problems on bends etc., due to the angle of the returning echo. It also reduces the effective diameter at the base of the sound 'cone' and so minimizes the risk of false calls due to localized metal loss such as pitting corrosion. Work on the transducers themselves has also virtually eliminated most of these early problems.

As with the MFL tools, the mechanical developments have contributed a very great deal to resolving certain problems with UT tools. A good example of this is the PII UltraScan tool.

Although the internals of this tool remain confidential, the most prominent external feature is the transducer array at the rear. The transducers are embedded into a polyurethane 'cage' which is in effect towed behind the pig. The cage flexes, maintaining the transducers in close and constant relationship to the pipe wall, even when passing through bends or reductions in diameter. This design has allowed the tool to inspect dual diameter pipelines. However, those tools with a large stand-off can be more easily adapted to bi-directional use, which has proved useful in, for example, offshore loading lines.

In instances where a gas pipeline cannot be inspected by an MFL tool, perhaps due to excessive wall thickness, a UT tool can sometimes be used by running batching pigs in the line at either end of a slug of liquid in which the UT tool travels. Such an operation is not easy as it is essential to maintain a solid slug of liquid and, being a gas line, speed control of the resulting pig 'train' may prove to be very difficult.

Research into the use of ultrasonics to inspect gas pipelines using EMAT (Electro Magnetic Acoustic Transducer) technology has been going on for at least two decades, but it is only recently that it has been successfully applied to pipeline inspection - initially for the detection and measurement of Stress Corrosion Cracking (SCC). Further details of this technology will be found in section 8.4 which discusses crack detection.

8.2.2.3 EDDY CURRENTS

Eddy current technology has been used for many years in geometry tools, but now it has been introduced for detecting and measuring metal loss. The basic simplicity of this technology allows the ILI tools using it to be extremely light and small. It has therefore proven useful for inspecting the smaller, more complex pipelines found in subsea production systems, refineries and industrial plant.

Eddy currents are electrical currents which occur when an alternating magnetic field is induced into the pipe wall. These eddy currents are affected by any changes in the physical characteristics of the material or of its geometry. The frequency of the alternating field will determine how deep these currents will penetrate, but it is generally accepted that the frequency required to penetrate the full wall thickness of a typical pipe would be so low as to generally make the pigs' allowable speed of travel unacceptable. However, quite high frequencies can be used for detecting 'surface' defects (e.g. internal corrosion) so it is possible to apply the technology for this purpose.

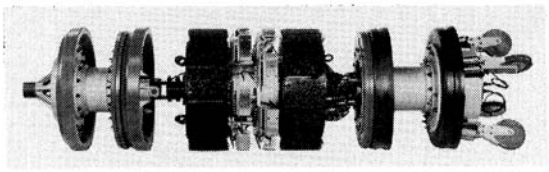
8.2.3 TYPICAL SERVICES USING "MFL" TOOLS

As stated at the beginning of this section, the specifications and capabilities of each tool are constantly being up-graded so the following is intended only to provide a brief guide. Information about the full range of services provided by each, or any specific details should be obtained directly from the suppliers, the

contact details for whom are listed in the Buyer's Guide, Section 16.

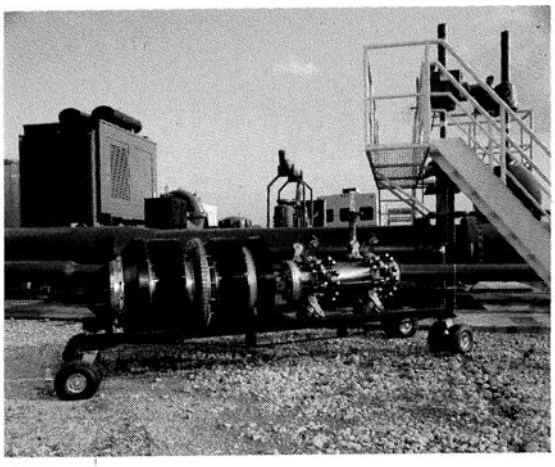
8.2.3.1 Linalog (Tuboscope Vetco Pipeline Services)

Tuboscope introduced the first of all the commercially available intelligent pigs in 1965.



Linalog Standard Resolution Tool *Courtesy: Tuboscope Vetco*

Unlike their competitors, Tuboscope generally utilize electromagnets rather than permanent magnets to induce the flux into the pipe wall and this is described in more detail above. But in common with all other tools it has been and still is undergoing constant improvement and development to take advantage of new technologies as they emerge. Tuboscope was the first company to offer a 4" MFL tool.



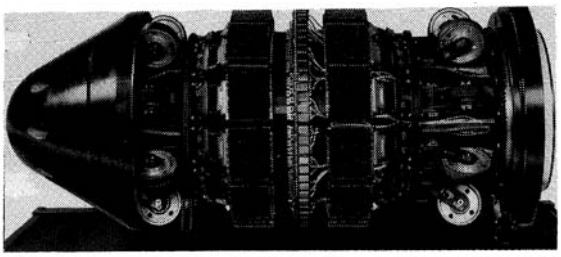
Linalog TruRes® Inspection Tool *Courtesy: Tuboscope Vetco*

Tuboscope have now introduced a very wide range of 'high resolution' tools, some of which, apart from having new sensor arrays, utilize eddy currents to determine whether any metal loss is internal or external. They have also introduced new software called "Linalog Plus". This can be used with the new and the standard tools to provide greatly enhanced reporting.

In 1996, Tuboscope acquired Vetco Pipeline Services Inc and merged the two operations to form Tuboscope Vetco Pipeline Services Inc.

8.2.3.2 MagneScan (PII Pipeline Solutions)

Some of these tools can trace their lineage back to work which was originally begun by Trans-Canada Pipeline on magnetic intelligent pigs well over 30 years ago.



Early MagneScan Tool *Courtesy: PII Pipeline Solutions*

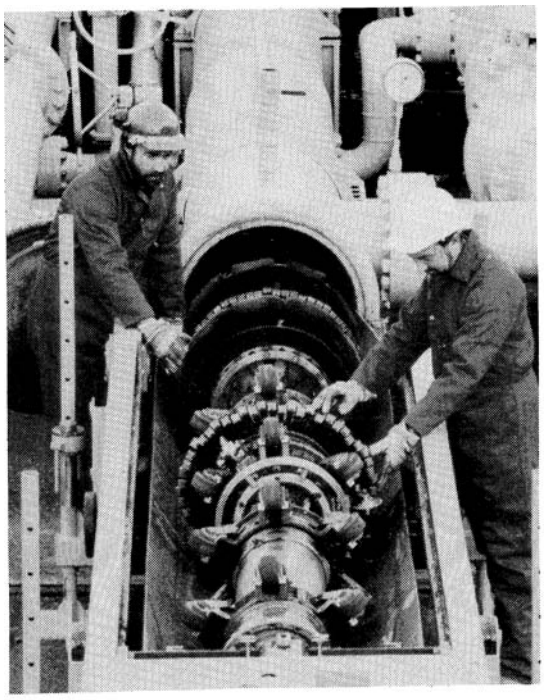
The first 'MagneScan' tool (shown above) was launched by Pipetronix GmbH in 1977. It was generally more compact than the later 'High Resolution' tools, particularly in the larger sizes, comprising a single unit instead of the more common multiple modules used today.

Some years earlier, the then "British Gas" (pipelines) had notified the pigging industry of their requirements for an ILI tool. The general consensus was that it could not be done. British Gas felt that such a tool was essential, so they invested heavily in an R&D program to meet their objectives. This resulted in the creation of the British Gas On-line Inspection Center and the development of what became known as the "second generation" pigs.

With the privatization of British Gas, the On Line Inspection Center became Pipeline Integrity International (PII), a part of BG plc.

Subsequently, ownership of PII changed and the company itself made a number of acquisitions. Eventually, Pipetronix also became a member of the PII Group, which is itself now a part of GE Power Systems.

The technical expertise and inventories of both PII and Pipetronix was combined to offer the present range of tools which are now marketed under the 'MagneScan' name.

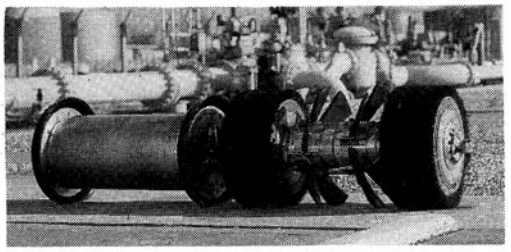


MagneScan Tool *Courtesy: PII Pipeline Solutions*

The MagneScan range now provides for MFL inspection of virtually all pipeline sizes and lengths, and even for the inspection of some dual diameter pipelines. PII have also carried out a great deal of development work in connection with improved methods of reporting and advanced studies into risk analysis and defect assessment.

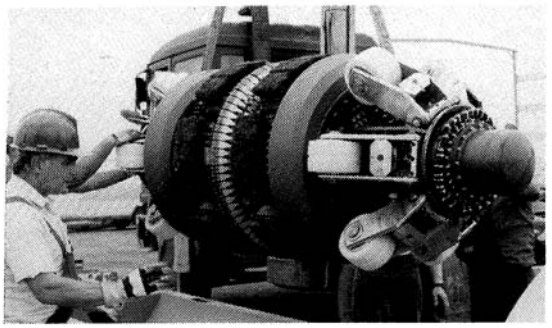
8.2.3.3 Corrocontrol (TRAPIL)

Although the principle of operation of the Corrocontrol pig is similar to the others, it differs in that the magnets and sensors are usually mounted on the rear module and not on one of the leading modules.



Corrocontrol *Courtesy: Trapil*

8.2.3.4 HiRes Metal Loss Mapping (H Rosen Engineering GmbH)



Rosen HiRes Metal Loss Mapping Tool *Courtesy: H Rosen Engineering*

H Rosen Engineering (Rosen) have been developing ILI tools for well over 20 years and introduced their first Metal Loss Mapping tools in 1987. They now offer a full range from 4" to 56" and were one of the first companies to offer the results in the form of a client software package called ROSOFT. This enables the client to manipulate the data obtained and present it in almost any form required for a given purpose.

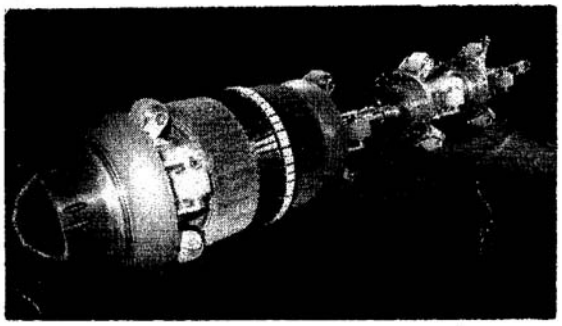
8.2.3.5 Vectra MFL Tool (BJ Process & Pipeline Services)

This is one of the later MFL tools (1996) and has a number of highly sophisticated features. Like all ILI tools, it has certain limitations with respect to the speed at which it can be run for optimum inspection of the pipeline. The latest BJ tools, have active speed control and can, for example, travel at 10 ft/sec (3 m/sec) in a pipeline operating in excess of 40 ft/sec (12 m/sec). This can result in major savings for operators as throughput does not need to be compromised during an inspection.

The tool uses Hall Effect and Eddy Current sensors to measure external and internal metal loss and a particularly novel feature is its use of inertial navigation to provide GPS co-ordinates for the location of defects to within 1 meter, without the need for above-ground markers. This latter facility is a direct result of the experience gained with the "Geopig" which is described in a later section.

Neural network computational techniques are used during the interpretation and data analysis to prepare accurate reports and "VECTRAView" software is provided to enable the client to display and analyze the results.

Like most other companies in the ILI field, further research and development is proceeding at a fast pace and has led to the use of a 'tri-axial' sensor head configuration which facilitates the detection and sizing of narrow axial corrosion features.



MFL Inspection Tool *Courtesy: BJ Process & Pipeline Services*

8.2.3.6 MFL/DMR Tools (3P Services GmbH)

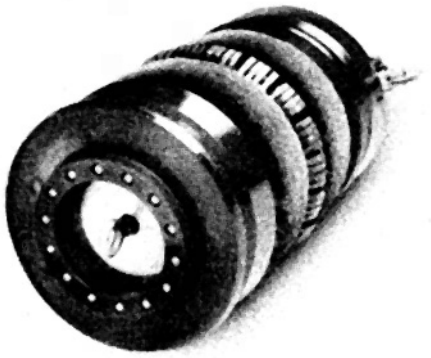
3P Services originally developed MFL tools for use on the smaller pipelines, typically those used for in-field and plant services. Now, the range has been expanded to cover sizes from 3" to 36" using MFL technology and a system called DMR (Direct Magnetic Response) for the inspection of heavy wall pipelines.

The company has specialized in the inspection of very difficult - or even 'unpiggable' pipelines and has amassed a great deal of expertise in dealing with such problems.

8.2.3.7 Magpie MFL Tool (T.D.Williamson Inc.)

Described as 'compact, rugged and robust', the tool designed and operated by Magpie Systems Inc, a TDW company, is designed to provide a simple, reliable and cost-effective metal loss inspection service.

It can be used in conjunction with a simple Above Ground Marker system to provide accurate location of defects. All of the unfiltered data gathered by the tool is included with the detailed report, as well as the software to facilitate any subsequent analysis.



Magpie MFL Tool *Courtesy T D Williamson Inc.*

8.2.3.8 High ReSolution Tool (Cornerstone Pipeline Inspection Group)

The development of the Cornerstone Pipeline Inspection Group (CPIG) 'High ReSolution' tool was spurred on by the implementation of the US Department of Transportation's Integrity Management Rule.

Marathon Ashland Pipe Line LLC who operate over 4,000 miles of lines affected by the Rule, were concerned about the ability of the existing ILI companies to be able to meet the demand. They therefore supported CPIG, one of their existing pipeline integrity suppliers, in the development of this range of tools.

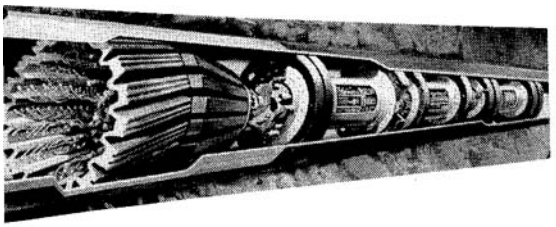
The relatively shorter tool length and long range capability is claimed to significantly reduce the cost of an ILI survey.

8.2.4 TYPICAL SERVICES USING "UT" TOOLS

8.2.4.1 UltraScan WM (PII Pipeline Solutions)

The UltraScan system is the result of many years of development work carried out in conjunction with the Kernforschungszentrum Karlsruhe in Germany. The first UltraScan tool was designed for wall-thickness measurement and was introduced in 1985. This became known as the UltraScan WM. These tools have an impressive track record and have been successfully run in dual diameter pipelines and even in gas pipelines by being immersed in a slug of liquid.

As already mentioned, one of the most interesting visible features is the polyurethane transducer carrier which flexes with the internal geometry of the pipe in order to keep the transducers at a fixed stand off distance.



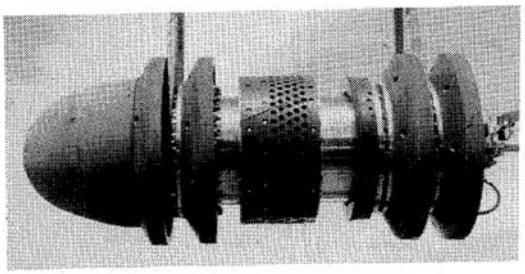
UltraScan Tool *Courtesy: PII Pipeline Solutions*

The data is presented on a PC or in hard copy in the form of a color chart which quickly and clearly shows the extent of the changes in wall thickness (C-Scan) together with a B-Scan which provides the depth of the various defects.

When necessary, the UltraScan WM tool can be adapted to almost eliminate the problems of detecting and measuring pitting and channel corrosion. Pits well below 0.4" (10 mm) in diameter can be identified and sized.

8.2.4.2 Ultrasonic Inspection Tool (NKK Corporation)

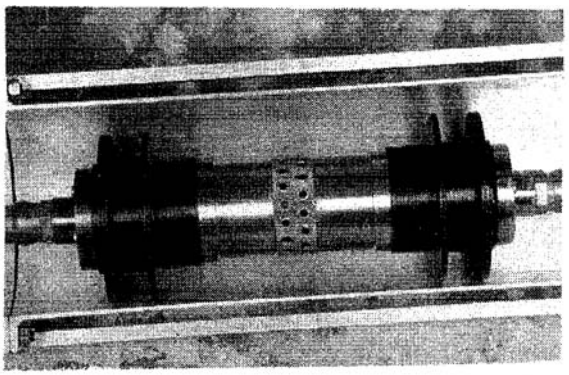
NKK carried out development work on ultrasonic ILI tools for a number of years and this culminated with the introduction in 1987, of a series of tools with which NKK provide inspection services. The original size range was from 16" to 48" but it is understood that smaller tools may be introduced. The specifications are very impressive with some tools allowing a maximum speed of up to 10 ft/sec (3 m/sec).



Ultrasonic Inspection Tool *Courtesy: NKK*

8.2.4.3 Ultrasonic Tool (BJ Process & Pipeline Services)

This tool was announced in 1994 and was built specifically for inspecting heavy wall flow lines. It is unique in several ways. The 6" prototype comprises 6 modules and incorporates an internal valving arrangement that allows it to travel bi-directionally, always driving on the front module. It can negotiate 5D bends and can carry out three dimensional ultrasonic inspections on wall thicknesses ranging from 0.25" (6.4 mm) to 1.5" (38 mm).



Sonar Array *BJ Process & Pipeline Services*

Beryllium-Copper canister construction coupled with solid-state electronics provide a tool which is resistant to H2S, with a maximum operating temperature of 158°F (70°C). The raw data can be displayed on screen for preliminary review within about one hour in 'B', 'C', and 'D' scans.

The 6" prototype can inspect lines up to 6.2 miles (10 kms) long. It has 32 transducers which are arranged such that four are fired simultaneously at right angles to each other to allow the tool to automatically compensate for any eccentricity between itself and the pipe.

8.2.5 SERVICES USING EDDY CURRENT TOOLS

H Rosen Engineering are believed to have been the first company to apply eddy current technology to directly detect metal loss. Their first tool was announced in early 1994. It uses high frequency eddy currents to detect and measure internal corrosion and is undoubtedly a result of the technological know-how gained by them with their EGP geometry pig described elsewhere in this section. The first pig of this type is thought to have been for 6" pipe. But as the tools are provided on an 'as required' basis, there is theoretically no limit to the size range.

Since then other companies have applied this technology to MFL inspection, often to enhance a particular aspect of the task.

8.3 GEOMETRY SERVICES

8.3.1 GENERAL

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; and there are the more common risks and problems of third party damage.

Any of these events may cause physical damage, resulting in dents, buckles, gouges etc., but they may not (indeed they rarely do) cause the line to rupture immediately. Mostly, they result in deformation of the pipe. They are what might be called "insidious defects". The dictionary definition of "insidious" is "acting gradually and imperceptibly but with grave consequences" - and that is what some forms of physical damage can do to a pipeline. So it is vitally important that every significant deviation from the ideal shape for a pressure vessel, i.e. perfectly round, is investigated.

Quite apart from the danger inherent in diameter reductions, they may also restrict the free passage of inspection pigs. This is particularly important when running large, heavy ILI tools such as those using MFL technology which, if they became stuck in a reduction, could completely block the line.

However, to investigate and if necessary eliminate diameter reductions, it is first necessary to locate and define them, and this is the main purpose of the range of 'geometry' pigs.

The *Gauging Pig* has been used for many years to check whether there are any reductions in the internal diameter. This is simply a utility pig with a metal plate fitted which has been machined to a percentage (commonly 95%) of the nominal inside diameter of the pipeline. The idea is that should this pig successfully negotiate the pipeline then it is reasonable to assume that the pipeline does not have any reductions in diameter greater than the predetermined percentage amount.

Frequently though, the gauging plate is damaged and the operator then has the problem of determining what caused the damage, where

it is and whether or not the plate has now further damaged the pipeline. In severe cases the pig may not emerge at all and be stuck in the pipeline.

Some of these inherent problems can be overcome by using aluminum gauging flanges but these still do not provide information as to the type, extent or location of the problems. So the most common use for the gauging pig today is simply to determine whether or not a full geometry survey is necessary - a sort of "go" - "no go" gauge. Gauging pigs are available from most of the utility pig manufacturers.

In addition to the geometry pigs mentioned later in this section, it is common practice to precede a metal loss inspection survey with a geometry pig. As a result, the majority of companies offering metal loss surveys, now also have their own geometry measurement tools.

8.3.2 TECHNOLOGIES

There are two basic technologies which are currently used for geometry surveys: electro-mechanical and eddy currents. These are discussed below.

8.3.2.1 ELECTRO-MECHANICAL

The majority of geometry tools utilize this type of technology. Changes to the internal diameter of the pipeline, caused by such things as ovality, dents, partially closed valves, changes in wall thickness etc., are detected by 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 on a skid or wheel, or indirectly, by being mounted inside one of the drive cups. Any change in diameter causes these arms or fingers to move and this motion is translated mechanically, usually to a central rod which passes through seals into an instrument package installed within the pig body.

In the earlier tools, the diameter changes are recorded by simply fitting a stylus to the end of the rod. This provides a continuous trace on a strip of pressure sensitive chart paper, which shows the changes as the trace moves up or down. The strip chart is wound onto two spools one of which is driven forward by a stepper motor. The stepper motor receives pulses from the odometer wheels which are also pressed against the pipe wall.

The odometer wheels, which are used on almost all ILI tools, usually have a known circumference, such that each rotation represents a certain distance traveled along the pipe. On an electro-mechanical geometry tool, the electronics may be arranged such that each rotation of the wheel triggers the stepper motor and drives the chart forward a set distance. The resulting chart is therefore proportional to the length of the pipeline. The combination of the chart being driven forward and the stylus moving up and down across it, provides a trace which clearly indicates the reductions and their magnitude as well as an accurate location.

Later models of this type of tool convert the motion of the central rod into an electrical signal, which is digitally recorded. This allows the report to be studied on a PC and allows the scale to be adjusted at any point in order to study in much greater detail any anomalies which have been recorded. These later systems allow for much more rapid interpretation and can help to eliminate errors which may otherwise occur due to misinterpretation by the survey technicians.

8.3.2.2 EDDY CURRENTS

Eddy currents are electrical currents which occur when an alternating magnetic field is induced into the pipe wall. These eddy currents are affected by any changes in the physical characteristics of the material or of its geometry.

It is this effect that makes the use of eddy currents ideal for geometry measurement and

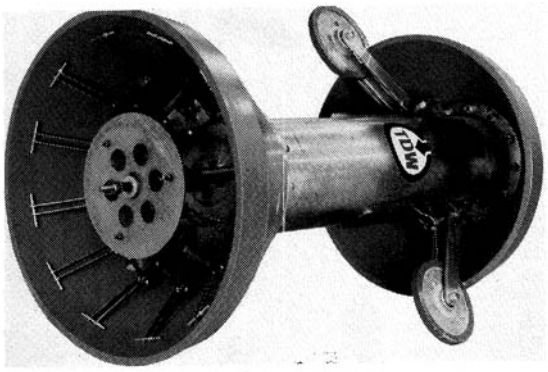
one company (H Rosen Engineering GmbH) has used this technique now for over two decades.

8.3.3 TYPICAL SERVICES USING ELECTRO MECHANICAL TOOLS

8.3.3.1 "Kaliper" Pig (T.D. Williamson Inc.)

T.D. Williamson (TDW) introduced the Kaliper pig in the 1960's to overcome the problems of using gauging pigs. Once a gauging pig had indicated there was a problem the time and cost of locating it was prohibitive.

As described above, by using an odometer wheel to measure the distance traveled and a stylus to indicate the extent of the damage, the resulting paper chart provided a trace which was proportional in length to the pipeline and on which were indicated the reductions of diameter. Skilled analysis could not only provide a measure of the reduction but also a reliable estimate of its shape and probable cause.



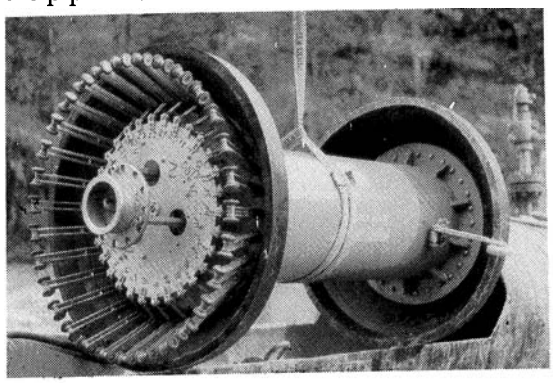
Kaliper Pig *Courtesy: T.D. Williamson, Inc.*

The Kaliper pig has been continuously developed and improved and now contains an electronic package and computer analysis which greatly enhances both the accuracy and the amount of information which it can provide.

8.3.3.2 CalScan (PII Pipeline Solutions)

When it was introduced in 1981, the CalScan was simply called the Caliper Pig or Cal Pig. It is similar in concept to the TDW Kaliper pig.

The CalScan is equipped with a high-sensitivity data recording system for locating and measuring anomalies in the inside diameter of the pipeline.

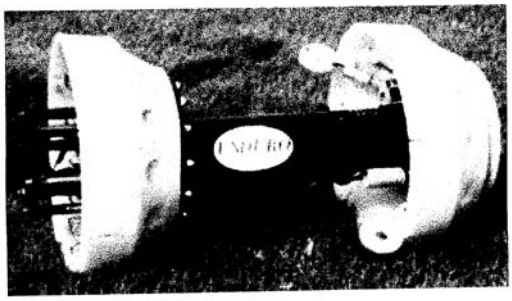


CalScan *Courtesy: PII Pipeline Solutions*

8.3.3.3 DigiTel Data Logger (Enduro Pipeline Services Inc.)

Once the basic principle of measurement is established it is inevitable that all pigs utilizing that principle will resemble one another to some extent. However, like other ILI tools, constant development based on field experience over many years has led to dramatic improvements.

The latest tools not only provide details of the size, orientation and location of anomalies but also the position of bends, their angle, radius and direction of turn and can provide a GIS mapping facility directly from the data gathered.



DigiTel Data Logger *Courtesy: Enduro Pipeline Services Inc.*

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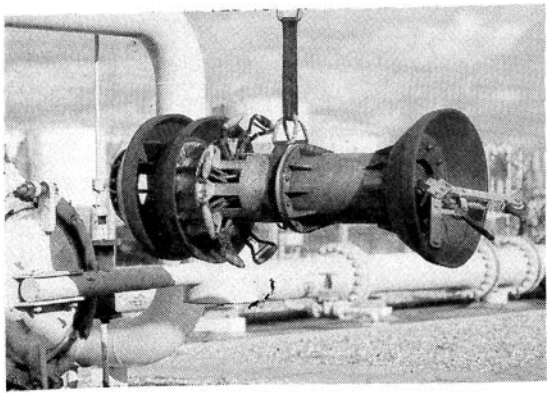
8.3.3.4 Geocontrol (TRAPIL)

Geocontrol is an electronic geometry pig designed and manufactured in France. The "fingers" are mounted behind the front cup and deflect to conform to any reduction in diameter. In so doing, the measurements are recorded and stored in digital form within the instrument package.

It has an unusual approach to distance measurement in that it is capable of making a fixed number of measurements. The overall length of the pipeline to be surveyed is then divided by this fixed number and the odometer wheels are set to trigger the measurement and recording device at each of these calculated increments.



Geocontrol *Courtesy: Trapil*

8.3.3.5 CAL Tool (Tuboscope Vetco Pipeline Services Inc.)

Like the products of a number of other suppliers, the latest Tuboscope CAL geometry tools have evolved from relatively simple devices into multi-purpose, highly sophisticated tools.

The multi-module CAL tools not only define and locate diameter reductions, but detect and record welds and bend radii. They can operate at speeds from 0.2 to 10 m/s and are currently available in sizes 6" to 40".

8.3.3.6 GEOPIG (BJ Pipeline Inspection Services)

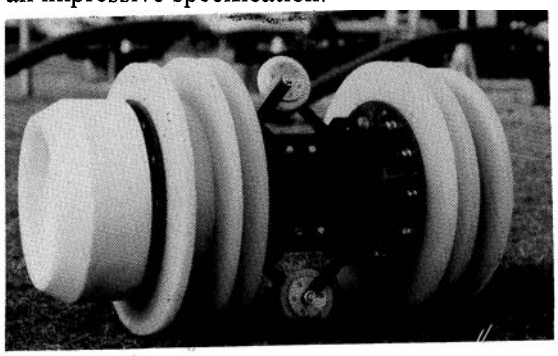
With the advances in geometry tools, the border between them and 'mapping tools' becomes difficult to define. The GEOPIG tool combines geometry measurement with profile monitoring and mapping. As the latter is its prime function, its description is included more fully in the section pertaining to that type of inspection.

8.3.4 TYPICAL SERVICE USING EDDY CURRENT TOOLS

8.3.4.1 ID Mapping Tool (H Rosen Engineering GmbH)

Rosen's first geometry pig was called the Electronic Gauging Pig or "EGP". This worked on the principle of a strain gauge and had sensors mounted in the sealing discs. The information was fed to a portable data processing unit which allowed the analysis to be done in the field immediately after the run and the results shown in detail on a VDU (Visual Display Unit).

A development of this soon followed which utilizes eddy currents, a non-contact method, to provide a profile of the inside diameter of the pipeline. It utilizes a similar portable data analysis package, complete with VDU, that its predecessor had. It is a well proven tool with an impressive specification.



ID Mapping Tool *Courtesy: H Rosen Engineering GMBH*

In much the same way as the previously mentioned tools, this has since led to a whole family of 'mapping' tools covering 'XYZ', backfill and sediment measurement.

8.4 CRACK DETECTION

8.4.1 GENERAL

Cracking of any sort, particularly in the longitudinal plane is potentially a very serious fault. Because of this, a few tools were developed specifically to detect longitudinal cracking.

A great deal of the early work on ILI crack detection tools was done by Dr. Hartmut Goedecke (PII Pipetronix) who developed the first viable crack detection tool, using eddy current technology, in 1969.

In the early 1970's, AMF Tuboscope Inc. (now Tuboscope Vetco Pipeline Services Inc) introduced the Linalog WLC (Weld Line Cracking) and the Linalog SCC (Stress Corrosion Cracking) pigs. Both these tools used MFL techniques. The problem with using MFL is that for flux leakage to occur (and so indicate a defect) the flux path must be interrupted by metal loss at some angle to its normal direction of travel. As the MFL ILI tools normally induce the flux into the pipe wall in a longitudinal plane, the WLC pig and probably the SCC pig also, were designed to rotate, causing the flux to be induced in the form of a helix. These early tools were never widely used and with the improvements in the modern magnetic flux leakage and ultrasonic tools, the more serious defects can often be picked up during a normal corrosion survey. However, it must be emphasized that pigs designed for normal metal loss surveys cannot be expected to routinely locate cracks.

These original tools are no longer available, but research has continued to enable MFL techniques to be used for longitudinal crack detection. PII have now introduced "TranScan", an MFL tool which rotates to induce a transverse magnetic flux.

Work has also been going on for some time into the development of ultrasonic pigs fitted with angle probes designed specifically to detect longitudinal and stress corrosion cracking (SCC) but it is only comparatively recently that these have been introduced.

As previously mentioned, PII have also succeeded in applying EMAT (Electro Magnetic Acoustic Transducer) technology to crack detection.

8.4.2 TECHNOLOGIES

8.4.2.1 MAGNETIC FLUX LEAKAGE (MFL)

MFL techniques are described fully in 8.2.2.1. For crack detection, this technique is modified principally by rotating the tool to induce the magnetic field around, rather than along the pipe wall.

8.4.2.2 ULTRASONICS (UT)

Although, due to the hoop stresses, cracking generally occurs in the longitudinal plane, it can occur in virtually any direction. Cracks also tend to propagate so they need to be detected when they are still very small. Stress corrosion cracks are also generally very small, and often occur in small localized clusters. With the current state-of-the-art, all of this points mainly to the use of ultrasonics for it's detection. The principles of conventional ultrasonic inspection are described in 8.2.2.2.

8.4.2.3 EMATS

Paper IPC02-27056 entitled *Development of 36" EmatScan® Crack Detection Tool* which was presented at the 2002 International Pipeline

Conference in Calgary, Canada, provides details of both the tool and the technology involved.

It explains that Electro Magnetic Acoustic Transducers or EMATS, work on the principle that the metal grid of a steel plate can be excited by electromagnetic waves to oscillate and so generate an ultrasonic pulse. To make this work in pipeline inspection, a magnetic field must be present in the plate, the transducer coil must be within 1mm of its surface and, contrary to conventional UT inspection, the medium in the pipeline must not be a liquid. It is this last factor which makes the development of such a tool highly desirable for inspecting gas pipelines.

8.4.3 SERVICE USING MFL TOOLS

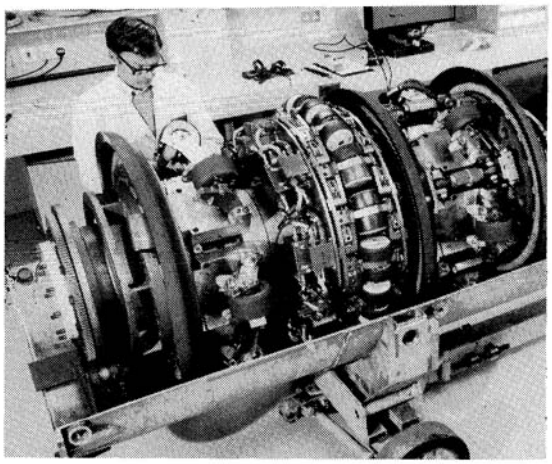
8.4.3.1 TranScan (PII Pipeline Solutions)

As mentioned in 8.4.1 above, PII have adapted their conventional MFL technology to a new rotating tool called TranScan. To provide the high resolution necessary to detect longitudinal defects, the tool is fitted with two separate magnetizer units and new display software was developed for reporting the results.

8.4.4 TYPICAL SERVICES USING "UT" TOOLS

8.4.4.1 Elastic Wave Tool (PII Pipeline Solutions)

Pipeline Integrity International (PII) introduced this highly sophisticated 'elastic wave' tool for locating stress corrosion and fatigue cracking in the longitudinal plane. Ultrasonic signals, transmitted through liquid filled wheels, are pulsed circumferentially around the pipe wall to detect any defects. The wheels enable the tool to be used in gas as well as liquid lines.



Elastic Wave Tool *Courtesy: PII Pipeline Solutions*

8.4.4.2 UltraScan CD (PII Pipeline Solutions)

The "UltraScan CD" Crack Detection tool closely resembles its predecessor, the UltraScan WM. Capable of detecting all forms of cracking, including SCC, it was introduced in 1994 and has established an enviable track record. Although designed to detect cracks from 0.08" (2 mm) deep by 1.2" (30 mm) long, it is said to have exceeded this specification by a large margin.

The tool uses the well established 45° shear wave technique with the sensors mounted in a similar 'cage' to that used in the UltraScan WM tool. There are an exceptionally large number of sensors. The original 24/26" version of the tool for example, used 480 sensors mounted on 16 skids. Two sensors per skid monitor both the wall thickness and the position of the girth welds as an aid to positioning.

8.4.5 SERVICE USING EMATS

8.4.5.1 EmatScan CD (PII Pipeline Solutions)

As described in 8.4.2.3 above, this is a new tool designed primarily to detect Stress Corrosion Cracking (SCC) in gas pipelines without the need to run the tool in a liquid batch.

