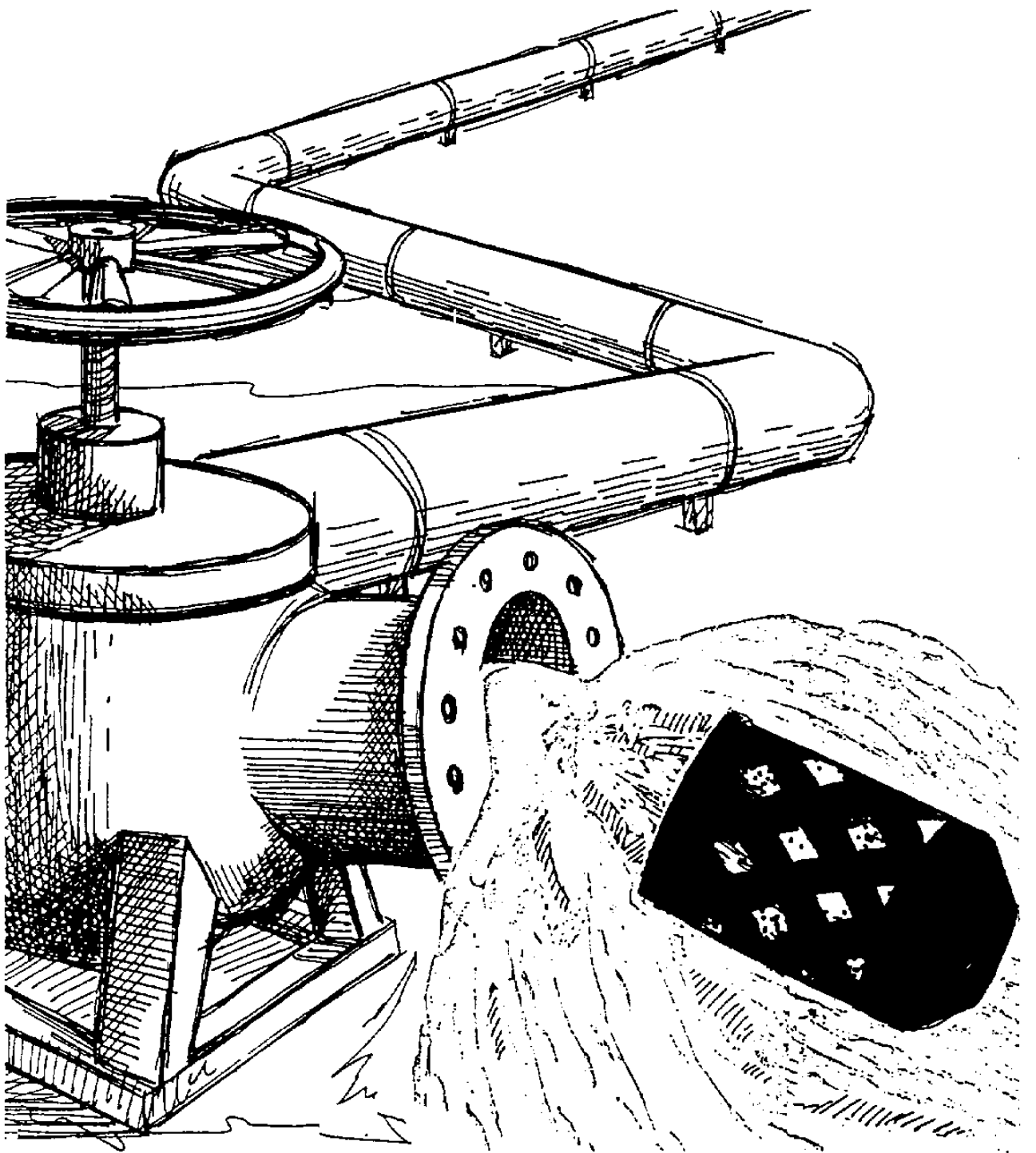


## **COBALCH RØRRENSNING**

### **Råd og vink om design af rørsystemer**



## 1.0 Pipeline design for pigging

The ideal pipeline for pigging world:

- 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
- contain no valves or any other devices
- be pumping a light, refined oil at a speed of about 1 meter per second.

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, 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.

### 1.1 Pipeline dimensions

#### 1.1.1 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 pigging product and the elastomer components. An epoxy lined steel pipeline will create 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 160 kilometers apart (100 miles)
- refined products pipelines, 240 miles apart (150 miles)
- crude oil pipelines, 320 kilometers apart (200 miles)

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 800 kilometers (500 miles) between pig traps and there is crude oil pipeline in the United States that has approximately 960 kilometers (600 miles) between pig traps.

