Why pigs get stuck and how to avoid it

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Operators and contractors have been running pigs successfully for years. Every so often, a problem occurs and one becomes stuck, stalled or damaged in the pipeline. As the need for innovative one-off pigs for specialist applications arises, the risk of this occurring increases. Sufficient planning and analysis should be performed to allow the pigs to run successfully and perform their duty in the line effectively. This includes stringent testing, CAD work and analysis. This paper looks at the main reasons for pigs sticking and stalling in lines and examines what can be done about it. The paper looks at several different categories of failures, identifies the root cause of the problem and looks at how these scenarios might best be avoided. The figures at the back of the paper may be used as guidelines for consideration and avoidance of the problems discussed.

Introduction

The ability to successfully pig a pipeline is central to the maintenance of the line. This allows operations such as pre-commissioning, removal of wax in crude oil lines, inspection and the ability to swab liquid hold-up from gas lines to take place. With the increase in dual and multi-diameter lines, this is even more critical and pigging should be treated no different to any other offshore or pipeline equipment, with a sufficient level of design, analysis and planning performed.

In dewaxing oil lines, there is an increasing move to use pigs rather than expensive chemicals. The risk of plugging the line must then be considered and aspects such as the type of pig, pigging frequency and scenario planning (for example, change in flow velocity during pigging) employed. Multi-diameter lines are also becoming increasingly popular. The secret is recognising when a pigging application is a special and requires more attention than normal. The cost of a shut-down due to a stuck pig can be very large, especially offshore. Therefore, it is increasingly critical that the pigs negotiate the pipeline successfully and perform well.

This paper is an attempt to summarise the main reasons why pigs become stuck, stalled or damaged in the line and to determine what can be done about it in advance to avoid the problem. The following areas are covered: -

1. Pigs that plug a pipeline and cause a blockage;
2. Build-up of wax in front of pigs causing a wax plug;
3. Unintentional bypass leading to a stuck pig with product flowing past it;
4. Jack-knifing of dual module pig;
5. Excessive wear leading to failure of seals and drive;
6. Mechanical damage;
7. Failure due to the environment, material selection;
8. Other failures that do not fall into the categories above.

This is not intended to be a complete or exhaustive list, but an indication of known problems to use as a starting point. The figures in the back of the paper summarise the main points and can be used to review a pigging operation or pig design, in conjunction with this text.

1. Pigs Plugging a Pipe

An incorrectly designed or selected pig can plug the line by virtue of the components on-board. In some cases, this can damage the pig and lead to failure. Plugging the line is a case in point. In the worst cases, the more pressure applied to try to move the blockage, then the more jammed the pig becomes. The solution may be a costly pig cut-out and line repair.

A classic example of a jammed pig results from omission or loss of guide bars on receiver outlets when receiving spheres. Figure 1 shows the sphere jammed in the offtake, that results - quite literally - in things going pear-shaped. This can also occur in any line where flow is directed out from such a branch. This can also occur with standard pigs. To overcome the problem, bars need to be fitted to the tee, or in the case of a sphere, a sphere tee or flow tee needs to be considered.

Bi-directional pigs use guide discs to keep the pig close to the centreline of the pipeline. Guiders really need to be undersized at about 99% of the line Internal Diameter. The guider should be sized in relation to the smallest expected diameter in the line and seals sized to suit accordingly for sealing in all line sizes. If an oversized, hard guider is used, this can cause problems on launching (difficulty in engaging the pig in the reducer) and lead to high differential pressures, or a stuck pig (See Figure 2). It is also important to ensure that the guider and seals do not interfere or lock as this may cause damage to the seals. Generally, all the components on a pig need to be sized correctly with respect to the pipeline.

Incorrect selection of valves, fixtures and fittings in the line can lead to stuck pigs jamming the line. Incorrect valve selection, such as a gate vale for example can lead to a stuck pig. The valves should ideally be full-bore ball valves (see Figure 3). Allowance should be made for ball valves that are not fully shut. This is especially true in smaller diameter lines where a small intrusion of the valve can lead to a relatively large obstruction, damage to the pig and possible jamming of the line.

The lack of correct information can also be a source of problems. It is common to be informed that all the bends in the pipeline are 5D radius bends, but when the pig is run it is revealed that there were 3D bends in the line! If there is any suspicion of lack of information, then some conservative approach is required. This should be agreed with the client. For example, aim for smaller bend radius, or what every the problem is perceived to be, see Figure 4.

Figure 5 shows another classic situation that can arise when pigs catch up with each other. The rear pig pushes into the back of the pig in front, acts on the seals pushing them harder onto the wall, locking and a plug is formed. In this case, the more force applied to free the pigs then the harder they become lodged in the line, until something gives way. The way to avoid this is to provide suitable bumper noses at design time, front and back of the pig, even if it is not planned to put more than one pig in the line.