8.5 PROFILE MONITORING AND MAPPING

8.5.1 GENERAL

Knowing where a pipeline actually is compared to where the drawings say it is, can be vitally important, especially in an area where major construction work is planned. Normally, for a new pipeline, a set of 'as-laid' drawings are prepared. But not all the subsequent modifications to a line are properly recorded and over time, the position of the line may vary considerably. Ground surveys can be carried out, but unless this is done at very close intervals, a 'dog-leg' or similar deviation may be missed.

Even if a pipeline is not physically moved from its original location, its stability can be a major concern. It can be equally, and sometimes even more important to know simply when there is any movement. This movement may be due to subsidence, earthquakes, erosion (typically of the sea bed) or warming of the surrounding soil in permafrost areas. However, a 'profile mapping pig' can usually provide a complete survey very quickly.

8.5.2 TECHNOLOGIES

Various methods are used to provide a 3-D route-map of a pipeline, but two of the earliest techniques involved gyroscopes and pendulums.

8.5.2.1 GYROSCOPES

To monitor the profile of a pipeline the pig must be capable of measuring and recording its position in all three axes on a continuous basis. This is almost exactly the task of a typical modern inertial navigation system on board an aircraft. These systems rely on gyroscopes and the technology and equipment is sufficiently advanced to be used as the basis for monitoring the profile of a pipeline.

8.5.2.2 PENDULUMS

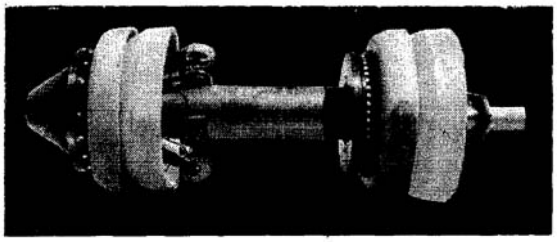
Another logical device for monitoring the relative position of a pig is a simple pendulum. These are frequently used in conjunction with other devices to record the "o'clock" position of, for example, a defect in the pipe wall. They were also used in some early experimental pigs to record how many times a pig rotated during its travel through a pipeline.

8.5.3 TYPICAL PROFILE MONITORING AND MAPPING SERVICES

8.5.3.1 GEOPIG (BJ Process & Pipeline Services)

This tool was developed using state of the art technology and provides detailed information related to plan, profile and location of displacement and curvature, as well as diameter reductions. It is therefore a combination of both a geometry and curvature monitoring tool.

Introduced in 1989 the GEOPIG has since, like most other ILI tools, undergone continual further development to optimize its inspection capabilities.



Geopig *Courtesy: BJ Process & Pipeline Services*

The heart of the system is a "Strap Down Inertial Navigation System" (INS). This contains both linear accelerometers and angle rate gyroscopes to provide the position and attitude of the pig along its trajectory within the pipeline. Integration of this inertial data with that of a Global Positioning System (GPS) survey allows accurate calculation of pipeline

curvature, the orientation of that curvature and/or other detected features as well as their position in a three dimensional coordinate system.

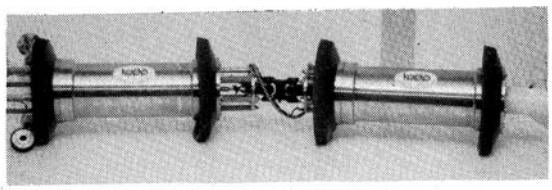
The INS is installed inside the pig body, which in turn is supported on elastomer drive discs. Although this ensures that the INS will travel in close approximation to the center line of the pipe, it is recognized that the pig's pitch and heading will not always coincide with the slope and azimuth of the pipeline. As a result, the pig is fitted with a ring of sonars at each end of the inertial system to provide constant readings of the pig-to-pipe attitude. The sonar data can be used to provide an accurate assessment of dents, ovalities and other shape-related anomalies in terms of both their size and orientation. Finite element models can also be created to compute the pipe wall stresses or to simulate the response to changes in loading conditions.

The Geopig uses odometer wheels for distance and instantaneous speed measurements and it also incorporates weld-detect, pressure and temperature sensors as well as an electromagnetic transmitter for tracking purposes.

'GEODENT' software is provided with the report and data to enable the results to be manipulated and displayed in a variety of different ways.

8.5.3.2 ScoutScan (PII Pipeline Solutions)

The "ScoutScan" was introduced early in 1992. It measures and records the three spatial coordinates (X, Y and Z), delivering positioning data which can then be drawn to scale directly onto geographical maps. It is therefore very useful in determining or verifying the position of piping systems. It is also available as an additional module on a MagneScan survey



ScoutScan *Courtesy: PII Pipeline Solutions*

8.5.3.3 OSCAR Pig (Copipe Systems Ltd)

OSCAR has been designed for obtaining data on the curvature of pipelines. It carries a measuring unit which enables accurate determination of both horizontal and vertical curvature as well as the exact plane of bending in any out-of-straight features. It can be equipped with additional sensors similar to those fitted to Copipe's Advanced Data Logger. These include temperature and pressure recorders and accelerometers.

8.6 LEAK DETECTION AND LOCATION

8.6.1 GENERAL

Most pipeline systems are equipped with automatic leak detection alarm systems. The majority work on the principle of "mass balance" that is to say that the volume of fluid entering the pipe must equal 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.

Because a leak results in loss of pressure, then a method generally referred to as "pressure decay" is often used. In principle this is a relatively simple method in that a utility pig or series of pigs are inserted into the pipeline and pumped along to some predetermined point before being halted. The pressure ahead of and behind the pig(s) is monitored to determine in which direction the leak lies. If the pressure decays in front of the pig(s) then the pig is moved in that direction and halted again. This procedure is repeated moving the pig(s) either backwards or forwards, depending on which side the pressure decay occurs, until the leak has been isolated. Clearly on long pipelines this can be a very expensive and time consuming operation. A number of companies offer this type of leak location service, including TRAPIL, A Hak and H Rosen Engineering.

The pigs used for this type of leak location are generally simple bi-directional utility pigs or spheres equipped with a location or tracking device. They therefore do not qualify as ILI tools and so are not discussed further in this section. However a number of interesting ILI tools have been developed using different technologies.

It should be noted that leak detector pigs are one of the very few types of ILI tool that may be sold to pipeline operator's for their own use. The results from almost all other types of ILI tool require skilled interpretation and analysis. They are therefore not sold, but are used by their manufacturers to provide a comprehensive service.

8.6.2 TECHNOLOGIES

8.6.2.1 ULTRASOUND

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 and although a number of ILI tools were developed utilizing this basic phenomena, only two have been introduced on a commercial basis, one of which has been in continual use for well over 20 years.

8.6.2.2 METERING

The liquid escaping due to a leak in a pipeline causes a small but perceptible flow within the line, 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.

8.6.2.3 RADIOACTIVE TRACERS

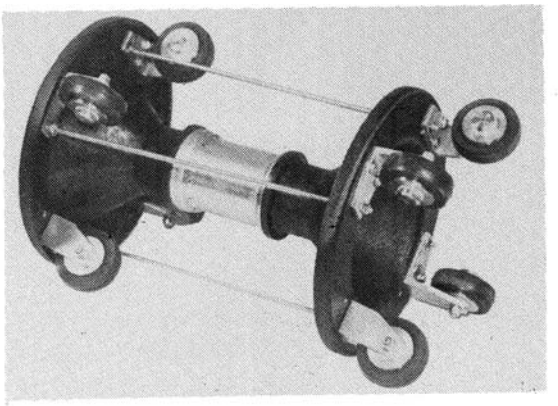
This method was sometimes used before the dangers of radio-activity were fully understood. The idea was simply to inject a radio-active substance into the fluid within the pipeline and then traverse the line from above using a Geiger counter to detect any resulting high levels of radio activity. This approach was abandoned for some years until the technology became such that extraordinarily low levels of radio activity could still be clearly detected and at least one system is now based upon this method.

8.6.3 TYPICAL SERVICES USING ULTRASOUND

8.6.3.1 MLD (H Maihak AG)

Originally developed by Shell, the MLD tool has been manufactured and further developed by Maihak for many years. It is also used by some companies who provide leak detection services for liquid pipeline operators. The tool is especially useful in countries where the authorities would otherwise require an annual pressure test to prove the pipeline. It detects the sound emitted by a leak with an on-board hydrophone. Unlike most other pigs, the MLD

does not have any drive cups or seals. Instead it travels on wheels. This is to ensure that the pig itself does not emit any sounds which the hydrophones may pick up and record as a leak. The MLD is available in a full size range, from 6" to 40".



MLD Pig *Courtesy: H. Maihak AG*

8.6.3.2 Leak Detector Pig (EDAG)

EDAG Engineering + Design AG are a research and development company who have been involved for over 20 years mainly in the automotive industry.

The EDAG Leak Detector Pig has been designed primarily for use in pipelines carrying hydrocarbon products, particularly oil. It analyses and stores ultrasonic signals together with the pressure, date, time and distance. The analogue signals received by the sensors are converted and stored in digital form. This allows the tool to operate for up to 15 days. The data is stored on EEProms to ensure there is no loss of data even if there should be a failure of any sort.

At the end of a run, the tool is downloaded into a PC and specially developed software is used to display the results. This can be in tabular or graphical form and viewed either on the screen, or printed out. There is a zoom facility so that areas of interest can be studied in more detail.

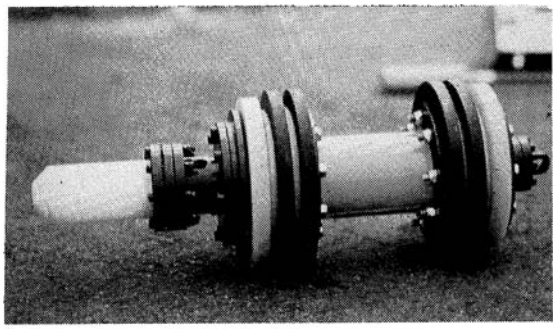
The results are very impressive. For example, on a 280 mile (450 kms) long line it is claimed that a leak signal would not be missed even if it occurred over a distance of just 1 meter.

The tool is not only used to detect leaks. It can also be used to monitor normal noise levels, or in places where the noise may point to other operational events such as valve positions etc.

8.6.4 SERVICE USING FLOW METERS

8.6.4.1 LDP (H Rosen Engineering GmbH)

One of the two systems used by Rosen to detect leaks, the LDP has a highly sensitive flow meter housed within its body. The tool transmits both the volume and the direction of the flow through the pipe wall which enables the approximate position of the leak to be determined.



Leak Detection Pig *Courtesy: H Rosen Engineering GmbH*

The system is designed for a maximum pressure of 210 bar (3000 psi) and, it is claimed, can detect leaks as small as 0.1 lt./h. - "which is less than one drop per second". The system is also effective where there is more than one leak present.

The other Rosen system is based on 'pressure decay' as previously described and is therefore not considered to be an ILI tool.

8.6.5 SERVICE USING RADIOACTIVE TRACERS

8.6.5.1 Leak Detection System, (Synetix Services)

This method of leak detection has been made possible by the development of highly sensitive detectors which allow the use of very low level, short half-life radioactive sources.

The tracer fluid is introduced into the pipeline and leaks out into the surrounding line cover. A pig carrying the detector is then launched which records the time at which the leak is detected. With radioactive markers attached to the line at known points, it is possible to quite accurately locate the leak by reference to the time intervals between the markers which precede and/or follow the detection of the leak.

8.7 BEND MEASUREMENT

8.7.1 GENERAL

When running large and very heavy instrumented pigs it is essential to ensure that they do not become stuck in the pipeline. This would not only result in damage to an expensive tool, but could cause serious, if not catastrophic damage to the pipeline. It would also involve a shutdown to remove it.

Most ILI tools are designed to negotiate 3D bends so a potential problem is that they would become firmly stuck if they entered a 1.5D bend. Such a situation could be caused by a lack of, or incorrect, 'as laid' records.

A significant amount of work has therefore been done in the development of pigs which are capable of negotiating tight bends and recording their position and true radius.

One method suggested by Alyeska Pipeline Company was to mount a series of odometer wheels around the pig so that the distance traveled by the outer wheel around a bend could be compared with the distance the opposite wheel had traveled and so calculate the bend radius.

Another, more simple technique was to mount a gauging flange of a calculated diameter at approximately the center point of the pig on the premise that, if the pig had to negotiate a tighter bend radius than the minimum calculated, then the gauging plate would be damaged as a result. This would not say what the actual radius was but it would indicate that the actual radius was less than that allowable. This method is still sometimes used as a quick check.

In recent years a great deal of work has gone into bend detection and measurement and reliable methods have been developed. As a result, many geometry tools now offer this as part of the service.

8.7.2 TECHNOLOGIES

8.7.2.1 MECHANICAL

The radius of a bend is a physical aspect so it is not surprising that mechanical solutions to the problem predominate. The first, most obvious and most applied method was the gauging plate previously referred to. The problem with this though is not only its inability to provide a measurement of the bend but there is no way of measuring the pig to pipe attitude as the pig traverses the bend. Thus, even an acceptable bend may damage the gauging plate simply because of its relative position to the pipe wall at that moment.

A far better and more reliable approach is to use a two module pig and measure the angle

which the modules make relative to each other as they traverse a bend.

8.7.2.2 ELECTRICAL TRANSDUCERS

This is the most recently applied technology and again relies on the relative motion of different parts of the pig - although these parts are adjacent to one another and not in separate modules.

8.7.3 TYPICAL SERVICES USING ELECTRO-MECHANICAL METHODS

8.7.3.1 DigiTel Data Logger (Enduro Pipeline Services Inc.)

EPS developed their original bend locator tool by a simple and ingenious system. Basically it comprised two Electronic Gauging Pigs in tandem with a specially designed universal joint and cable assembly running between them. As the pig train negotiated a bend so the cable assembly was deflected and recorded the magnitude of the deflection as well as the span length of the bend.

The DigiTel Data Logger is described in 8.3.3.3 and is one of the services which combines both bend detection and geometry measurement in the same tool.

8.7.3.2 CAL Tool (Tuboscope Vetco Pipeline Services Inc.)

As for the DigiTel tool described above, the CAL tool provides both geometry and bend measurement as standard. Further details will be found in 8.3.3.5.

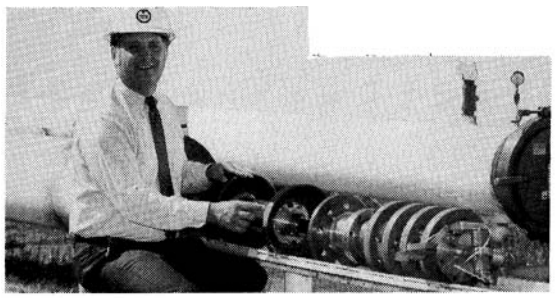
8.7.3.3 BVT (T.D.Williamson Inc.)

The BVT (Bend Verification Tool) is essentially an 'add-on' which is available if bend detection is also required on one of T.D.Williamson's standard Kaliper Surveys (see 8.3.3.1).

8.7.4 SERVICE USING TRANSDUCERS

8.7.4.1 RMT (T.D.Williamson Inc.)

T D Williamson Pipeline Surveys announced their Bend Radius Measurement Tool (RMT) in early 1993. It is currently available in sizes from 6" to 12" and is designed to not only detect bends, but to define them as well. It is a dual module design. The rear module is flexible and conforms to the shape of the bend. The extent of this flexing is measured by transducers and the data is stored for preliminary on-site analysis on completion of the run.



Radius Measurement Tool(RMT) *Courtesy: T.D. Williamson Inc.*

8.8 PHOTOGRAPHIC AND VIDEO INSPECTION

8.8.1 GENERAL

In the early days of intelligent pigging particularly, the instruments were such that it was hard to place reliance on the information they provided, especially when to act upon such information may involve significant costs. In any event it was felt that if a defect could not

only be located and sized, but also visually inspected, it would be of significant help to the operator.

Some early research was carried out into photographic pigs and T.D.Williamson Inc. developed one which took probably the first-ever photograph inside a gas pipeline operating at about 600 psi (40 bar).

It was later thought that if the Kaliper pig could be combined with a photographic pig then the report could contain a photograph of the actual problem located. However, as experience and confidence in the instruments used in ILI tools increased, so the perceived need for visual confirmation decreased and less emphasis was placed on the development of this type of pig.

However there were, and still are, a few situations where visual confirmation or information is desirable. It may, for example, be useful when inspecting insitu coatings and for helping to identify some of the less obvious problems. Clearly it is not possible in crude oil pipelines nor in any line where the visibility is poor.

A number of photographic and video recording pigs were commercialized but no photographic pigs now exist. With the miniaturization of video cameras, it is possible to fit these to otherwise quite standard pigs. As a result, there are now no known ILI tools dedicated solely to video recording.

Pigs for visual inspection have never been widely used in hydrocarbon pipelines and in water pipelines access to the line is usually such that a tethered crawler type video system can be used. Tethered systems are far better suited to visual inspection as the camera can be halted, moved backwards or forwards or repositioned at will. As a result, video recording pigs have had very limited applications. Tethered systems are not classified as 'pigs' so they are not discussed in detail in this manual, neither are the self propelled (motor driven) types, but a list of useful contacts for this type of service is included in the appendices.

8.9 LINE COVER AND SPANNING

8.9.1 GENERAL

Until recently, subsea pipelines had to undergo periodic inspection for any loss of concrete weight coating, loss of anodes, or for spanning, using side-scan sonar. This technique, whilst well proven, is very expensive and is weather dependent, so for some time a method of carrying out this work from inside the line was sought. Such a system has recently been introduced.

8.9.2 TECHNOLOGIES

8.9.2.1 ACOUSTICS

A direct and seemingly logical approach to detecting spanning was patented by T.D.Williamson in the early 1980's. The principle was to strike the interior wall and use the resonance of the pipeline to determine whether there was any cover. Sensitive instrumentation could, it was thought, differentiate between different types of cover and different lengths of span. To date, there is no known ILI tool using this technology, but it is understood that further work is being done in this area.

8.9.2.2 RADIOACTIVE EMISSIONS

A great deal of work was carried out in Scandinavia in the late 70's in connection with

the use of radiation to identify the type and depth of line cover on subsea pipelines and at least one ILI tool was proposed. This work was eventually abandoned, but a similar approach was taken by British Gas plc (now PII Pipeline Solutions) who eventually introduced a 'Burial and Coating' tool.

More recently, H Rosen Engineering have developed a multi-channel 'Backfill Mapping Tool' based on a highly sensitive passive gamma ray detection system. The main purpose of this tool is to detect free spans and concrete weight coating anomalies.

8.10 MISCELLANEOUS ILI TOOLS

8.10.1 SAAM (Weatherford Pipeline & Specialty Services)

Generally referred to as a "Smart Utility Pig", Weatherford's SAAM (Smart Acquisition Analysis Module) tool provides a low cost means of inspecting pipelines, enabling the operator to make informed decisions regarding more costly inspection methods.

The SAAM tool comprises a steel cylinder which houses a circuit board, memory card, power pack and a series of instruments and sensors. Secured entirely within a standard utility pig, SAAM travels down a pipeline recording changes in pig behavior, and ultimately, pipeline condition. These data readings are then analyzed into useful information using the proprietary SAAM software. The standard tool can be used in pipelines from 6" diameter upwards. Specials can also be engineered to order.

The SAAM tool can be used for a variety of tasks including the detection of debris/wax, mechanical damage, bends measurement, internal pipeline condition assessment (general corrosion), the diagnosis of pigging problems and logging of pipeline process data.

8.10.2 Data Loggers

With the dramatic developments in electronic engineering, particularly in the areas of data storage and analysis, it has become possible to gather large amounts of information using very small instruments. There are now a number of "Data Loggers" available which can be installed inside otherwise standard utility pigs to measure and record certain deviations from the 'norm'. Typical data includes differential pressure across the pig, temperature, and acceleration. When interpreted by skilled technicians, this data can reveal a considerable amount of information about the condition of the pipeline.

Typically, the instruments are canisters roughly 4" (100 mm) in diameter by about 18" (450 mm) long - similar in size to a pinger. They may be purchased outright, but more often they are supplied as part of a 'mail-order' service. The instrument is pre-set and sent to the pipeline operator who installs it in one of the regular pigs. After the run, it is sent back to the supplier for down-loading and analysis and a report is submitted shortly afterwards.

This type of inspection is not intended to replace a full pipeline survey, but it can be a very inexpensive way to determine whether a survey should be carried out and what sort of survey it should be.

Companies offering data loggers include:
BJ Process & Pipeline Services (FREDA), and Copipe Systems Ltd (SDL - Simple Data Logger) and ADL (Advanced Data Logger).

8.11 SURVEY SELECTION AND PREPARATION

8.11.1 SELECTION CRITERIA

Selection of the basic type of instrumented pigging service will obviously depend upon the information required. If it is to locate a suspected dent, then a geometry pig would be used. If a corrosion survey is required, a metal loss pig will be necessary.

Having decided on the basic type, the selection of the individual pig or service company to carry out the survey will depend on a number of factors.

The first step in the selection process should be to draft the "requirements" for the information required. This should state as precisely as possible, the information actually needed. Care should be taken to avoid including things that would simply be "nice to know". The cost of a survey will rise dramatically with an increase in either the amount or the level of information requested; so will the time it takes to get the results.

The requirements, when compared with the manufacturers specifications, will automatically eliminate some options, but where the pig specifications are close to the requirements, or where some particular data is unpublished it would be worth contacting the supplier for clarification. Frequently, intelligent pigs can be easily modified to meet a particular requirement; maximum working pressure being a typical example.

Assuming there is more than one instrumented pig which seemingly meets the requirements, there are a number of other considerations; the two most important probably being track-record and cost.

Track-record is difficult to assess. The views of past users are very important, but it must be remembered that technology, particularly in this field, is changing very fast. Those applying the latest (and presumably therefore, the best) technology are unlikely to have amassed a long track record with its use. But a fundamental requirement would be to have considerable pipeline industry experience.

Cost is another area which is not as clear-cut as it would at first seem. In addition to the direct cost of the survey, there is the cost to the operator of running the survey. Most survey companies now require a "clean" line so there is probably little difference in the cost to achieve that. The main differences occur in the amount of support services the operator is expected to provide, the number of times the instrumented pig must be run (either to achieve full coverage, or due to a pig system failure) and to any loss of throughput due to the need to regulate the speed.

8.11.2 INFORMATION REQUIRED

8.11.2.1 GENERAL

The first step is usually to contact the supplier(s) who will probably ask for completion of a standard questionnaire. They may ask for this prior to a meeting, so that they can prepare themselves and bring the relevant data, examples etc. and so make the first meeting more useful. However, some suppliers prefer to visit the operator immediately and complete the questionnaire at that time. The reason for the latter course of action being that it does not burden the customer and it ensures that any uncertainties in the questionnaire are properly addressed at the outset. One thing is certain: there will be a number of meetings before the survey can actually begin.

8.11.2.2 PRE-SURVEY QUESTIONNAIRE

The information required by the inspection company prior to the survey can at first seem excessive. However, time spent in the early stages in ensuring a good 'first time' run is always well rewarded.

The level of information required will vary with the situation, the type of survey and the inspection company used. However, a paper by W R Gwartney and Ed Schaefer delivered at the 1992 Pipeline Pigging and Inspection Technology Conference in Houston included the following list of items which may be included in the questionnaire prior to a metal loss survey:

1. **Company details:** Name, address, telephone & fax numbers and contact name
2. **Pipeline details:** Size, nominal wall thickness, location of launching and receiving traps, total length of line, other wall thicknesses in the line with their approximate length and locations, is pipe welded or seamless? pipe specification, and whether onshore or offshore, and details of internal or external coatings.

3. **Details of pipeline fittings:** Bends (giving minimum bend radius, nominal bore) If miter bends then describe, block valves (giving make and type, minimum bore, individual location and any known voids), check valves (giving make, type and model number, minimum nominal bore, length and depth of bowl and whether the valve can be locked open), tees and branches (giving type of tee, diameter of branch, o'clock position of branch, angle to line, distance between adjacent tees, whether sphere tee or if barred the spacing a size of bars), other connections (for offshore installations) specifying the type of connection, its name and model, details of any other components or features and any other conditions that might affect pigging such as miter bends, bell and spigot couplings, chill rings, thread and collar couplings, acetylene welds, repair clamps, weld deposits, etc.

4. **Trap facilities:** Detailing access in front of traps with any access limitations including overhead clearance, available lifting facilities, availability and type of power at both launcher and receiver. For the launch and receive traps themselves, enter launcher dimensions on sketch (usually provided) specifying whether reducer is concentric or eccentric, angle and direction if trap not horizontal, give details of any trap internal fittings, height of trap center line, whether there is a purge valve between the mainline valve and reducer and whether there is a pressure equalization line. On the receiver details should also be given of any available cleaning facilities.

5. **Product details (during inspection):** Product type, operating temperature (minimum, maximum and normal), operating pressure (minimum, maximum and normal), product flow rates during run (minimum, maximum and normal), wax, CO2, saltwater and H2S contents, and for liquid lines, whether slack line conditions are present.

6. **Pipeline history and records:** Age of line, whether line maps available, date of last metal-loss inspection survey, previous metal-loss inspection company, corrosion expected (internal or external), whether cleaning pigs are used, whether geometry or bend-detection surveys have been conducted and when, together with the results.

8.11.3 PREPARING THE LINE

For a geometry survey, where a severe reduction is suspected, a utility cleaning pig may become 'stuck', so it may be necessary to run a foam pig first. In extreme cases, it may be better to run the geometry pig alone, but in any event, the supplier will make his recommendations prior to each survey.

For corrosion surveys, a high standard of pre-run preparation is required to ensure, firstly that the inspection pig will pass safely through

the line and secondly that as it does it performs correctly. A magnetic cleaning pig usually forms part of the sequence. This is to remove ferrous debris which would otherwise foul the magnets on an MFL type intelligent pig and may also damage the tool, regardless of which type is used.

Ultrasonic pigs will only work in a homogeneous liquid, so if required for a gas pipeline, they must be run in a liquid slug. Wax deposits also affect the performance of most inspection pigs, so a thorough cleaning program is therefore usually essential prior to the inspection run.

It is important not to try to reduce the overall time and the cost of a survey by cutting down pre-survey preparation. This is invariably counter-productive because a re-run is all too often required which immediately eliminates any gains which may otherwise have been made.

8.11.4 SURVEY RESULTS

One thing the operator must not expect is instant results. With geometry surveys it is sometimes possible to indicate whether or not there are any serious problems as soon as the pig is removed from the line, but mostly the technicians are under strict instructions not to make any comment before they have had time to properly analyze the data.

The time taken to do the analysis will vary with the type of pig and the length and complexity of the line as well as with the work-load of the supplier. A simple geometry survey may only take a few hours (and this can be important if the results are needed to determine whether it is safe to run some other pig which is waiting to be launched). By contrast, a corrosion or metal loss survey report may take several weeks.

The type of report will again vary with the type of service offered and the type of pig used, as will the way in which the results are used. Further details of the report presentation for different types of survey are included in the previous sections.

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9.0 PIG SIGNALING, LOCATION and TRACKING

Pig signaling is a method of indicating when the pig has reached a certain point in the pipeline. Signalers are not intended to be used to find pigs whose location within the pipeline is not known.

A signaler is a device which is attached to the pipeline that is activated by the passage of a pig. It may be a mechanical device that gives a visual indication when the pig has passed that location or it may operate a micro-switch to give an electrical signal at some remote site. This could simply turn on a light to indicate passage of the pig or it could start a sequence of valve operations to automatically allow the pig to pass a pump station.

The signaler may be triggered by the pig physically moving a lever which protrudes into the line (referred to as an 'intrusive signaler') or by remotely sensing the pigs' presence from outside the pipe wall by, for example, a change in the magnetic field or by ultrasonics. Such methods are referred to as 'non-intrusive'.

Pig locating is a method of determining the position of a pig; normally when it is stationary and usually due to it being either held up (due to low flow conditions) or stuck (due to damage or an obstruction). This normally requires the pig to carry a transmitter device of some kind and a receiver is carried along the line to locate it.

Intrusive Visual Pig Signaler *Courtesy: G.D. Engineering*

Pig tracking is a method of literally following the path of the pig either continuously or, more likely by locating it at a series of predetermined points. This can be achieved by various methods including transmitter and receiver systems, mass balance via computer calculations and by acoustics. Pig signalers may be used in conjunction with other methods to assist tracking, but they are not suited for this purpose when used alone.

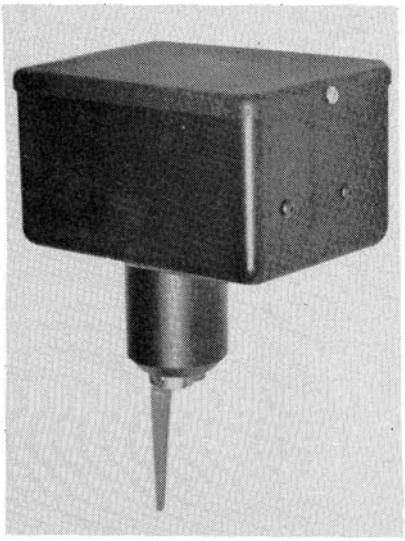
9.1 PIG SIGNALERS

9.1.1 TYPES

Pig signalers are of two types. The intrusive type requires that the trigger comes in contact with the pig or other device it is to detect. Non-intrusive signalers do not require physical contact with the pig and can be mounted on or near the pipeline.

9.1.1.1

Most pig signalers used at on-shore locations are mechanical devices installed on the pipeline and are of the intrusive type. That is, some component, normally the trigger, projects into the pipeline and is exposed to the pipeline product and the operating conditions.



Intrusive Electrical Pig Signaler *Courtesy: T.D. Williamson, Inc.*

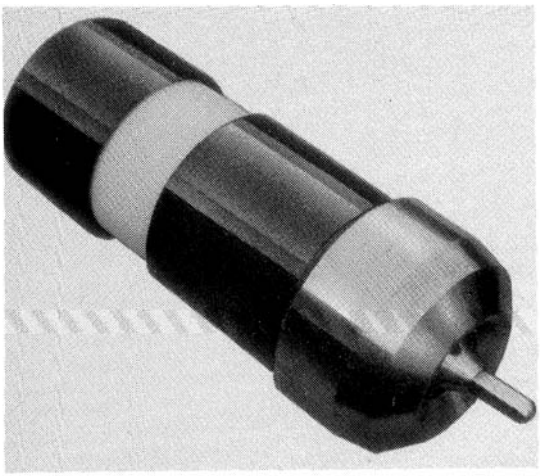
Some of these signalers have a means whereby the internal components can be removed for replacement or repair while the pipeline remains in service. To do this, they may have an isolation valve as an integral part of the signaler, however most have a means for attaching a valve which allows the internal components to be removed without loss of the pipeline product.

Many intrusive pig signalers can be installed on a pressurized, operating pipeline. A housing, normally with a 2" nominal bore, is welded to the pipeline. After welding, a valve is attached and an under pressure drilling, or 'tapping' machine is used to drill a hole in the wall of the pipeline. The signaler is then lowered through the valve and screwed into the housing using either the tapping machine or a special jacking device .

Many of the signalers are designed so that the valve can be removed. It can then be installed again at some later date if it becomes necessary to take the signaler out for maintenance or repair.

Intrusive signalers comprise two basic types; trigger and plunger, both of which extend into the pipeline and are moved by physical contact with the pig.

The specific design of each type will vary according to the manufacturer but the movement of the trigger or plunger is translated into either a rotational or axial movement of a shaft. The shaft either extends through dynamic or static seals, or is coupled magnetically to the unpressurized side of the signaler on the exterior of the pipeline.



Intrusive Visual Pig Signaler *Courtesy: Inpipe Products Ltd.*

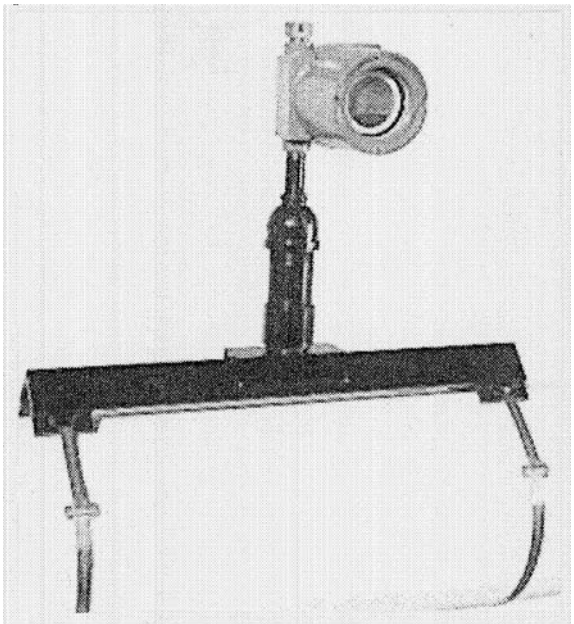
The movement of the shaft may translate into a visual signal to indicate when the pig has passed or it may actuate a micro-switch that gives an electrical signal that can be used for whatever purpose the customer desires. The switches fitted to signalers are usually of a very low power rating and therefore the electrical signal is used to actuate relays rather than providing the power direct. Many pig signalers can give both a visual signal and an electrical signal if this is required.

The plunger type of intrusive signaler is actuated by the pig actually depressing the plunger. This means that the pig must be firm enough to move the plunger, which must be pressure balanced to allow it to move easily against the line pressure.

9.1.1.2 NON-INTRUSIVE

Non-intrusive pig signalers do not project through the pipe wall into the pipeline. They are mounted externally and are triggered by some signal emitted by the pig. Typically, the signals are generated by either magnetic fields, radio transmitters, or by radioactive isotopes.

For a non-intrusive magnetic signaler to be triggered, the pig must normally carry a permanent or an electro-magnet. The sensors in a magnetic signaler react to a change in the magnetic field. Some measure the strength of the field and are triggered at a certain level, others automatically zero out any static background magnetic fields and are triggered by the changes in the magnetic field. They must therefore be located in a position where there is no movement of any significant mass of metal which might cause the signaler to trigger prematurely.



Non-Intrusive Pig Signaler *Courtesy:T.D. Williamson, Inc.*

The main advantage of this type of signaler is that it can be installed on an operating pipeline without requiring welding or penetration of the wall of the pipeline. They are also convenient to use on a temporary basis and can be easily moved from place to place and then removed for reuse elsewhere.

Signalers that receive a radio signal transmitted by the pig are not common. Transmitter systems are more usually applied to pig location and tracking.

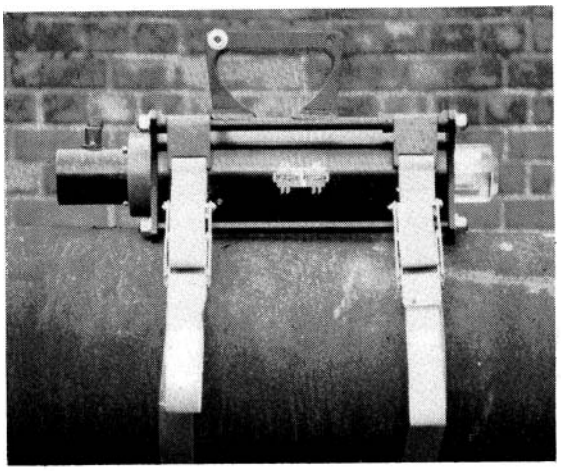
The use of a radioactive source to provide a signal is also comparatively rare. It can only be carried out by a licensed service company and generally requires a number of special permits beforehand. It too is therefore generally confined to pig location and tracking rather than simple signaling.