#### 1.1.2 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.

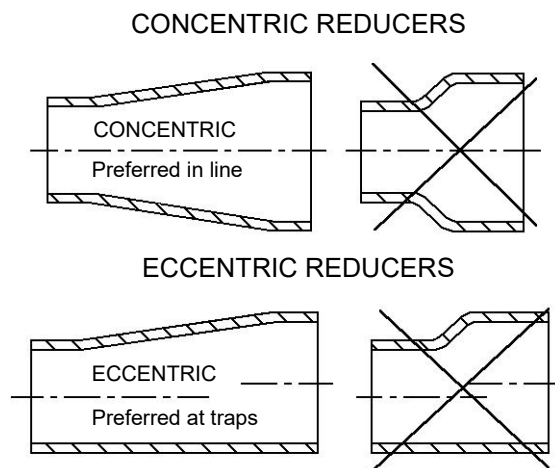
Consideration must also be given to the wall thickness in comparison to the pipe diameter since large diameter, thin wall pipe may be suitable for the operating conditions but may be difficult to install because of the handling of thin wall pipe. The wall thickness may also vary because of external conditions such as the population density near the pipeline right-of-way, highway crossing, 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.

### 1.1.3 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 gr. 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 oversized and the center line of the pig when it is in the trap is almost on the same center line as the pipe.



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 pipes 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 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.

## 1.2 Pipeline materials

### 1.2.1 Base materials

Most pipelines are of steel. however they are also made of cast iron, asbestos cement, reinforced concret, 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 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 diameter and pressures increased, pipeline companies changed the material to steels of higher yield strengths in order to minimise 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 higher carbon contents. 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.

## 1.2.2 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 lining 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.

## 1.2.3 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 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.

# 1.3 Bends

## 1.3.1 Forged bends

Bends with a relatively short radius must be factory made and are generally forged to a number of different 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 bends are 1 1/2D (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 1 1/2D bend and 36" radius for the 3D bend.

Forged bends are available with 90 degree, 45 degree and sometimes 22 1/2 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.

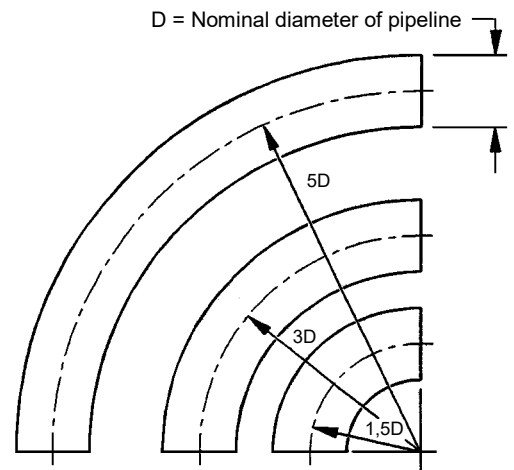
Short radius (one D) bends should not be used in pipelines if pigs are to be run. Long radius elbows (1 1/2D) are, with a few exceptions, really only suited for spheres. Pigs can be designed to pass long radius elbows but they are generally less effective than those that require a longer radius bend.

For pigging bends should have a minimum radius as follows:

- 1,5D for pipelines 4" and smaller
- 3D for 6" through 12" lines
- 5D 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.



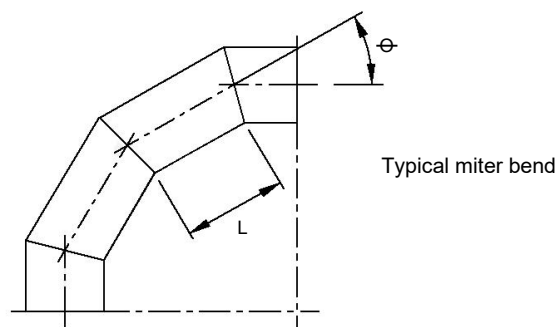
### 1.3.2 Field bends

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.

### 1.3.3 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.



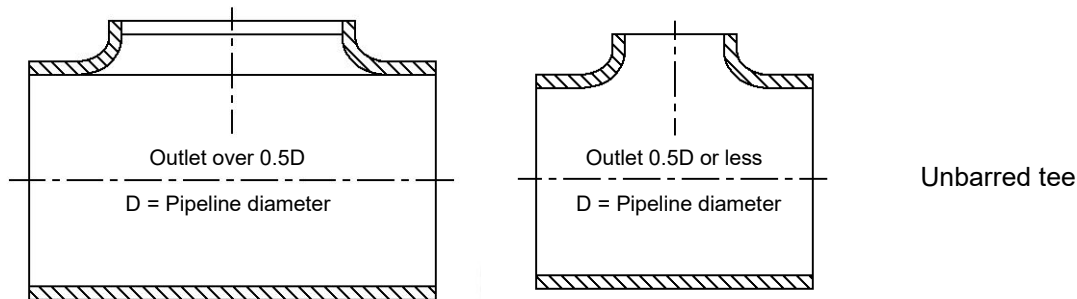
## 1.4 Offtakes

### 1.4.1 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 "nossing" into the side outlet, but it will help to guide any other attachment such as cleaning brushes or blades, wheels, sensors, ect..

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.