The remote possibility of pigs meeting in tees and wyes should be considered in complex lines. Figure 6 shows this occurring when the pig launching sequencing is incorrect. Although this does not often occur, the way around it is to allow one pig to be broken easily by the other. Again, a conservative analysis is required in such a case.

The use of High Friction pigs has become increasingly popular as a means to providing a barrier during repairs in low pressure. Sometimes these pigs are designed to be set at a thinner wall section than where there are launched. This is shown in Figure 7. The result is very high deflections in the seals at the thick walled section, higher differential pressure than planned and subsequent damage to the seals and the pig. In this case, the high friction pig can become a plug (Desirable sometimes perhaps but not in the absence of control!). The result is failure. High Friction pigs need to be designed correctly and tested in a representative facility.

2. Build-up of wax

An extreme case of plugging a pipeline can arise when dewaxing a line. This is a special case of line plugging which requires attention. Figure 8 shows how the wax plug can arise. Experience suggests that huge pressures can be withstood by the wax plug before yielding (Differential pressures up to 100 bar / 1450 psi have been reported before plugs are either reversed or the line needs to be cut to remove the problem (a costly solution on land never mind subsea!).

The essential model of how the plug occurs is: -

- Pig removes wax from the pipe wall;
- Wax builds up to a critical level;
- Wax immediately in front of the pig hardens as the liquid is squeezed out and the pressure to move the plug increases;
- Eventually, the pig becomes part of the wax movement and it is the wax plug that actually performs the cleaning!
- Finally, the pressure required exceeds what is available or safe, and the line is plugged.

To avoid this possibility, bypass is included through the pig to sweep the wax along ahead of the pig and so avoid the problem in the first place. The rate of bypass must be carefully selected however. If the flow rate is low, then it may be only possible to have a small bypass rate that may not be adequate to carry the wax forward.

Finally, on the subject of debris, other debris types can also jam pigs or cause damage and so again correctly designed bypass is required, see Figure 9. The sand can force the pig upwards and can cause severe wear to the pig. Such dust and debris in the line should be removed by a carefully designed and selected cleaning program. Bypass is one of the best solutions in an overall progressive cleaning program. The correct rate of bypass to overcome the expected volume of debris in the line must be determined.

3. Unintentional Bypass

Although bypass is used to aid in the cleaning of lines and removal of unwanted liquid, it is also a source of potential problems. Unintentional bypass is defined as the situation arising when the drive product flows past the pig either due to a breakdown of the seals or because of some line components.

Figure 10 shows a typical example of this. The pig has a bypass system which routes bypass through the pig body and then back again through a jetting head at the front of the pig. At the tee, the low-pressure gas finds a leakage path which results in all the flow being diverted around the front of the pig and so stalling the pig. To avoid this it is necessary to carefully consider the flow conditions and perform the necessary calculations to ensure that the bypass ports are properly sized.

A similar situation is possible with a sphere in a tee or indeed a Y-piece. This is shown in Figure 11. The problem is due to the insufficient seal length of a sphere or any pig that is shorter than the open length of the Y. To overcome this the wye internal diameter should increase slightly, or the wye can be sloped so that the pig rolls and re-engages with the outlet. The problem can also be overcome by careful selection of the internal geometry of the wye, using a profiled internal. This can be used in gas pipelines to “fire” the sphere across the gap. For standard pigs, dual module pigs are frequently employed to span the wye opening length.

Figure 12 shows how a pig can lose drive due to travel nose down. Most pigs travel nose down due to higher friction at the bottom of the pipe compared to the top as a result of pig mass. This is especially relevant in dual diameter pigging where support is difficult. The pig should be designed to maximise the flip pressure of the seals (i.e. the pressure at which the seals blow over as a result of the pressure behind them). The difference between flip pressure and drive pressure is a measure of the safety of driving this pig through the line. This is especially relevant in bends and other line features. Good support systems are available today that can be used to overcome this problem.

Pigs can sometimes fail to reverse when required to do so. Figure 13 shows what can happen when the flow is reversed in the line. There are three possible situations (ignoring the possibility of discs locking on guiders as discussed above): -

1. Pig body moves and the pig seals flip over to allow the pig to move backwards as required;

2. Pig seals do not flip back but the pig judders off in reverse. Although this can be used to reverse the pig, care must be taken as damage to the seals can occur;

3. Finally, there is too much resistance to motion and the flow blows over the seals and bypasses the pig. The pig is therefore stalled.

To overcome this problem, the friction should be minimised and the seals supported such that the pig moves according to situation 2.