9.1.2 APPLICATIONS

Pig signalers are used for many applications to assist with the operation of a pipeline by giving a signal to indicate that a pig has passed a certain point. They are usually positioned downstream of the launching trap with a visual indicator to let the trap operators know that the pig has been successfully launched and that it is in the main stream of the pipeline.

Some companies install pig signalers further downstream, often at the station property line that gives an electrical signal to the pipeline control room to indicate that the pig has been launched and has cleared all station piping.

Pig signalers are usually also positioned on the nominal bore section of the receiving trap, close to the reducer, to indicate that the pig is in the trap and has cleared the isolation valve.



Sub-Sea Non-Intrusive Pig Signaler *Courtesy: PII Pipeline Solutions*

Additional pig signalers may be installed upstream of the trap to alert the control room so that the station piping can be arranged properly for receiving the pig. This generally means ensuring that the trap valve is fully open and that there is some flow through the trap. It may also mean that product needs to be monitored and perhaps valving changes made if the pig has contaminated the product with dirt or is being used between batches of different products.

Pig signalers may also be installed upstream of an intermediate booster station that does not have pig traps.

This signal will alert the station operators to start the automatic valving changes so that the pump can be slowed down and circulate while the upstream and downstream pressures equalize so that the pig will pass the station. Another pig signaler downstream can give a signal to reset all valves and controls for normal pumping conditions. This procedure can eliminate the high electricity demand required to restart an electric motor and pump.

A detailed example of how pig signalers can be used to facilitate the passage of two batches of dissimilar products through a booster station, while minimizing the mixing of the products, will be found in Section 10.

9.1.3 SELECTION

There are many different makes and types of signaler so it can be difficult to select the best one for a particular situation.

Occasionally, the type of pig may determine the signaler that must be used. For example, if a foam pig is to be run, then mechanical, trigger operated signalers are preferred. Plunger types do not protrude very far into the pipeline and the foam body may be too soft to actuate it. Non-intrusive types require the installation of a magnet or other detectable source, so if a foam pig carrying one were to break up, it could be left in the pipeline. Recovery of a radioactive isotope, especially subsea, is extremely difficult and a magnet will attach itself to the pipe wall and be very difficult to retrieve.

In spite of the large number of models to choose from, when deciding upon a signaler for use on a platform or on land pipelines, there are three aspects which can reduce the options and make selection easier:

1. An intrusive signaler should have a bi-directional trigger. Some are fitted with a unidirectional trigger, but then, if for any reason the pig moves backwards (perhaps due to surging) or it is necessary to pig in the reverse direction, the unit must be removed, otherwise the trigger, and often the pig too, will be seriously damaged. However, in some makes, the unidirectional trigger provides for much greater movement of the signaler's mechanism and this allows wider tolerances in the set up.

2. In most situations, an intrusive signaler should have a trigger rather than a plunger. A trigger can be extended to give a signal in oversize portions of the pipeline or shortened for special conditions, perhaps when the pipeline product contains wax or ice which can give false signals.

A plunger must be tapered to allow the pig to pass and this can only be achieved by having a minimal projection into the pipeline. A foam pig is unlikely to actuate it and frequently, the cast polyurethane seals on a mandrel pig will also fail to depress it. Another drawback of the plunger types is that they need a pressure balance orifice to prevent them being actuated by line pressure. This orifice can become plugged by dirt and wax which often causes them to seize completely.

3. A signaler should be capable of being removed from the pipeline while it is under pressure. This enables it to be serviced or replaced at any time. This is particularly important on the launcher installation where the unit is normally mounted downstream of the main trap valve. This does not mean that a permanent valve is always needed. In fact, it is generally better if the design allows for a valve to be installed only when the unit has to be removed, because when valves are in service for long periods without being exercised they may not give a positive seal.

For subsea installations, non-intrusive signalers are now almost standard. They are also being increasingly used elsewhere as they have some obvious advantages, not least being the ability to move them from place to place. Servicing is also greatly simplified.

The most common non-intrusive systems are those based upon detecting a change in the surrounding magnetic field. They require a permanent magnet to be installed in the pig and utilize the principles of a magnetometer to sense the change in the magnetic field as the pig passes.

Another non-intrusive and very reliable system is based upon the detection of low-level radiation. This requires a radioactive isotope to be installed in the pig. The main drawback to these systems is that they can only be used by approved operators and so they are generally supplied as a service.

9.2 PIG LOCATION and TRACKING

When running pigs in a pipeline for the first time, or when the conditions in the pipeline are uncertain, it is desirable to be able to locate the pig should the need arise. In some cases, especially during commissioning, where a train of pigs may be used, it could be essential to be able to locate individual pigs.

Most locating devices are dependent upon something, which is attached to the pig so modifications must be made, and the attachments fitted, prior to inserting the pig into the pipeline.

It should be remembered that locating and tracking are basically two different procedures.

In its simplest form tracking can be just listening to the noises of the pig through the pipe wall while walking along the pipeline right-of-way, or more likely, to wait at certain points along the pipeline such as valve pits and listen for the pig to pass.

However, depending on the type of noises being generated by the pig this form of tracking can be very difficult. There is a lot of truth in a well known cartoon picture which shows a pipeliner walking away with only one ear while the other ear is stuck to the frost covered pipeline!

Another major problem with these rather primitive methods is that if the pig should stop, usually all noises from the pig will also stop - and then it becomes a locating procedure rather than tracking.

Pig location has always been high on the list of priorities for pipeliners and as a result there are now a great many methods available. Fortunately they tend to be complementary rather than real alternatives so selection of the best method for any given situation does not normally present too many problems.

9.2.1 NOISEMAKERS

The pig cups (seals) usually make a noise as they pass the welds at the pipe joints. However, the type and density of the material surrounding the pipeline will greatly affect the ability to hear the noise the pig is making. To increase the noise and simplify tracking, pigs were fitted with 'noisemakers'. Some of the earliest noisemakers were simply pieces of chain attached to the pig that would be dragged along inside the pipe to make a noise.

As pipeliners sought better noisemakers for tracking their pigs, they used star wheels from pipe cleaning machines and mounted them on cleaning pigs in place of brushes. They also used sprockets from various pipeline machinery and attached them to pigs so they would roll along the pipe wall and make a noise. One type of noisemaker was basically a cam wheel attached to the springs of a cleaning pig. The wheel(s) had a step in the circumference so that when the step rolled into place it would "thump" the pipe wall.

Another innovation was to use amplifiers to enable the pipeliner to get out of the weather and yet still hear the pig as it passed. With the amplifier it was possible to hear the pig approaching at a distance of one to two miles (2 to 3 kilometers) in a liquid filled line. Geophones worked well to listen for the noise of the cups as they passed the joint welds; other types of amplifiers were used to listen for other pipeline noises. This method was further developed for use in gas lines where it is now said to be possible to hear a pig at distances of up to 30 miles (50 kilometers). This is discussed later in the section on Acoustics.

Most of the methods used for tracking pigs worked reasonably well, but if the pipeliner was not at the precise location where a pig stopped, none of them would be of any help, so other devices were needed to locate a pig once it had stopped.

9.2.2 ISOTOPES

Isotopes can be an effective means of locating pigs but they require licensed operators to install and retrieve the isotope and it must be accounted for at all times.

There can be problems with long life isotopes which have a half-life of many years. They are usually very small and are inserted into a container mounted on the pig. If for any reason the container becomes detached or the isotope falls out, then clearly the situation can become difficult and dangerous.

An alternative is to use a short life isotope which may have a half-life of less than 24 hours so that if something happens, the isotope will degrade quickly and not remain a hazard. However, because of the short half-life it may be necessary to use a more powerful source initially in order to have an adequate signal along the entire length of the pipeline.

When isotopes are used the pigs are located by using radiation detectors. The effectiveness of these systems depends not only upon the strength of the isotope and the sensitivity of the detector, but also on the depth of the pipeline and the type and the condition of the material surrounding the pipeline. Wet soils for example, would shield a lot of the radiation.

9.2.3 TRANSMITTERS

Electromagnetic systems are the most common means of pig location. A coil is placed on the pig and an alternating magnetic field is emitted.

The alternating field penetrates the pipe wall and the soil over the pipeline. In order to extend battery life and to obtain a distinctive signal the transmitter is pulsed, often with one second on and two seconds off.

The unit attached to the pig comprises two parts. These are the sealed battery pack, and the transmitter, which is protected by a housing made of plastic or other non-magnetic material. The battery life can range from 30 hours up to 100 days depending on size and requirements.

The receiver comprises a search coil, amplifier and headset. The signal from the transmitter is received by the search coil and will be displayed visually on a meter and acoustically by the amplifier emitting an audible signal. Typically, these systems have a range of 15 to 18 feet (5 to 6 meters). If used subsea, the range is reduced to 3 to 6 feet (1 to 3 meters).

Since the signal is emitted radially from the pipeline, the maximum signal strength is measured exactly over the centerline of the pipeline. This allows for very accurate pig location. However, the strength of the signal weakens quickly on either side, so the location of the pipeline must be predetermined for this system to work well.

9.2.4 PINGERS

Pingers have been used for many years by the marine industry as subsea markers and they were later adapted for use within a pipeline.

Since the pinger was originally used for subsea marking, it works best in liquid pipelines. The liquid acts as a carrier for the signal from the pinger to the pipe wall and then into the water outside the pipe. The batteries in the pinger often give a useful life of 1000 hours. The pinger emits a "ping" every few seconds, which is detected by receivers, installed in a workboat in the area over the pipeline.

The pinger does not work as well in gas pipelines. Several methods have been used to get the source of the "ping" closer to the pipe wall and avoid losing signal strength in the gas atmosphere between the transmitter and the pipe wall. Pingers are now made for use in gas pipelines but these generally need a much higher power output.

If, for whatever reason, the signals are weak, the ship being used for tracking may tow a "fish". This contains the receiver and will put it much closer to the pipeline and the source of the "ping".

9.2.5 TRANSPONDERS

An acoustic transponder is a receiver-transmitter which transmits an acoustic reply on a preset frequency after receiving a recognized interrogation pulse broadcast from a vessel. The transponder is installed on the pig similar to the pinger. By monitoring the signal from the transponder it is possible to determine whether the pig is moving toward or away from the vessel. By measuring the time for the reply from the pig it is possible to determine the distance from the vessel to the pig. Then, with the water depth determined by other means it is possible to calculate the pig location. It is claimed that this system can locate a pig within ten feet (3 meters).

Since each transponder can have an individual reply frequency, it is possible for a vessel to track several pigs at the same time. This can be useful when pig "trains" are being run.

When using the transponder system to locate or track a pig, the vessel uses maps of the pipeline route to navigate within 1 to 3 miles (3 to 5 kilometers) of the pipeline. Once contact has been made with the transponder on the pig the vessel can be moved to obtain the maximum signal, and position itself until the distance to the pig is equal to the water depth. This means the vessel is directly over the pig, so its location

can then be determined from the navigational positioning equipment already located on the vessel.

9.2.6 MAGNETS

Using magnetism cannot only signal pigs, but they can also be tracked by this method. In both cases, magnets are installed in the pig and the sensors in the system detect the change in the magnetic field as the pig passes.

For best results the pig body is made of stainless or other non-magnetic material to avoid reducing the strength of the magnetic field which is generated by the magnet. Magnets placed on standard utility pig bodies can be used but will be much less effective.

When using the magnetic system, a magnetometer is placed over or near the pipeline and changes in the magnetic field are registered by the magnetometer as the pig passes. The effectiveness of this system can often be improved by drilling holes in the ground cover and placing the magnetometer over and near the pipeline.

It should be noted that it is the *change* in magnetic field strength which is being monitored and not a specific level or strength of field. If working near a road or any other area where there may be traffic or movement of significant metallic objects, false signals may result. Therefore, the magnetometer should be placed at least 100 feet (33 meters) from the source of such possible interference.

The magnetic system can also be used underwater, however the magnetometer must be placed near the pipeline. One method that has been used is to place a system combining magnetics and pingers on or near the pipeline. The magnetometer detects the pig and activates the pinger which can be detected easily by the operator without him being directly at the magnetometer location. This method may require a diver to install the detector, but it allows monitoring for an almost unlimited time at a remote location.

Because this system relies on detecting a change in the magnetic field, it will be less effective at locating a pig once it has come to a stop. To overcome this, a magnetic pulse generator (MPG) can be installed in the pig instead of a permanent magnet. By switching on and off automatically, it constantly changes the magnetic field around the pipe and makes it possible for the sensors to detect. The system using the MPG is very similar to that used in the transmitter systems previously described, but, because it works on DC rather than AC, the accuracy of location is much greater. It is claimed to be able to locate the position of a MPG to within 2" (50 mm).

9.2.7 ACOUSTICS

As already described, noise in the form of vibration pulses are generated when the seals of a moving pig pass the weld joints in the pipeline. These pulses can be amplified to give a usable audio signal in gas pipelines. By recording the signals and comparing them to known features of the pipeline, the location of a pig can be determined. By using features including bends, offtakes, valves, wall thickness changes as well as the pipe tally, the distance the pig has traveled can be determined by correlation.

The effective distance, over which this type of system will work, will depend upon gas pressure, velocity, the weight of the pig and the diameter of the pipeline. In general, the larger the pipeline, the higher the gas pressure, and the higher the velocity of the pig, the better the signal. A heavier pig, which is also generally related to the size, will also increase the signal strength.

The range of this system is reported to be 18 to 30 miles (20 to 50 kilometers) from the launching trap as the pig moves away, and

approximately the same range as the pig approaches the receiving trap.

9.2.8 E.L.F. SYSTEMS

Extremely Low Frequency (E.L.F.) systems have been used for many years by the navies of the world for communications with submarines. However, the equipment has been such that it has been impractical for industrial use. Receiving antennae for example are thought to stretch for sometimes hundreds of miles.

E.L.F. systems can communicate through almost any medium so it was recognized that they would have particular advantages if they were be adapted to provide through wall communication on pipelines.

These systems enables a pig to be located accurately as well as allowing bi-directional data communication between the pig within the pipeline and a command transmitter/data receiver at some remote point external to the pipeline.

Reliable through-pipewall data communication has become a critical aspect of many remote maintenance and repair systems, especially those involving pipeline isolation tools, or 'plugging pigs'.

9.2.9 PRESSURE PULSES

Believed to have first been used in the Far East to locate a blockage in a pipeline under a major city, Pressure Pulses have since been used successfully elsewhere, particularly in subsea pipelines. The method can locate any form of blockage, so it can be used to find pigs, hydrates or anything else blocking the line.

In principle it is extremely simple. A pressure pulse is generated at one end of the pipeline by, for example, rapidly cycling a valve. The pulse travels down the line and is reflected off the blockage. By knowing the time taken to receive the 'echo' and the speed of sound in the medium, the distance can be calculated.

This method does require a high degree of accuracy in measurement and at least one company (Pitchford In-Line) have developed special techniques and equipment to perform this task.

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10.0 OPERATING PROCEDURES

10.1 GENERAL

The purpose of operational pigging is to obtain, and then maintain optimum pipeline efficiency. This means achieving maximum throughput per unit of power consumed, while safeguarding the pipeline by keeping the internal pipe wall surfaces in the best possible condition.

To achieve this, good record keeping is mandatory, and the correct pig must be used. Maintenance of the pig itself and of the other components is also essential to obtain optimum results.

10.1.1 OPERATING EFFICIENCY

It is important that records be kept so that pipeline operating efficiency can be measured. These records may consist of through-put, power consumed to achieve the through-put, pressure drop through the pipeline and quality of the product delivered. Once these records are available, it will be possible to determine baseline parameters that can be used to measure changes in efficiency. These changes may be either decreases or increases and therefore will give guidance for making decisions concerning pigging.

When power consumption increases or through-put decreases, clearly something has changed. The change may be due to the interior condition of the pipe wall. It may be wax deposition, settlement of foreign material on the bottom of the pipe, liquid deposits (in gas pipelines) or other similar factors that can increase the friction between the pipeline product and the pipe wall.

10.1.2 PIG EFFECTIVENESS

When the probable cause of the decrease in efficiency has been determined, it is then possible to decide upon the type of pig or pigs that will be needed to improve the conditions in the pipeline. Each pig is designed to achieve the best performance for specific requirements. Section 5 will provide more detail on how to select utility pigs. In addition, supplier literature will usually give details concerning the usage, as well as the various features, advantages and benefits of the different types of pig being offered and, when they know what the pigging needs are, their sales office staff will provide useful advice.

When the pigging program has been started the baseline parameters can be compared with the same parameters measured after the pigging run to determine the change in efficiency. The first pig run will probably show the greatest improvement, however, sometimes many pig runs will be required to achieve optimum efficiency.

The effectiveness of a pigging program can often be assessed by monitoring the amount of foreign material which accumulates in the receiving pig trap after each run. This can then help to determine the number of pigging runs which will be required to achieve the desired results.

If the pipeline product is a clear liquid, it should possible to measure the effectiveness of the pigging run by monitoring the discoloration of the liquid at the receiving trap.

The burnishing of the inside pipe wall by repeated pig runs will also improve the efficiency of the pipeline but changes due to this will usually not be very great.

Once an acceptable level of efficiency has been achieved, regular monitoring of the base

parameters will be necessary to establish and maintain a regular, routine pigging program.

10.1.3 PIGGING LOG

As has already been stated several times, to maintain efficient operating conditions of the pipeline, it is important to keep records of all pigging operations. As a minimum, the following information should be monitored and recorded for each pigging run:

- Date of the run
- Type of pig
- Condition of pig before and after the run
- The results, as monitored at the receiving end of the pipeline.

These records can be used to determine if the optimum frequency of pigging is being used and whether the best type of pig is being used for the desired results. Extracts from On Stream Systems' "PIGLOG", a manual record keeping and pig logging system is shown in Section 13B.

The logging system should also record inspection and maintenance data, including the 'before and after' dimensions of the sealing elements and the cleaning elements. This all helps to reorder spare parts and establish guide lines for replacing components of the pig.

10.1.4 COST BENEFITS

Perhaps most importantly, an effective record system will make it possible to determine the cost per pig run. This can then be compared to the assessed income derived from improved pipeline efficiency as shown in the pipeline operational records and to establish the optimum pigging program and schedule for each pipeline.

10.2 PRE-RUN CHECKS

10.2.1 PIG INSPECTION AND MAINTENANCE

A pig cannot perform it's intended function if it is not in good condition for the job to be done. Further details of what must be done for an effective pig maintenance program is included in Section 5, however some aspects are included here for ease of reference.

Regardless of the maintenance program which has been set up, the diameter of the seals should again be measured before the pig run to give confidence that pig will traverse the pipeline without difficulty. Unless a special diameter measuring tape is used, the only way to do this without disassembling the pig is by measuring the circumference of the sealing portion of the seals and dividing this measurement by 3.14 to find the diameter. The diameter of the seals must be greater than the inside diameter of the pipe through which the pig will be run.

Check the logs to find the expected life of the seals. They should also be double checked for any damage. The front sealing element in particular must have no tears, punctures or other defects that might cause a failure. On a cleaning pig it is sometimes possible to use a seal which is not suitable for the front, in a position further back . A sealing pig, whether used for batching different products or for the separation of liquids and gases, should have all of the seals of the same quality since the purpose of this pig is to maintain a good seal within the pipeline.

The effective unrestrained diameter of the cleaning elements should also be measured to ensure that they will make good contact with the pipe wall throughout the run. What this diameter should be will depend upon the type and mounting of the cleaning elements as well as the pipeline conditions, and is another vital

piece of information that can be determined by keeping proper records of previous pig runs.

Brush-type cleaning elements should be inspected for corrosion and breakage. It is essential to do everything possible to avoid bristle breakage within the pipeline as these can be carried through and cause damage to valves, instrumentation and other pipeline equipment. This is even more important if the bristles are stainless steel. A stainless steel bristle when lying in contact with the carbon steel pipe wall in wet conditions could set up electrolytic corrosion cells.

Proper cleaning and storage will help minimize brush problems but regular, careful inspection is mandatory.

In addition to checking the condition of the seals and cleaning elements, it is necessary to double-check all components of the pig. All nuts, bolts, cotter pins and any other fasteners should be checked to be sure they are tight and in good condition. On one recorded incident, a cotter pin was omitted in the rear of a pig and it gradually disassembled itself. The parts were distributed over about 50 miles (80 kilometers) of pipeline as pieces came off the back of the pig. The front seal and part of the pig body finally came to rest - in a valve.

On wear compensated pigs the springs must be checked for cracks or other damage. If the springs are not in good condition, it can cause abnormal wear on the sealing elements and other parts of the pig. The spring itself may break, often due to fatigue, leaving a cleaning element and a piece of this hardened steel spring in the pipeline. The next pig may then push it out, perhaps putting a small, but potentially dangerous gouge in the pipe wall. It must also be remembered that the cleaning elements, through the springs, support most of the weight of the pig body and once this support is lost, the wear on the seals can be very severe.

The conditions within a pipeline can be very severe and therefore it is necessary that all pig components be in good condition at the start of every pigging run.

10.2.2 SIGNALERS

The signalers play an important part in the pig run. They are almost always installed at each end of the pipeline. At the start, to confirm that the pig has left the launching trap and is in the pipeline, and at the finish to indicate that it has arrived in the receiving trap.

Signalers may also be used at intermediate points, typically to give a signal to the station control so that the pump can be shut down to allow the pig to pass through. Alternatively, to simply change the valving so that the station is in a circulating mode, avoiding the high power consumption to restart.

Signalers can perform many other important functions for the pipeline operator. They may for example be used to provide the control room with a constant update on the pig's progress, or indicate when it has entered or cleared a potentially difficult section such as a river crossing.

If the signaler has not been regularly serviced and used, it should be checked to be sure that the it is working correctly. This applies whether it is a visual signaler installed locally, or if it is an electrical signaler at some remote site.

Some signalers can be manipulated manually, externally, to verify that they are in good working condition. Others may be checked by manually exercising the micro-switch to check that the signal is received at a remote site.

When there is no mechanical connection between the tripping device inside the pipeline and the signaling device, it may not be possible to check the entire signaler without removing it from the pipeline.

In this event, if the point where the signaler is installed is subjected to pipeline pressure, it can only be removed if:

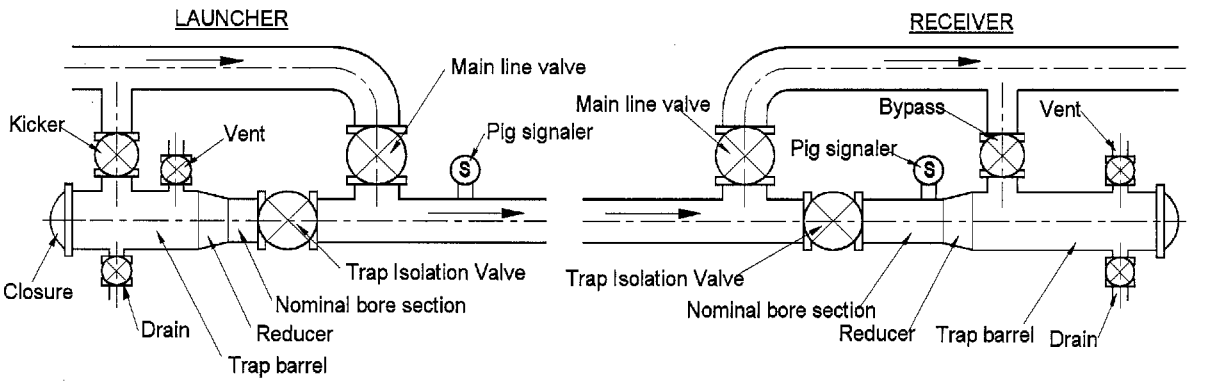
a. it has been designed to be removed under pressure and -
b. the proper extracting tools are available.

Under no circumstances should any attempt be made to remove a signaler (or any other connection) without first establishing that it is safe to do so.

As with any other aspect, when records are kept in the pigging logs about failures of signalers or other devices, they provide excellent guidance for determining a proper maintenance and repair program.

10.3 PIG LAUNCHING AND RECEIVING

IMPORTANT NOTE: The following is not intended to be a definitive set of procedures which are applicable to all pipelines, but simply a framework which could provide the basis for developing formal operating procedures. Operating procedures must be developed separately for each pipeline, taking into account all the variables such as the product, station design, valves, pressure, line size, pig type etc.



Basic Configuration and Terminology for Pig Launcher and Receiver

Traps are a means of access to the inside of the pipeline. It is therefore a fundamental requirement that all valves must give a good seal and be in good working condition, so regular maintenance is essential.

Details of the design of pig stations is included in Section 4.0, but there are a number of operational aspects which should be noted and checked.

There must be good access to the trap whether it is for launching or receiving.

It is almost impossible to prevent spillage of some of the product along with the sludge, dirt and debris removed from the pipeline. Provision must therefore be made to handle this waste material in a safe manner. In addition to the fact that it is often flammable, it may cause other hazards in the work area and grating or other means must be provided to prevent slipping and possible falls by the operating personnel.

Connections that could result in spillage should be piped so that the waste material is taken away from the work area. Drain connections in particular must be piped to a container designed to allow for the safe disposal of the waste.

Pigs over about 12" are usually too heavy to be handled manually, so lifting equipment should be provided to move the pigs between the traps and the vehicle which is used to transport them. These lifting devices are often pneumatically or hydraulically operated to avoid having electrical equipment in a potentially hazardous area.

10.3.1 LAUNCHING PROCEDURES (Typical)

Company policies vary as to how the trap is normally left after the previous use. After a pig is launched, one procedure is to leave the main line trap valve open and the trap pressurized until preparing for the next usage. Another procedure is to close the trap isolation valve, drain the trap and leave it with the drain and vent open until the next time of use. A third method, which requires a thermal pressure relief valve to be permanently installed, is to close the trap isolation valve, drain the trap and leave it with the drain and vent closed until the next time of use. It is usually considered to be important that the trap is not blocked closed when full of product, especially a liquid, even when a relief valve is fitted, as changing temperatures might create pressures that are not within the design limits.

The first step then is to verify whether there is any internal pressure in the trap before commencing any part of the launch procedure. Note that for safety or operational reasons, there may be more than one valve on any of the connections, in which case all of them should be opened or closed as the case may be. Then, referring to the drawing, a typical launch procedure would be as follows.

Step 1 Verify that the trap isolation valve is closed.
Step 2 Verify that the kicker valve is closed.
Step 3 Open the drain valve(s) to drain the trap of any residual product.
Step 4 Open the vent valve to assist the trap to drain and to verify that the trap is depressuized.
Step 5 Check pressure gauge(s) on the trap to verify the trap is depressurized.
Step 6 If hazardous products have been in the trap, purge them with an inert product.
Step 7 Remove the safety lock on the trap closure.
Step 8 Open the trap closure.
Step 9 Install the pig with the lead cup firmly in contact with the reducer between the barrel and the nominal bore section of the trap.
Note: Normally, only one pig will be installed within the trap for launching at any one time. An automated trap for pigs or spheres will require additional steps to control the launching of the pigs, one at a time.
Step 10 Clean the closure seal and the other sealing surfaces, then shut the closure door.
Step 11 Install the safety lock on the closure.
Step 12 Close the drain valve(s).
Step 13 Slowly open the filler valve on the kicker valve bypass line, if one has been fitted. If not, then slightly open the kicker valve to fill the trap.
Note: The flow through the kicker line into the trap should not be more than the capacity of the pressure equalizing line on the trap, otherwise the pig may move forward during the filling procedure.
Step 14 When the trap is filled, close the vent valve.
Step 15 Leave the filler valve (or the kicker valve) open until it has been verified that the pressure in the trap has equalized with the pipeline pressure, then close it.
Step 16 Fully open the trap isolation valve to the pipeline.

Step 17 Obtain permission to launch the pig from the pipeline control center.
Step 18 Fully open the kicker valve.
Step 19 Partially close the main line valve to create flow through the launching trap. Monitor the pig signaler and when pig has passed, immediately open the main line valve fully.
Note: If the pipeline flow is so low that the flow through the pressure equalizing line on the trap plus the leakage around and through the pig prevents it from launching, it is advisable to wait until higher flow rates are available for pigging. Pigging at very low flow rates is possible but it is not very effective and it is not recommended.
Step 20 The trap may be left in this condition or if it is to be left depressurized, repeat Steps 1 through 6.

10.3.2 RECEIVING PROCEDURES (Typical)

At receiving traps also, company policies vary as to how the trap is normally left after the previous use. The options are the same as they are for the launcher but are repeated for ease of reference.

After a pig is received, one procedure is to leave the trap isolation valve open and the trap pressurized until preparing for the next usage. Another procedure is to close the trap isolation valve, drain the trap and leave it with the drain and vent open until the next time of use. A third method, which requires a thermal pressure relief valve to be permanently installed, is to close the trap isolation valve, drain the trap and leave it with the drain and vent closed until the next time of use. It is usually considered to be important that the trap is not blocked closed when full of product, especially a liquid, even when a relief valve is fitted, as changing temperatures might create pressures that are not within the design limits.

The first step is always to verify whether there is any internal pressure in the trap before commencing any part of the receiving procedure. Also, again note that for safety or operational reasons, there may be more than one valve on any of the connections, in which case all of them should be opened or closed as the case may be. Then, referring to the drawing, a typical receiving procedure would be as follows.

Step 1 Check the pressure within the Receiving Trap.
If it is already at full pipeline pressure, proceed to Step 2.
If it is partially pressurized, it is usually best to drain down completely before refilling, so proceed as follows:
a) Verify that the trap isolation valve is closed.
b) Verify that the bypass valve is closed.
c) Open the drain valve(s) to drain the trap of any residual product.
d) Open the vent valve to assist the trap to drain and to verify that the trap is depressurized.
When the trap is completely depressurized, proceed as follows:
A) Check that the vent valve is open
B) Close the drain valve.
C) Slowly open the filler valve on the bypass line piping, if one has been fitted. If not, then slightly open the bypass valve to fill the trap.
D) When the trap is filled, close the vent valve.
E) Leave the filler valve (or the bypass valve) open until it has been verified that the pressure in the trap has equalized with the pipeline pressure, then close the filler valve (if used).
Step 2 Fully open the bypass valve.
Step 3 Fully open the trap isolation valve.
Step 4. Monitor the pig signaler for pig arrival.
Step 5 Partially close the main line valve to insure that the pig is completely within

the trap, then immediately fully open it again.
Step 6 Close the trap isolation valve.
Step 7 Close the bypass valve.
Step 8 Open the drain valve or valves.
Step 9 Open the vent valve.
Step 10 Check pressure gauge(s) on the trap to verify the trap is depressurized.
Step 11 If the trap contains a hazardous product, purge with an inert product.
Step 12 Remove the safety lock on the trap closure.
Step 13 Open the trap closure.
Step 14 Remove the pig from the receiving trap.
Step 15 Clean the closure seal and the other sealing surfaces, then shut the closure door.
Step 16 Install the safety lock on the closure.
Step 17 If the trap is to be left unpressurized, it may be left in the current condition. If it is to be left pressurized, repeat Steps A through D of Step 1, and leave the filler and/or the bypass valve open.

10.4 PIGGING THROUGH A PUMP STATION (Typical)

IMPORTANT NOTE: The following is given purely as an example of how pig signalers can be used to allow a pig, which is separating two dissimilar products, to pass a booster station with minimum interface mixing. It is not intended to be, nor can it be, a definitive method as such systems must be designed specifically to suit each particular pipeline.

The following sketch is a schematic arrangement of the main piping referred to below. It is not intended to show all the piping, valves and related equipment required for a pump station.

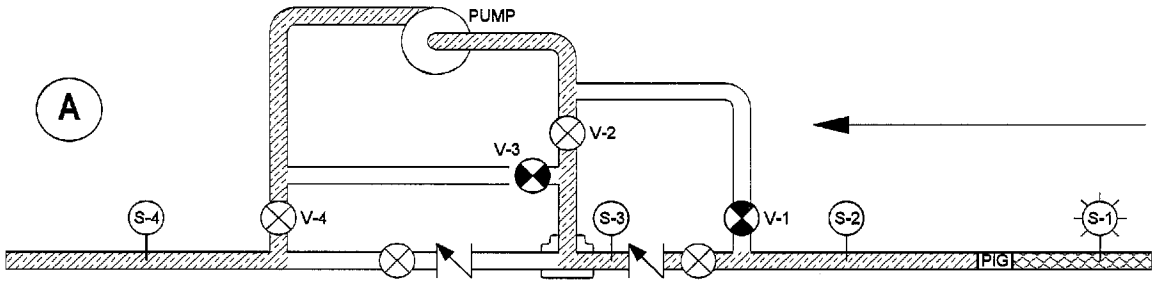
The purpose of the operation is to pass the product which is behind the pig, through the station booster pump and then back behind it, so that the pig leaves the station in the same position relative to the interface of the two products as it was in when it arrived.

To accomplish this, it is first necessary to determine the time it takes to flush the station piping at the current pumping rate. To do this, two pig signalers (S-1 and S-2) are located just upstream of the pump station. The distance between them is calculated such that the volume of product between the two signalers is equal to the volume of product within the station piping. The 'station piping volume' would be from the special flow tee near signaler S-3, through the piping and back to Valve V-3, including the volume of product within the pump.

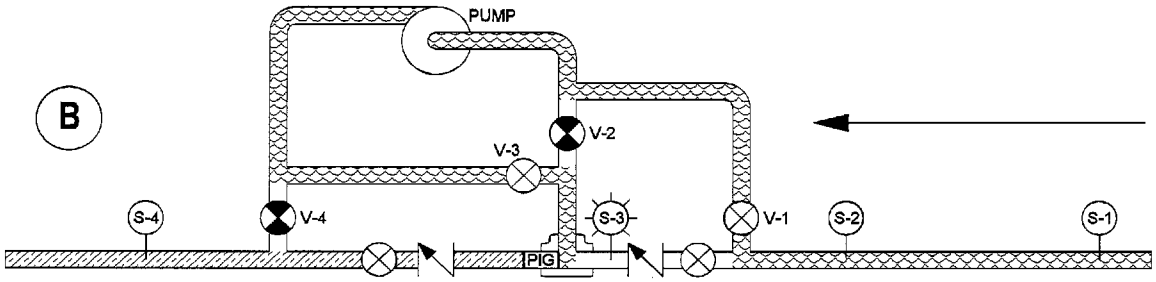
Valve actuators must open and close the valves quickly and the operating sequence must be such that some valves may start closing before others start opening. This operation must be designed specifically for the conditions of each pipeline and pump station according to line size, make of valves, valve operators and other related equipment.

As the pig approaches the pump station it passes signaler S-1. The signal starts a timer at the station control which continues counting until the pig passes signaler S-2. This gives an accurate indication of the time that will be required to flush the station piping.

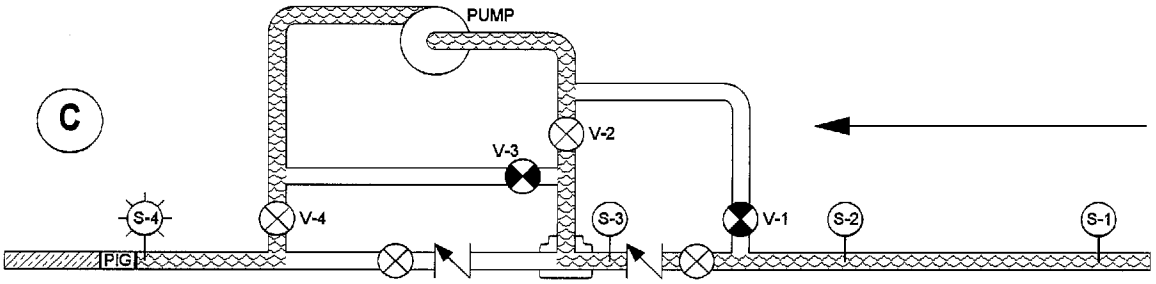
When the pig trips signaler S-3, it starts a prearranged sequence of operations. The pig will automatically stop in a flow tee that is part of the normal pump suction piping. Meanwhile, the signal from S-3 starts another timer which will count down the time previously measured to flush the station piping. This will allow time for all the product that was in front of the pig, but within the station piping, to be completely replaced by the product that was behind the pig.