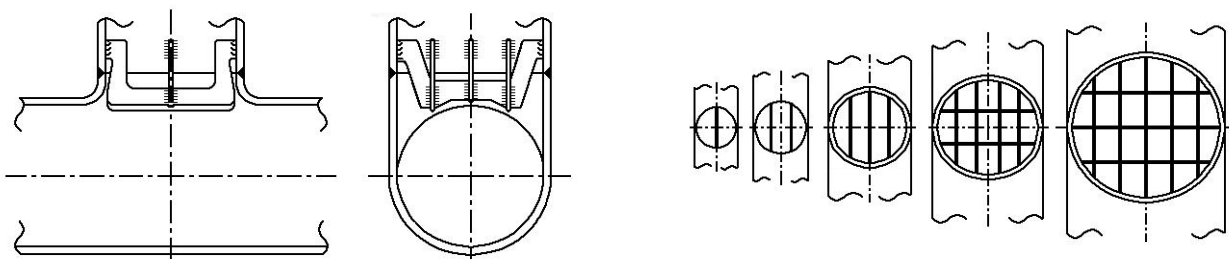
#### 1.4.2 Barred tees

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 ect. 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"x4" tees) to about 4" (100 mm) apart for the larger sizes (e.g. 30"x30" 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 larger. Most tapping fitting manufacturers make fittings that will allow guide bars to be installed across the outlet after the tap has been made.



#### 1.4.3 Sphere or flow tees

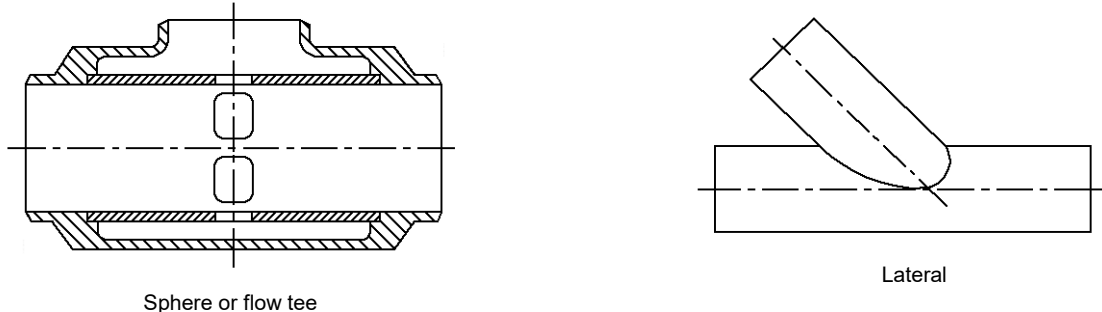
A sphere has a single line seal and therefore it will not pass some offtakes that a pig, with its multiple seals, would pass. The single line seal allows the driving fluid to bypass at the offtake and the sphere may stop at that point.

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.

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.



#### 1.4.4 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.

### 1.5 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.

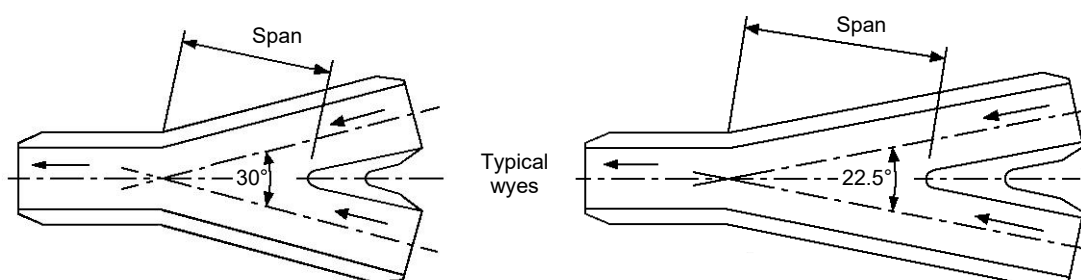
There are a growing number of wye junctions installed. It must be remembered that pigs can only traverse these in one direction: from the laterals into the main line. Thus any possible advantage of utilizing the bi-directional capability of a particular type of pig in these lines is partially, or totally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

#### 1.5.1 Convergence angle

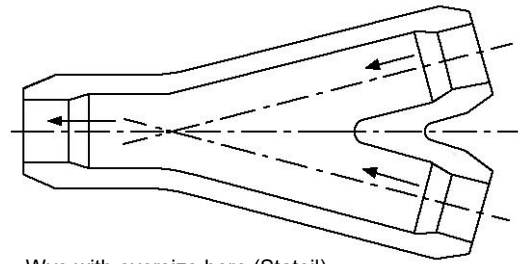
Most wyes installed to date have a 30 degree included convergence angle. At least one is known to have a 22 degree convergence angle and another is 25 degrees. The shallower angle reduces the impact that the pig makes with the opposite side as it traverses the junction, but it increases the length over which the pig will lose its 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.

#### 1.5.2 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.



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.