Figure 14 shows another important situation that can arise, where a pig stalls due to line components that are in close proximity. In this case, tees are considered but other components such as bends, wyes, valves etc could also cause problems. This is occurring more frequently as space considerations on the topside and on manifolds becomes a premium. To avoid the problem, the location of seals relative to the offtakes must be taken into account and dual module pigs employed if required.

Inappropriate buckling of seals is a problem in dual diameter pigging, but is applicable to normal pigging too. This is shown in Figure 15. The problem can be avoided by correct selection of seal diameter, thickness and flange diameter relative to the pipeline internal diameter. Design methods to achieve this exist that can be used to avoid the problem.

Figure 16 shows another potential problem again from dual diameter pigging, but that should also be considered for other applications. The length of a reducer is vital insofar as it affects the location of seals. A Dual diameter pig means just that – it operates in just two diameters (large and small) but not necessarily in the intermediate line sizes. This causes a problem if the reducer is too long and therefore no seal is working effectively. This can cause a conflict between inspection pigging (which requires a long reducer to allow the sensors to work effectively) and conventional pigging (requires a short reducer for the reasons above). The problem is overcome by careful design of the seals and the pig length.

Figure 17 shows another example where a bypass pig is traveling through a line at normal production flow. Due to a reduction in flowrate, the total flow now passes through the pig and the pig stalls. To rescue the pig, it may be necessary to launch another pig to push it out. The necessary bypass requirements must be met, however. Such possibilities should be considered in the pigging procedure and steps taken to avoid it.

4. Jack-knifing

It is often necessary to utilise dual module pigs in order to span wyes while still allowing the pig to negotiate bends. An example is an inspection pig where a number of modules are used for data logging, battery power and housing magnets and sensors. Such pigs consist of a front module, a rear module, and some sort of joint between these modules. These pigs should be driven on the front module to allow it to pull the rear pig along by using open bypass ports on the rear module. Occasionally this is forgotten or circumstances arise that transfer drive onto the rear. This can cause the tool to jack-knife and stall.

Figure 18 shows the effect of driving on the rear module. The pig is pushed laterally by an imbalanced load. The result is that the seals move off the centreline, causing them to flip and the pig stalls. The design should ensure that this cannot happen and drive is always transferred to the front module via suitable pressure bypass ports. Correct controls should be in place to ensure that this is the case before launching.

This problem can occur occasionally even with correct bypass to the front module. Figure 19 shows a dual module pig in a bend with low-pressure gas (for example during dewatering). In this instance, gas can find a path around the pig. This in turn sets up a pressure drop across the entire pig that effectively results in the pig being driven from the rear. As a result, the pig is loaded laterally and fails as before. Correct selection of the support system to keep the pig central and correct seal sizing is required to overcome this problem.

5. Excessive Wear

The pig seals provide a wiping action in the line, but also provide drive, allowing the pig to move forward. If the seals are damaged then it is possible that the pig will stall. One way this can happen is if the seals wear out, then flip forward and allow the product to leak past.

Wear can occur if the system is very abrasive and under a combination of one or more of the following factors: -

- High differential pressure;
- Low Pig Velocity;
- Rough pipeline internal surface;
- Low viscosity fluid;
- Smaller pipeline diameter.

For example, a large diameter line carrying crude oil with a low differential pressure pig can allow pig travel of several thousand kilometers/miles. On the other hand, smaller diameter lines with rough surfaces and drier products can lead to rapid wear and pig failure.

Polyurethane is a highly abrasive resistant material in its own right. Very little can be done to improve on it, but there are ways, and certain additives can be used to improve lubrication etc. There can often be a trade off however, as this can result in lower strength or tear resistance for instance.

Figure 20 shows a model used to predict how far a pig might be expected to travel in a pipeline under certain conditions. This should be used as a first estimate of piggable distance. If this shows that there is a risk of failure, then methods of wear mitigation need investigating. These include addition of lubricant to the line, reduction in differential pressure, addition of high wear kits or other commonly employed methods.

6. Mechanical Damage

Mechanical damage, defined as the loss of integrity of structural elements and components on the pig, can lead to loss of drive or usefulness of the pig. This can be because of design problems or unexpected circumstances in the line that leads to damage to the pig.

Velocity Excursions are sudden high accelerations and subsequent high velocities of pipeline pigs usually in lower pressure gas pipelines. This can lead to damage at bends for example (consider at a Z-spool for instance). The problem can be modelled and an example is shown in Figure 21 where a sudden acceleration from thick walled sections during dewatering with Nitrogen results in high loads on the pigs at the bends. Such excursions can lead to the loss of inspection data since these pigs are normally required to operate between 1 and 4m/s.