Pig Approaching Pump Station



Pig in Flow Tee



Pig Leaving Pump Station

Simultaneously, the signal from S-3 closes Valve V-2, and opens Valve V-1. This effectively relocates the position of the pump suction branch, but still keeps the suction with the product that is behind the pig.

When the timer signals that the station piping has been flushed, Valve V-4 closes as Valve V-3 opens to effectively relocate the pump discharge branch. This diverts the product that entered the station piping from behind the pig to be also discharged behind the pig and push it out of the pump station into the main pipeline.

When the pig reaches signaler S-4, the signal notifies the controller that the pig is clear of the station and resets all controls for the next incoming pig. Normally the controls will be such that if another pig enters the system before the first pig passes signaler S-4, the same sequence will be initiated so that it can pass the station in the same manner as the previous pig.

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11.0 INDUSTRIAL PIGGING SYSTEMS

11.1 INTRODUCTION

Industrial, or plant pigging systems are usually used to remove a product from a process pipeline and are often referred to as 'pig clearing systems'. The product is cleared either for cleaning, perhaps including sterilization, or more commonly for changing over to a different product.

Such systems are becoming widely used in plants designed for such things as lube-oil blending, confectionery, paint, pharmaceuticals, food processing and beverages. They are often concentrated at 'each end' of the process; typically, in the distribution of the raw materials to the various production lines and in the packaging and bottling plant immediately prior to despatch. As such, they tend to be small diameter, generally in the range of 2" to 8"

The pigs are generally of a special design, particularly if there is a risk of product contamination, and often remain semi-permanently in the line, shuttling to and fro between 'stations', driven alternately by either another product, a liquid (which may be water, perhaps containing some agent), or a gas (which is often compressed air). This generally requires a fully automated system to be installed.

IST Molchtechnik GmbH (IST), a leading company in this field, list the following advantages for these systems:

- space saving: less pipes and fittings
- air and bubble free transfer of product
- time saving; pipe cleaning reduced to minimum
- product saving: no product mix, no loss of rinsing agents, no cleaning of waste products
- cost saving in design of plant: less pipes, pumps, meters, filters, fittings
- pipes remain clean, no product growth on walls
- pipes are always empty, no product is kept in the pipes, reducing risk of human error and loss of product
- automation reduces operation time and eliminates errors
- return of excess product in the line in case of overfill of tank
- emptying sloping inclined lines
- as no product is stowed in the pipes, heating can be eliminated

As with any pigging system, it is not just the pig which needs careful design. The pipework and the various fittings must also be designed and fabricated to become part of an integral, reliable package.

11.2 BASIC SYSTEM DESIGN

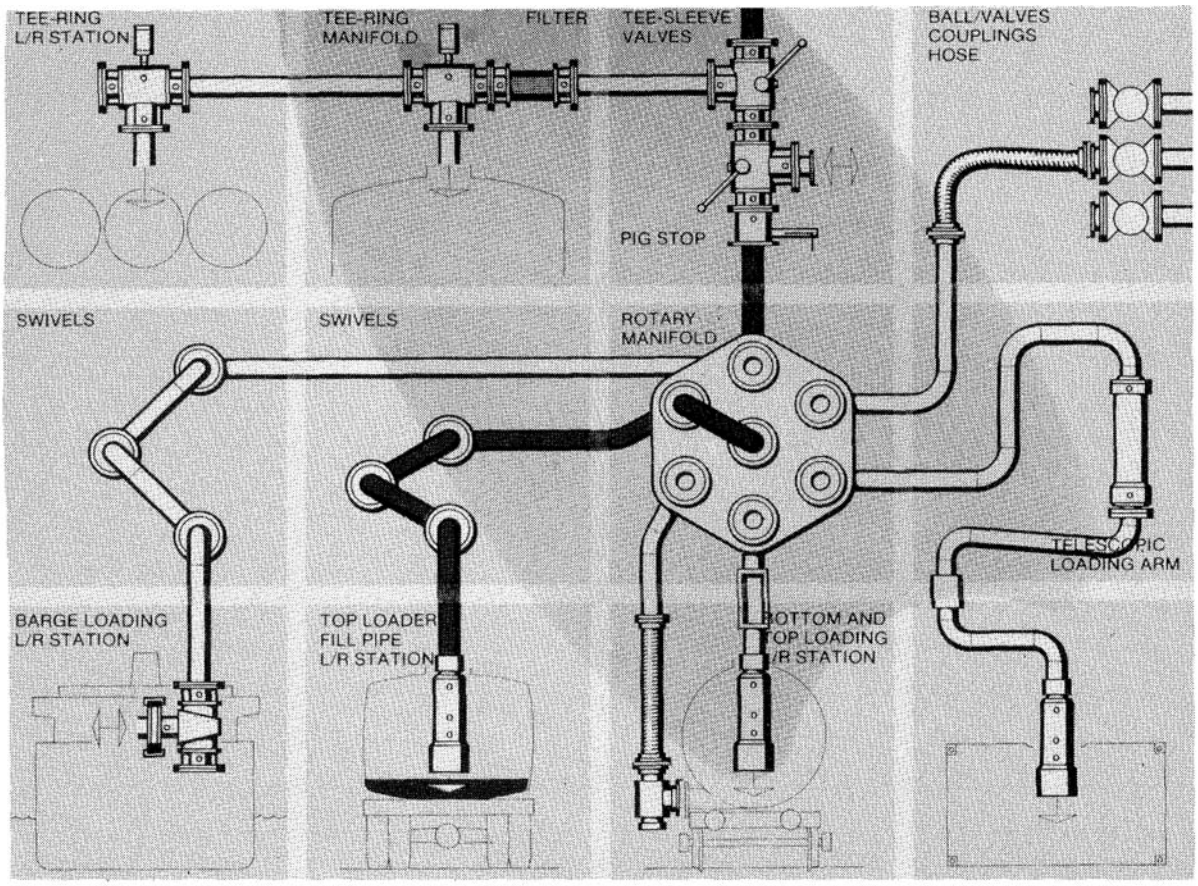
11.2.1 ONE PIG and TWO PIG SYSTEMS

One of the most fundamental decisions in designing a plant pigging system is whether to use one or two pigs. With one pig, the product in the line can only be pushed in one direction. In most cases however, it is necessary to pig in the reverse direction as well; perhaps to return some excess product or to evacuate and clean the line prior to pumping the next batch. Most

systems are therefore designed for two pigs to be installed in each piggable section.

11.2.2 PROPELLING MEDIUM

The medium required to propel the pigs will depend almost entirely on the type of service and the economics. For small systems, compressed air or gas is commonly utilized, but this generally becomes uneconomic with larger sizes and/or longer runs. The equipment required to supply, handle and move the medium would also play a major part in the decision process, not forgetting the safety aspects.



Typical applications and piping fittings for plant piping

Courtesy: IST Molchtechnik GmbH.

11.3 PIG DESIGN

Although spheres and foam pigs are sometimes used, they do not generally seal well enough for most plant pigging purposes. The pigs must not absorb or contaminate the product. Also, as most pigs need to carry a magnet to indicate their position and to trigger the sequencing systems, they are not ideal physically.

Typically, pigs for these systems will be based upon the bi-directional pig, using a series of discs mounted on a central shaft. For the lower end of the size range, they may be molded as one piece or even machined from solid material. The larger ones may also be molded, but are often made by threading discs and spacers onto a central bolt, which is commonly made of stainless steel. This basic simplicity allows a

wide range of materials to be used without severe cost penalties; typically, Polyurethane, EPDM, SBR, Viton, Neoprene, Nitrile and Teflon.

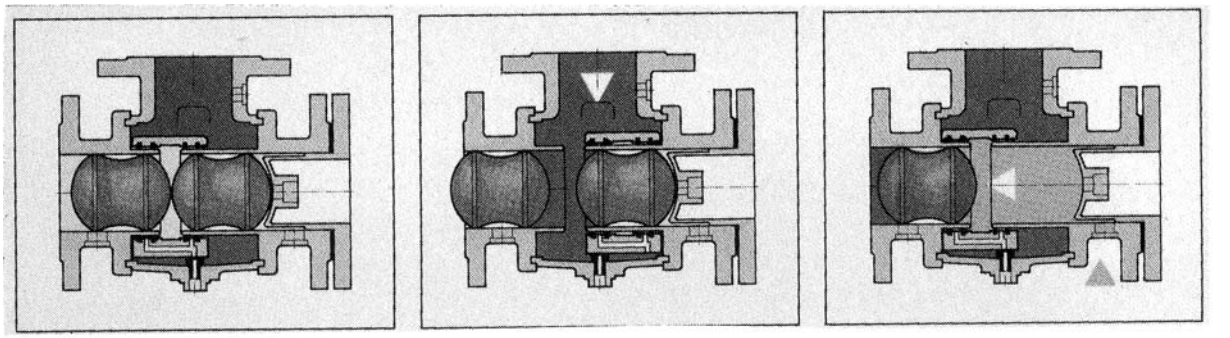
IST, who were mentioned previously, have developed a special pig for plant pigging systems called the "DUO-Pig". It has a "double mushroom" shape providing a double seal in the front and rear. It is normally molded from Vulkollan (a polyurethane compound) but is also available in most of the materials mentioned above. The foam core can be made to different densities to provide optimum performance for a given duty.

It is claimed to seal throughout its travel in the pipe through bends and even over dents, bulges, ridges, etc. It has relatively small sealing surfaces which are designed to produce the least possible friction combined with a maximum of cleaning effect. The stated average force to drive it through the pipe is 15 to 20 psi (1 to 1.3 Bar). Normal speed is given as being about 7 feet/sec (2m/sec).

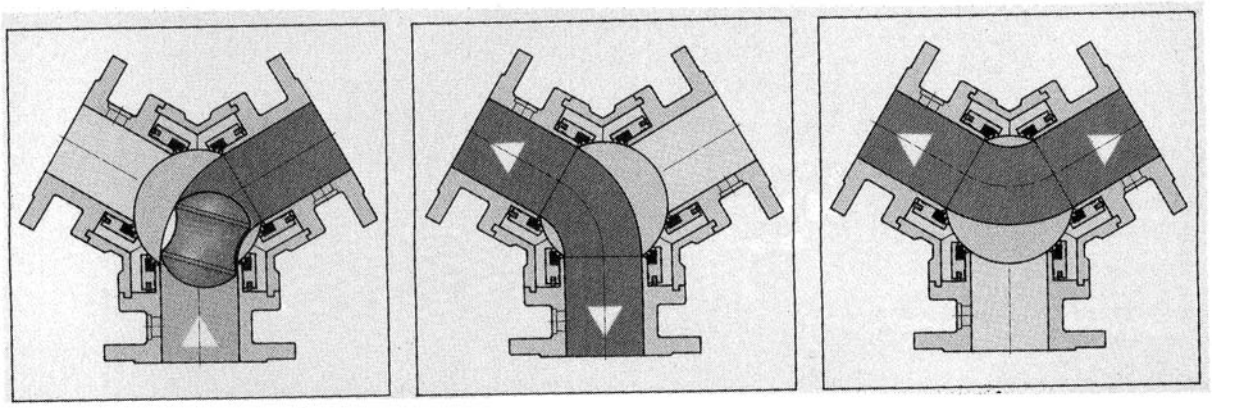
11.4 VALVES and FITTINGS

The small size, frequent operation and automation of plant pigging systems means that more care and tighter tolerances are required during the design and installation of the pipework and fittings than would be the case for large diameter, long distance transmission or distribution pipelines.

There are a number of proprietary products, including special launch/receive valves, three-way valves, manifolds and loading lances which can be incorporated into a purpose built plant pigging system, but IST have developed a virtually complete range.



Launching Fittings for an Industrial Pigging System *Courtesy: IST Molchtechnik GmbH*



Diverter Fitting for an Industrial Pigging System *Courtesy: IST Molchtechnik GmbH*

Some idea of the critical nature of the detail design of such systems can be obtained from the list of features which IST consider to be important:

- absolute full and smooth bore to pass the pig
- connections for accessories like pressure gauges, air connectors and pig sensors
- leak detection port (for valves only)
- pressure relieved valve seats (for valves only)
- simple and low cost conversion from manual operation to automation

IST's range of fittings includes 'Tee Sleeve Valves', Wye Valves (diverters), and Manifolds, for diverting a pig from one line into one of a large number of others. There are a number of different types of Launching and Receiving Stations including 'open and closed' pig stations, end of line stations, portable stations (end of hose stations), loading arm stations, and filter stations.

In addition to these basic items, a great many other piggable accessories are required such as sight glasses, ball valves, hoses, couplings, swivels and loading arms. Other items would include pig sensor equipment (including non-intrusive signalers), valve actuators, limit switches, control panels etc.

11.5 PIPEWORK

11.5.1 GENERAL

The prime objective is to provide for smooth pig passage at steady, controllable speeds. The pig will be an interference fit and will need a positive pressure behind it (the differential pressure, or 'DP') to cause it to move. Any variation in the amount of interference will alter the DP and, if the medium ahead of, and behind the pig is compressible (i.e. a gas), the pig may travel with 'stop - start' motion (often referred to as 'speed excursions') and this must be avoided. Apart from the difficulty of controlling a process efficiently under these conditions, it can also damage the system, and may be dangerous.

To minimize this problem, all components in the system must be designed and selected to provide as near constant bore as possible, with smooth internal surfaces. The ends should be deburred with all sharp edges removed and the internal surfaces should be oiled and then capped to prevent corrosion during transit or storage. Note that sandblasting and other surface treatments may actually *increase* surface roughness and should not normally be used.

11.5.2 PIPES

Most standard ASTM or DIN pipe is suitable for plant pigging systems however the specification and materials used will often be determined by the type(s) of product to be transported..

11.5.3 BENDS

The absolute minimum bend radius should be 3D (i.e. the bend radius to the centerline equal to three times the nominal diameter). However, in the smaller diameters especially, a minimum of 5D is preferred and up to 10D if possible. Ovality and reductions in diameter due to changing wall thickness can be a major problem at bends and this must be avoided.

11.5.4 JOINTS

Any type of joint can be used provided it meets the prime objective of providing smooth pig

passage as described above. Some of the more common joints are discussed below.

11.5.4.1 FLANGED

Slip-on and ring-type joint flanges do not allow the inside diameters of each pipe joint to butt up closely together, so weld neck flanges are generally preferred. The flange bore must be carefully aligned with the pipe bore and any weld penetration removed. Flange gaskets should be sized and installed so as to provide a continuous bore with no protrusion into the bore. Dowels may be used to ensure alignment of mating flanged joints.

11.5.4.2 SCREWED

Conventional screwed joints do not allow for the pipe ends to butt together and so are generally unsuitable for plant pigging systems.

11.5.4.3 BUTT WELDED

For butt welding, the ends of each joint should be machine cut to ensure that they are square. Alignment of the bores can be difficult and may require the outside diameters to be machined back to ensure concentricity and effective use of the line-up clamp. Contrary to normal pipeline practice, unless there is an overriding requirement, weld penetration should be avoided and the set-up for welding should allow for no root gap.

11.5.4.4 WELDING RINGS

Most plant pipework is not subjected to high pressures and stringent code requirements so accurate alignment of the bore for pigging may be obtained by sliding the machined ends of each pipe into a close fitting collar. Once the two ends are firmly butted together, the collar may be fillet welded to the outside diameter of the pipe. By making the collar a shrink fit the problem of fluids being trapped between the inside diameter of the collar and the outside diameter of the pipe is virtually eliminated.

11.5.5 BRANCH CONNECTIONS

Tees are not normally a feature of plant pigging systems because, even if the branch had valves, they still permit a substantial pocket of fluid to be left behind as the pigs pass, making effective clearing very difficult. However, there is a need for very small connections for such things as pressure gauges, vents etc. and these should be installed to provide as small a recess as possible and to avoid any protrusion into the line.

11.5.6 HANGERS and BRACKETS

Hangers or brackets should be clamped on to the pipe and not welded. Welding to the outside can affect the inside surfaces and may cause local distortion.

11.6 CLEANING AND COMMISSIONING

Provided care has been taken during construction to avoid dirt and debris being left in the line, the work needed to clean it in preparation for commissioning should, subject to the eventual service, be relatively simple.

If cleaning is carried out using compressed air, then attention must be paid to the question of safety and only qualified personnel should be allowed in the vicinity and the work carried out to approved procedures. Throughout the cleaning operation, all connections and components which could be damaged by debris should be adequately protected.

Procedures will vary, but it is common to begin by air blowing through the line to remove loose, light debris. Cleaning pigs may then follow to remove heavier debris. These may be simple disc pigs, coated foam pigs or, if it is necessary

to remove scale (for example), brush pigs may be used.

Commonly, the line is then flushed. The product used for flushing will often be determined by the intended service. It must be remembered that if water is used, it could cause corrosion and ruin the inside surface. If chemical cleaning is employed, it may be applied as a batch, between two pigs.

During, or immediately after the final cleaning operation it is important to monitor and record the pressure against time during pigging. A significant increase or decrease could indicate a problem with the pipeline internal geometry. A pig equipped with a thin, slotted aluminum gauging flange may help to confirm whether there is a reduction in the diameter and the time should give a reasonably accurate idea of its location. pressure trace determine be an added advantage

Most plant systems are designed so that they can be emptied (or 'cleared'), so provided all the ancillary equipment, control systems etc. have been checked out, they are in effect commissioned (i.e. ready for use) as soon as the final cleaning and gauging work is completed.

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12.0 ANCILLARY PRODUCTS and SERVICES

12.1 TETHERED TOOLS

There are a large number of tools designed to operate within a pipeline which do not strictly qualify as "pigs" because they are not free swimming, but are connected to the outside via a cable or umbilical. These are often referred to as 'tethered tools'.

If the pipeline can be shut down and there is access to the open end of the pipe, then provided the tool does not have to work over too great a distance, and there are not too many bends, tethered tools can have many advantages. In general, most of the tasks which are performed by ILI tools (instrumented pigs) can be performed equally well, and often better, by tethered tools provided these conditions prevail.

Most tethered tools are either pigged into position, or are motor driven into position on wheels. There are one or two types which use two sets of expandable shoes mounted at each end of a pneumatic cylinder. By alternately locking the front shoes and retracting the cylinder, then locking the rear shoes and extending it, the tool can move forwards or backwards, adopting a motion similar to that of a caterpillar.

The tether is simply pulled into the pipe behind the tool. If the pipe contains a product the tether is fed through a special seal unit installed at the open end of the pipe.

The tether not only feeds the hydraulic, pneumatic or electrical power needed by the tool, but it may contain wiring for instrumentation and data feedback and can incorporate a high tensile steel cable for recovering the tool when the job is completed. The tether is usually also marked at intervals to provide a useful measuring device, allowing the position of the tool to be determined very accurately.

The first section below, covering metal loss (corrosion) inspection using tethered tools, is covered in some detail due to its particular relationship to pipeline pigging. The remainder of this Section however, is not intended to give a detailed description of these tools; but simply to provide an awareness of some of those that are available together with an idea of their capabilities.

A list of the suppliers of tethered tools, together with their contact details will be found in Section 16.

12.1.1 METAL LOSS (CORROSION) INSPECTION

There are critical piping systems that cannot be inspected by instrumented pigs because the systems cannot accommodate them or are not suitable for pigging. Typical examples are:

1 Tanker loading lines from offshore points to shore where there are no offshore pig traps. There may also be flexible or reduced size piping at the offshore end.

2 Offshore piping such as platform risers which may contain abrupt changes in the inside diameter or other physical changes which are beyond the capabilities of the existing range of instrument pigs.

3 Plant piping that is inaccessible because of the location or because it is insulated, or perhaps sections of bare pipe that are simply too labor intensive to inspect externally with present hand held methods.

Pipeline and plant operators use non-destructive testing (NDT) as an economic means to assess the condition and integrity of their piping systems. The results of this testing are used to determine the maintenance programs.

External spot checking does not give adequate coverage of the entire piping system and to increase the coverage becomes very expensive so it was decided to try to use the successful instrument pig technology in 'non-piggable' piping.

12.1.1.1 ULTRASONICS

Where the pipeline is full of a liquid, the most suitable way to quantify and differentiate internal and external corrosion is probably the ultrasonic stand-off method. It is therefore well suited to the many lines that are filled with crude oil or sea water and the stand-off of the transducers makes the tool less vulnerable to damage.

One system, pioneered by Röntgen Technische Dienst bv (RTD) in Holland is called PIT (Pipeline Inspection Tool). It is a tethered ultrasonic tool that can be propelled into and out of the piping, transmitting the inspection data back through a cable to a control room at the launch/receive point. This provides instant results, however the information is also recorded on tapes or discs to be used for detailed analysis.

RTD use a wheeled crawler system to move the instrument. The tether incorporates a strong steel cable to assist in moving the tool if the crawler needs assistance. The signals are transmitted by fiber optics. This system has been found to be suitable for distances up to about 10 1/2 miles (17,000 meters). The crawler is suitable for sizes 16 inch (400 mm) and larger. For sizes less than 16 inch it is necessary to use differential pressure to move the instrument and a special seal unit, or stuffing box, is required to feed the tether and signal carrier through into the end of the (then) pressurized line. A 10 inch (250 mm) tool has been used over a length of 3.9 miles (6300 meters).

A. Hak, another Dutch company has developed similar equipment which they refer to as the 'Piglet'. This tool transmits data through a glass fiber filament which is unwound from a spool attached to the tool. This is claimed to virtually eliminate any restrictions due to the number and angle of bends in the line. The size range is from 4" (100 mm).

A relatively common application for this type of tethered tool is the inspection of offshore loading lines. These are usually less than 10 miles (16 km) in length and access is only possible at the onshore end. Instrument pigs are not designed to be bi-directional and many of these systems will not allow current pig designs to traverse the piping.

The inspection of risers on offshore platforms is another typical application, but these present different problems. There are often sudden diameter changes which might be as much as 15% and, where the riser is a gas pipeline, there must be a method of filling it with liquid in order to use the ultrasonic inspection system.

Because much of the inspection is carried out in the vertical plane and around tight bends, a 'spider' has been developed to contain the instrument and keep it centered within the pipe at all times. To achieve full coverage, the transducers oscillate from side to side, which in practice gives some overlap of the inspected areas.

12.1.1.2 REAL TIME RADIOGRAPHY

A lot of plant piping can be inspected with inspection pigs or tethered tools but a considerable proportion is thermally insulated and this often presents problems for inspection which are beyond the capabilities of either of them. Not only does the insulation prevent visual or ultrasonic inspection, it may retain moisture that can cause corrosion. Systems have been developed to determine the places

where moisture has collected in the insulation but corrosion can also exist in areas that are dry.

Radiography is used extensively to detect corrosion under the insulation and its metal protective cover, but in 1994 two real-time radiography (RTR) systems were developed. The RTR system provides an image of the metal loss on a hand held monitor. It will allow a two man crew to inspect about 330 feet (100 meters) of piping per day.

12.1.1.3 EDDY CURRENTS

Several attempts have been made, and with some success, to apply low-frequency eddy currents to establish the presence and severity of corrosion under the insulation on piping.

The rate of decay of eddy currents depends on conductivity, magnetic properties, and the shape and size of the component. Algorithms and interpretation software have been developed for inspection of components with up to 4 inches (100 mm) of thermal insulation and tests are understood to have provided an extremely good reproducibility and accuracy, regardless of the presence of chicken wire and aluminum, or galvanized steel sheeting in the insulation.

Low-frequency eddy currents are also suitable for measuring through thick non-conductive and non-magnetic coatings, or thick layers of deposit. A typical example is to measure the wall thickness of a riser pipe, despite the presence of severe marine growth. Because of its non-contact remote sensing capabilities, this technique also has potential for high temperature applications.

12.1.1.4 MAGNETIC FLUX LEAKAGE

Systems based on Magnetic flux leakage (MFL) have been used for many years for the inspection of pipelines, and a number of companies also use this technology with tethered tools to inspect short runs of difficult piping. This includes lagged, clad, or buried utility and plant piping, which has always been a problem especially where it involves road, rail, or river crossings.

PII Pipeline Systems developed a vehicle, which comprises three articulated modules with a towing cone at the front and a radio transmission cone (to which the umbilical is connected), at the rear. The magnetic module is located behind the towing cone and contains the magnets, which induce a flux into the pipe wall. It also carries the sensors, which detect variations in the flux caused by changes in the pipe wall thickness.

The signals are fed via the electronics module to the PC and display screen at the base station, thus providing a constant readout to the engineers, on-site. The on-site PC can be programmed to either give numerical data on defect size or to provide suggested actions by a simple color code: Green = no action required, Amber = keep under review, Red = repair or replace.

Power is provided by a generator at the launch site and transmitted to the power module via the umbilical.

12.1.2 CCTV (VIDEO) INSPECTION

Closed Circuit TV, or video cameras are probably the most common application of tethered tools for inspection purposes.

They can only be used in relatively clean empty pipes or in pipes containing a clear liquid, typically water.

The miniature camera carries its own lighting and can usually be manipulated to look in a particular direction. Typically the camera would be aimed straight ahead, but if an anomaly is detected, it can be moved to enable the operator to study the defect from various angles.

This form of inspection is really only suitable for relatively short runs and relies totally on the powers of observation of the operator. However, the image can be recorded, either continuously, or whenever an anomaly is being inspected, for viewing at some later stage.

12.1.3 PIPELINE ISOLATION

There are a number of tools of this type, which are used for pipeline isolation. They are basically tethered plugging pigs. In fact, some of the plugging pigs have been developed from these tethered tools. (See Section 6).

They are available for various operating pressures, from around 15 psi (1 bar) to well over 1000 psi (69 bar). The pressure withholding capability is often limited more by the pipe wall thickness than it is by the tool.

12.1.4 INTERNAL PIPELINE ALIGNMENT

One tool for this purpose was a joint venture development of Houlder Offshore Limited and H Rosen Engineering GmbH. It was designed specifically as an internal alignment clamp for pipeline welding operations. It was self-powered and could travel in any direction and was also capable of carrying out a radiographic inspection on completion of the weld.

12.1.5 CLEANING

There are a very large number of tethered tools for internally cleaning short sections of pipe. Being powered, they can be fitted with many types of cleaning elements including brushes, blades, scraper knives etc. which can be rotated or moved backwards and forwards. They are therefore especially useful for removing hard deposits such as scale and tar.

They are generally used by specialist service companies, often in conjunction with other tools designed to remove the loosened debris. Some of these tools have been developed by these companies for their exclusive use.

12.2 IN SITU INTERNAL COATING

There are only a limited number of companies specializing in 'in situ' internal coating. One of these is UCISCO Inc. They have found that there are three critical factors which influence the success of any coating project: surface preparation, coating selection and coating application. The wrong choice in any area may cause premature failure of the coating. Their approach to a typical job normally includes the following:

Surface preparation is the first step of any coating job. It is essential to thoroughly clean the inside of the pipe to properly prepare its surface. This is to remove all deposits from the line, including rust, scale, and salts that could interfere with the coating bond. After cleaning, the line should be completely dry and under a purge of an inert gas to prevent flash rusting.

A typical cleaning process involves scouring the inside of the pipeline with an abrasive material, such as flint, which is propelled in a low-pressure, high velocity stream of nitrogen. The cleaning particles impact the wall of the pipe at a low angle of incidence, gouging and/or chipping away the deposit. Removed material is then carried through the line with the nitrogen, and collected at the outlet. After abrasive cleaning, pigs and/or solvents are used to remove any remaining dust.

Occasionally, the cleaning process may uncover very thin, hard deposits, such as magnetite, which are more economically cleaned with chemicals. Also, by removing rust or scale, cleaning may expose leaks that must be repaired before coating.

Coating selection is the second critical aspect. A wide variety of coatings have been used to internally coat in-place pipelines but they must generally have specific thixotropic properties to enable the coating to be spread onto the pipe wall and then immediately "gel" to prevent it from running or sagging.

The most commonly used coating is a two-part polyamide-cured epoxy. This polyamide coating is recommended for lines carrying potable, fresh and salt water; crude oils, transportation fuels, natural gas, and some solvents. However, the final coating selection must first be discussed with a professional in situ coating service company and in most cases it is good practice to install a test spool cleaned and coated under field conditions to assure compatibility with the intended service.

Coating application to in-place pipelines is achieved by placing the coating material between two pigs and propelling the 'pig train' through the line. Various types of pigs, including multiple-cup-and-disc, bi-directional disc, and spherical pigs are commonly used.

The coating thickness is affected primarily by the size of the cup pigs and the coating train speed. By controlling the differential pressure across the coating train and hence the train's speed, the required coating thickness can be achieved. Nitrogen is normally used as both the driving force and backpressure.

12.3 SCALE REMOVAL

Scale can usually be removed by the proper use of suitably aggressive cleaning pigs such as the various grades of wire brush foam pigs, and utility pigs equipped with brushes or steel blades. Some special pigs have been developed for this purpose, typically the "Studded Foam Pigs" and the "Pin Wheel Pig".

Typical deposits may include paraffin, asphaltene, sediments, silica, coke, iron sulfides, calcium or other corrosive products which are often extremely difficult to remove.

The "Studded Foam Pig" developed and patented by Decoking Descaling Technology Inc., is a relatively simple pipeline pig which can remove hard deposits from the interior of a pipe. The pig, being symmetrical, permits travel in both directions which is important when cleaning industrial heaters and pipelines.

The body is formed of high strength polyethylene, polypropylene, rubber or polyurethane. The flexibility and hardness of the body are adapted to the intended use. This body has circumferential and longitudinal ribs, forming square recesses which retain an internally threaded anchor. This allows different types of studs to screwed in. Studs are available in various sizes, shapes and hardness and are selected on the basis of the hardness of the deposit, the extent of the build-up, the location of the deposit, and the tube or pipe material.

In use, the pig is inserted into a pipe and is propelled by a fluid, usually water. The pressure acting on one end of the pig causes it to expand, forcing the studs into contact with the pipe wall and dislodging the scale. If they become worn, the studs can be removed and replaced. Furthermore, the stud height can be adjusted using shims. This controls the rate of deposit removal and also sets the amount of liquid bypass around the pig body which flushes out the loosened deposits, reducing the possibility of blocking the pipe.

The "Pin Wheel Pig" is generally used on the longer and larger diameter pipelines and is used as part of a service rather than being sold outright. Further details are included in Section 6 but basically, the cleaning assemblies consist of a number of heavy duty polyurethane discs which have an outside diameter significantly less than the inside diameter of the pipeline.

Protruding radially from the circumferential edge of each disc are a number of steel pins with hardened tips which are radiused to prevent damage to the pipe wall. The diameter across any two opposite pins is greater than the inside diameter of the pipeline so that when the pig is traveling through the line, the pins are bent back at a slight angle. This both assists in the cleaning action and also compensates for any wear.

None of the wax or scale removed from the pipe wall will actually be pushed forward by the pig itself. This will be left behind in the line for removal by another type of specialist pig as part of the overall program.

12.4 CHEMICAL CLEANING

If conventional pigging methods are unable to clean the line sufficiently, then chemical treatment may be considered. The type of chemical(s), their strength, contact time, and overall procedures will be dictated by the circumstances and each individual situation will be different. Specialized equipment will usually be required and permits to work may also be necessary. It is therefore vital to seek professional advice and assistance before adopting this approach as mistakes may be irreversible and errors can be very costly indeed.

12.5 DRAG REDUCING AGENTS

Drag Reducing Agents (DRA), or 'Flow Improvers' as they are sometimes called, are chemical, formulations which, when added to the product in a pipeline (often crude oil), change the fluid flow characteristics.

Normally used in 'parts per million' doses, the improvement in the flow caused by the addition of DRA, effectively reduces the pipe wall friction and hence the pressure losses. This allows greater throughput for the same pressure drop or equal throughput for a lower pressure drop.

There are obvious advantages to pipeline operators in using this, but due to cost, it is generally a short term solution to throughput problems.

12.6 GEOGRAPHICAL INFORMATION SYSTEMS

A Geographical Information System (GIS) is a very useful tool for the pipeline manager. Software, hardware and data have been combined by the use of the computer to give valuable information quickly to the pipeline personnel.

The information contained in a GIS can be tailored to suit the needs of a particular pipeline. These systems may, for example, contain the following data:

- name, address and telephone number of the landowner
- engineering data such as depth of burial, pipe wall thickness
- crop compensation data since pipe installation
- aerial photographs, video images or other site photographs

- environmental data such as the location of nature reserves
- location of weld defects or areas of identified corrosion.

The software has been developed to make this information usable after short training periods.

Additional information can be added such as:

- the best access route to that section of the pipeline
- who to contact with names and telephone numbers
- which settlements might fall within the area affected by any release from the pipeline.

Instrument pig data can be stored in and accessed through the GIS and pipeline pigging companies have been working to integrate the results of inspection surveys into these systems. It makes it possible to quickly identify all areas where corrosion has exceeded some predetermined value or perhaps all areas where corrosion has occurred on the inside or the outside of the pipe.

The benefit of using GIS is that it allows analysis of one set of data and rapid comparison of that, with some other data.

The ability to add important information such as population density and environmental sensitivity makes it possible to improve risk assessment studies and set priorities for maintenance.

12.7 FITNESS FOR PURPOSE ASSESSMENT

12.7.1 BACKGROUND

High-resolution magnetic based inspection equipment allows pipeline operators to determine the condition of their pipeline by detecting and sizing all significant defects. When the operator receives the report of the inspection findings, what should he do next?

That question was at the forefront of pipeline operations for a number of years but it was not until quite recently that there was a satisfactory answer.

Worldwide experience has shown that an initial 'high level' hydrostatic pressure test can, in the absence of defect growth, assure freedom from failure during service of the manufacturing and construction defects which survive. But defects can be introduced during service and periodic inspection of pipelines by high-resolution internal inspection can reveal them. These additional defects must be carefully assessed.

Methods are now available which allow pipeline operators to assess the integrity of the pipeline after the inspection. The methods are based on "fitness for purpose" techniques which relate the severity of defects to the pipeline operating conditions. These often result in the calculation of a Maximum Allowable Operating Pressure (MAOP) which will apply until the defects have been removed.

In a paper entitled "Life after Inspection" and recommended for 'further reading' in Section 15, British Gas (now PII Pipeline Solutions) said that in developing their own "fitness for purpose" methods, they had found that there is very little guidance in national codes on some things, including the following:

- How to determine the remaining life of the pipeline after the high-resolution internal inspection.
- If the internal inspection finds corrosion and it cannot be eliminated, the pipeline operator needs to decide what to do, knowing that the corrosion will continue.

- How to use the inspection as a tool to determine suitability for uprating or life extension.

As a result, the company applied their knowledge and experience to develop "fitness for purpose" methods which allow the operator to assess accurately the significance of defects detected by an inspection and so define safe operating strategies. In so doing, they have found that a properly conducted fitness for purpose assessment may actually allow larger defects than those permitted by the good workmanship requirements of the fabrication code with no reduction in the safety or integrity of the pipeline. Many regulatory authorities and codes are now recognizing the proven acceptability of such fitness for purpose assessments.