Wye with oversize bore (Statoil)

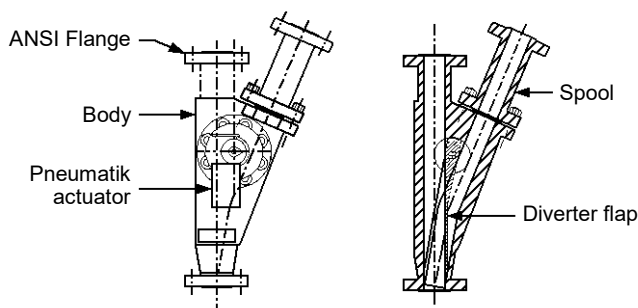
## 1.6 Diverters

Most pipelines 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 growing demand, 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.

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 recently been patented for industrial pigging systems utilizes magnetic forces to guide the pig into the desired branch. For pipelines however, all except 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.

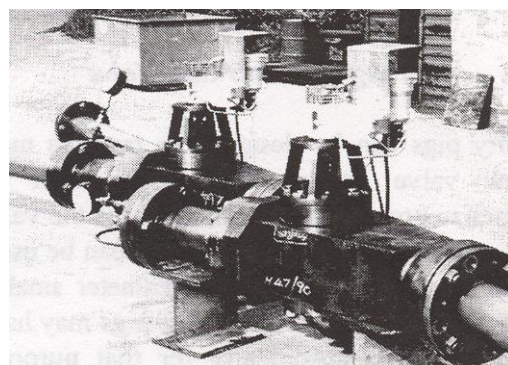
Typical diverters for low pressure pipeline systems are made by Webb Services Inc. and GD Engineering, while high pressure diverters of this basic design have been patented by BP/Seanor a.s. in Norway and Cooper Oil Tools. The Cooper Oil Tools design is unusual in that one outlet is on te center line 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.

Coop oil Tools also manufacture 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 seperately bored holes, one above the other, and at differing angles, so that it forms a continuous pipeline from 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 Tool



Pig diverter Courtesy: Cooper Oil Tools

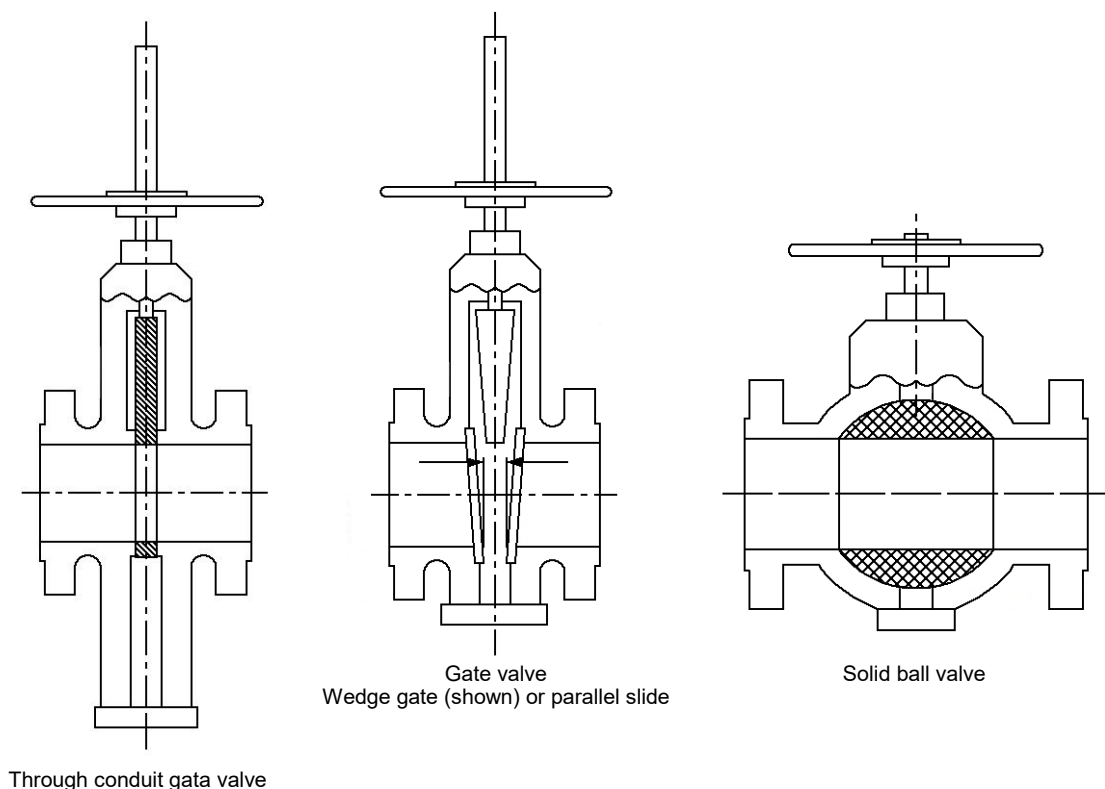


## 1.7 Valves

### 1.7.1 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.



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.