Figure 22 discusses another type of damage to couplings between pig modules due to snatch loads or high compressive/tensile loadings. The type of joint needs careful consideration and strength calculations performed to determine the worst load cases. Stress calculations must be performed to make sure that the joint can withstand such loads. Another possibility is to design out the problem. For example, allowing the joint to swivel can alleviate torsional stress in the component.

The limitations of the joint should be carefully understood before use. It is prudent to have some backup in the event of coupling failure to keep both modules together. Only commonly employed joints should be used (U-joints, ball and socket types etc), unless there is no choice and then a high level qualification of the joint is essential. It is useful to set up the pigs such that they can be pushed out by another pig in the event of being left in the line, or at least that the two modules will drive along even if the joint breaks.

Figure 23 shows what excessive line pressure (for example in pressure tests or in deep water) can do to a pig with an isolated cavity inside. Line pressure can cause the pig body to collapse. Such cavities should be avoided altogether if possible or if necessary then they should be subject to careful design, regarded as a vessel in their own right, and tested before deployment.

When seals are oversized too much then there is a risk of tearing the discs out of boltholes. This can rip the discs from the boltholes and cause failure (See Figure 24). This is generally a seal selection issue and usually occurs with self-acting type seals. The best way to avoid this is to optimise the seal thickness and oversize. Any unnatural seal thicknesses or oversizes should be avoided. The thickness should be somewhere around the nominal linesize of the pipe (20” pipeline with 20mm seal thickness for example). Oversizes greater than 10% are severe.

Large diameter pigs have high masses and may freefall down risers. This can lead to damage of the pig and the operation may be affected adversely (for example, during flooding of the line, gas may ingress into the test water during such an event). High velocities can also lead to burning of the polyurethane seals. Two-phase flow can result in damage to the pig in down hill sections, as pigs are accelerated in gas into a liquid column, see Figure 25.

7. Environment

Figure 26 shows a number of environmental issues to be considered. The typical temperature range for standard polyurethane is about 80 degrees C, but this depends on the immersion time. This can be increased by selecting more specialised urethanes of which there are a number on the market. High pressure can cause gas ingress into the seal or pig material that may result in explosive decompression.

Chemicals and their effects on polyurethane are well known. For instance, Methanol degrades Polyurethane at elevated temperatures and renders it soft and toffee-like! At low temperatures, it behaves satisfactorarily. It is therefore necessary to understand the operating conditions and the products in the line.

8. Others

Figure 27 shows a scenario that occurred while testing a 10" x 16" dual diameter pig. Although a pig generally moves under a nose down moment, it is very difficult to believe that this could have occurred. Given the forces involves, polyurethane offers very little support against pressure forces (for example a 1 bar / 14.5psi differential pressure in 10" pipe is half a tonne / 0.55 tons). The lesson is to "Expect the Unexpected", but also to appreciate the forces involved and how this can deform the pig.

The last thing to say on this is to try to avoid any unexpected situations by gathering as much information as possible. Missing information or unknown line components can lead to a stuck pig. If the information is not available then a very conservative analysis should be employed.

Conclusions

There are many reasons why a pig can become stuck or damaged, but with the correct planning, design, analysis and testing, this can be avoided. The figures presented in the back of this paper can be treated as a preliminary checklist of possible problems and by treating each in turn, they can aid in the process. They can also be added to, based on other experiences.

Generally, pig differential pressure should be minimised. High differential pressures result in large forces acting on the pig. These forces can either damage the pig or act to pull the pig off-centre and lead to leakage or loss of drive.

Good analysis where required will provide the necessary missing information, but like everything it is only as good as the input. If it is not known then a conservative approach is required. A very good starting point is to accurately list and describe the Functional Requirements for the pig - in terms of both getting the pig from the launcher to the receiver but also in terms of functionality and getting good performance from the pig along the line.

If there is any doubt at all, then testing is necessary. A well-designed test program can be inexpensive if executed correctly and can answer any remaining questions that might arise, subject to the limitations of the test facility. Nevertheless, in conjunction with the design and analysis, this should ensure that the pig negotiates the line. Judicious design can overcome the seemingly conflicting requirements of the pig and allow a balance to be achieved

It is important that all the information is known or documented at the design stage and is agreed between all involved. A generalised scheme to avoid stuck pigs is as follows: -

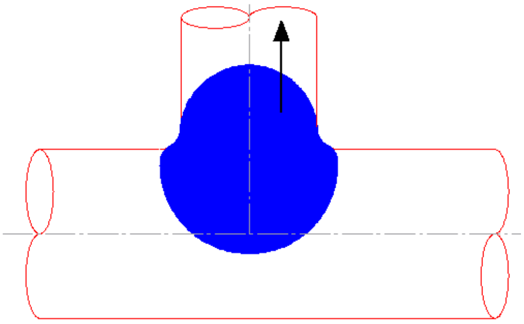
- Gather the information;
- Clearly define and agree the Functional Requirements;
- Do the design and the necessary calculations;
- Layout the pig in the line components;
- Select the pig;
- Test and revise the design if necessary (iterate);
- Implement.