12.7.2 DEFECT ASSESSMENT

Defect assessment is a job which must be carried out by experts. The ANSI/ASME publication B31.G, 'Manual for determining the residual strength of corroded pipelines' provides much of the information needed to assess long, complex and interacting corrosion. However a full and proper assessment is necessarily highly complex. It must consider many aspects, including, but certainly not limited to:

- Defects in pipeline girth welds for both brittle and ductile failure.

- Plain smooth dents which, although they may have little effect on the failure pressure of the pipe, can exhibit short fatigue lives and need to be assessed for such failure.

- Dents containing defects (gouge and associated cracking). These are the most severe pipeline defect. Combined dent/defects are very unstable and generally fail at very low pressures and exhibit very low fatigue lives.

- The axial length of a defect and the hoop stress. These combine to determine whether failure through the pipe wall will be a stable leak or an unstable rupture, but stress corrosion cracking and hydrogen induced cracking each tend to congregate in forms which interact to give ruptures rather than leaks.

12.7.3 FITNESS FOR PURPOSE

Each defect must be assessed to determine its potential effect on the operating pipeline. Defects such as metal loss, cracks, dents etc. must be analyzed to assess their cause, how long they have existed and how they will affect the pipelines' fitness for purpose.

Establishing 'fitness for purpose' requires accurate and reliable inspection data, thorough defect assessment - and a sophisticated computer program. This will provide the pipeline operator with advice on the significance of the defects, at what point the pipeline is likely to fail, when and how often it should be inspected, and whether it is more cost-effective to recoat, repair or replace certain sections of the pipeline.

It results in a far better knowledge of the pipeline than would be possible from a hydrostatic retest. So much so that it may be possible to uprate the pipeline so that it can be safely operated at higher pressures.

Fitness for purpose assessments are also valuable in extending the design life of a pipeline. In this event, other questions may need to be considered such as whether there will be a change in the design operating conditions, the remaining fatigue life due to pressure cycles etc.

It must be emphasized that a fitness for purpose assessment is only as good as the inspection report. A reliable, accurate inspection tool is required if the technique is to be successfully applied and, as has already been stated; experts must carry out the work.

12.8 DECOMMISSIONING

There continues to be a great deal of discussion going on about the methods and requirements for abandonment of pipelines. Typical procedures for abandoning a hydrocarbon pipeline in environmentally sensitive areas might include product removal, cleaning, inspecting/testing and finally, inerting. It is possible that some evidence of the condition of the pipeline might be needed to obtain the approval to abandon it, and this may well involve the use of one or other of the ILI tools.

If it were a hydrocarbon carrying pipeline, then clearly a basic requirement would be to remove the remaining product. The product used to propel the pig during this phase of the operation will depend upon the overall procedure, but nitrogen would probably be high on the list of options.

If the line is to be abandoned without inerting, it may be necessary to ensure that it is clean, because eventually it would corrode away and any remaining contents would pollute the surrounding area. But however well cleaned, a hydrocarbon pipeline would inevitably constitute some hazard due to the fumes which would emanate. It is therefore more likely that it would be filled with an inert substance, and this too would require pigs.

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Section 13

APPENDIX "A"

Pig Maintenance Records

The following are extracts from the "Piglog" system developed by On-Stream Systems Ltd. and will provide guidance in developing sensible procedures for the maintenance and care of mandrel type utility pigs.

GUIDELINES FOR PIG MAINTENANCE

The following applies only to rigid bodied pigs with metal bodies and (usually) polyurethane cleaning and sealing elements. It is intended to provide guidance when no formal procedures or other recommendations are available.

Approval for the use of any or all of these guidelines, and for appropriate safety measures, must be obtained from an authorized person before they are adopted.

ALL PIGS SHOULD BE ALLOCATED A UNIQUE REFERENCE NUMBER.

This is used to record all runs and the maintenance/service work carried out on each.

1. CLEANING

If the pig is heavily caked in wax, remove excess by scraping. Steam cleaning is acceptable for metal components, but the polyurethane components should not be exposed to temperatures above 180°F (80° C) for extended periods, particularly in the presence of water. Diesel fuel, kerosene, or a suitable proprietary product may be used as solvents if required.

2. MAINTENANCE

DISASSEMBLE AND INSPECT

Once clean, the pig should be carefully inspected for damage, particularly the elastomer parts. Failure of urethane components frequently occurs at or near to the flange fixing holes. This is not visible without removing the fixing flange and it is recommended that this be done after each run. Flexing of the urethane components after removal will normally identify tears or cracking.

CUPS/SEALS

Each seal should be given a unique number using a permanent marker pen. To prevent it being erased, this number should be applied at some point which will not be exposed after assembly (e.g. under a fixing flange). The position of a seal should be identified by numbering from the front of the pig, the front cup being No. 1, the second No. 2 etc.

Drive seals should be changed if there is significant damage or if the radial distance from the center-line of the pig to the circumference of the seal at any point is equal to, or less than half the inside diameter of the pipeline.

Front cups which are within the above limits, but which are liable to exceed them during a subsequent run, may, provided the line length is not excessive, be installed on the rear of the pig.

The harder scraper discs mounted at the front and rear of 'bi-directional' pigs are designed to be equal to or slightly less than the line ID. These are unlikely to need changing unless they have worn down to 5% or more below the original diameter at any point - however this will also depend upon the length of the pipeline and the intended purpose of the pig.

When reassembling the seals and other elastomer components which are not fitted with ferrules (i.e. metal spacers which are molded into the component), **do not over tighten the bolts**. Excessive "squeeze" will distort the contours of the component and cause premature failure.

IN ALL CASES, THE RECOMMENDATIONS OF THE MANUFACTURERS SHOULD BE OBTAINED.

CLEANING ELEMENTS

Scraper blades or brushes (if used) are subjected to heavy wear and should be renewed frequently. They rely on their flexibility to perform effectively. Apart from the obvious need to prevent their attachment bolts from contacting the pipe wall, they should not be used after the bristles or blades have worn down to within approximately 60% of their original length (on long or arduous lines, this may need more careful consideration).

BODY, SPRINGS AND OTHER METAL COMPONENTS

Metal components should be visually inspected, and if there is evidence of any damage (i.e. dents or "bruising") it is advisable to check all welds with dye penetrant. Springs are also subject to fatigue and must always be regularly checked with dye penetrant, as should the welds attaching the cup/seal/disc flanges to the pig body.

Metal components should be painted and touched up whenever bare metal is exposed.

3. STORAGE

PIGS

Pigs should be stored either in cradles which support the body or at least on their ends. Polyurethane, in line with most elastomers will take a permanent set if subjected to a constant load at one point, so pigs should never be left lying on their cups/discs.

METAL COMPONENTS and SPARES

Metal component parts must be protected against corrosion while in storage.

ELASTOMER COMPONENTS and SPARES

Cups/seals/discs should be stored in short stacks taking care the lips are supported all round (i.e. concentric to each other).

Polyurethane in particular is subject to hydrolysis. Excessive temperature and humidity causes deterioration of the material. They should be stored away from direct sunlight. A darkening color will sometimes indicate a breakdown in the material and a simple check can be made by attempting to force a sharp object (e.g. a pen-knife) into the material. The amount of penetration will be minimal with a good material. If in doubt, the hardness should be checked against the manufacturers specifications.

Large quantities of polyurethane parts should not be kept in stock. Re-ordering on say a quarterly basis and a **strict system of first in - first out** should eliminate potential problems due to material failures.

PIG MAINTENANCE RECORD

OPERATING COMPANY/DIVISION (Owner): _____

PIG IDENT No: _____ TYPE: _____

Returned from RUN NO: _____ On (Date): _____

1. COMMENT (if necessary) ON CONDITION ON ARRIVAL: _____

_____

2.. CLEANING METHOD USED: _____

3. DISASSEMBLY/INSPECTION:- Tick (√) if OK, (X) if replaced, OR add relevant note.

a) BODY incl. cup flanges and fixing brackets ( )

OR: _____

b) BYPASS PORTS ( )

OR: _____

c) SEALS/CUPS* No. ___( ) No. ___( ) No. ___( ) No. ___( )

No. ___( ) No. ___( ) No. ___( ) No. ___( )

OR: _____

_____

d) SPRINGS (if fitted) ( )

OR: _____

e) BRUSHES/BLADES (if fitted) ( )

OR: _____

f) OTHER ITEMS/FEATURES (?): _____

_____

IMPORTANT NOTE: If the component bearing the IDENT No. is replaced, the replacement part should either bear the same number or the new number MUST be noted on this form alongside the old number.

COMMENTS _____

_____

_____

_____

continue on separate sheet if necessary

Prepared by: _____ Date: _____ Copies to: _____ *

Refer to "Guidelines for Pig Maintenance". 178/03 © 1992 On-Stream Systems Ltd.

PIG CUP/SEAL REGISTER

CUP/ SEAL IDENT	Cup/Seal Type and Supplier	Requisition &/or Order No./Date	Fitted to PIG INDENT	Position* and date fitted	In this position for Run Nos.:					New position* and date	In new position for Run Nos.:					Remarks

* Refer to "Guidelines for Pig Maintenance"

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APPENDIX "B"

Pig Log Sheets and Run Records

The following are extracts from the "Piglog" system developed by On-Stream Systems Ltd. and will provide guidance in developing sensible procedures for developing, recording and monitoring pigging programs.

PIG REGISTER

PIG IDENT NUMBER	PIG MAKE/SUPPLIER	PIG TYPE and CONFIGURATION	ORDER No./DATE	REMARKS

Form No: 178/01 © 1992 On-Stream Systems Limited

PIG RUN RECORD

PIG RUN NUMBER: _____ PIG IDENT NUMBER: _____
Pipeline System/Section No: _____ Length: _____ Diameter _____
From: _____(Launch) To: _____(Receive)

LAUNCH DATA

L1 - Operating conditions before launch: a) Production rate: _____(state units)
b) Pressure (state units): At launcher _____(A) At receiver _____(B) A - B =_____(**ΔP1**)
L2 - Pig condition **before launch**:
a) Pig in good condition? - Yes/No*. If No, or in doubt, DO NOT LAUNCH
b) Bypass ports open? - Yes/No*. If Yes, how many? _____
L3 - Pig launched at: _____(hr./min.) on: _____(day/month/year)

RECEIVING DATA

R1 - Pig arrived at: _____(hr./min.)on: _____(day/month/year)
R2 - Operating conditions **after arrival**: a) Production rate: _____(state units)
b) Pressure (state units): At launcher _____(C) At receiver _____(D) C - D =_____(**ΔP2**)
R3 - Pig condition after arrival:
a) Cup/seal/disc wear: Normal? - Yes/No* (If No, describe in 'Comments')
b) Physical damage, parts missing? - Yes/No* (If Yes, describe in 'Comments')
c) Bypass ports open? - Yes/No*. If Yes, how many clear? _____ How many blocked? _____
R4 - Material received/removed from trap**:
a) Description: _____
b) Amount: _____ Samples taken? Yes/No*

Did all pigging facilities (i.e. signalers, closures, valves etc.) function correctly? - Yes/No*
(If No, describe in 'Comments')

COMMENTS

_____
_____
_____
_____
_____
_____
_____
_____
_____

continue on separate sheet if necessary

Prepared by: _____ Copies to: _____

* Delete as necessary
** See notes: "Using the System"

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PIG RUN SUMMARY

Pipeline System/Section No: _____ Length: _____ Diameter: _____ From (launch): _____ To (receive): _____

PIG RUN No.	PIG IDENT No.	LAUNCH (Date/Time)	RECEIVE (Date/Time)	Average Pig Speed (PV1)	Flow Rate BEFORE (FV1)	Flow Rate AFTER (FV2)	Average Flow Velocity (FV3)	ΔP1 BEFORE	ΔP2 AFTER	ΔP1-ΔP2	PIG 'SLIP' FV3-PV1	Remarks

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APPENDIX "C"

Terminology used in the Pipeline Pigging Industry

In any specialized part of industry, a "language" or "jargon" will develop to describe the various unique aspects. This makes it difficult for those not directly concerned, to understand or to communicate their needs - and even more difficult for those whose mother tongue is not English. The following list of definitions may therefore be helpful when discussing matters relating to pipeline pigging.

** These definitions are reproduced by kind permission of the Gas Research Institute, Chicago, Illinois, USA.*

Anomaly — *Any kind of imperfection, defect, or critical defect that may be present in the wall of the pipe.

API B31G — See ASME B31G

ASME B31G — *A commonly used analysis criterion for metal loss anomalies in pipes.

Ball Valve — Valve that has a spherical element with a hole bored through it equal to the line diameter so that it open or closes by a quarter-turn rotation.

Bar — Unit of pressure. One bar is equal to 0.987 standard atmospheric pressures, 14.50 psi, or 100 kpa.

Barrel — Unit of volume measurement used for petroleum and its products.

1 barrel	= 42 US gallons
1 barrel	= 35 Imperial gallons (approx.) = 159 liters (approx.)
6.29 barrels	= 1 cubic meter

Batching — The use of pigs to separate batches of dissimilar fluids in the same pipeline.

Batching Pig — *A utility pig that forms a moving seal in a pipeline to separate liquid from gas media or to separate two different products being transported in the pipeline. The most common configurations of batching pigs are cup pigs and sphere pigs.

Bellhole — *An excavation in a local area to permit a survey, inspection, maintenance, repair, or replacement of pipe section.

By-Pass — Any leakage (whether deliberate or otherwise) past the pig, normally from the rear of the pig to the front. *Also* a pipe connected around a valve or other control mechanism in a flow line in order to maintain flow during adjustments or repair.

Calibration Digs *Exploratory excavations, or bellholes, of portions of the pipeline in which an in-line inspection tool has recorded an indication.

Caliper Pig An Instrumented pig for measuring and recording changes in the internal diameter of a pipeline. Also referred to as a Geometry Pig.

Camera Pig *A configuration pig that carries a video or film camera and light sources for photographing the inside surface of a pipe on an intermittent or continuous basis.

Check Valve A valve whose purpose is to prevent flow from returning in the direction from which it came. Most check valves have no means of outside actuation, depending on flow, or gravity, or both. Also known as Non-Return Valve.

Cleaning Pig *A utility pig that uses cups, scrapers, or brushes to remove dirt, rust, mill scale, or other foreign matter from the pipeline. Cleaning pigs are run to increase the operating efficiency of a pipeline or to facilitate inspection of the pipeline.

Closure The door fitted to a trap through which the pig is inserted or removed.

Condensate Liquid hydrocarbons which separate out from natural gas, usually due to cooling.

Configuration Pig *An instrumented pig that collects data relating to the inner contour of a pipe wall or of the pipeline. Geometry pigs, camera pigs, and mapping pigs are types of configuration pigs.

Cubic Meter Unit of volume often used to measure natural gas (at 1 atmosphere pressure and 0 degrees C). 1 cu. meter = 35.34 cu. ft.

Cup Flip A pig cup which 'reverses' or 'turns over' usually, but not always, due to an excessive build-up or pressure across it.

Cup Pig *A utility pig that is supported and driven by cups made of a resilient material such as neoprene or polyurethane. At least one of the cups forms a piston-like seal inside the pipe.

Dew Point The temperature at which water vapor will condense out of air.

Double Block and Bleed A valving arrangement which ensures no flow in a pipeline, even though the valves may leak. It consists of two block valves in the main line, with a small bleed valve draining the line between the block valves.

Differential Pressure The difference in pressure between any two points in a pipeline (in pigging, often between the back and the front of the pig).

Diverter A device, usually in the shape of a wye, which is installed at a point where a pipeline divides into two and which directs the pig along whichever line is selected. (see also 'Wye')

Down-Stream In the same direction as the direction of flow.

DP (Delta P) See Differential Pressure.

Equilibrium A point at which no further liquid drop-out will occur unless there is a change in the operating conditions (i.e. maximum drop-out for a particular set of conditions). Also used when opposing pressures are equalized.

Flow Regime The form or behavior of the contents of the pipeline when operating under (normally) multi-phase conditions.

Full Well-Stream Fluid The unprocessed product of a well (which may contain gases, liquids and solids).

Gate Valve Valve which opens or closes by sliding a disc which is mounted on guide rails, between two seat rings fitted in the bore of the valve.

Gauging Pig *A utility pig that is permanently deformable by obstructions in the pipeline and thus, upon retrieval from the line, provides evidence of the worst-case obstruction in a given pipeline segment.

Gel Pig A chemically-based formulation which, when injected into a pipeline, creates a highly-viscous slug which is capable of holding solids in suspension, yet which exhibits very low shear forces at the pipe wall. A pre-cast gel pig, designed to dissolve after a set time, is sometimes used for pigging a line which is considered likely to cause a conventional pig to stick.

Geometry Pig *A configuration pig designed to record conditions, such as dents, wrinkles, ovality, bend radius and angle, and occasionally indications of significant internal corrosion, by making measurements of the inside surface of the pipe.

Globe Valve Valve which opens or closes by raising or lowering a disc onto a seat ring, the bore of which is normally at right angles to the bore of the connecting pipework.

Hold-Up Liquids (usually condensate) which are formed or 'drop out' of a gas and which gather to form a slug.

Hydrostatic Test Pressure test in which a system is filled with water and held for a specific time at some predetermined pressure.

ILI In-line inspection. The inspection of a pipeline from the inside using an 'intelligent pig'. Often referred to in Europe as "On-Line Inspection" (OLI).

In-line Inspection Tool (ILI Tool) *The device or vehicle, also known as an 'intelligent' or 'smart' pig, that uses a non-destructive testing technique to inspect the wall of a pipe. An in-line inspection tool is one type of instrumented tool.

Intelligent Pig or Tool *See In-line Inspection Tool.

Instrumented Pig or Tool *A vehicle or device used for internal inspection of a pipe, which contains sensors, electronics, and recording or output functions integral to the system. Instrumented tools are divided into two types: (1) configuration pigs, which measure the pipeline geometry or the conditions of the inside surface of the pipe, and (2) In-line Inspection tools that use non destructive testing techniques to inspect the wall of the pipe for corrosion, cracks, or other types of anomalies.

Lateral A pipe joining the pipeline at an angle, usually at an angle of less than 90 degrees. (also see 'Tee').

Launcher *A pipeline facility used for inserting a pig into a pressurized pipeline.

Liquefied Natural Gas (LNG) Natural gas that has been liquefied by refrigeration or pressure in order to facilitate storage or transport, it generally consists of methane.

Liquefied Petroleum Gas (LPG) Butane, Propane and other 'light ends' which has been separated out from gas or crude oil and liquefied by refrigeration or pressure, to facilitate storage or transport. LPG reverts to its gaseous state at atmospheric pressure.

Mapping Pig *A configuration pig that uses inertial sensing or some other technology to collect the data that can be analyzed to produce an elevation and plan view of the pipeline route.

Mandrel Pig A pig which is assembled from a number of component parts, normally onto a central shaft or body.

Metal Loss *Any of a number of types of anomalies in pipe in which metal has been removed from the pipe surface, usually due to corrosion or gouging.

Multi-Phase Any condition other than single phase.

Natural Gas Liquids (NGL) Liquid hydrocarbons found in association with natural gas.

Non-Return Valve See Check valve.

Offtake An opening, usually at 90 degrees, for the input or exit of product to the pipeline. May be the same size as the pipeline or smaller. Also called 'outlet'.

On Line Inspection	See In-line Inspection.
Pig	*A generic term signifying any independent, self contained device, tool, or vehicle that moves through the interior of the pipeline for purposes of inspecting, dimensioning, or cleaning.
Pig Cups	The elastomer seals fitted to a pig which, being of a larger diameter than the inside diameter of the pipe, create a seal and thus provide the driving force.
Pig Locator	A device which is used to find (or locate) a pig, normally, but not necessarily, when it is stationary.
Pig Signaler	A device fitted to a pipeline which is triggered (i.e. gives a signal) when the pig passes it.
Plug Valve	Valve in which a cylindrical or tapered-cylindrical section is turned by one-quarter turn to open or close.
Pup	A short piece of pipe used to make up the distance between the ends of two longer sections.
Receiver	*A pipeline facility used for removing a pig from a pressurized pipeline.
Reducer	A fitting designed to be the transition from one pipe size to another.
Riser	The pipe which connects an offshore production platform to a subsea pipeline.
SCFM	Standard Cubic Feet per Minute. A standard measurement of gas flow, where volumes of gas are converted to cubic feet at one atmosphere of pressure.
Slug	A mass of liquid of indeterminate volume within a gas pipeline.
Slug Catcher	A pipework or tank system designed to collect the slugs on arrival at the gas-processing facility and prevent them from damaging or interfering with the processing equipment.
Smart Pig	*See in-line inspection tool.
Sphere Pig	*Spherical utility pig made of rubber or urethane. The sphere may be solid or hollow, filled with air or liquid. The most common use of sphere pigs is as a batching pig.
Spool Piece	Fabricated section of piping (with or without flanges) assembled on site into a larger piping system.

Swabbing	Usually used to describe the use of a pig to remove liquids (i.e. to remove water after a hydrostatic pressure test).
Swage	Component used to join two pipes of different diameters, it is smaller at one end than at the other. Generally longer than a equivalently-sized reducer.
Swing Check Valve	Check valve in which the closing element (the clapper) is suspended from the top and swings out of the way of the flow, pigs, etc.
Tee	A fitting used where one pipe enters another, usually at right angles. (See also 'Lateral').
Through-Conduit Valve	A gate valve that has a hole bored to the line diameter in an extension to the disc so that in the open position, it presents a smooth continuous circular cross-section to the flow, suitable for passing pigs, scrapers, etc.
Trap	A vessel installed at each end of a pipeline to either launch or receive pigs.
Two-Phase	Hydrocarbons in both a gas and a liquid phase (normally gas and condensate or gas and oil.
Up-Stream	In a direction opposite to the direction of the flow.
Utility Pig	A pig which performs a physical function (i.e. cleaning, separating, de-watering).
Wye	A fitting installed where two pipelines merge into one and where the lines are required to be pigged. (See also 'Diverter')

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APPENDIX "D"

ABBREVIATIONS AND ACRONYMS

AGA	American Gas Association
API	American Petroleum Institute
ASME	American Society of Mechanical Engineers
BS	British Standard
DICA	Direction Des Carburants (France)
DIN	German Standards
DNV	Det Norske Veritas (Norway)
DOT	Department of Transportation (USA)
GRI	Gas Research Institute (USA)
ILI	In-line inspection
ISO	International Standards Organization
IP	Institute of Petroleum (UK)
MAOP	Maximum allowable operating pressure
MFL	Magnetic flux leakage
NACE	National Association of Corrosion Engineers (USA)
NDE	Nondestructive evaluation
NDT	Nondestructive testing
NPD	Norwegian Petroleum Directorate
OPS	Office of Pipeline Safety, a division of the US. Department of Transportation (DOT)
SMYS	Specified minimum yield stress
TUV	Technischer Uberwachungs Verein (Germany)
UT	Ultrasonic testing

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APPENDIX "E"

DESCRIPTIONS OF PIPELINE IMPERFECTIONS AND CONDITIONS

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The following are descriptions of imperfections anomalies, defects and conditions that are found in natural gas transmission pipelines. The definitions have been obtained from different technical references and dictionaries but have been selected as relating to pipelines. The descriptions are intended to be generic, but may apply to other structures and materials. The ultimate goal is to provide a common language within the pipeline pigging industry, worldwide.

Buckle A partial collapse of the pipe due to excessive bending associated with soil instability land slides, washouts, frost heaves, earthquakes, etc.

Corrosion General External:- Metal loss due to electrochemical, galvanic, micro biological, or other attack on the pipe due to environmental conditions surrounding pipe.

General Internal:- Metal loss due to chemical or other attack on the steel from liquids on the inside of the pipe. Electrochemical attack can also occur on local cells, but this condition is less frequent.

Pit:- Local concentrated cell corrosion on the external or internal surfaces that results from the generation of a potential (voltage) difference set up by variations in oxygen concentrations within and outside the pit. The oxygen-starved pit acts as the anode and the pipe surface acts as the cathode.

Selective Corrosion:- A localized corrosion attack along the bond line of electric resistance welds (ERW) and flash welds (FW), that leads to the development of a wedge shaped groove that is often filled with corrosion products.

Stress Corrosion Cracking:- A progressive inter granular and/or transgranular cracking that results from a combination of applied tensile stress, cathodic protection currents, and a suitable corrosive environment.

Cracks Fatigue:- Progressive cracking in the base material, weld, or weld zone that is caused by pressure cycling or oscillatory stresses associated with the operation of the system.

Girth Weld:- Cracks in the weld or weld zone of the butt weld that connect sections of pipe.

Seam Weld:- Cracks in the weld or weld zone of the longitudinal seam weld of the pipe.

Dent A local depression in the pipe surface caused by mechanical damage that produces a gross disturbance in the curvature of the pipe without reducing the pipe wall thickness. The depth of a dent is measured as a gap between the lowest point of the dent and a prolongation of the original contour of the pipe.

Disbonded Coating Any loss of bond between the protective coating and steel pipe as a result of adhesive failure, chemical attack, mechanical damage, hydrogen concentrations, etc.

Erosion Destruction or removal of material by abrasive action of moving fluids (or gases) usually accelerated by the presence of solid particles or matter in suspension.

Gouges Mechanical or forceful removal of metal from a local area of the surface on the pipe that may work to harden the pipe and make it more susceptible to cracking.

Hard Spots Local changes in hardness of the steel in the pipe resulting from non uniform quenching procedures used during the manufacture which changes the chemistry of the steel. Hard spots, when stressed, are subject to failure from mechanisms, such as hydrogen stress cracking.

Holidays Discontinuities in a coating, such as pinholes cracks, gaps, or other flaws, that allow areas of the base metal to be exposed to any corrosive environment that contacts the coating surface.

Inclusions Foreign material or particles in a metal matrix. These are usually compounds, such as oxides, sulfides, or silicates, but may be any substance that is foreign to the matrix whether it is soluble or insoluble.

Lack of Fusion (LOF) In a weld, any area or zone that lacks complete melting and coalescence (fusion) of a portion of the weld. This may occur between weld passes or between weld and base materials.

Lack of Penetration In the welding process, failure to achieve fusion of the base metal to the desired or planned depth.

Lamination A type of imperfection or discontinuity with separation or weakness, usually aligned parallel to the worked surface of a metal.

Mechanical Damage Damage from outside forces that modifies the dimensions or profile of the pipe (dents, gouges).

Obstructions Any restriction or foreign object that reduces or modifies the cross section of the pipe to the extent that flow is affected or pigs can become stuck (ovality, collapse, dents, undersized valves, wrinkles, bends and weld drop through). Also any foreign object in the pipeline.

Ovality A condition in which a circular pipe forms into an ellipse, usually as the result of external forces

Porosity Small voids or pores in the weld metal, usually gas filled.

Radius Bends The radius of the bend in the pipe as related to the pipe diameter (D). Example: A 3D bend would have a radius of three times the nominal diameter of the pipe measured to its centerline.

Slivers A thin elongated anomaly caused when a piece of metal is rolled into the surface of the pipe. A sliver is usually metallurgically attached at only one end. In MFL inspections, a sliver is sometimes called a lamination.

Wrinkles Ripples that occur on the inner radius of a pipe when the pipe is cold bent.

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APPENDIX "F"

PIGGING TEST LOOPS - WORLD-WIDE

Most suppliers, research organiztions and operating companies have test loops and they are often available for hire. The following are some typical examples.

COUNTRY	OWNER	LOCATION	DIA	LENGTH
Germany	Rosen	Lingen	6"	538 ft./164m
			16"	538 ft./164m(?)
Holland	Gasunie	Westerbork	12"	2143 ft./653.45m
			24"	2124 ft./647.42m
	Shell	Amsterdam	16"	328 ft./100m
Norway	Reinertsen	Trondheim	6"	98 ft./30m(?)
			20"	98 ft./30m(?)
	Forut Teknologi	Narvik	12"	262 ft./80m
	Statoil	Kårstø	40"	350 ft./110m(?)
			20"	300 ft./90m(?)
United Kingdom	British Gas	Low Thornley	12"	1099 ft./335m
			24"	1099 ft./335m
			36"	1099 ft./335m
	BHR	Cranfield	16"	984 ft./300m
	UKAEA	Harwell	6"	98 ft./30m
			12"	164 ft./50m
	Pipeline Engineering	Richmond, Yorks.	18/20"	98 ft./30m(?)
			8/12"	130 ft./40m(?)
United States	GRI	Columbus, OH	12"	2296 ft./700m(?)
			24"	6822 ft./2080m
	Tuboscope	Houston, TX	8"	2624 ft./800m
			30"	2624 ft./800m
	T D Williamson	Tulsa, OK	12"	1100 ft./335m

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APPENDIX "G"

SOME USEFUL CONVERSION TABLES

PIPE DIAMETERS

Nominal Size		Outside Diameter	
Inches	Millimeters	Inches	Millimeters
4	100	4.500	114.3
6	150	6.625	168.3
8	200	8.625	219.1
10	250	10.750	273.0
12	300	12.750	323.8
14	350	14.000	355.6
16	400	16.000	406.4
18	450	18.000	457.2
20	500	20.000	508.0
22	550	22.000	558.8
24	600	24.000	609.6

Nominal Size		Outside Diameter	
Inches	Millimeters	Inches	Millimeters
26	650	26.000	660.4
28	700	28.000	711.2
30	750	30.000	762.0
32	800	32.000	812.8
34	850	34.000	863.6
36	900	36.000	914.4
38	950	38.000	965.2
40	1000	40.000	1016.0
42	1050	42.000	1066.8
44	1100	44.000	1117.6

PIPE WALL THICKNESS

Inches	Millimeters
.133	3.38
.140	3.56
.145	3.68
.154	3.91
.179	4.55
.200	5.08
.216	5.49
.218	5.54
.226	5.74
.237	6.02
.250	6.35
.258	6.55
.280	7.11

Inches	Millimeters
.300	7.62
.318	8.08
.322	8.18
.337	8.56
.344	8.74
.365	9.27
.375	9.53
.406	10.31
.432	10.97
.436	11.07
.438	11.13
.500	12.70
.562	14.27

Inches	Millimeters
.594	15.09
.625	15.88
.656	16.66
.674	17.12
.688	17.48
.719	18.26
.750	19.05
.812	20.62
.844	21.44
.864	21.95
.875	22.23
.906	23.01
.938	23.83

Inches	Millimeters
1.000	25.40
1.031	26.19
1.094	27.79
1.125	28.58
1.156	29.36
1.219	30.96
1.281	32.54
1.312	33.32
1.406	35.71
1.500	38.10
1.620	41.28
1.750	44.45
1.875	47.63
2.000	50.80

TEMPERATURE

Read T in center column, then left to convert to °C and right to convert to °F

°C	T	°F
-45.6	-50	-58
-40.0	-40	-40
-34.4	-30	-22
-28.9	-20	- 4
-23.3	-10	14
-17.8	0	32
-12.2	10	50
-6.7	20	68
-1.1	30	86
4.4	40	104
10.0	50	122
15.6	60	140
21.1	70	158
26.7	80	176
32.2	90	194

°C	T	°F
37.8	100	212
43.3	110	230
48.9	120	248
54.4	130	266
60.0	140	284
65.6	150	302
71.1	160	320
76.7	170	338
82.2	180	356
87.8	190	374
93.3	200	392
98.9	210	410
104.4	220	428
110.0	230	446
115.6	240	464

°C	T	°F
121.1	250	482
126.7	260	500
132.2	270	518
137.8	280	536
143.3	290	554
148.9	300	572
154.4	310	590
160.0	320	608
165.6	330	626
171.1	340	644
176.7	350	662
182.2	360	680
187.8	370	698
193.3	380	716
198.9	390	734

LENGTH

1 inch	=	25.4000 millimeters
	=	2.5400 centimeters
	=	0.0254 meters
1 foot	=	304.8000 millimeters
	=	30.4800 centimeters
	=	0.3048 meters
1 mile	=	1.6094 kilometers
1 millimeter	=	0.0394 inches
1 centimeter	=	0.3937 inches
1 meter	=	39.3700 inches
1 meter	=	3.2808 feet
1 kilometer	=	0.6214 miles

VOLUME

1 Barrel	=	42.000 US gallons (liquid)
	=	34.9909 Imperial gallons
	=	5.6146 cubic feet
	=	158.9871 liters
	=	0.1590 cubic meters
1 US gallon (liquid)	=	0.0238 barrels
	=	0.1337 cubic feet
	=	0.00379 cubic meters
	=	3.7854 liters
	=	0.0038 cubic meters
	=	0.8327 Imperial gallons
1 Imperial gallon	=	0.0286 barrels
	=	0.1605 cubic feet
	=	277.4171 cubic inches
	=	4.5460 liters
	=	0.0045 cubic meters
	=	1.2009 US gallons (liquid)
1 liter	=	0.0010 cubic meters
	=	1000.0000 cubic centimeters
	=	0.2200 Imperial gallons
	=	0.2642 US gallons (liquid)

VELOCITY

1 mile per hour	=	0.0167 miles per minute
	=	0.0003 miles per second
	=	88.0000 feet per minute
	=	1.4667 feet per second
	=	1.6094 kilometers per hour
	=	26.8225 meters per minute
	=	0.4470 meters per second
1 kilometer per hour	=	0.0167 kilometers per minute
	=	0.0003 kilometers per second
	=	16.6667 meters per minute
	=	0.2778 meters per second
	=	0.6214 miles per hour
	=	54.6800 feet per minute
	=	0.9113 feet per second
1 foot per second	=	0.6818 miles per hour
	=	1.0973 kilometers per hour
	=	0.3048 meters per second
1 meter per second	=	3.6000 kilometers per hour
	=	2.2369 miles per hour
	=	3.2808 feet per second

MASS

1 pound	=	0.4536 kilograms
1 kilogram	=	2.2046 pounds

WEIGHT OF WATER @ 62°F/16.67°C

1 barrel	=	349.9860 pounds
	=	158.7512 kilograms
1 US gallon	=	8.3370 pounds
	=	3.7820 kilograms
1 Imperial gallon	=	10.0122 pounds
	=	4.5420 kilograms

APPROXIMATE WEIGHT OF CARBON STEEL

1 cubic inch	=	0.2830 pounds
	=	0.1280 kilograms
1 cubic foot	=	489.0000 pounds
	=	221.8000 kilograms
1 cubic centimeter	=	0.0080 kilograms
	=	0.0170 pounds
1 cubic meter	=	7810.0000 kilograms
	=	17300.0000 pounds

PRESSURE

1 foot head water @ 60°F	=	0.4335 pounds per square inch
	=	0.0305 kilograms per square centimeter
	=	0.0299 bars
	=	0.3048 meters of water
1 meter of water	=	0.1000 kilograms per square centimeter
	=	0.0967 bars
	=	3.2808 feet of water
1 pound per square inch	=	0.0689 bars
1 bar	=	14.5039 pounds per square inch

MISCELLANEOUS CONVERSIONS

1 Newton	=	0.2250 Pounds
1 pound	=	4.4480 Newtons

OTHER USEFUL FORMULAE

Flow in a pipeline:

$$\text{Meters per second} = \frac{\text{Barrels per day}}{275 \times d^2}$$

$$\text{Feet per second} = \frac{\text{Barrels per day}}{83.82 \times d^2}$$

Where d = inside diameter of pipe in inches

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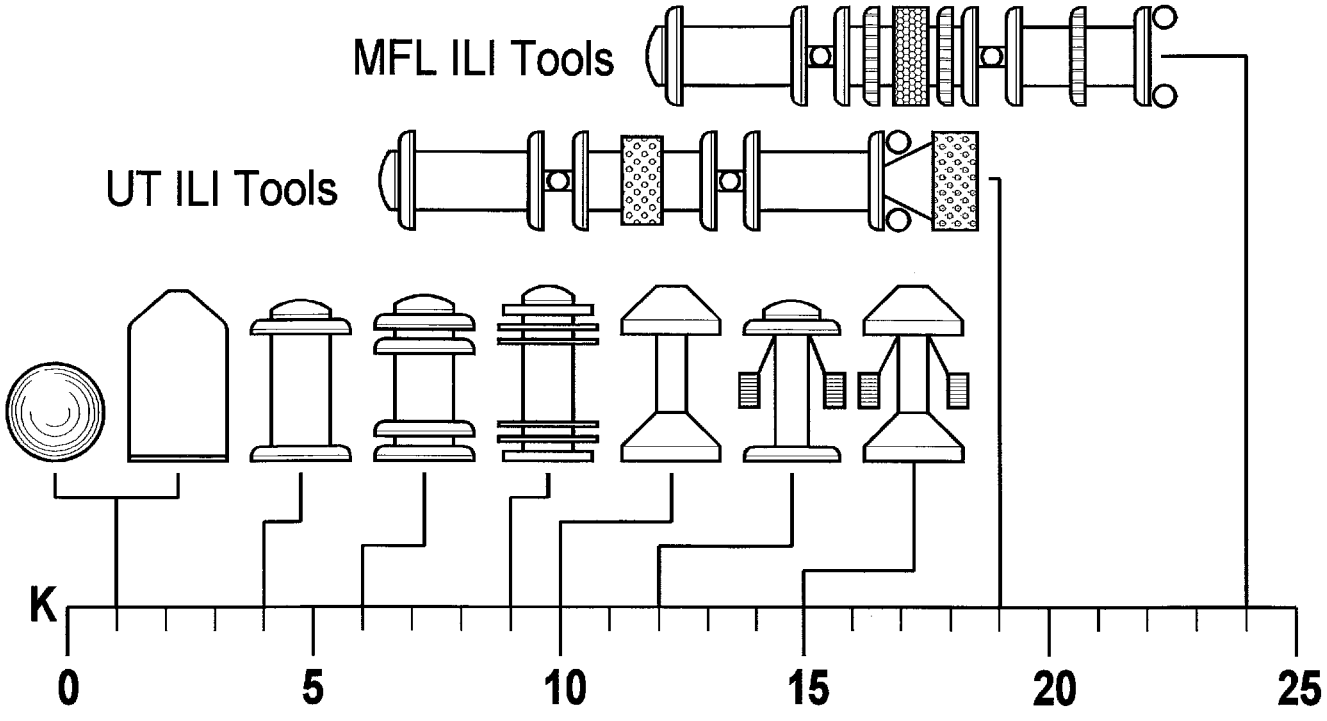
APPENDIX "H"

TYPICAL DP REQUIRED TO DRIVE DIFFERENT TYPES OF PIGS



$$DP\ (bars) = \frac{K}{Nom'l\ dia.\ (ins.)}$$

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14.0 PIGGING ANECDOTES

THE HISTORY OF PIPELINE PIGGING

The authors are indebted to the late J. Frank Gray providing the following brief history of pipeline pigging.