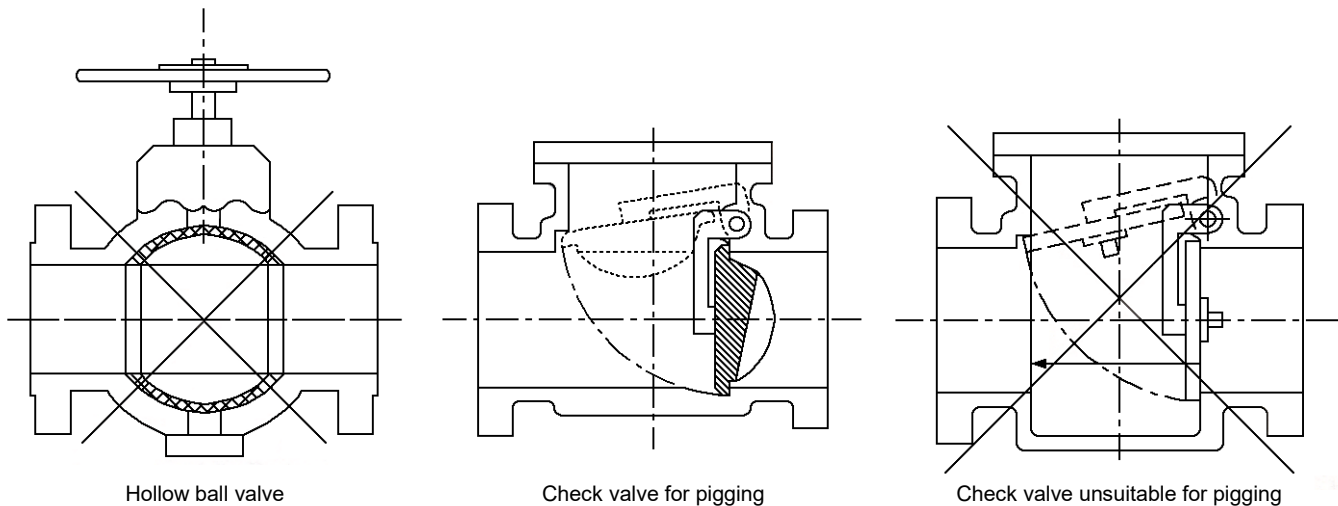
If wedge gate or parallel slide valves are already installed, or for some reason must be used, it is important to know the dimension of the gap between the seat rings to enable the correct pig to be selected. Valve manufacturers frequently confuse "full bore" with "full flow" so it is essential to specify 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 than 1:5 (30 degrees) should be provided.

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.

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.

### 1.7.2 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.



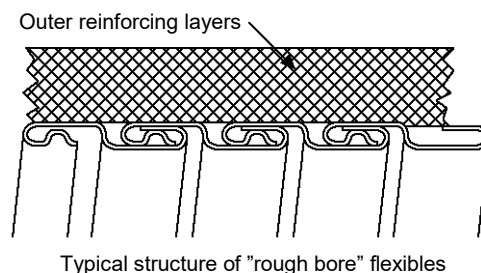
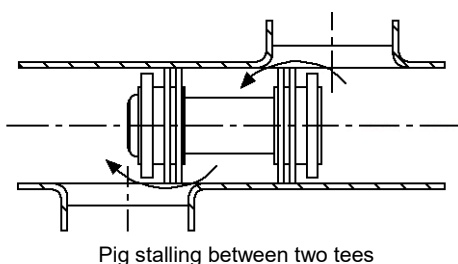
The pig will push the clapper to the fully open position with no noticeable change in pig speed, so the resulting movement is very quick. This means that the clapper needs to have a relatively smooth surface for the pig contact so it can pass with the minimum of difficulty. Some check valves may have 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.

Spheres are not suited 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.

## 1.8 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. 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).



## 1.9 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.

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 and 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.

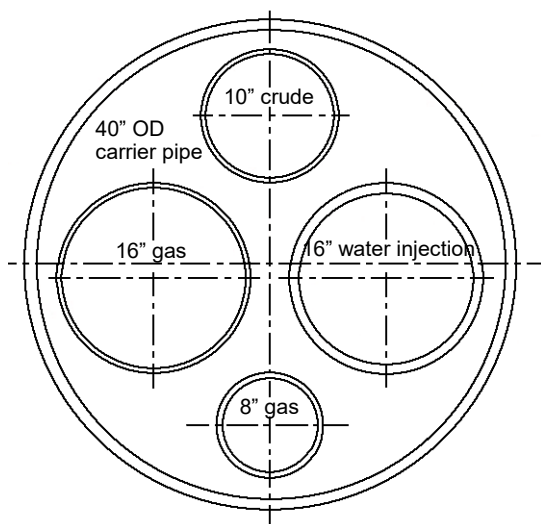
As far as is known, flexible pipe manufactures have not issued any formal specifications with respect to pigging but they do recommend that metal to metal contact between the pipe wall and the pig be avoided. This effectively rules out the use of wire brush type pigs and the possibility of running MFL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

## 1.10 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.

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.