It should be remembered that all pipelines are different and also an appreciation of what is a special pipeline and what is not is important. Special pipelines, demanding special attention are Dual diameter, slow pigging, thick wall/deepwater, heavy dewaxing/low velocity and many more.

Safe pigging!

1. Sphere jammed in Offtake

Sphere jams into a branch line due to flow diversion and causes a jam.

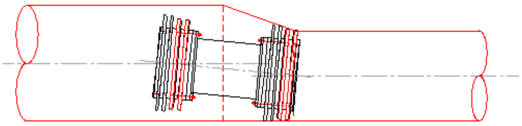


Require to provide a bar arrangement in receivers or special flow/sphere tees in the pipeline.

This can also occur with standard pigs where there is flow from branch lines. The barring arrangements should be checked. In dual diameter lines, special barring arrangements may be necessary.

2. Incorrect Sized Pig Components

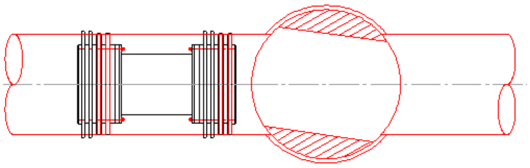
Oversized guiders can cause pigs to misalign and jam in launcher reducer. Pig components should be sized to the actual pipeline with an allowance for wear and other such factors.



Guiders need to be sized correctly to 99% of the smallest line Internal Diameter and then seals sized to suit. Avoid seals locking on guiders as this may lead to rapid wear and seal damage.

3. Incorrect Valve/Valve not fully open

Use of the incorrect valve in line (valves need to be full bore ball valves or through-conduit gate valves, ideally), or when the valves are not fully opened.

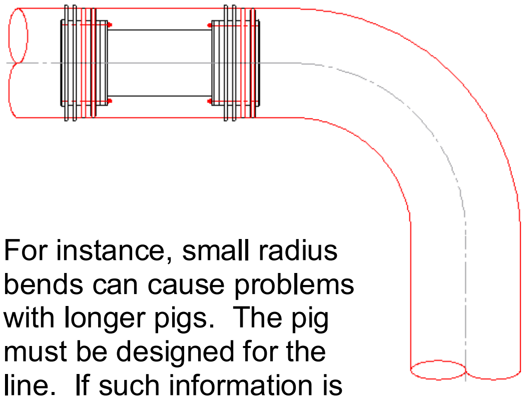


This is a problem especially in smaller diameter lines at 12” and smaller and has been known to severely damage the pig.

Checks in the operating procedure should be in place to check the opening of the valves, but the pig design should also consider this eventuality.

4. Insufficient Information (Wrong bend radius, for example)

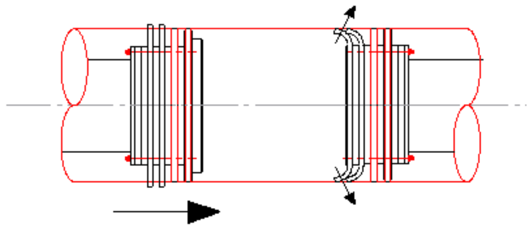
Insufficient information regarding the design of the pipeline can be a problem, especially with older pipelines.



For instance, small radius bends can cause problems with longer pigs. The pig must be designed for the line. If such information is unknown, then some conservative assumptions must be made and agreed.

5. Pig pushing on pig in front

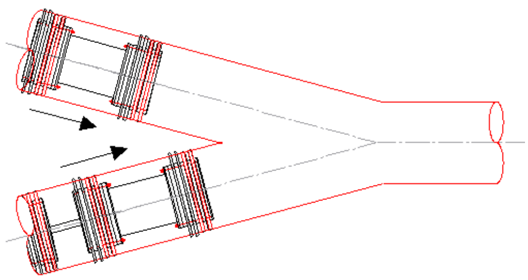
When one pig pushes into the rear of another pig, there is a possibility of plugging as it acts on the seals, forcing them harder against the pipe wall and locking: -



To mitigate against this it is advisable to have bumper noses, both front and rear. This should be provided even if it is only planned to have one pig in the line.

6. Colliding pigs

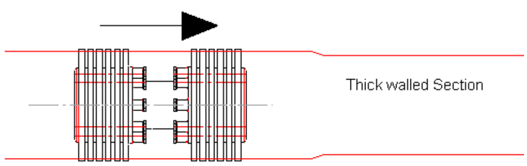
In more complex systems, there is a possibility of pigs meeting at wyes or tees. This can cause a blockage: -



The risk can be reduced by good communications and pigging operating procedures. In addition, one pig may be made sacrificial, i.e. it is broken in two by the main pig, should this occur.