The history of pipeline pigging is interesting and probably lacking in full truth, however the following is usually accepted as an answer to many questions about the history of pipeline pigs.

The first pigging operation took place around the year of 1870, a few years after Colonel Drake discovered oil in Titusville, Pennsylvania.

Before pipelines were used for transporting it, the oil was trucked to the refinery by horse drawn tank wagons. This proved to be very difficult during winter months because of heavy snows and frozen wagon tracks, and in wet weather when wagons would sink in the mud.

To improve upon this method of transportation a pipeline was constructed, the material of which is not recorded, but each length of pipe was almost certainly joined by the bell and spigot method that we see today in plastic pipe.

After transporting crude oil for a year or two through this pipeline, the flows began to decrease and the pumping pressure increased, indicating that there were deposits building up on the walls inside of the pipe.

Many things were tried to remove the paraffin deposits but nothing worked effectively for any period of time. Eventually the idea of pumping something through the pipeline was considered. It has been suggested that a bundle of rags tied in a ball was used and with positive results. Later, bundles of leather were used in place of the rags. Leather will swell when wet so it created a tight seal going through the pipeline.

Another story concerning the history of pipeline pigging takes place around 1904 when a 4 inch steel gas line was installed in Montana. During the construction, there was a rock slide which covered the line and it was not known whether there was a buckle or a flat spot, so a rubber ball was made to pump through the pipeline to find out. Upon exiting it was determined that if there was any damage to the pipe it was not sufficient to restrict the flow. It was also discovered that a lot of debris was left in the pipeline such as rocks, dirt, sand, tools, etc. Rubber Balls (spheres) have been used ever since as displacement pigs and for meter proving.

The question most people ask is "How did a pig get its name?"

One story goes that two pipeliners were told to go out to the pipeline and listen for the pipe cleaner to go by. This pipe cleaner consisted of a steel pipe or mandrel body with flanges welded on both ends. Discs made of leather sheets were stacked together to provide thickness and attached to the flanges. As the pipe cleaner traveled down the line pushing out debris, it made a

These stories are generally accepted as possibly being true. Whether they are true or not, they at least indicate that pigs have been around for a long time. For more than half of a century pigs consisted of steel bodies and rubber, leather or urethane cups or discs. They were equipped with wire brushes, scrapers, knife blades and other devices for plowing.

Until 1960 most pipe cleaning was limited to the oil and gas industry. Then the foam bullet shaped pig was developed. It was referred to as the "Polly Pig" because it was made of Polyurethane foam.

Although the oil and gas industry remains the largest user of the foam pig, many new industries such as municipal water and sewer, processing industries, petrochemical, mining and other industries are now using pigs in their pipelines, realizing gains such as energy savings, increased flows, decreased pumping pressures, cleaner product and salvaged product.

The lessons learned from standard pigging operations to clean, dewater, fill and displace product from pipelines, and the pressures, speeds and problems incurred have contributed greatly to the development of instrumented pigs. These were introduced in the late 1960s and development is continuing to the present day.

The development and improvement of all types of pipeline pigs has been an ongoing process and this trend is set to continue. There are now literally hundreds of different types, some with specific or limited use and others which are standard products. Apart from the main functions of sweeping, drying, wiping, cleaning, scraping, inspection and integrity monitoring, 'semi-intelligent' pigs now perform additional functions such as alerting and initiating actions involving pumps and valves, and making an input in computerized operations, sometimes by through pipe-wall communications.

There is no doubt that the pigging industry will continue to make full use of new technology as it emerges in order to meet the challenges of tomorrow.

- AND THERE ARE OTHER PIGGING STORIES . . . . .

In any specialist field of activity, stories abound. Fishermen, golfers, flyers, doctors - possibly even accountants! - have stories to tell. Pipeliners are no exception, indeed pipeline pigging is a rich source of colorful stories. The following have been gathered together by the authors. Some are based on personal experience, that is to say they are factual (honestly!) while others have been handed down - possibly with a little embellishment.

Many are amusing, but as with a lot of humor, just beneath the surface there are some salutary lessons - usually involving a lack of appreciation of the tremendous power of a pipeline under pressure - and not treating it with the greatest respect. So when you read some of these stories, by all means smile - but don't scoff. We all learn from mistakes - but hopefully from the mistakes made by others!!

The Biggest Candle in the World??

In the early days of pipeline pigging, communications were very different from what we consider normal today. A 12" crude line was to be cleaned so that it could be changed to a different service. The ends were cut and a temporary trap installed at the upstream end and a pit was dug at the downstream end to hold the residue cleaned from the pipeline. A pig was placed in the pipeline and air was used to propel the pig. At first there was very little movement because the pig was removing and pushing large slugs of wax from the pipe wall. The personnel at the downstream end sent a messenger to the upstream end telling them to increase pressure since little was happening. The rate of flow increased and as the distance from the pig to the downstream end shortened the speed of the pig increased. The residue was being extruded from the open end of the pipe creating an endless 12" diameter candle - and at a ever increasing rate. By the time another messenger arrived telling them to reduce pressure, the personnel on the downstream end were abandoning the site - at an even faster rate!!

Abra Cadabra!

A six-inch instrument pig was being run in a pipeline located in a swampy area. The receiving end was on a small platform and was not equipped with a receiving trap. The contractor said he would catch the pig with nets which would protect the pig as well as catch it. However, when the pig arrived it was traveling at such a speed that the nets failed to stop it and it continued on into the swamp. There were many people at the site and it was thought that it would be easy to find, but it's still there - somewhere.

Pigging people quickly develop a healthy respect for the awesome power which can be unleashed by the pressure in a pipeline. A pig in a 36" pipeline operating at 1000 p.s.i. (69 bar) has a potential force of over 1,000,000 pounds - or more than 450 tons behind it. This would be enough to launch a fully loaded 747 'jumbo jet' vertically! Fortunately it only takes a very low pressure to keep a pig moving, but if they do get stuck -- watch out! The following are just some of the things which have occurred.

The Misguided Missile

Tests were being carried out using a 6" straight section of pipe with a launcher and receiver at each end. The aim was to establish what transition angle was needed to go from standard to heavy wall pipe without causing dangerous accelerations (speed excursions) for different types of pig. One pig held up in the reduction and the pressure was increased to move it. Suddenly it came free, went *through* the closure door (without opening it!) and was caught by a chain link security fence over 50 yards away - which it effectively demolished!

'Centripigal' Force - 1

On one occasion when visiting a refinery, one of the authors was asked to inspect damage to their four inch lube oil pipeline. There were bulges on the outside of all the 90 degree elbows in the pipeline and the pigs were being damaged. When questioned about pigging procedures they explained that a batching type pig was inserted into the pipeline and propelled with compressed air to remove the lube oil in the pipeline. This worked well and the pig traversed the few hundred feet of pipe line in a few minutes. To ensure that all of the lube oil had been removed the pig was then taken back to the launching site and rerun. The second run, which did not have the lube oil in front to control the pigging speed was run in much less time than the first run. In fact, the speed of the pig on the second run was so high that the pig was hitting the 90 degree elbows, damaging them on the outside radius as well as damaging the front of the pig. The operator had difficulty understanding why two pig runs made consecutively could be so different. It was recommended that the second run be made by pressurizing the complete pipeline and propelling the pig by releasing the pressure slowly at the downstream end. That solved the problem.

'Centripigal' Force - 2

A 20 inch river crossing had been replaced by a new section of pipe. After the new section had been pressure tested, it was necessary to pig the river crossing to remove the dirt that had settled from the test water which had been taken from the river. A pig was inserted at the upstream end of the new section and one of the temporary workers was instructed to open the valve to propel the pig through the pipeline to the trap at the end of the line. The worker opened the 20 inch main line valve instead of the valve on the small bypass line. The pig 'took off' and traversed the new piping of the river crossing at very high speed. When the pig reached a 90 degree elbow on the other side of the river it continued in a straight line - not around the elbow, but through it! It was later estimated that the pig was traveling in excess of 100 miles per hour (one hundred and sixty kilometers per hour).

And if its speed and acceleration that excites you . . .

During a series of trials using compressed air in a 32" test loop, the dual module pig was holding up at a change of wall thickness before coming free and reaching what were clearly dangerous speeds. This, and other problems requiring a solution resulted in the installation of instrumentation in the pig body. It was found that the pig accelerated to a speed of 170 mph (75 m/sec) within a distance of only 250 feet (75 m) - which ended with a 5D bend. It was found that this bend regularly generated sustained lateral accelerations in excess of 50g!

Who needs a can crusher?

A train of 4 steel bodied pigs was being run in a 36" pipeline when the lead pig caught up on a block valve which had not fully opened. All four pigs arrived at the receiver together, fitting comfortably on the internal tray. Not one of the pigs - which were each originally over 4.5 feet (1.4 m) long - was now more than 12" in long. They had been completely crushed.

Pipeline spheres - or just a load of balls?

A major European pig manufacturer, G D Engineering, once had an advertisement for sphere tees which read as follows:

"It is generally agreed that spheres are among the most obstinate pieces of equipment that pipeline engineers have to contend with. Spheres will, without provocation, enter and proceed up pipelines totally unsuited to their diameter, wedge themselves firmly into the barred openings of a tee, or spin against the bars until they either tear themselves to ribbons or, to everyone's amazement, disappear completely from the system".

So not surprisingly, there are a large number of pigging stories which concern spheres. Here are some of them:

Jumping the Queue

Spheres were run regularly through a 36" pipeline. One day, one failed to arrive. Another sphere was launched and this arrived on schedule having apparently overtaken the missing sphere. Reference to the 'as laid' drawings showed no off takes or check valves where the sphere could have lodged and a check on all the records showed that it definitely had been launched. Yet another sphere was launched and this time, when the trap was opened, both it, and the missing sphere were there. The mystery was solved when on close inspection it was found that the missing sphere had a major failure to its inflation valve which caused it to deflate and lose its seal. It hung up within the pipeline sufficiently for the next sphere to crush it and pass by before it was brought in by the next sphere.

Cuckoo spheres?

An operating company had been using utility pigs in their pipeline. However the ease of using spheres was considered a justified reason to use them instead. Since there had not been any problem when using the utility pigs, no problem was anticipated with the spheres. A sphere was launched and after the normal transit time, it had not arrived at the receiving trap. The pipeline was studied but no fault was found to explain the spheres' non arrival. A second sphere was launched and again it did not arrive at the receiving trap. Again the pipeline was surveyed and studied but again no fault was found for the non arrival of either sphere. Since there was no apparent drop in the flow in the pipeline, a third sphere was launched and again it did not arrive at the receiving trap. The mystery deepened, but with still no measurable increase in pressure drop it was decided to try a fourth sphere. It was launched and at the appropriate time a sphere arrived at the receiving trap. This still did not explain what was happening to the spheres. Another sphere was launched and again one was received, and this pattern was repeated. The theory arose that somewhere three spheres were 'hung up' and each additional sphere would cause the one in the lead to travel to the receiving trap. It was finally realized that there were three check (non-return) valves in the system and the mystery was resolved. The first sphere had stopped in the first valve. The second sphere then pushed the first sphere out and itself stayed there. Meanwhile the first sphere traveled along until it was stopped in the second valve, and so on until there was a sphere lodged in each valve. Only then, did the spheres begin to re-appear. . .

Capital Punishment

Spheres as well as foam pigs will follow the flow within the pipeline almost regardless of the configuration of the pipeline. On one occasion a 36" pipeline was running spheres as batch separators and a pump station without traps had to be passed. The valves on the suction and discharge had to be operated in a specific manner to allow the pigs to pass the station. This was not done on one occasion and the 36" sphere traversed the 24" suction line as far as the strainer. Needless to say it was not reusable after entering the strainer; indeed it could not even be removed with normal tools. It was finally decided to burn the sphere out to make the strainer available for reuse.

Some sample!

Tests were being conducted to determine the effectiveness of pigs and spheres as batch separators within the pipeline. It was necessary to take samples of the product immediately ahead of, and behind the pig or sphere that was being used to separate the different products. This sometimes meant that a sample was being taken just as the sphere passed the sampling point. Since the sphere would try to follow the direction of flow, the sample at that time usually included a small piece of the sphere that was exactly the same diameter as the sampling connection.

And it's not just spheres; foam pigs have also developed a reputation for sometimes having a mind of their own . . .

You can't please everybody!

A pig manufacturer designed a new pig and a 30" version was sent with a technician to be field tested. A natural gas company had agreed to let the new pig be run in their pipeline for evaluation. The technician witnessed the pig being put into the launching trap and later its removal at the receiving trap. When discussing the effectiveness of the pig with the pipeline personnel it was learned that they did not like it. When asked why, they said that they had to open the receiving trap to remove this pig whereas they could blow their foam pigs out through the vent!

The ultimate 'bi-directional' pig

A short section of pipe was being pigged as part of a test program. It was noticed that, although they were launched nose first, the foam swabs were nearly always received 'rear end first'. Several theories were offered to explain this happening. After careful study and testing it was discovered that as the swab passed a tee the nose of the swab would expand into the branch of the tee and the line flow would cause the pig to reverse and then continue its journey backwards. This occurred consistently, even though there was no flow through the branch of the tee.

Foam pigs are nice and soft - Aren't they?

A 4" foam pig held up in an open ended test loop and when it came free, traveled over 30 yards across a road and hit a neighboring factory wall, cracking the brickwork!.

And on a serious note . . .

A large diameter foam pig got sucked into a 4" diameter drain line on a receiver. The pressure in the trap was about 2000 p.s.i. and the drain comprised a flexible hose attached to the hard piping on the trap. When the foam pig reached the flexible, it was torn off - causing a fatal injury.

Not running a pig at all can sometimes be beneficial . . .

The Silent Policeman!

When inside diameter measuring (or geometry) pigs first became available, one pipeline owner could see the benefit of such a pig but he did not want to incur the extra expense. He hired the geometry pigging supplier to demonstrate their pig and to give their sales literature to the pipe laying contractors. He then instructed the supplier to put the instrumented pig in their truck and ensure that it could be seen by all of the contractors personnel. It was the pipeline owners belief that he would get a better pipe in the ground just through the threat of using the instrumented pig, and would incur much less expense than he would for the actual instrument pig survey. The owner admitted to the geometry pig supplier that his past experience had shown that he could get a workable pipeline - and he was not sure that he really wanted to know the inside condition of his pipeline anyway!

Low Bidder

A contract was let to the low bidder to dry a section of pipeline prior to putting the new section into service. What the pipeline company inspector saw was unusual to say the least. The contractor had the compressor to supply the dry air that was needed, but instead of the usual foam pigs, he had purchased foam mattresses and was cutting them into chunks that he could insert into the pipeline to remove any water or other liquids as part of the drying process. The other unusual part of the procedure was that the contractor had backed and parked a horse trailer at the receiving end of the pipeline. Most horse trailers are enclosed except the rear and this was ideal for catching and retaining the mattress chunks as they traversed the pipeline!--Yes, it worked.

What is Acceptable?

A pipeline company agreed to test a new design of pig, so the manufacturer had it delivered to the launching station. The station crew launched the pig and it was later received at an intermediate station. The crew there decided that it had not performed very well and was not acceptable for further testing. After a shift change at this intermediate station, the new crew saw the pig had been received and, assuming that the testing was to be continued, promptly launched it into the next section. The pig completed its run and the crew who received it at the end reported that the test was successful and that the pig had been received in good condition.

The lesson to all manufacturers. If it's worth making a test, it's worth sending a person to witness it and report the results.

Consolidating Pigs

An experimental polyurethane pig was made with an external shape that was thought to be ideal for traversing the pipeline and giving good results. It was 36" in size, so to reduce the weight and provide flexibility it was made hollow with a hole in the rear so it would not collapse under pipeline pressure. On its first test the pig was launched satisfactorily, but it was not received when expected - nor after a long additional waiting period. Obviously the pig was stuck so a 36" foam pig was launched to push it out. This worked, and both pigs were received about the time they were expected. What was not expected was the way in which they arrived. Apparently the test pig had reached some obstruction that caused an increase in the differential pressure which then inflated it. It expanded so much that it locked onto the pipe wall and the increased pressure ruptured the nose of the pig, allowing the pipeline flow to continue through its hollow body. When the foam pig arrived, it too tried to flow through the test pig, but fortunately it could not squeeze through the hole in its nose. But it did succeed in dislodging it, and the two pigs arrived at the receiving trap together. Very together - the 36" foam pig was completely inside the test pig! Additional tests were not required.

'Stealth' pig

What's a good pigging speed? A few miles per hour, or a few metres per second perhaps. How about 1.3 miles per year! That was the average speed of a pig which was launched in Conoco's 6", 30 mile long pipeline in North East England in 1972. It arrived in 1996!. Although the pig went 'missing', there was no noticeable decrease in pipeline performance or throughput during this period. The pig, which was presumably designed using 'stealth' technology, was cleaned ready to be put on display at Conoco's Theddlethorpe terminal.

And finally,

When is a Pig Not a Pig?

A European manufacturer of fruit jelly (jam) uses a loaf of sliced bread to pig their process pipework! A paint manufacturer uses plastic coffee cups and another uses tennis balls. Pigs have also been used in milk, wine, dough, chocolate, pineapple juice--and 'who knows what else' pipelines!

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15.0 ACKNOWLEDGMENTS and FURTHER READING

15.1 ACKNOWLEDGMENTS

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Special thanks are also due to the Gas Research Institute (GRI) in the United States for permission to reproduce the Definitions from the Appendices to the Topical Reports: GRI 91/0365 (In-Line Inspection of Natural Gas Pipelines) and GRI 91/0367 (Magnetic Flux Leakage Technology for Natural Gas Pipeline Inspection).

15.2 FURTHER READING

Gas Research Institute Topical Report No. GRI 91/0365: In-Line Inspection of Natural Gas Pipelines.

Gas Research Institute Topical Report No. GRI 91/0366: Assuring the Integrity of Natural Gas Transmission Pipelines.

Gas Research Institute Topical Report No. GRI 91/0367: Magnetic Flux Leakage Technology for Natural Gas Pipeline Inspection.

"Pipeline Pigging Technology" - Pipes & Pipelines International (Scientific Surveys Ltd.)

"Pipeline Pigging Technology, 2nd Edition" - Pipes & Pipelines International (Scientific Surveys Ltd.)

Pipeline Pigging & Inspection Technology Conference Proceedings - A series covering many years. Contact Scientific Surveys Ltd. or Clarion Technical Conferences for details.

"An Introduction to Pipeline Pigging" - by the Pigging Products & Services Association. Available from Pipes & Pipelines International (Scientific Surveys Ltd.) or Clarion Technical Conferences.

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16A - BUYER'S GUIDE CLASSIFICATIONS

This "Buyer's Guide" section is in three parts. The first, the product and service classifications, are listed below in alphabetical order. The supplier's names (with main locations) are listed under each of these headings in the second part and their full contact details are given under their names, which are in alphabetical order in the final part.

1. UTILITY PIPELINE PIGS, SPARES AND ACCESSORIES

Mandrel Type Pigs
Foam Pigs
Solid Cast Pigs
Spheres

2. SPECIALIST UTILITY PIGS

Hyperbaric Pigs and Spheres
Magnetic Cleaning Pigs
Meter Prover Spheres
Multi-Diameter Pigs
Plugging Pigs (pipeline isolation) - Low/Medium Pressure
Plugging Pigs (pipeline isolation) - Medium/High Pressure
Soluble Pigs
Special Purpose/Customized Pigs

3. PIPELINE PIGGING COMPONENTS AND EQUIPMENT

Closures
Pig Diverters
Pig Handling Systems
Pig/Sphere Launch Valves
Launch Pins
Meter Provers
Pig/Sphere Traps (Launchers/Receivers)
Pipe plugs/stoppers
Safety Interlocks/Systems
Sphere Flow Tees
Sphere Lifters
Wyes (Convergers)

4. PIG LOCATORS/TRACKERS AND SIGNALERS

Pig Locators/Trackers - Magnetic
Pig Locators/Trackers - Miscellaneous
Pig Locators/Trackers - Pingers
Pig Locators/Trackers - Radioactive
Pig Locators/Trackers - Transmitters
Pig Locators/Trackers - Transponders
Signalers - Intrusive
Signalers - Non-intrusive - Magnetic
Signalers - Non-intrusive - Ultrasonic
Signalers - Non-intrusive - Other Technologies

5. PIPELINE PIGGING SERVICES (INCLUDING EQUIPMENT HIRE)

Gel Pigging (all types)
Hire - Compressors, Pumps and Related Equipment
Insitu Internal Pipe Coating
Leak Detection and Location
Pig Location/Tracking Services
Pipeline Cleaning
Pipeline Commissioning
Pipeline Dewatering and Drying
Pipeline Purging/Inerting
Pipeline Slug Inhibition
Pressure Testing

6. IN-LINE INSPECTION PIGGING SERVICES

Bend Radius Measurement
Crack Detection
Data Loggers
Geometry/Diameter Reduction
Leak Detection
Metal Loss - Magnetic Flux Type
Metal Loss - Ultrasonic Type
Metal Loss - Other Technologies
Pipeline Profile/Mapping
Pipe Spanning/Line Cover
Product Sampling
Variable Speed Pigs
Wax Deposition Measurement

7. CABLE OPERATED INSPECTION PIGGING SERVICES

Crack Detection
Metal Loss - Magnetic Flux
Metal Loss - Ultrasonic Type
Metal Loss - Other Technologies
Pipe Alignment Clamp
Pipeline Profile
Plugging Pigs (pipeline isolation)
Visual - Photographic/Video

8. INDUSTRIAL PIGGING EQUIPMENT AND SERVICES

Control Systems
Custom pigs
Fittings/Components
Installation

9. PIGGING CONSULTANCY SERVICES

Utility Pigging
In-Line Inspection Pigging
Cable Operated Inspection Pigging
Industrial Pigging
Pig Location and Tracking
Legal/Legislative Requirements

10. OTHER COMPANIES & ORGANIZATIONS INVOLVED WITH PIGGING

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16B - PRODUCTS and SERVICES

Product and service headings are listed alphabetically with suppliers names (with main locations) listed alphabetically under each.

1. UTILITY PIPELINE PIGS, SPARES AND ACCESSORIES

Mandrel Type Pigs

ALBAB Trading Co Ltd. (Saudi Arabia)
Apache Pipeline Products (Canada)
The Carver Corporation (US)
G A Cotten Co. (US)
Elastomers Australia (Australia)
Enduro Pipeline Services Inc. (US)
Fullkote Pipeline Services Inc. (Canada)
GD Engineering (UK, US)
Girard Industries Inc. (US, UK)
GRM Fluid Controls (Canada)
Hydrocarbon Resources Development Co Pvt Ltd. (India)
Industrial Pipeline Products Pty Ltd. (Australia)
International Pipeline Products Ltd. (UK)
Kleiss & Co. (Netherlands)
Knapp Polly Pig Inc. (US)
NGKS International Corp. (Canada)
Oil States Industries (US)
PII Pipeline Solutions (UK, Germany, US)
Pigging Technology International Ltd. (Canada)
Pigs Unlimited Inc. (US)
Pigtek Ltd. (UK)
Pipeguard of Texas (US)
Pipeline Cleaners Inc. (US)
Pipeline Dehydrators Inc. (US)
Pipeline Engineering (UK, UAE)
Pipeline Technologies Co. (China)
Plainsman Mfg. Ltd. (Canada)
Rosen Group (Germany, Netherlands, US, Australia, Malaysia)
S.U.N. Engineering Inc. (US)
Techno Pipe GmbH (Germany)
Tuboscope Vetco Pipeline Services (US, UK, Brazil, Mexico, Canada)
Vee Kay Vikram & Co. (India)
T D Williamson Inc. (US, UK)
Yong Shun Pigging services Co Ltd. (China)

Foam Pigs

ALBAB Trading Co Ltd. (Saudi Arabia)
Alexander Cardew Ltd. (UK)
Decoking Descaling Technology Inc. (Canada)
Elastomers Australia (Australia)
Enduro Pipeline Services Inc. (US)
Fullkote Pipeline Services Inc. (Canada)
GD Engineering (UK, US)
Girard Industries Inc. (US, UK)
GRM Fluid Controls (Canada)
Hydro Kleen Systems Inc (Canada)
Industrial Pipeline Products Pty Ltd. (Australia)
International Pipeline Products Ltd. (UK)
Kleiss & Co. (Netherlands)
Knapp Polly Pig Inc. (US)
Oil States Industries (US)
PII Pipeline Solutions (UK, Germany, US)
PEC Corporation (Japan)
Pectel Group (UK)
Pigging Technology International Ltd. (Canada)
Pigs Unlimited Inc. (US)
Pipe Equipment Specialists Ltd. (UK)
Pipeguard of Texas (US)
Pipeline Pigging Products Inc. (US)
Pipeline Engineering (UK, UAE)
Pipeline Technologies Co. (China)
Plainsman Mfg. Ltd. (Canada)
Star Products (US)
Techno Pipe GmbH (Germany)
Ura-Flex Mfg. Inc. (US)
Vee Kay Vikram & Co. (India)
T D Williamson Inc. (US, UK)
Yong Shun Pigging services Co Ltd. (China)

Solid Cast Pigs

ALBAB Trading Co Ltd. (Saudi Arabia)
Alexander Cardew Ltd. (UK)
Apache Pipeline Products (Canada)
Decoking Descaling Technology Inc. (Canada)
Elastomers Australia (Australia)
Enduro Pipeline Services Inc. (US)
Fullkote Pipeline Services Inc. (Canada)
Girard Industries Inc. (US, UK)
GRM Fluid Controls (Canada)

Hydro Kleen Systems Inc (Canada)
Industrial Pipeline Products Pty Ltd. (Australia)
International Pipeline Products Ltd. (UK)
Kleiss & Co. (Netherlands)
Knapp Polly Pig Inc. (US)
Oil States Industries (US)
PII Pipeline Solutions (UK, Germany, US)
Pectel Group (UK)
Pigging Technology International Ltd. (Canada)
Pigs Unlimited Inc. (US)
Pipeline Dehydrators Inc. (US)
Pipeline Engineering (UK, UAE)
Pipeline Technologies Co. (China)
Plainsman Mfg. Ltd. (Canada)
Rosen Group (Germany, Netherlands, US, Australia, Malaysia)
Star Products (US)
S.U.N. Engineering Inc. (US)
Techno Pipe GmbH (Germany)
Ura-Flex Mfg. Inc. (US)
Vee Kay Vikram & Co. (India)
T D Williamson Inc. (US, UK)

Spheres

ALBAB Trading Co Ltd. (Saudi Arabia)
Alexander Cardew Ltd. (UK)
Fullkote Pipeline Services Inc. (Canada)
GD Engineering (UK, US)
Girard Industries Inc. (US, UK)
GRM Fluid Controls (Canada)
Industrial Pipeline Products Pty Ltd. (Australia)
International Pipeline Products Ltd. (UK)
Kleiss & Co. (Netherlands)
Knapp Polly Pig Inc. (US)
Oil States Industries (US)
Pectel Group (UK)
Plainsman Mfg. Ltd. (Canada)
Pigs Unlimited Inc. (US)
Pipeguard of Texas (US)
Pipeline Engineering (UK, UAE)
Techno Pipe GmbH (Germany)
Vee Kay Vikram & Co. (India)
T D Williamson Inc. (US, UK)

2. SPECIALIST UTILITY PIGS

Hyperbaric Pigs and Spheres

International Pipeline Products Ltd. (UK)
Pronal S.A. (France)
Pipeline Engineering (UK, UAE)
Techno Pipe GmbH (Germany)
Vee Kay Vikram & Co. (India)

Magnetic Cleaning Pigs

PII Pipeline Solutions (UK, Germany, US)
Pigtek Ltd. (UK)
Pipeline Engineering (UK, UAE)
Rosen Group (Germany, Netherlands, US, Australia, Malaysia)
Tuboscope Vetco Pipeline Services (US, UK, Brazil, Mexico, Canada)
Vee Kay Vikram & Co. (India)
T D Williamson Inc. (US, UK)

Meter Prover Spheres

International Pipeline Products Ltd. (UK)
Oil States Industries (US)
Pipeline Engineering (UK, UAE)
Techno Pipe GmbH (Germany)
Vee Kay Vikram & Co. (India)

Multi-Diameter Pigs

Apache Pipeline Products (Canada)
Enduro Pipeline Services Inc. (US)
FTL Seals Technology Ltd (UK)
GD Engineering (UK, US)
GRM Fluid Controls (Canada)
Industrial Pipeline Products Pty Ltd. (Australia)
International Pipeline Products Ltd. (UK)
Knapp Polly Pig Inc. (US)
NGKS International Corp. (Canada)
Oil States Industries (US)
PII Pipeline Solutions (UK, Germany, US)
Pigging Technology International Ltd. (Canada)
Pigs Unlimited Inc. (US)
Pigtek Ltd. (UK)
Pipeline Dehydrators Inc. (US)
Pipeline Engineering (UK, UAE)
Pipeline Technologies Co. (China)
Rosen Group (Germany, Netherlands, US, Australia, Malaysia)

S.U.N. Engineering Inc. (US)
Star Products (US)
Techno Pipe GmbH (Germany)
Tuboscope Vetco Pipeline Services (US, UK, Brazil, Mexico, Canada)
Vee Kay Vikram & Co. (India)
T D Williamson Inc. (US, UK)

Plugging Pigs (pipeline isolation) - Low/Medium Pressure

BJ Process & Pipeline Services (Canada, US, UK, UAE)
International Pipeline Products Ltd. (UK)
Pipeline Engineering (UK, UAE)
Pronal SA (France)
Techno Pipe GmbH (Germany)
Vee Kay Vikram & Co. (India)

Plugging Pigs (pipeline isolation) - Medium/High Pressure

IPSCO Flowserve (UK)
ITAS (Norway)
KH Tecnomarine Ltd./Online Electronics Ltd. (UK, US)
Oil States Industries Inc., HydroTech Division (US, UK)
Plugging Specialists International AS [PSI] (Norway, Singapore, US)

Soluble Pigs

Select Industries Inc. (US)

Special Purpose/Customized Pigs

ALBAB Trading Co Ltd. (Saudi Arabia)
Apache Pipeline Products (Canada)
BKW Inc. (US)
Enduro Pipeline Services Inc. (US)
GD Engineering (UK, US)
Girard Industries Inc. (US, UK)
GRM Fluid Controls (Canada)
Industrial Pipeline Products Pty Ltd. (Australia)
International Pipeline Products Ltd. (UK)
Kleiss & Co. (Netherlands)
Knapp Polly Pig Inc. (US)
NGKS International Corp. (Canada)
PII Pipeline Solutions (UK, Germany, US)
Pigging Technology International Ltd. (Canada)
Pigs Unlimited Inc. (US)
Pigtek Ltd. (UK)
Pipeline Pigging Products Inc. (US)
Pipeline Engineering (UK, UAE)

Pipeline Technologies Co. (China)
Rosen Group (Germany, Netherlands, US, Australia, Malaysia)
S.U.N. Engineering Inc. (US)
Techno Pipe GmbH (Germany)
Vee Kay Vikram & Co. (India)
T D Williamson Inc. (US, UK)

3. PIPELINE PIGGING COMPONENTS AND EQUIPMENT

Closures

Enduro Pipeline Services Inc. (US)
Frames Energy Systems bv (Netherlands)
GD Engineering (UK, US)
Halliburton (UK, US, Dubai)
Hydrocarbon Resources Development Co Pvt Ltd. (India)
Industrial Pipeline Products Pty Ltd. (Australia)
International Pipeline Products Ltd. (UK)
LTS Inc. (US)
Pipeline Engineering (UK, UAE)
SiirtecNigi SpA (Italy)
Techno Pipe GmbH (Germany)
Tube Turns Technologies Inc. (US)
Vee Kay Vikram & Co. (India)
T D Williamson Inc. (US, UK)

Pig Diverters

BKW Inc. (US)
Cooper Cameron (UK) Ltd. (UK)
GD Engineering (UK, US)
Industrial Pipeline Products Pty Ltd. (Australia)
International Pipeline Products Ltd. (UK)
Pipeline Engineering (UK, UAE)
Techno Pipe GmbH (Germany)
Webb Services Inc. (US)
T D Williamson Inc. (US, UK)

Pig Handling Systems

BJ Process & Pipeline Services (Canada, US, UK, UAE)
BKW Inc. (US)
Decoking Descaling Technology Inc. (Canada)
GD Engineering (UK, US)
Halliburton (UK, US, Dubai)
Hydro Kleen Systems Inc (Canada)
Industrial Pipeline Products Pty Ltd. (Australia)
International Pipeline Products Ltd. (UK)