Typical arrangement of Subsea pipe bundle

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.

## 1.11 Operating conditions

### 1.11.1 Product

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

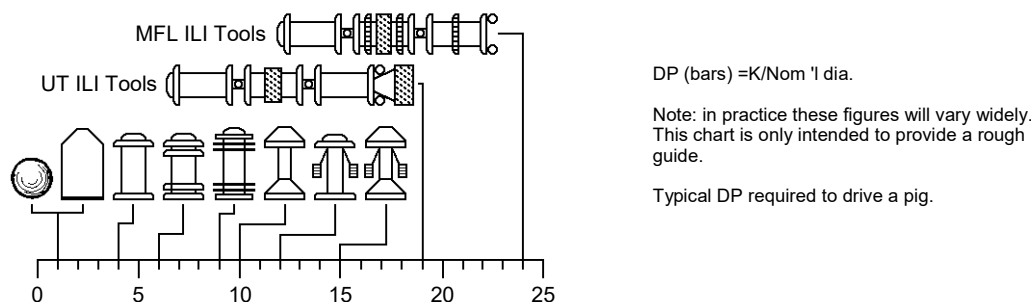
### 1.11.2 Pressure

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 75 m/sec. within a distance of only 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.



### 1.11.3 Temperature

Most pigs use polyurethane seals and the allowable temperature range for this material is generally between 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 65° C. If 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.

### 1.11.4 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 1-4 m/sec. Indeed this range has proven to be very effective for utility pigging as well.

## 2.0 Pig launching

### 2.1.1 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 in 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.

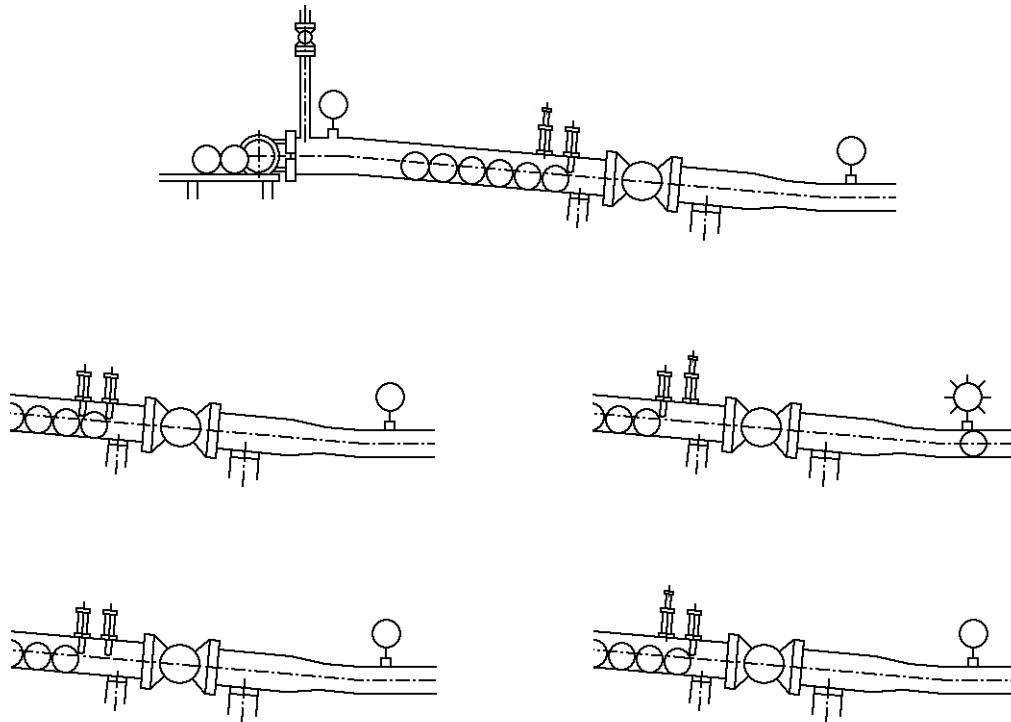
When loading the spheres, the downstream pin is extended and the spheres are simply rolled into the trap such that the first sphere comes to rest against the launch pin and this in turn holds back the remainder. When upstream pin is also extended, the first sphere is trapped between the two pins. This 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. 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 larger sizes they becom 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.