7. High Friction Pigs

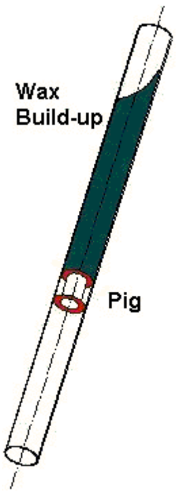
High Friction pigs should be designed to drive in all pipe sections (thick walled included) not just the section where it is planned to set the tool: -



This could lead to serious damage to the pig as seals are torn from boltholes. In general, all pigs should be designed to deal with all the internal diameters of the line and if in doubt, a test performed.

8. Plugging with wax

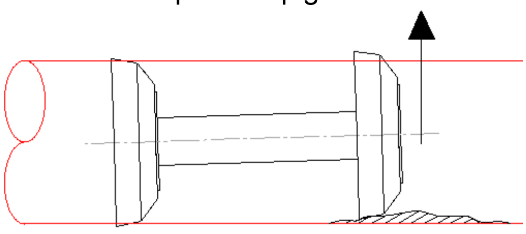
Wax build up in front of pigs can plug a pipeline. The wax is scraped off the pipe wall, gathers in front of the tool, hardens and eventually plugs the line. The cost of rectifying this situation should it occur is potentially huge, especially offshore: -



This can be avoided by correct selection of pig and the correct bypass rates through the pig to allow the debris to be maintained in suspension downstream of the pig.

9. Debris in the line

Debris such as sand can damage a pig as it can lift the pig up and cause rapid wear to the top of the pig.

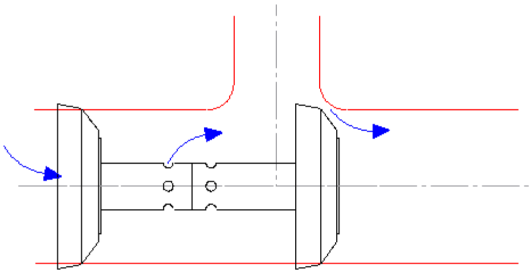


Again, the most effective way around this is to provide sufficient bypass through the pig.

The bypass must be strong enough however, to move the debris along in front of the pig.

10. Flow around the pig

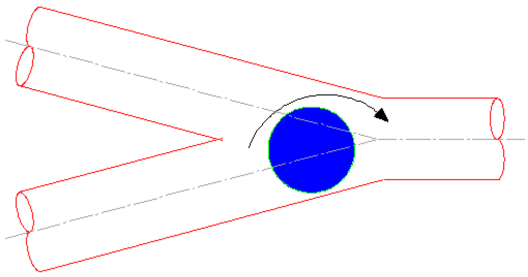
The flow of fluid through or around the pig at pipeline features such as branches and offtakes, wyes etc must be considered.



This can lead to a stalled pig if the bypass system is incorrect, too much bypass or too low fluid flow rate. Also, need to consider the position of offtakes.

11. Insufficient Sealing Length

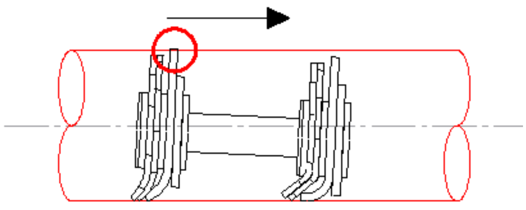
At components such as wyes and tees, the sealing length needs to span the branch opening length. If not there is a risk of stalling in this component: -



If necessary, a dual module pig should be used to span the component. Spheres can be made to accelerate past the wye (by altering the internal profile of the wye).

12. Nose down

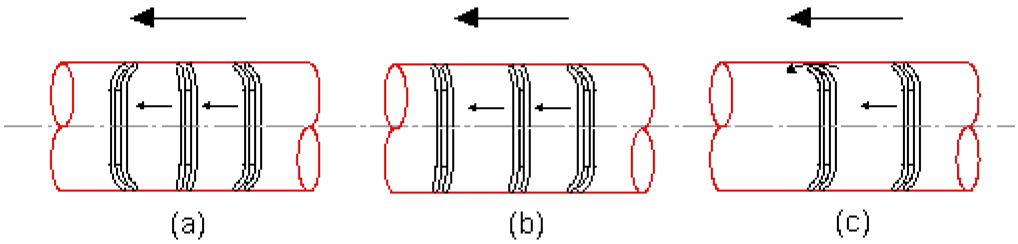
In dual diameter pigging, in particular, but in all pigs, in general, there is a tendency for pigs to nose down in the large diameter line: -



This can cause the rear seal to flip (red circle) and product can flow over the off-centre front seal. Modern support techniques should be employed and seals sized appropriately.