PII Pipeline Solutions (UK, Germany, US)
Pigging Technology International Ltd. (Canada)
Pigs Unlimited Inc. (US)
Pigtek Ltd. (UK)
Pipeline Engineering (UK, UAE)
Pipeline Technologies Co. (China)
SiirtecNigi SpA (Italy)
Vee Kay Vikram & Co. (India)
T D Williamson Inc. (US, UK)

Pig/Sphere Launch Valves

Argus Machine Co Ltd. (Canada)
Decoking Descaling Technology Inc. (Canada)
GD Engineering (UK, US)
Girard Industries Inc. (US, UK)
Halliburton (UK, US, Dubai)
Hydro Kleen Systems Inc (Canada)
Industrial Pipeline Products Pty Ltd. (Australia)
ITAG (Germany)
Pipeline Engineering (UK, UAE)
Tuboscope Vetco Pipeline Services (US, UK, Brazil, Mexico, Canada)
Vee Kay Vikram & Co. (India)
Weir Valves & Controls (UK)

Launch Pins

GD Engineering (UK, US)
Industrial Pipeline Products Pty Ltd. (Australia)
International Pipeline Products Ltd. (UK)
Pipeline Engineering (UK, UAE)
RC SubSea (Norway)
Techno Pipe GmbH (Germany)
Vee Kay Vikram & Co. (India)
T D Williamson Inc. (US, UK)

Meter Provers

Skeltonhall Ltd. (UK)

Pig or Sphere Traps (Launchers and Receivers)

BKW Inc. (US)
Enduro Pipeline Services Inc. (US)
Frames Energy Systems bv (Netherlands)
Fullkote Pipeline Services Inc. (Canada)
GD Engineering (UK, US)
Girard Industries Inc. (US, UK)

Halliburton (UK, US, Dubai)
Hydrocarbon Resources Development Co Pvt Ltd. (India)
Industrial Pipeline Products Pty Ltd. (Australia)
International Pipeline Products Ltd. (UK)
Jenkins Newell Dunford Ltd (UK)
Kleiss & Co. (Netherlands)
LTS Inc. (US)
Pigging Technology International Ltd. (Canada)
Pigs Unlimited Inc. (US)
Pipeline Dehydrators Inc. (US)
Pipeline Engineering (UK, UAE)
Pipeline Pigging Products Inc. (US)
Pipeline Technologies Co. (China)
RC SubSea (Norway)
Scomark Engineering Ltd. (UK)
SFE Global (US, Canada)
SiirtecNigi SpA (Italy)
Skeltonhall Ltd. (UK)
S.U.N. Engineering Inc. (US)
Techno Pipe GmbH (Germany)
Tuboscope Vetco Pipeline Services (US, UK, Brazil, Mexico, Canada)
Vee Kay Vikram & Co. (India)
T D Williamson Inc. (US, UK)

Pipe Plugs and Stoppers

ALBAB Trading Co Ltd. (Saudi Arabia)
Beugas Equipment bv (Netherlands)
GD Engineering (UK, US)
International Pipeline Products Ltd. (UK)
Pipeline Engineering (UK, UAE)
Pronal S.A. (France)
Techno Pipe GmbH (Germany)
Tube Turns Technologies Inc. (US)
Vee Kay Vikram & Co. (India)
T D Williamson Inc. (US, UK)

Safety Interlocks and Systems

Castell Safety International Ltd. (UK)
Frames Energy Systems bv (Netherlands)
Smith Flow Control Ltd. (UK)

Sphere Flow Tees

GD Engineering (UK, US)
Hydrocarbon Resources Development Co Pvt Ltd. (India)
Industrial Pipeline Products Pty Ltd. (Australia)

International Pipeline Products Ltd. (UK)
Oil States Industries Inc., HydroTech Division (US, UK)
Pigs Unlimited Inc. (US)
Pipeline Engineering (UK, UAE)
Skeltonhall Ltd. (UK)
Techno Pipe GmbH (Germany)
Vee Kay Vikram & Co. (India)
T D Williamson Inc. (US, UK)

Sphere Lifters

GD Engineering (UK, US)
International Pipeline Products Ltd. (UK)
Pipeline Engineering (UK, UAE)
Pipeline Technologies Co. (China)
Sahara Industrial Services (SAPESCO) Ltd. (Egypt)
Techno Pipe GmbH (Germany)
Vee Kay Vikram & Co. (India)
T D Williamson Inc. (US, UK)

Wyes (Convergers)

BKW Inc. (US)
GD Engineering (UK, US)
Hydrocarbon Resources Development Co Pvt Ltd. (India)
Industrial Pipeline Products Pty Ltd. (Australia)
Oil States Industries Inc., HydroTech Division (US, UK)
Pipeline Engineering (UK, UAE)
Techno Pipe GmbH (Germany)
Vee Kay Vikram & Co. (India)
Webb Services Inc. (US)
T D Williamson Inc. (US, UK)

4. PIG LOCATORS/TRACKERS AND SIGNALERS

Pig Locators/Trackers - Magnetic

Control Devices Inc. (US)
Online Electronics Ltd. (UK, US)
PII Pipeline Solutions (UK, Germany, US)
Pigtek Ltd. (UK)
Pipeline Technologies Co. (China)
Sahara Industrial Services (SAPESCO) Ltd. (Egypt)

Pig Locators/Trackers - Miscellaneous

BJ Process & Pipeline Services (Canada, US, UK, UAE)
Industrial Pipeline Products Pty Ltd. (Australia)

Kleiss & Co. (Netherlands)
Nautronix Ltd. (UK)
Online Electronics Ltd. (UK, US)
PII Pipeline Solutions (UK, Germany, US)
Pigtek Ltd. (UK)
Pipeline Technologies Co. (China)
Sahara Industrial Services (SAPESCO) Ltd. (Egypt)
T.U.E. (Systems) Ltd. (UK)
Vee Kay Vikram & Co. (India)

Pig Locators/Trackers - Pingers

Nautronix Ltd. (UK)
Online Electronics Ltd. (UK, US)

Pig Locators/Trackers - Radioactive

Synetix Services (Tracerco Diagnostics) (UK, US, Singepore)

Pig Locators/Trackers - Transmitters

Control Devices Inc. (US)
Crostek Corp. (Canada)
GD Engineering (UK, US)
Fullkote Pipeline Services Inc. (Canada)
Industrial Pipeline Products Pty Ltd. (Australia)
Online Electronics Ltd. (UK, US)
PII Pipeline Solutions (UK, Germany, US)
Pipeline Inspection Co. Inc. (US)
Pipeline Technologies Co. (China)
Rosen Group (Germany, Netherlands, US, Australia, Malaysia)
Hermann Sewerin GmbH (Germany)

Pig Locators/Trackers - Transponders

Ixsea Oceano Ltd. (UK, France)
Nautronix Ltd. (UK)
Online Electronics Ltd. (UK, US)

Signalers - Intrusive

Apache Pipeline Products (Canada)
Enduro Pipeline Services Inc. (US)
Frames Energy Systems bv (Netherlands)
GD Engineering (UK, US)
GRM Fluid Controls (Canada)
Hydrocarbon Resources Development Co Pvt Ltd. (India)
Industrial Pipeline Products Pty Ltd. (Australia)
International Pipeline Products Ltd. (UK)

Pigs Unlimited Inc. (US)
Pipeline Engineering (UK, UAE)
Pipeline Technologies Co. (China)
Skeltonhall Ltd. (UK)
Techno Pipe GmbH (Germany)
Vee Kay Vikram & Co. (India)
T D Williamson Inc. (US, UK)

Signalers - Non-intrusive - Magnetic

Apache Pipeline Products (Canada)
GRM Fluid Controls (Canada)
Inline plc (US, UK)
NGKS International Corp. (Canada)
Nautronix Ltd. (UK)
Pigs Unlimited Inc. (US)
Pigtek Ltd. (UK)
Pipeline Engineering (UK, UAE)
Pipeline Inspection Co. Inc. (US)
Pipeline Technologies Co. (China)
S.U.N. Engineering Inc. (US)
T.U.E. (Systems) Ltd. (UK)
Vee Kay Vikram & Co. (India)
T D Williamson Inc. (US, UK)

Signalers - Non-intrusive - Ultrasonic

BJ Process & Pipeline Services (Canada, US, UK, UAE)
ClampOn AS (Norway)
Fluenta a/s (Norway)

Signalers - Non-intrusive - Other Technologies

Crostek Corp. (Canada)
Pipeline Inspection Co. Inc. (US)
T.U.E. (Systems) Ltd. (UK)

5. PIPELINE PIGGING SERVICES (INCLUDING EQUIPMENT HIRE)

Gel Pigging (all types)

BJ Process & Pipeline Services (Canada, US, UK, UAE)
Brown Corrosion Services Inc. (US)
Challenger Special Oil Services (France)
Copipe Systems Ltd (UK)
A Hak Industrial Services bv (Netherlands, Germany, Spain)
Halliburton (UK, US, Dubai)
HydroChem Industrial Services Inc. (US)

PII Pipeline Solutions (UK, Germany, US)
Pipeline Services LLC (PLS) (UAE)
Pipeline Technologies Co. (China)
Sahara Industrial Services (SAPESCO) Ltd. (Egypt)
John Smart Consulting Engineers (US)
TRAPIL (France)
Tuboscope Vetco Pipeline Services (US, UK, Brazil, Mexico, Canada)

Hire - Compressors, Pumps and Related Equipment

BJ Process & Pipeline Services (Canada, US, UK, UAE)
Fullkote Pipeline Services Inc. (Canada)
Halliburton (UK, US, Dubai)
PII Pipeline Solutions (UK, Germany, US)
Pipeline Dehydrators Inc. (US)
Pipeline Services LLC (PLS) (UAE)

Insitu Internal Pipe Coating

Challenger Special Oil Services (France)
Cosmo Engineering Co. Ltd. (Japan)
Fullkote Pipeline Services Inc. (Canada)
A Hak Industrial Services bv (Netherlands, Germany, Spain)
PII Pipeline Solutions (UK, Germany, US)
Pipeline Services LLC (PLS) (UAE)
Pipeline Technologies Co. (China)
Sahara Industrial Services (SAPESCO) Ltd. (Egypt)
UCISCO Inc. (US)

Leak Detection and Location

BJ Process & Pipeline Services (Canada, US, UK, UAE)
BJB Company (US)
Challenger Special Oil Services (France)
Hydrostatic Testing Consultants Ltd.. (UK)
PII Pipeline Solutions (UK, Germany, US)
Rosen Group (Germany, Netherlands, US, Australia, Malaysia)
Sahara Industrial Services (SAPESCO) Ltd. (Egypt)
TRAPIL (France)
Tuboscope Vetco Pipeline Services (US, UK, Brazil, Mexico, Canada)

Pig Location/Tracking Services

3P Services GmbH & Co. KG (Germany)
BJB Company (US)
Enduro Pipeline Services Inc. (US)
Fullkote Pipeline Services Inc. (Canada)
Hydrostatic Testing Consultants Ltd.. (UK)

Industrial Pipeline Products Pty Ltd. (Australia)
Ixsea Oceano Ltd. (UK, France)
NGKS International Corp. (Canada)
Nautronix Ltd. (UK)
Online Electronics Ltd. (UK, US)
PII Pipeline Solutions (UK, Germany, US)
Pigs Unlimited Inc. (US)
Pigtek Ltd. (UK)
Pipeline Engineering (UK, UAE)
Pipeline Pigging Products Inc. (US)
Pipeline Services LLC (PLS) (UAE)
Pipeline Technologies Co. (China)
Rosen Group (Germany, Netherlands, US, Australia, Malaysia)
Sahara Industrial Services (SAPESCO) Ltd. (Egypt)
Synetix Services (Tracerco Diagnostics) (UK, US, Singepore)
Techno Pipe GmbH (Germany)
TRAPIL (France)
Tuboscope Vetco Pipeline Services (US, UK, Brazil, Mexico, Canada)
Vee Kay Vikram & Co. (India)
T D Williamson Inc. (US, UK)

Pipeline Cleaning

3P Services GmbH & Co. KG (Germany)
AJAKS S.A. (Poland)
ALBAB Trading Co Ltd. (Saudi Arabia)
Baker Petrolite Corp. (US)
BG Technical Ltd. (Nigeria, US)
BJ Process & Pipeline Services (Canada, US, UK, UAE)
BJB Company (US)
Challenger Special Oil Services (France)
Copipe Systems Ltd (UK)
Cornerstone Pipeline Inspection Group (US)
Cosmo Engineering Co. Ltd. (Japan)
Decoking Descaling Technology Inc. (Canada)
Enduro Pipeline Services Inc. (US)
Fullkote Pipeline Services Inc. (Canada)
Girard Industries Inc. (US, UK)
Gulf Petrochemical Services LLC (Oman)
A Hak Industrial Services bv (Netherlands, Germany, Spain)
Halliburton (UK, US, Dubai)
Hydro Kleen Systems Inc (Canada)
Hydrostatic Testing Consultants Ltd.. (UK)
IKM Testing AS (Norway, UK, Asia)
Industrial Pipeline Products Pty Ltd. (Australia)
Inline plc (US, UK)
Kleiss & Co. (Netherlands)
N-SPEC® (US)

NDT Systems & Services AG (Germany)
PII Pipeline Solutions (UK, Germany, US)
Pectel Group (UK)
Perco Engineering Services Ltd. (UK)
Pigs Unlimited Inc. (US)
Pigtek Ltd. (UK)
Pipeline Dehydrators Inc. (US)
Pipeline Pigging Products Inc. (US)
Pipeline Services LLC (PLS) (UAE)
Pipeline Technologies Co. (China)
Rosen Group (Germany, Netherlands, US, Australia, Malaysia)
Sahara Industrial Services (SAPESCO) Ltd. (Egypt)
SFE Global (US, Canada)
Tuboscope Vetco Pipeline Services (US, UK, Brazil, Mexico, Canada)
UCISCO Inc. (US)
Vee Kay Vikram & Co. (India)
T D Williamson Inc. (US, UK)
Yong Shun Pigging services Co Ltd. (China)

Pipeline Commissioning

Baker Petrolite Corp. (US)
BG Technical Ltd. (Nigeria, US)
BJ Process & Pipeline Services (Canada, US, UK, UAE)
BJB Company (US)
Challenger Special Oil Services (France)
Copipe Systems Ltd (UK)
Decoking Descaling Technology Inc. (Canada)
Enduro Pipeline Services Inc. (US)
Girard Industries Inc. (US, UK)
Gulf Petrochemical Services LLC (Oman)
A Hak Industrial Services bv (Netherlands, Germany, Spain)
Halliburton (UK, US, Dubai)
Hydro Kleen Systems Inc (Canada)
Hydrocarbon Resources Development Co Pvt Ltd. (India)
Hydrostatic Testing Consultants Ltd.. (UK)
IKM Testing AS (Norway, UK, Asia)
Industrial Pipeline Products Pty Ltd. (Australia)
PII Pipeline Solutions (UK, Germany, US)
Pipeline Dehydrators Inc. (US)
Pipeline Engineering (UK, UAE)
Pipeline Technologies Co. (China)
Rosen Group (Germany, Netherlands, US, Australia, Malaysia)
Sahara Industrial Services (SAPESCO) Ltd. (Egypt)
Tuboscope Vetco Pipeline Services (US, UK, Brazil, Mexico, Canada)
UCISCO Inc. (US)
Vee Kay Vikram & Co. (India)
T D Williamson Inc. (US, UK)

Pipeline Dewatering and Drying

ALBAB Trading Co Ltd. (Saudi Arabia)
Baker Petrolite Corp. (US)
BG Technical Ltd. (Nigeria, US)
BJ Process & Pipeline Services (Canada, US, UK, UAE)
BJB Company (US)
Challenger Special Oil Services (France)
Copipe Systems Ltd (UK)
Cosmo Engineering Co. Ltd. (Japan)
Fullkote Pipeline Services Inc. (Canada)
A Hak Industrial Services bv (Netherlands, Germany, Spain)
Halliburton (UK, US, Dubai)
Hydrocarbon Resources Development Co Pvt Ltd. (India)
Hydrostatic Testing Consultants Ltd.. (UK)
IKM Testing AS (Norway, UK, Asia)
Industrial Pipeline Products Pty Ltd. (Australia)
PII Pipeline Solutions (UK, Germany, US)
Pectel Group (UK)
Pigs Unlimited Inc. (US)
Pipeline Dehydrators Inc. (US)
Pipeline Services LLC (PLS) (UAE)
Pipeline Technologies Co. (China)
Sahara Industrial Services (SAPESCO) Ltd. (Egypt)
SFE Global (US, Canada)
Tuboscope Vetco Pipeline Services (US, UK, Brazil, Mexico, Canada)
UCISCO Inc. (US)
Vee Kay Vikram & Co. (India)
T D Williamson Inc. (US, UK)

Pipeline Purging/Inerting

ALBAB Trading Co Ltd. (Saudi Arabia)
Baker Petrolite Corp. (US)
BG Technical Ltd. (Nigeria, US)
BJ Process & Pipeline Services (Canada, US, UK, UAE)
BJB Company (US)
Brown Corrosion Services Inc. (US)
Challenger Special Oil Services (France)
Copipe Systems Ltd (UK)
A Hak Industrial Services bv (Netherlands, Germany, Spain)
Halliburton (UK, US, Dubai)
IKM Testing AS (Norway, UK, Asia)
PII Pipeline Solutions (UK, Germany, US)
Pipeline Dehydrators Inc. (US)
Pipeline Services LLC (PLS) (UAE)
Pipeline Technologies Co. (China)

Sahara Industrial Services (SAPESCO) Ltd. (Egypt)
John Smart Consulting Engineers (US)
Tuboscope Vetco Pipeline Services (US, UK, Brazil, Mexico, Canada)
UCISCO Inc. (US)
Vee Kay Vikram & Co. (India)
T D Williamson Inc. (US, UK)

Pipeline Slug Inhibition

Baker Petrolite Corp. (US)
BG Technical Ltd. (Nigeria, US)
BJ Process & Pipeline Services (Canada, US, UK, UAE)
Brown Corrosion Services Inc. (US)
Challenger Special Oil Services (France)
Copipe Systems Ltd (UK)
Gulf Petrochemical Services LLC (Oman)
Halliburton (UK, US, Dubai)
Hydrostatic Testing Consultants Ltd.. (UK)
IKM Testing AS (Norway, UK, Asia)
N-SPEC® (US)
PII Pipeline Solutions (UK, Germany, US)
Pipeline Technologies Co. (China)
John Smart Consulting Engineers (US)
T D Williamson Inc. (US, UK)

Pressure Testing

BJ Process & Pipeline Services (Canada, US, UK, UAE)
BJB Company (US)
Challenger Special Oil Services (France)
Copipe Systems Ltd (UK)
Cosmo Engineering Co. Ltd. (Japan)
Gulf Petrochemical Services LLC (Oman)
A Hak Industrial Services bv (Netherlands, Germany, Spain)
Hydrocarbon Resources Development Co Pvt Ltd. (India)
Hydrostatic Testing Consultants Ltd.. (UK)
IKM Testing AS (Norway, UK, Asia)
Industrial Pipeline Products Pty Ltd. (Australia)
International Pipeline Products Ltd. (UK)
H O Mohr Research & Engineering Inc. (US)
PII Pipeline Solutions (UK, Germany, US)
Pipeline Dehydrators Inc. (US)
Pipeline Services LLC (PLS) (UAE)
Pipeline Technologies Co. (China)
Sahara Industrial Services (SAPESCO) Ltd. (Egypt)

Tuboscope Vetco Pipeline Services (US, UK, Brazil, Mexico, Canada)
UCISCO Inc. (US)
Vee Kay Vikram & Co. (India)
Yong Shun Pigging services Co Ltd. (China)

6. IN-LINE INSPECTION PIGGING SERVICES

Bend Radius Measurement

3P Services GmbH & Co. KG (Germany)
BJ Process & Pipeline Services (Canada, US, UK, UAE)
Enduro Pipeline Services Inc. (US)
NDT Systems & Services AG (Germany)
NGKS International Corp. (Canada)
PII Pipeline Solutions (UK, Germany, US)
Pipeline Technologies Co. (China)
Rosen Group (Germany, Netherlands, US, Australia, Malaysia)
Tuboscope Vetco Pipeline Services (US, UK, Brazil, Mexico, Canada)
Vee Kay Vikram & Co. (India)
T D Williamson Inc. (US, UK)
Weatherford Pipeline & Specialty Services (UK)

Crack Detection

NDT Systems & Services AG (Germany)
NGKS International Corp. (Canada)
PII Pipeline Solutions (UK, Germany, US)
Pipeline Technologies Co. (China)
Rosen Group (Germany, Netherlands, US, Australia, Malaysia)
TRAPIL (France)
Tuboscope Vetco Pipeline Services (US, UK, Brazil, Mexico, Canada)
Vee Kay Vikram & Co. (India)

Data Loggers

BJ Process & Pipeline Services (Canada, US, UK, UAE)
Copipe Systems Ltd (UK)
Pipeline Engineering (UK, UAE)
Weatherford Pipeline & Specialty Services (UK)
Yong Shun Pigging services Co Ltd. (China)

Geometry/Diameter Reduction

3P Services GmbH & Co. KG (Germany)
Advanced Engineering Solutions Ltd. (UK)
BJ Process & Pipeline Services (Canada, US, UK, UAE)
Enduro Pipeline Services Inc. (US)
NDT Systems & Services AG (Germany)

NGKS International Corp. (Canada)
Pigtek Ltd. (UK)
PII Pipeline Solutions (UK, Germany, US)
Pipeline Engineering (UK, UAE)
Pipeline Technologies Co. (China)
Rosen Group (Germany, Netherlands, US, Australia, Malaysia)
TRAPIL (France)
Tuboscope Vetco Pipeline Services (US, UK, Brazil, Mexico, Canada)
Vee Kay Vikram & Co. (India)
T D Williamson Inc. (US, UK)
Weatherford Pipeline & Specialty Services (UK)

Leak Detection

3P Services GmbH & Co. KG (Germany)
CALtec (UK)
Challenger Special Oil Services (France)
EDAG Engineering and Design AG (Germany)
A Hak Industrial Services bv (Netherlands, Germany, Spain)
Hydrostatic Testing Consultants Ltd.. (UK)
Maihak AG (Germany)
PII Pipeline Solutions (UK, Germany, US)
Pipeline Technologies Co. (China)
Rosen Group (Germany, Netherlands, US, Australia, Malaysia)
TRAPIL (France)

Metal Loss - Magnetic Flux Type

3P Services GmbH & Co. KG (Germany)
Cornerstone Pipeline Inspection Group (US)
NGKS International Corp. (Canada)
PII Pipeline Solutions (UK, Germany, US)
Pipeline Technologies Co. (China)
Pipeline Services LLC (PLS) (UAE)
Rosen Group (Germany, Netherlands, US, Australia, Malaysia)
TRAPIL (France)
Tuboscope Vetco Pipeline Services (US, UK, Brazil, Mexico, Canada)
T D Williamson Inc. (US, UK)

Metal Loss - Ultrasonic Type

Diascan Technical Diagnostics (Russia)
NDT Systems & Services AG (Germany)
NGKS International Corp. (Canada)
NKK Corporation (Japan, UK, US)
PII Pipeline Solutions (UK, Germany, US)
Pipeline Technologies Co. (China)
Tuboscope Vetco Pipeline Services (US, UK, Brazil, Mexico, Canada)

Metal Loss - Other Technologies

3P Services GmbH & Co. KG (Germany)
PII Pipeline Solutions (UK, Germany, US)
Rosen Group (Germany, Netherlands, US, Australia, Malaysia)
Tuboscope Vetco Pipeline Services (US, UK, Brazil, Mexico, Canada)

Pipeline Profile/Mapping

3P Services GmbH & Co. KG (Germany)
Baker Petrolite Corp. (US)
BJ Process & Pipeline Services (Canada, US, UK, UAE)
Enduro Pipeline Services Inc. (US)
NDT Systems & Services AG (Germany)
NGKS International Corp. (Canada)
PII Pipeline Solutions (UK, Germany, US)
Pipeline Technologies Co. (China)
Rosen Group (Germany, Netherlands, US, Australia, Malaysia)
Tuboscope Vetco Pipeline Services (US, UK, Brazil, Mexico, Canada)
Weatherford Pipeline & Specialty Services (UK)

Pipe Spanning/Line Cover

BJ Process & Pipeline Services (Canada, US, UK, UAE)
Enduro Pipeline Services Inc. (US)
NGKS International Corp. (Canada)
PII Pipeline Solutions (UK, Germany, US)
Pipeline Technologies Co. (China)
Rosen Group (Germany, Netherlands, US, Australia, Malaysia)
Weatherford Pipeline & Specialty Services (UK)

Product Sampling

PII Pipeline Solutions (UK, Germany, US)
Rosen Group (Germany, Netherlands, US, Australia, Malaysia)

Variable Speed Pigs

GRM Fluid Controls (Canada)
Inline plc (US, UK)

Wax Deposition Measurement

BJ Process & Pipeline Services (Canada, US, UK, UAE)
Enduro Pipeline Services Inc. (US)
PII Pipeline Solutions (UK, Germany, US)
Rosen Group (Germany, Netherlands, US, Australia, Malaysia)

7. CABLE OPERATED INSPECTION PIGGING SERVICES

Crack Detection

Optimess Engineering GmbH (Germany)
Röntgen Technische Dienst bv (Netherlands)

Metal Loss - Magnetic Flux

3P Services GmbH & Co. KG (Germany)
Atlas Wireline Services (US, Canada)
Diascan Technical Diagnostics (Russia)
Fullkote Pipeline Services Inc. (Canada)
PII Pipeline Solutions (UK, Germany, US)
Schlumberger Well Services (US)

Metal Loss - Ultrasonic Type

Cosmo Engineering Co. Ltd. (Japan)
A Hak Industrial Services bv (Netherlands, Germany, Spain)
Optimess Engineering GmbH (Germany)
Röntgen Technische Dienst bv (Netherlands)

Metal Loss - Other Technologies

Optimess Engineering GmbH (Germany)
Röntgen Technische Dienst bv (Netherlands)

Pipe Alignment Clamp

Rosen Group (Germany, Netherlands, US, Australia, Malaysia)

Pipeline Profile

Schlumberger Well Services (US)

Plugging Pigs (pipeline isolation)

BJ Process & Pipeline Services (Canada, US, UK, UAE)
Oil States Industries Inc., HydroTech Division (US, UK)

Visual - Photographic/Video

Cosmo Engineering Co. Ltd. (Japan)
A Hak Industrial Services bv (Netherlands, Germany, Spain)
Optimess Engineering GmbH (Germany)

Röntgen Technische Dienst bv (Netherlands)
Rosen Group (Germany, Netherlands, US, Australia, Malaysia)
Schlumberger Well Services (US)

8. INDUSTRIAL PIGGING EQUIPMENT AND SERVICES

Control Systems

Challenger Special Oil Services (France)
Ceripro Co. (France)
Energy-Environmental Engineering GmbH (Germany)
GD Engineering (UK, US)
Hygienic Pigging Systems Ltd. (UK)
IST Molchtechnik GmbH (Germany, UK, US)
Industrial Pipeline Products Pty Ltd. (Australia)
Inline plc (US, UK)
International Pipeline Products Ltd. (UK)
LTS Inc. (US)
Maintrend Services Ltd (UK)
OEG Co. Ltd. (Japan)
PII Pipeline Solutions (UK, Germany, US)
Pectel Group (UK)
Pigs Unlimited Inc. (US)
Pigtek Ltd. (UK)
Pipeline Engineering (UK, UAE)
Pipeline Technologies Co. (China)
Südmo Components GmbH (Germany, South Africa)
Techno Pipe GmbH (Germany)
Vee Kay Vikram & Co. (India)
T D Williamson Inc. (US, UK)

Custom pigs

Alexander Cardew Ltd. (UK)
Ceripro Co. (France)
Challenger Special Oil Services (France)
Decoking Descaling Technology Inc. (Canada)
Enduro Pipeline Services Inc. (US)
Energy-Environmental Engineering GmbH (Germany)
GD Engineering (UK, US)
Girard Industries Inc. (US, UK)
Hydro Kleen Systems Inc (Canada)
Hygienic Pigging Systems Ltd. (UK)
Industrial Pipeline Products Pty Ltd. (Australia)
Inline plc (US, UK)
International Pipeline Products Ltd. (UK)
IST Molchtechnik GmbH (Germany, UK, US)
Kleiss & Co. (Netherlands)

Knapp Polly Pig Inc. (US)
Maintrend Services Ltd (UK)
OEG Co. Ltd. (Japan)
PII Pipeline Solutions (UK, Germany, US)
Pectel Group (UK)
Pigging Technology International Ltd. (Canada)
Pigs Unlimited Inc. (US)
Pigtek Ltd. (UK)
Pipeline Dehydrators Inc. (US)
Pipeline Engineering (UK, UAE)
Pipeline Pigging Products Inc. (US)
Pipeline Technologies Co. (China)
Rosen Group (Germany, Netherlands, US, Australia, Malaysia)
Südmo Components GmbH (Germany, South Africa)
Techno Pipe GmbH (Germany)
Tuboscope Vetco Pipeline Services (US, UK, Brazil, Mexico, Canada)
Vee Kay Vikram & Co. (India)
T D Williamson Inc. (US, UK)
Yong Shun Pigging services Co Ltd. (China)

Fittings/Components

Ceripro Co. (France)
Decoking Descaling Technology Inc. (Canada)
Enduro Pipeline Services Inc. (US)
Energy-Environmental Engineering GmbH (Germany)
GD Engineering (UK, US)
Girard Industries Inc. (US, UK)
GRM Fluid Controls (Canada)
Hydro Kleen Systems Inc (Canada)
Hygienic Pigging Systems Ltd. (UK)
Industrial Pipeline Products Pty Ltd. (Australia)
Inline plc (US, UK)
International Pipeline Products Ltd. (UK)
IST Molchtechnik GmbH (Germany, UK, US)
LTS Inc. (US)
Maintrend Services Ltd (UK)
OEG Co. Ltd. (Japan)
PII Pipeline Solutions (UK, Germany, US)
Pectel Group (UK)
Pigs Unlimited Inc. (US)
Pipeline Dehydrators Inc. (US)
Pipeline Engineering (UK, UAE)
Pipeline Pigging Products Inc. (US)
Pipeline Technologies Co. (China)
Südmo Components GmbH (Germany, South Africa)

Techno Pipe GmbH (Germany)
Vee Kay Vikram & Co. (India)
T D Williamson Inc. (US, UK)

Installation

Ceripro Co. (France)
Challenger Special Oil Services (France)
Enduro Pipeline Services Inc. (US)
Energy-Environmental Engineering GmbH (Germany)
GD Engineering (UK, US)
Hygienic Pigging Systems Ltd. (UK)
Industrial Pipeline Products Pty Ltd. (Australia)
International Pipeline Products Ltd. (UK)
IST Molchtechnik GmbH (Germany, UK, US)
Pectel Group (UK)
Pipeline Engineering (UK, UAE)
Pipeline Services LLC (PLS) (UAE)
Südmo Components GmbH (Germany, South Africa)
Tuboscope Vetco Pipeline Services (US, UK, Brazil, Mexico, Canada)
Vee Kay Vikram & Co. (India)
T D Williamson Inc. (US, UK)
Yong Shun Pigging services Co Ltd. (China)

9. PIGGING CONSULTANCY SERVICES

Utility Pigging

3P Services GmbH & Co. KG (Germany)
ALBAB Trading Co Ltd. (Saudi Arabia)
Baker Petrolite Corp. (US)
Battelle (US)
BG Technical Ltd. (Nigeria, US)
BJ Process & Pipeline Services (Canada, US, UK, UAE)
BJB Company (US)
Challenger Special Oil Services (France)
Copipe Systems Ltd (UK)
Cosmo Engineering Co. Ltd. (Japan)
DEL (UAE)
Enduro Pipeline Services Inc. (US)
Fullkote Pipeline Services Inc. (Canada)
Glendee (UK) Ltd. (UK)
A Hak Industrial Services bv (Netherlands, Germany, Spain)
Halliburton (UK, US, Dubai)
Hydrocarbon Resources Development Co Pvt Ltd. (India)
Hydrostatic Testing Consultants Ltd.. (UK)
IKM Testing AS (Norway, UK, Asia)
Industrial Pipeline Products Pty Ltd. (Australia)

Inline plc (US, UK)
International Pipeline Products Ltd. (UK)
Trevor Jee Associates (UK)
Knapp Polly Pig Inc. (US)
LTS Inc. (US)
H O Mohr Research & Engineering Inc. (US)
N-SPEC® (US)
NDT Systems & Services AG (Germany)
PII Pipeline Solutions (UK, Germany, US)
Pigging Technology International Ltd. (Canada)
Pigs Unlimited Inc. (US)
Pigtek Ltd. (UK)
Pipeline Dehydrators Inc. (US)
Pipeline Engineering (UK, UAE)
Pipeline Pigging Products Inc. (US)
Pipeline Research Ltd. (UK)
Pipeline Services LLC (PLS) (UAE)
Pipeline Technologies Co. (China)
John Pitchford Pipeline Inspection Consultant Ltd. (UK)
Rosen Group (Germany, Netherlands, US, Australia, Malaysia)
Sahara Industrial Services (SAPESCO) Ltd. (Egypt)
John Smart Consulting Engineers (US)
Tom Sowerby (UK)
Techno Pipe GmbH (Germany)
Tuboscope Vetco Pipeline Services (US, UK, Brazil, Mexico, Canada)
Vee Kay Vikram & Co. (India)
Vhelbherg International (UK)
T D Williamson Inc. (US, UK)
Yong Shun Pigging services Co Ltd. (China)

In-Line Inspection Pigging

Battelle (US)
Brown Corrosion Services Inc. (US)
Challenger Special Oil Services (France)
DEL (UAE)
Inline plc (US, UK)
Trevor Jee Associates (UK)
NGKS International Corp. (Canada)
Pipeline Research Ltd. (UK)
Pipeline Technologies Co. (China)
John Pitchford Pipeline Inspection Consultant Ltd. (UK)
Röntgen Technische Dienst bv (Netherlands)
John Smart Consulting Engineers (US)
Tom Sowerby (UK)
Vhelbherg International (UK)
Weatherford Pipeline & specialty Services (UK)

Cable Operated Inspection Pigging

Brown Corrosion Services Inc. (US)
DEL (UAE)
Inline plc (US, UK)
John Smart Consulting Engineers (US)
Tom Sowerby (UK)
Vhelbherg International (UK)

Industrial Pigging

BJ Process & Pipeline Services (Canada, US, UK, UAE)
Baker Petrolite Corp. (US)
Ceripro Co. (France)
Challenger Special Oil Services (France)
Enduro Pipeline Services Inc. (US)
Energy-Environmental Engineering GmbH (Germany)
GD Engineering (UK, US)
Girard Industries Inc. (US, UK)
Halliburton (UK, US, Dubai)
Hygienic Pigging Systems Ltd. (UK)
Industrial Pipeline Products Pty Ltd. (Australia)
Inline plc (US, UK)
International Pipeline Products Ltd. (UK)
IST Molchtechnik GmbH (Germany, UK, US)
LTS Inc. (US)
Maintrend Services Ltd (UK)
H O Mohr Research & Engineering Inc. (US)
OEG Co. Ltd. (Japan)
Pectel Group (UK)
Pigs Unlimited Inc. (US)
Pigtek Ltd. (UK)
Pipeline Dehydrators Inc. (US)
Pipeline Engineering (UK, UAE)
Pipeline Pigging Products Inc. (US)
Pipeline Research Ltd. (UK)
Pipeline Services LLC (PLS) (UAE)
Pipeline Technologies Co. (China)
John Pitchford Pipeline Inspection Consultant Ltd. (UK)
Rosen Group (Germany, Netherlands, US, Australia, Malaysia)
Tom Sowerby (UK)
Südmo Components GmbH (Germany, South Africa)
Techno Pipe GmbH (Germany)
Tuboscope Vetco Pipeline Services (US, UK, Brazil, Mexico, Canada)
Vee Kay Vikram & Co. (India)
T D Williamson Inc. (US, UK)

Pig Location and Tracking

BJB Company (US)
Challenger Special Oil Services (France)
Crostek Corp. (Canada)
DEL (UAE)
Industrial Pipeline Products Pty Ltd. (Australia)
Inline plc (US, UK)
Trevor Jee Associates (UK)
H O Mohr Research & Engineering Inc. (US)
NGKS International Corp. (Canada)
Nautronix Ltd. (UK)
Online Electronics Ltd. (UK, US)
PII Pipeline Solutions (UK, Germany, US)
Pigtek Ltd. (UK)
Pipeline Research Ltd. (UK)
Pipeline Technologies Co. (China)
John Pitchford Pipeline Inspection Consultant Ltd. (UK)
Tom Sowerby (UK)
Vee Kay Vikram & Co. (India)
Vhelbherg International (UK)

Legal/Legislative Requirements

Joseph C Caldwell & Associates (US)

10. OTHER COMPANIES & ORGANIZATIONS INVOLVED WITH PIGGING

BHR Group (UK)
Clarion Technical Conferences (US)
Gas Research Institute (US)
Inline Inspection Association (US)
Oildom Publishing Company of Texas Inc. (US)
Pigging Products & Services Association (UK)
Pipes & Pipelines International (UK)
Scientific Surveys Ltd. (UK)

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16C - Companies Supplying Products and Services

Note that telephone and fax numbers have been given in their national forms. For international dialing, country and access codes will need to be added and, in some cases, the numbers themselves will need modification (e.g. for international dialing to the UK, the first zero is omitted).