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

## 3.0 Pig handling

### 3.1.1 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.

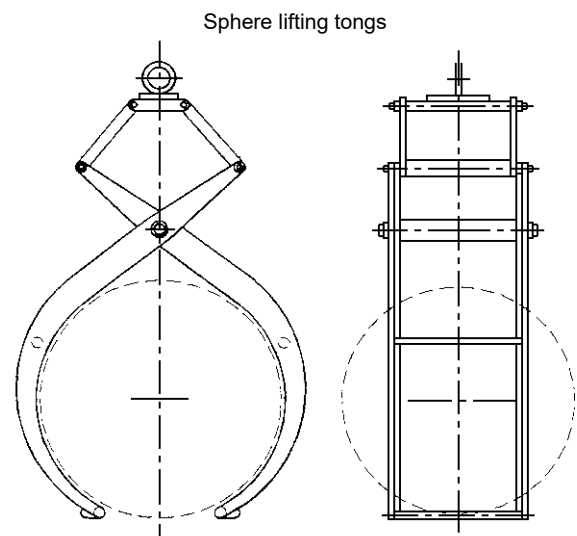
The area must be designed so that any fluids dripping from pigs that have been removed from the pipeline will be safely contained. The work area should be such that any spillage will be drained to a sump for safe disposal. This area may be covered with grating to provide a safe walkway for the operators.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

### 3.1.2 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 and this might best be handled using liftings tongs.



### 3.1.3 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.

### 3.1.4 Safety

Many pipeline 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.

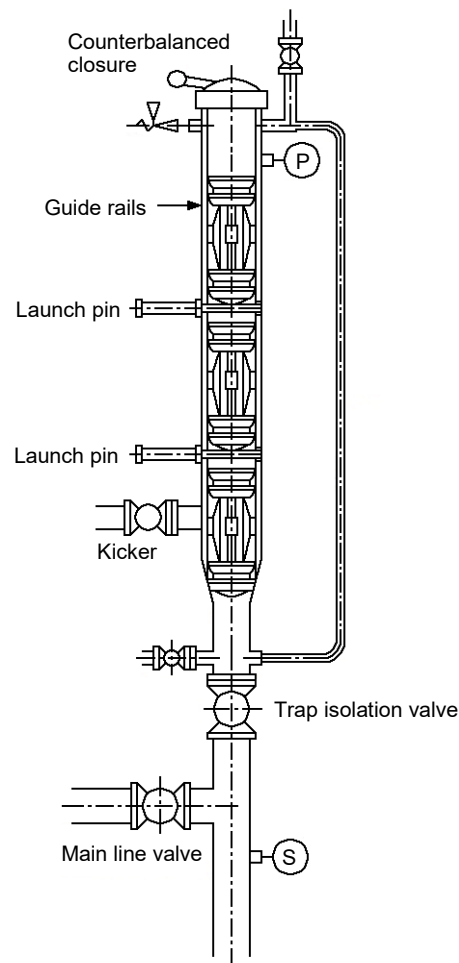
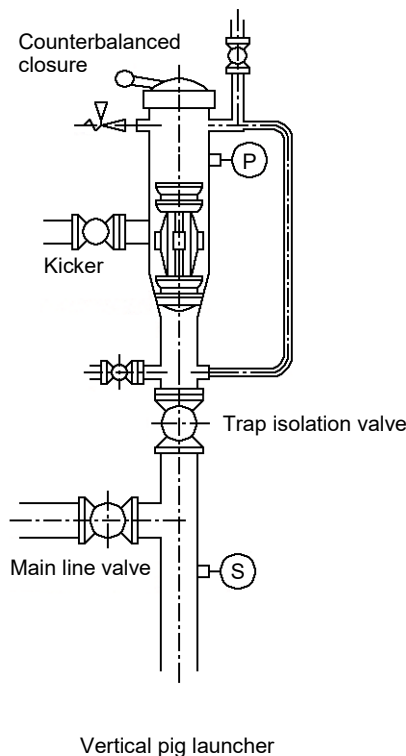
The products may also be toxic and therefore the atmosphere must be monitored to ensure the safety of the personnel in the area. Certain residues in the trap can vaporize when the pressure is reduced to atmospheric, or they may ignite spontaneously when exposed to atmosphere.

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.

## 4.0 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 unloading of ILI (In line inspection) tools and large pigs easier. It could also be argued that it 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.





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. 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 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.

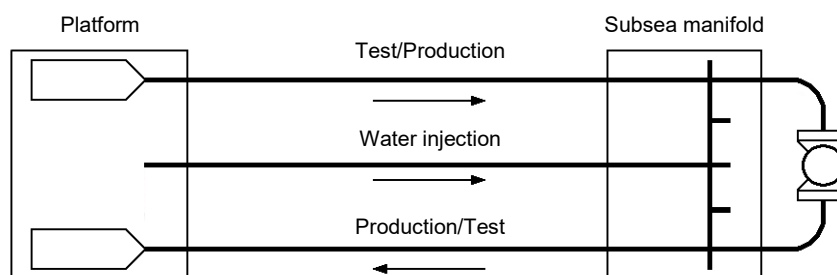
If it is received on a platform, it will also have to traverse a similar smaller diameter section at the end of its run too. This increases the differential pressure (DP) and if it is propelled by gas or air and is pushing a column of liquid ahead of it the DP will increase still further. As the liquid 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 by McAlpine Services & Pipelines is 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 is to have one pair of pig trap barrels mounted on rails that can 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 is fitted with a closure and a transition piece to reduce down from the trap to the pipeline size. The closures are TDW clamp ring types where the door can be swung completely clear. The trap barrel is then moved into position and the closure clamp ring is then used to lock the barrel into position for either launching or receiving. The barrel is fitted with a cassette to suit the particular pipeline. As far as is known, this system has not been put into service but the full scale test facility has worked successfully with 6", 12" and 20" utility and ILLI 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.