13. Reversal

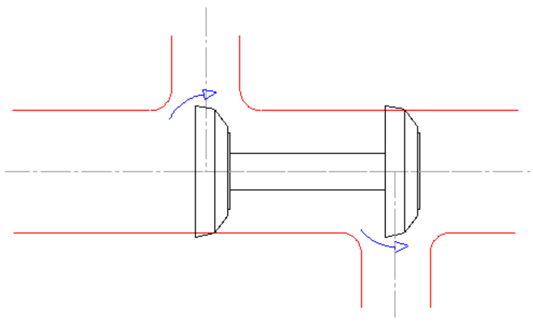
When reversing a pig by reversing the flow in the line, it is important to get the right interaction between the pig seal and the pipe wall: -



In diagram (a), the body of the pig moves first, then the seals reverse and normal drive is resumed. In (b) the seals do not reverse and the pig moves backwards in a juddering motion. Finally, in (c), the seals cannot support the pressure from the front of the pig and collapse, allowing the flow to bypass the pig. The pig stalls. Another aspect to consider in reversing pigs is the interference of pig component such as seals and guide discs.

14. Proximity of components

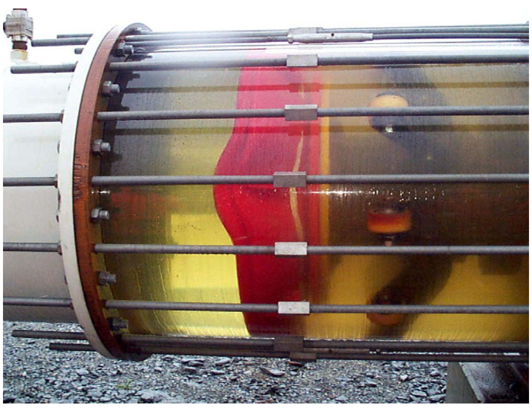
When line components are too close, there is a risk of bypass as the sealing length is incorrect: -



To avoid this, the configuration of the pig in terms of seal position must be carefully considered. In addition, in the pipeline design, sufficient length between line components should be allowed.

15. Buckling of Seals

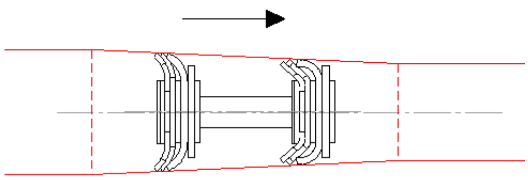
Buckling of sealing discs should be avoided when not required: -



This can now be designed out of the pig by appropriate selection of the seal geometry and flange selection. The problem is particularly important in dual and multidiameter pigging.

16. Reducer Length

In dual diameter pigging in particular, the length of the reducer should be carefully considered: -

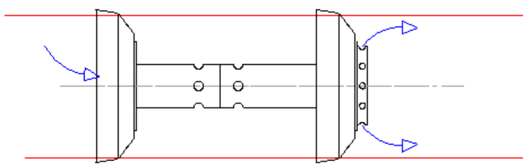


If not, then there is a risk that no seal is functioning correctly and the pig will stall.

There is a conflict here with inspection pigging where the reducer length should be as long as possible compared with utility pigging where it should be as short as possible.

17. Bypass with reduction in flow

A reduced flow rate means that the full flow of fluid can go through a bypass pig. This can occur when a standard bypass pig is in the pipeline and there is a sudden reduction in fluid flow: -

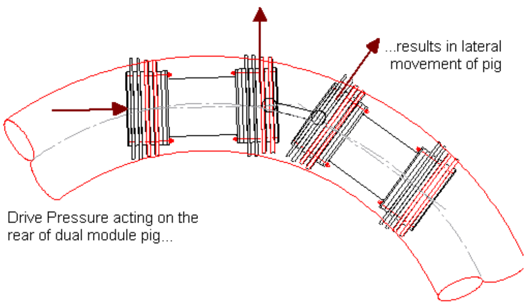


Conversely, an increase in flow rate can mean that there is insufficient percentage bypass through the pig.

For these reasons it is necessary to perform the necessary calculations to allow the correct bypass to be selected.