3P Services GmbH & Co. KG, Lenzfeld 9, 49811 Lingen, Germany
Website: www.3p-services.com Tel: 049 591 71007-0 fax: 049 591 71007-11

Advanced Engineering Solutions Ltd
South Nelson Road, South Nelson Industrial Estate, Cramlington Northumberland, NE23 1WF, UK
Website: www.aesengs.co.uk Tel: 01670 739999 fax: 01670 717999

AJAKS S.A.
Ostrowska 366/374 A, 61-312 Poznan, Poland
Website: www.ajaks.com.pl Tel: 061 870 50 15 fax: 061 879 86 30

ALBAB Trading Co. Ltd.
P O Box 31800, Alkhobar - 31952, Saudi Arabia
Website: www.energygroup-gcc.com Tel: 3 857 9780 fax: 3 859 1563

Apache Pipeline Products
2115-91 Avenue, Edmonton, Alberta, Canada T6E 1L1
Website: www.apachepipe.com Tel: 780 416 4850 fax: 780 416 4829

Argus Machine Co Ltd
5820 - 97 Street, Edmonton, Alberta, Canada T6E 3J1
Website: www.argusmachine.com Tel: 780 434 9451 fax: 780 434 9909 e-mail:

Baker Atlas
2001 Rankin Road, Houston, Texas 77073-5100, USA
Website: www.bakerhughes.com/bakeratlas Tel: 713 625 6010 fax: 713 625 4525

Baker Petrolite Corp.
12645 West Airport Blvd., Sugar Land, Texas 77478, USA
Website: www.bakerpetrolite.com Tel: 281 276 5400 fax: 281 275 7218

B.G. Technical Ltd.
No.8 25th Street, DDPA (Bendel Estate), Ugborikoko Effurun, P O Box 1920, Warri, Nigeria
Tel: 53 254492 fax: 53 254492
Other locations:
212, Trans Amadi Layout, Phase II, P O Box 6726, Port Harcourt, Nigeria
Tel: 84 236774 fax: 84 238581
BGT Inc., P.O. Box 1867, Sugar Land, Texas, USA 77487
Tel: 281 491 4232 fax: 281 491 4348

BHR Group
Cranfield, Bedford, MK43 0AJ, UK
Website: www.bhrgroup.com Tel: 01234 750422 fax: 01234 750074

BJ Process & Pipeline Services
6920-36 Street SE Calgary, Alberta, Canada T2C 2G4
Tel: 403 531 5400 fax: 403 236 8740
Other locations:
BJ Process & Pipeline Services Ltd., Badentoy Avenue, Badentoy Park Industrial Estate Portlethen, Aberdeen, AB1 4YB, UK
Tel: 01224 401401 fax: 01224 401501
Beeston Royds Industrial Estate, Geldered Road, Leeds, LS12 6EY, UK
Tel: 0113 251 1300 fax: 0113 251 1391
BJ Services Company Middle East, PO Box 61110, Oilfield Supply Centre, Warehouse No. B25-A, Dubai, UAE
Tel: 4883 5558 fax: 4883 8397
Pipeline Dehydrators Inc
414 Pinckney, P.O. Box 8898 Houston, Texas, 77249-8898, USA
Tel: 713 224 1105 fax: 713 229 0541

BJB Company
4707 Melville, Midland, Texas 79705, USA
Tel: 915 683 7808 fax: 915 683 7807

BKW Inc.
PO Box 581611, Tulsa, Oklahoma 74158, USA
Website: www.bkwinc.com Tel: 918 836 6767 fax: 918 836 0141

Battelle
505 King Avenue, Columbus, Ohio 43201, USA
Website: www.battelle.org Tel: 614 424 6424

Brown Corrosion Services Inc.
1648 West Sam Houston Parkway North, Houston, Texas 77043, USA
Tel: 713 468 4765 fax: 713 468 7518

CALtec
BHR Group Ltd, The Fluid Engineering Centre, Cranfield, Bedfordshire, MK43 0AJ, UK
Website: www.bhrgroup.com Tel: 01234 750422 fax: 01234 750074

Alexander Cardew Ltd.
Unit 27, Chelsea Wharf, 15 Lots Road, London SW10 0QJ, UK
Website: www.cardew.com Tel: 0207 235 3785 fax: 0207 352 4635

The Carver Corporation Inc.
113 E. Colorado Street, Walters, Oklahoma 73572, USA
Tel: 580 875 2307 fax: 580 875 3101

Ceripro Co.
2 Bis Avenue Jean Moulin, 90000 Belfort, France
Website: www.ceripro.com Tel: 03 84 58 96 85 fax: 03 84 58 96 88

Challenger Special Oil Services
49 bis, Ave Franklin Roosevelt, 75008 Paris, France
Website: www.challenger-sos.com Tel: 1 53 53 08 80 fax: 1 45 63 65 07

ClampOn AS
Damsgaardsgt. 131, N-5162 Laksevaag, Bergen, Norway
Website: www.clampon.com Tel: 55 948850 fax: 55 948855
Other location:
ClampOn Inc., 15720 Park Row, Suite 300, Houston, Texas 77084, USA
Tel: 281 492 9805 fax: 281 492 9810

Clarion Technical Conferences
3401 Louisiana St., Suite 255, Houston Texas 77002, USA
Website: www.clarion.org Tel: 713 521 5929 fax: 713 521 9255

Control Devices Inc.
524 South Main Street, Broken Arrow, Oklahoma 74012, USA
Website: www.pigging.com Tel: 918 258 6068 fax: 918 251 9851

Cooper Cameron (UK) Ltd.
Queen Street, Stourton, Leeds, LS10 1SB, UK
Website: www.camerondiv.com Tel: 0113 270 1144 fax: 0113 276 4564

Copipe Systems Ltd - PSL Group
Badentoy avenue, Portlethen, Aberdeen AB12 4YB, UK
Website: www.pslg.com Tel: 01224 783008 fax: 01224 783445

Cornerstone Pipeline Inspection Group
PO Box 3307, Houston, Texas 77253-3307
Website: www.cpig.com Tel: 713 869 5040

Cosmo Engineering Co. Ltd.
Tennoz Parkside Bldg., 5-8 Higashi-Shinagawa, 2-chome Shinagawa-ku, Tokyo 140, Japan
Tel: 3 5462 0172 fax: 3 5462 2118

G A Cotten Co.
PO Box 580066, Tulsa, Oklahoma 74158-0066, USA
Tel: 918 835 3663 fax: 918 835 3663

Crostek Corp
#4, 6320 - 50 Ave, Red Deer, Alberta, Canada T4N 4C6
Website: www.crostek.com Tel: 403 347 0346 fax: 403 309 2434

Decoking Descaling Technology Inc.
#2-4873 - 46 Street, Lacombe, Alberta T4L 2B2, Canada
Website: www.decoking.com Tel: 403 346 7444 fax: 403 342 7447

DEL
PO Box 908, Abu Dhabi, UAE
Tel: 2 671 6750 fax: 2 671 6750

Diascan Technical Diagnostics Centre Open Joint-Stock Company
Kuibyshev Str 7, 140501 Lukhovitcy, Moscow Region, Russia
Tel: 095 950 82 92, 950 82 95 fax: 095 950 82 91, 950 80 35

EDAG Engineering and Design AG
Website: www.edag.de Reesburgstrasse 1, D-36039 Fulda, Germany
Tel: 06 61 60 00-0 fax: 06 61 60 00-2 23

Elastomers Australia
P O Box 125, Niddrie, Victoria 3042, Australia
Tel: 03 9338 3033 fax: 03 9338 7580

Enduro Pipeline Services Inc.
5002 S 45th W Ave, Tulsa, Oklahoma 74107, USA
Website: www.enduropls.com Tel: 918 446 1934 fax: 918 446 8125

Energy-Environmental Engineering GmbH
Meiendorfer Strasse 205, D-22145 Hamburg, Germany
Website: www.2eg.de Tel: 040 333 9520 fax: 040 333 952 22

Fluenta a/s
Solsheimsgaten 9A, P O Box 2364, N-5037 Solsheimsviken, Norway
Website: www.akvaplan.no Tel: 55 599555 fax: 55 599500
Other locations:
Fluenta US Inc., 11757 Katy Freeway, Houston, Texas 77079, USA
Tel: 713 531 8833 fax: 713 531 8830

Frames Energy Systems bv
PO Box 21, 2380 AA Zoeterwoude, Netherlands
Website: www.frames-group.com Tel: 071 581 1800 fax: 071 541 4484

FTL Seals Technology Ltd
Bruntcliffe Avenue, Leeds 27 Business Park, Morley, Leeds LS27 0TG, UK
Website: www.ftlseals.co.uk Tel: 0113 252 1061 fax: 0113 252 2627

Fullkote Pipeline Services Inc.
4873 46th Street, La Combe, Alberta, Canada T4L 2B2
Tel: 403 343 7677 fax: 403 347 6597

Gas Research Institute
1700 S. Mount Prospect Road, Des Plaines, Illinois 60018-1804, USA
Website: www.gri.org Tel: 847 768 0500 fax: 847 768 0501

GD Engineering
Retford Road, Worksop, Notts S80 2PY, UK
Website: www.gdengineering.co.uk Tel: 01909 482323 fax: 01909 477902
Orther location:
GD Closure Systems, 6630 Roxburgh Drive, Suite 175, Houston, Texas 77041, USA
Tel: 713 896 8955 fax: 713 937 0968

Girard Industries Inc.
6531 N Eldridge Parkway, Houston, Texas 77041, USA
Website: www.girardind.com Tel: 713 466 3100 fax: 713 466 8050
Other locations:
Girard Industries Europe, Unit A3, Olympic Business Park, Dundonald, Ayrshire KA2 9BE, UK
Tel: 01563 851062 fax: 01563 851411

Glendee (UK) Ltd
18 Blezard Business Park, Brenkley Way, Seaton Burn, Newcastle upon Tyne, NE13 6DS, UK
Tel: 0191 217 1661 fax: 0191 217 1662

GRM Fluid Controls
2115 91st Avenue, Edmonton, Alberta, Canada, T6P 1L1
Website: www.grm.com Tel: 780 416 4823 fax: 780 416 4829

Gulf Petrochemical Services LLC
PO Box 1633, Jibroo, Postal Code 114, Sultanate of Oman
Website: www.gpsoman.com Tel: 601436 fax: 699446

A Hak Industrial Services bv
Steenoven 2-6, 4196 HG Tricht, P O Box 151, 4190 CD Geldermalsen, The Netherlands
Tel: 0345 579211 fax: 0345 579379
Other locations:
Integrated Plant & Pipeline Solutions GmbH, Am Heiligenstock 12, D-6366 Wölfersheim, Germany
Tel: 06036 5279 fax: 06036 5182
A Hak Servicios Quimicos y Petroquimicos SL, Calle del Cobre nr.14, Poligono Industrial
Camponuevo, 28863 Cobena, Madrid, Spain
Tel: 091 620 7990 fax: 091 620 7991

Halliburton
Halliburton House, Pitmedden Road, Dyce, Aberdeen AB21 0DP, UK
Website: www.halliburton.com Tel: 01224 776000 fax: 01224 776472
Other locations:
2600 South 2nd Street, Duncan, Oklahoma 73536-0439, USA
Tel: 580 251 4643 fax: 580 251 3189
PO Box 3111, Dubai, UAE
Tel: 4 331 0666 fax: 4 331 0442

Hydrocarbon Resources Development Co Pvt Ltd.
Oberoi Garden Estates No.4123, 'D' Wing, 4th Floor, Off Saki Vihar Road, Chandivali, Andheri (East), Mumbai - 400 072 India
Tel: 22 850 0971 fax: 22 850 0232

Hydro Kleen Systems Inc.
7889 48th Street, Red Deer, Alberta, Canada T4P 2H6
Website: www.hydrokleen.biz Tel: 403 347 8018 fax: 403 347 9433
Other locations:
Pinnacle Pigging Systems Inc., Box 1426, 210 Bourque Road, Nederland, Texas 77627, USA
Tel: 800 772 8018 fax: 403 347 9433
Hydro Kleen Systems Europe Ltd., The Armoury Building, Hawarden Airfield, Flint Road, Chester CH4 0GZ, UK
Tel: 01244 531666 fax: 01244 531600

HydroChem Industrial Services Inc.
900 Georgia Avenue, Deer Park, Texas 77536, USA
Website: www.hydrochem.com Tel: 713 393 5600 fax: 713 393 5950

Hydrostatic Testing Consultants Ltd.
Unit 427, Ash Road, Wrexham Industrial Estate, Wrexham, Clwyd LL13 9UG, UK
Website: www.htc.co.uk Tel: 01978 661182 fax: 01978 661184

Hygienic Pigging Systems Ltd
5 Edison Village, Highfields Science Park, University Boulevard, Nottingham NG7 2RF, UK
Website: www.hps-pigging.com Tel: 01159 254700 fax: 01159 254645

IKM Testing AS
Ljosheimveien 3, 4050 Sola, Norway
Website: www.ikm.no Tel: 51 64 90 00 fax: 51 64 90 01
Other locations:
IKM Testing UK Ltd., Euro-seas Centre, Blyth, Northumberland, NE24 1LZ , UK
Tel: 01670 541518 fax: 01670 541519
IKM Asia Pte. Ltd., 239 Pandan Loop, Singapore 128425
Tel: 777 8803 fax: 873 3951

Industrial Pipeline Products Pty Ltd.
25 Kolora Road, West Heidelberg, Victoria 3081, Australia
Tel: 03 9455 1088 fax: 03 9455 1080

Inline plc
P O Box 40877, Houston, Texas 77240-0877, USA
Website: www.inlineplc.com Tel: 713 973 0079 fax: 713 973 6614
Other locations:
Inline Services, P O Box 461, Horsham, West Sussex, RH13 7ZT, UK
Tel: 01403 790959 fax: 08701 321966
Pipeline Cleaners Inc, 1823 South 33rd, Fort Madison, Iowa, USA
Tel: 319 372 2061/800 372 2051 fax: 319 372 7091

Inline Inspection Association
14120 Interdrive East, Houston, Texas 77032
Website: www.iliassociation.org

International Pipeline Products Ltd.
Walkerville Industrial Estate, Catterick Garrison, North Yorkshire DL9 4RR, UK
Website: www.inpipeproducts.co.uk Tel: 01748 834577 fax: 01748 834121

IPSCO Flowserve
Sunningdale House, South Park Industrial Estate, Scunthorpe DN17 2TY, UK
Website: www.flowserve.com Tel: 01724 849904 fax: 01724 861033

IST Molchtechnik GmbH
Schierenberg 74, D-22145 Hamburg, Germany
Website: www.piggingsystems.com Tel: 040 679 9470 fax: 040 679 94710
Other locations:
Unit 4B, Barrowmore Enterprise Estate, Great Barrow, Chester CH3 7JS, UK
Tel: 01829 741555 fax: 01829 741555
431 Ohio Pike, Suite #211N, Cincinnati, OH 45255-3375, USA
Tel: 513 528 4949 fax: 513 528 4994

ITAG
Itagstrasse 5-17, D-29221 Celle, Germany
Website: www.itag-celle.de Tel: 05141 9140 fax: 05141 914234

ITAS
Postbox 739, 4090 Hafrsfjord, Nowway
Website: www.itas-no.com Tel: 51 552104 fax: 51 550600

Ixsea Oceano Ltd.
Unit 6, West Shore Business Centre, Long Craig Rigg, Edinburgh EH5 1QT, UK
Website: www.oceano.co.uk Tel: 0131 552 0303 fax: 0131 552 6619

Trevor Jee Associates
26 Camden Road, Tunbridge Wells, Kent TN1 2PT, UK
Website: www.tja.co.uk Tel: 01892 544725 fax: 01892 544735

Jenkins Newell Dunford Ltd
Retford, Notts., DN22 7AN, UK
Website: www.jnd.co.uk Tel: 01777 706777 fax: 01777 708141

KH Tecnomarine Ltd
1 Waldron Road, Montrose, Angus DD10 9BD, UK
Tel: 01674 663060 fax: 01674 663001

Kleiss & Co bv
Scheepmakersstraat 17, 3334 KG Zwijndrecht, The Netherlands
Tel: 0786 291328 fax: 0786 291314

Knapp Polly Pig Inc.
1209 Hardy St., Houston, Texas 77020, USA
Website: www.polypig.com Tel: 713 222 0146 fax: 713 222 7403
Other locations:
KPC (SEA) Ltd., Loyang Offshore Supply Base, Box No.5150, Loyang Crescent, Singapore 508988
Tel: 466 5533 fax: 466 1174
Knapp Limpro Naciomal SA De CV, P E Calles 199, APDO A-027, Guadalupe, N.L.Mexico 67150
Tel: 83 371717 fax: 83 377836

LTS Inc.
1193 Brittmore Park Drive, Houston, Texas 77041, USA
Website: www.ltsusa.com Tel: 832 467 4040 fax: 832 467 4240

Maihak AG
Semperstrasse 38, D-22303 Hamburg, Germany
Website: www.maikak.de Tel: 040 27894 0 fax: 040 27894 362

Maintrend Services Ltd
Telford Way, Stephenson Industrial Estate, Coalville, Leicestershire LE67 3HE, UK
Website: www.maintrend.co.uk Tel: 01530 817634 fax: 01530 817635

H O Mohr Research & Engineering Inc
12237 FM529, Houston, Texas 77041, USA
Website: www.stress.com Tel: 713 466 1527 fax: 713 896 6807

N-SPEC® a division of Brenntag
P O Box 81577, Lafayette, Louisiana 70598-1577, USA
Website: www.n-spec.com Tel: 337 272 0147 fax: 337 272 0153

NDT Systems & Services AG
Am Hasenbiel 6, 76297 Stutensee, Germany
Website: www.ndt-ag.com Tel: 07244 7415 0 fax: 07244 7415 97

NGKS International Corp.
32 Eleanor Circle, Richmond Hill, Ontario, Canada L4C 6K7
Tel: 905 771 9017 fax: 905 771 9065

NKK Corporation
14th Floor Park Tower, 3-7-1 Nishishinjuku Shinjuku-Ku, Tokyo 163-1014, Japan
Website: www.nkk.co.jp/products/engineering/pipeline-inspection
Tel: 03 3340 6098 fax: 03 3340 6106
Other locations:
NKK Europe Ltd., 4th Floor, West Block, 11 Moorfields High Walk, London EC2Y 9DE, UK
Tel: 0171 628 2161 fax: 0171 638 1374
NKK America Inc., 450 Park Avenue, New York, NY 10022, USA
Tel: 212 826 6250 fax: 212 826 6358

Nautronix Ltd.
Nautronix House, Howe Moss Avenue, Kirkhill Industrial Estate, Dyce, Aberdeen AB21 0GP, UK
Website: www.nautronix.com Tel: 01224 775700 fax: 01224 775800

OEG Co. Ltd.
1F Okada Building 2-1, Obase-cho, Tennoji-ku, Osaka, Japan
Tel: 06 6765 0817 fax: 06 6765 1424

Oildom Publishing Company of Texas Inc.
P O Box 941669, Houston, Texas 77094-8669, USA
Website: www.undergroundinfo.com Tel: 281 558 6930 fax: 281 558 7029

Oil States Industries
P O Box 670, Arlington, Texas 76004-0670, USA
Website: www.oilstates.com Tel: 817 548 4200 fax: 817 548 4250

Oil States Industries Inc., HydroTech Division
13111 Northwest Freeway, Suite 200, Houston, Texas 77040, USA
Website: www.oilstateshydrotech.com Tel: 713 510 2200 fax: 713 688 9166
Other location:
Oil States Industries HydroTech Division
Blackness Road, Altens Industrial estate, Aberdeen AB12 3LH, UK
Tel: 01224 896190 fax: 01224 896199

Online Electronics Ltd.
Suite 1, Unit 18, Riverside Business Centre, North Esplanade West, Aberdeen AB11 5RJ, UK
Website: www.online-electronics.com Tel: 01224 593500 fax: 01224 213903
Other location:
Millennium Tower, 10375 Richmond Avenue, Suite 1300, Houston, Texas 77042, USA
Tel: 832 242 3223 fax: 832 251 6691

Optimess Engineering GmbH
Gewerbepark Keplerstrasse 10-12, D-07549 Gera, Germany
Website: www.optimess.com Tel: 0365 734 9220 fax: 0365 734 9229

PEC Corporation
1-12-4 Suehiro-Cho, Tsurumi-Ku, Yokohama, Japan
Tel: 506 1560 fax: 506 1559

Pectel Group
Pectel Court, Burnt Mills Road, Basildon, Essex SS13 1DT, UK
Website: www.pectel-group.co.uk Tel: 01268 591222 fax: 01268 590998

Perco Engineering Services Ltd
Cornhill Close, Lodge Farm Industrial Estate, Northampton NN5 7UB, UK
Website: www.perco.co.uk Tel: 01604 590200 fax: 01604 590201

Pigging Technology International Ltd
5326-89th Street, NW, Edmonton, Alberta, Canada T6E 5P9
Website: www.powersurfr.com Tel: 780 450 9494 fax: 780 450 9393

Pigging Products & Services Association
PO Box 2, Stroud, Glos. GL6 8YB, UK
Website: www.piggingassnppsa.com Tel: 01285 760597 fax: 01285 760470
Other location:
P O Box 41737, Houston, Texas 77241-1737, USA

Pigs Unlimited Inc
23802 FM 2978, Suite B3, Tomball, Texas 77375, USA
Website: www.pigsunlimited.com Tel: 281 351 2749 fax: 281 351 4658

Pigtek Ltd
Unit 2, Turnoaks Business Park, Burley Close, Chesterfield, S40 2UB, UK
Tel: 01246 558855 fax: 01246 276223

PII Pipeline Solutions
Atley Way, Cramlington, Northumberland NE23 1WW, UK
Website: www.ge.com Tel: 0191 247 3200 fax: 0191 247 3101
Other locations:
Lorenzstrasse 10, D-76297 Stutensee, Germany
Tel: 07244 732-0 fax: 07244 732-123
7105 Business Park, Houston, Texas 77041, USA
Tel: 713 849 6300 fax: 713 937 0740

Pipe Equipment Specialists Ltd
66A Dukesway, Teeside Industrial Estate, Thornaby, Stockton-on-Tees TS17 9LT, UK.
Website: www.pipe-equipment.co.uk Tel: 01642 769789 fax: 01642 769456

Pipeguard of Texas
1544 Sawdust Road, Suite 607, The Woodlands, Texas 77380, USA
Website: www.pipeguard-texas.com Tel: 281 367 7384 fax: 281 367 7342

Pipeline Cleaners Inc. (See Inline plc)

Pipeline Dehydrators Inc. (See BJ Process and Pipeline Services Company)

Pipeline Engineering
Gatherley Road, Catterick Bridge, Richmond, North Yorkshire DL10 7JG, UK
Website: www.pipelineengineering.co.uk Tel: 01748 818341 fax: 01748 818039
Other location:
P O Box 4352, Abu Dhabi, United Arab Emirates
Tel: 2 626 7812 fax: 2 626 7812

Pipeline Inspection Co. Inc.
PO Box 55648, Houston, Texas 77255-5648 / 1919 Antoine, Houston, Texas 77055, USA
Website: www.picltd.com Tel: 713 681 5837 fax: 713 681 4838

Pipeline Pigging Products Inc.
PO Box 692005, Houston, Texas 77269, USA
Website: www.pipepigs.com Tel: 281 351 6688 fax: 281 255 2385

Pipeline Research Ltd
PO Box 5521, Glasgow G46 6YX, UK
Website: www.pipeline-research.com Tel: 0141 637 8093 fax: 0141 637 8093

Pipeline Services LLC (PLS)
PO Box 4500, Abu Dhabi, UAE
Tel: 2 555 4513 fax: 2 555 3993

Pipeline Technologies Co. of China Oil & Gas Pipeline Bureau (PTC)
No.166, Ainmin East Road, Langfang City, Hebei Province, P.R.China, 065000
Website: www.cnptc.com Tel: 316 217 4491 fax: 316 207 4927

Pipes & Pipelines International
PO Box 21, Beaconsfield, Bucks, HP9 1NS, UK
Website: www.pipemag.com Tel: 01494 675139 fax: 01494 670155

John Pitchford Pipeline Inspection Consultant Ltd.
1 Rectory Dene, Morpeth, Northumberland, NE61 2TD, UK
Website: www.pitchford-in-line.co.uk Tel: 01670 515251 fax: 01670 515251

Plainsman Mfg. Ltd.
305 McEntire Road, Edmonton, Alberta, Canada T6E 5J7
Tel: 780 406 9800 fax: 780 463 9800

Plugging Specialists International AS (PSI)
Fabrikkveien 15, PO Box 8011, Postterminalen, N-4068 Stavanger, Norway
Website: www.plugging.com Tel: 51 44 32 40 fax: 51 44 32 41
Other locations:
Plugging Specialists International (PSI)
c/o Cape, 22 Jalan Terusan, Singapore 619299
Tel: 6262 2282 fax: 6262 4351
Plugging Specialists International (PSI)
16225 Park Ten Place Drive, Suite 500, Houston, Texas 77084, USA
Tel: 281 994 4040 fax: 281 994 4041

Pronal SA
ZI Roubaix Est, BP 18, 59115 Leers, France
Website: www.pronal.com Tel: 032099 7500 fax: 032099 7520

Röntgen Technische Dienst bv
Delftweg 144, 3046 NC Rotterdam, Netherlands
Website: www.rtd.nl Tel: 010 208 8208 fax: 010 415 8022

Rosen Group
(Technology & Research Center) Am Seitenkanal 8, D-49811 Lingen (Ems), Germany
Website: www.RosenInspection.net Tel: 0591 91 360 fax: 0591 91 36121
Other locations:
Rosen Australia Pty Ltd
Adamco Business Park, Unit B3/2A Westall Road, Clayton, Victoria 3168, Australia
Tel: 3 9544 4922 fax: 3 9544 4933
H Rosen USA Inc., 14120 Interdrive East, Houston, Texas 77032, USA
Tel: 281 442 8282 fax: 281 442 8866
H Rosen Engineering (M) Sdn Bhd., No.6, Jalan Pengarah U1/29, Seksyen U1, HICOM Glenmarie Industrial Park, 40150 Shah Alam, Selangor, Malaysia
Tel: 3 7805 5000 fax: 3 7805 4000
Rosen Europe BV, Vondellaan 4, 7576 AC Oldenzaal, The Netherlands
Tel: 0541 587000 fax: 0541 587130

Sahara Industrial Services (SAPESCO) A.R.E.
Website: www.sapesco.com P O Box 703, #2 Road 256, New Maadi, Cairo, Arab Republic of Egypt
Tel: 2 519 4800 fax: 2 519 4900

Schlumberger Well Services
153 E. 53rd Street, 57th Floor, New York City, New York 10022, USA
Website: www.slb.com Tel:212 350 9400

Scientific Surveys Ltd.
PO Box 21, Beaconsfield, Bucks, HP9 1NS, UK
Website: www.pipemag.com Tel: 01494 675139 fax: 01494 670155

Scomark Engineering Ltd.
Church Gresley Industrial Estate, Church Street, Church Gresley, Swadlincote, Derbyshire, DE11 9NR, UK.
Tel: 01283 218222 fax: 01283 226468

Select Industries Inc.
PO Box 2450, Wichita Falls, Texas 76307, USA
Website: www.selectindustries.com Tel: 817 855 0461 fax: 817 855 2734

Hermann Sewerin GmbH
Robert-Bosch-Strasse 3, D-33334 Gütersloh, Germany
Website: www.sewerin.de Tel: 05241 934-0 fax: 05241 934-444

SFE Global
360 Grand Avenue, Suite 187, Oakland, California 94610, USA
Website: www.sfeonline.com Tel: 510 251 2517 fax: 510 251 2519
Other location:
SFE Global, #4, 3600-19th Street NE, Calgary, Alberta, Canada T2E 6V2
Tel: 403 293 0181 fax: 403 293 0180

SiirtecNigi S.p.A.
2 via Algardi, 20148 Milan, Italy
Website: www.sini.it/press.html Tel: 0239 2231 fax: 0239 223010

Skeltonhall Ltd.
70 Carwood Road, Sheffield S4 7SD. UK
Website: www.skeltonhall.co.uk Tel: 0114 243 1332 fax: 0114 244 9579

John Smart Consulting Engineers
14210 Carolcrest Drive, Houston, Texas 77079, USA
Tel: 281 493 5946 fax: 281 493 5946

Smith Flow Control Ltd.
6 Waterside Business Park, Eastways Industrial Estate, Witham, Essex CM8 3YQ, UK
Website: www.smithflowcontrol.com Tel: 01376 517901 fax: 01376 518720

Tom Sowerby
12 Maple Grove, Prudhoe, Northumberland NE42 6PU, UK
Tel: 01661 833571

Star Products
P O Box 404, Montgomery, Texas 77356, USA
Website: www.foampigs.com Tel: 409 448 6529 fax: 409 448 6529

Südmo Components GmbH
Industriestrasse 7, D-73469 Riesburg, Germany
Website: www.sudmo.com Tel: 09081 803-0 fax: 09081 803-158
Other location:
Südmo South Africa (Pty) Ltd., Unit 10, N'Dabeni, Cape Town, South Africa
Tel: 021 531 6646 fax: 021 531 0104

S.U.N. Engineering Inc.
10031 East 52nd St., Tulsa, Oklahoma 74146, USA
Website: www.sunengineeringinc.co Tel: 918 627 0426 fax: 918 627 3310

Synetix Services (Tracerco Diagnostics)
PO Box 1, Billingham, Cleveland TS23 1LB, UK
Website: www.ici.com Tel: 01642 375500 fax: 01642 370704
Other locations:
Synetix USA, 1100 Hercules, Suite 200, Houston, Texas 77058, USA
Tel: 713 488 0039 fax: 713 488 1646
Synetix-Dialog Alliance Asia, 122 Middle Road, #07-09 Midlink Plaza, Singapore 188973
Tel: 336 3377 fax: 338 9929

TRAPIL - Société des Transports Pétroliers par Pipeline
4 route du Bassin no.6, BP 36, 92230 Gennevilliers Cedex, France
Website: www.trapil.com Tel: 1 47 92 47 60 fax: 1 47 92 47 10

Techno Pipe GmbH
In der Au 13, D-61273 Wehrheim 1, Germany
Tel: (49) 6081 56066, fax: (49) 6081 59156

Tube Turns Technologies Inc.
2900 W Broadway, Box 32160, Louisville, Kentucky 40232-2160, USA
Website: www.tubeturns.com Tel: 502 774 6011 fax: 502 774 6304

Tuboscope Vetco Pipeline Services Inc.
PO Box 808, 2835 Holmes Rd, Houston, Texas 77001, USA
Website: www.tuboscope-pipeline.com Tel: 713 799 5401 fax: 713 799 5406
Other locations:
Tuboscope Pipeline Services Ltd., Unit 11, Woolmer Industrial Est., Bordon, Hants. GU35 9QE, UK
Tel: 01420 475855 fax: 01420 489538
Tuboscope Pipeline Services Canada Inc., 604 19th Avenue, Nisku, Alberta T9E 7WI, Canada
Tel: 780 955 8611 fax: 780 955 8615
Tuboscope do Brasil, R. Bartolomeu Portela, n 10 Apt 302, Botafogo, CEP: 22-290-190, Rio de Janeiro, Brazil
Tel: 21 2244 3770 fax: 21 2244 3931
Tuboscope Mexico SA de CV, Baltimore 92 Col. Nochebuena, C.P.03720 Mexico, DF
Tel: 55 5563 1920 fax: 55 5615 3492

T.U.E. (Systems) Ltd., HQS Wellington, Temple Stairs, Victoria Embankment, London WC2R 2PN UK
Website: www.tuesystems.com Tel: 01241 870442 fax: 0701 955332

UCISCO Inc. (a wholly-owned subsidiary of Praxair Inc.)
222 Pennbright, Houston, Texas 77090, USA
Website: www.praxair.com Tel: 713 872 2100 fax: 713 872 2111

Ura-Flex Mfg. Inc.
PO Box 696, Mansfield, Texas 76063, USA
Website: www.ura-flex.com Tel: 817 477 1166 fax: 817 315 7270

Vee Kay Vikram & Co.
B-205 Popular Centre Ring Road, Satellite, Ahmedabad - 380 015, India
Website: www.vkvc.com Tel: 79 677 9257, fax: 79 677 9079

Vhelbherg International
16 Regents Mews, Horley, Surrey RH6 7AN, UK
Website: www.vhelbherg.com Tel: 01293 821292 fax: 01293 821296

Weir Valves & Controls
PO Box B27, Huddersfield, West yorkshire HD2 2UR, UK
Website: www.weirvalve.com Tel: 01484 820820 fax: 01484 820220

TD Williamson Inc.
(Pigging Products) P O Box 1121, Tulsa Oklahoma 74101, USA
Website: www.tdwilliamson.com Tel: 918 447 5400 fax: 918 664 7091
(Pipeline Services) P O Box 1286, Tulsa Oklahoma 74101, USA
Tel: 918 447 5500 fax: 918 447 5550
Other location:
TD Williamson (UK) Ltd., Faraday Road, Dorcan Way, Swindon, Wiltshire SN3 5HF, UK
Tel: 01793 603600 fax: 01793 603601

Weatherford Pipeline & Specialty Services
Unit 3, Newhailes Industrial Estate, Musselburgh, EH21 6SY, UK
Website: www.pipeline-inspection.com Tel: 0131 653 3700 fax 0131 653 3707

Yong Shun Pigging Services Co Ltd.
92 Guang Ming Dong Road, Lang Fang, Hebei Province 06500, Peoples Republic of China
Website: www.pipelinepig.com.cn Tel: 316 221 1511 fax: 316 221 1911