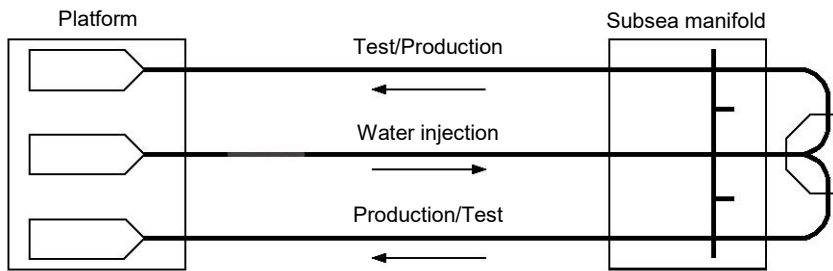
Conventional looped system

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.

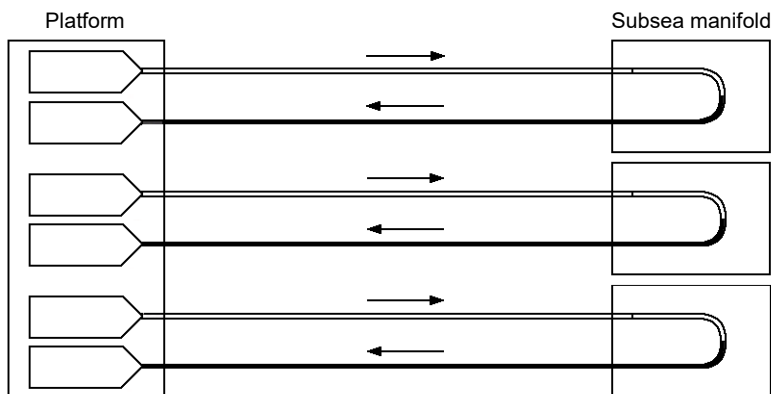
Pigging these flowlines may involve the installation of a subsea launcher, but the trend is more towards using a pigging loop to enable "round trip" pigging from the platform. This allows a pig to be launched from the platform, travel down one line, then cross over via a "pigging loop" to return back 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".

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.



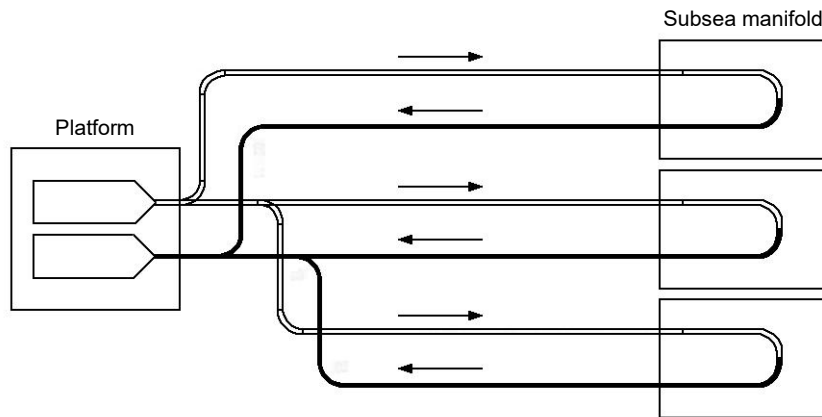
System using water injection line and diverter



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 later 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 diverter

## 5.0 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".

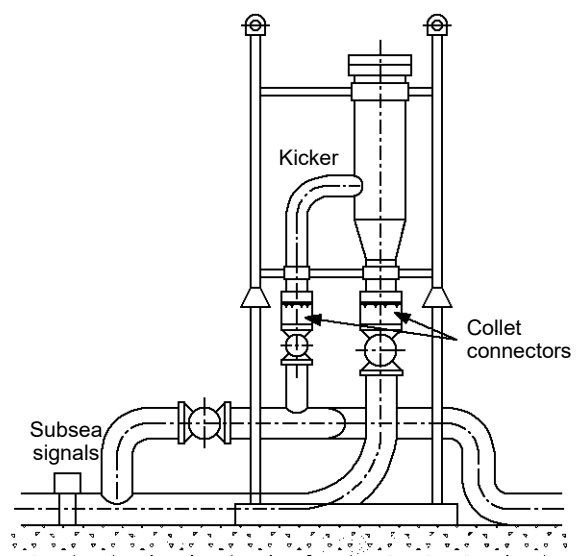
Subsea launch traps are not intended for routine operational pigging and they are generally stored onshore. Few such systems have yet actually been used to launch a pig, except as part of the commissioning procedure. In fact, most subsea pig launches to date have been from temporary traps or laydown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

Forbehold mod tekniske ændringer