18. Driving dual module pig on rear

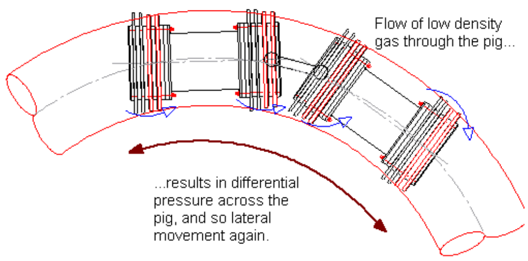
Dual module pigs driven on the rear tend to move laterally, especially in bends: -



This results in seals flipping and the pig stalls. To avoid this, pressure should be transferred to the front module via bypass ports on the rear. This allows the rear module to be towed and is more stable.

19. Dual Module Pig with leakage

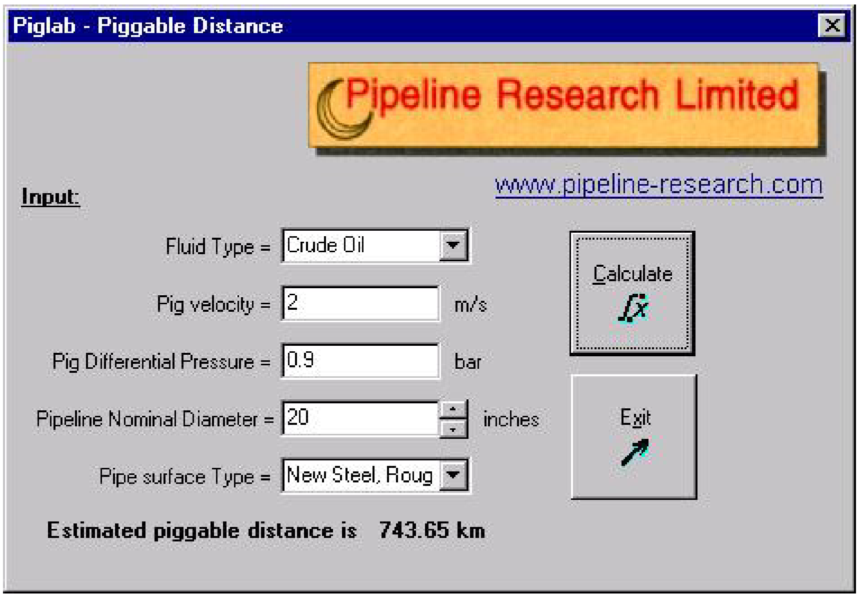
If a low density gas, for example, leaks through a dual module pig, then a differential pressure is set up across the pig and lateral movement can result again: -



This can be avoided using better support for the pig and correct sizing of seals.

20. Wear

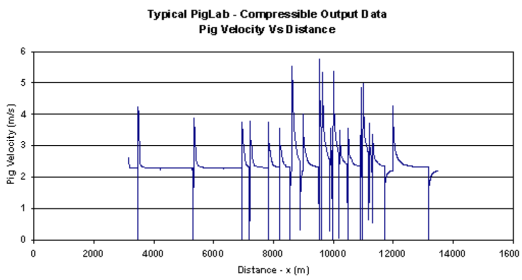
Seal wear by abrasion means that there is a maximum piggable distance associated with a given pig and pipeline. Pipeline parameters such as diameter and roughness, combine with operational details such as flow velocity, product type to determine the maximum piggable distance.



This can now be estimated given a number of input parameters as shown on the left.

21. Velocity Excursions

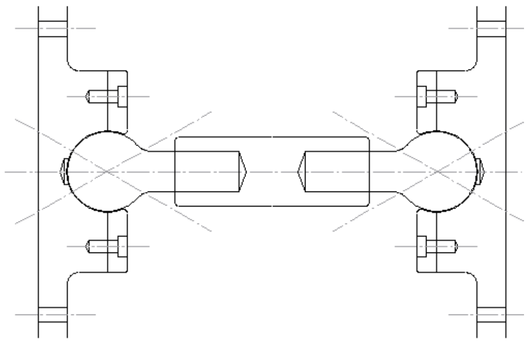
In gas pipelines, a pig can be subjected to large accelerations and velocities due to the compressibility of the system. This can lead to damage of the pig if accelerated into a bend for example: -



The graph shows pig velocity against distance in a low-pressure pipeline with many changes in internal diameter / wall thickness. The resulting increase or decrease in friction causes the pig to slow or accelerate.

22. Coupling Damage

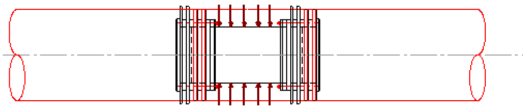
The coupling between the modules of a dual module pig must be strong enough to take the compressive or tensile, lateral or torsional loads it is subjected to: -



The joint must be capable of opening to the correct angle to allow the pig to negotiate the line features.

23. Trapped Cavities

If there is a trapped cavity on-board a pig, this could collapse under high pipeline pressure. This must be avoided especially in high-pressure pipelines or during pressure testing if the pig remains in the line: -

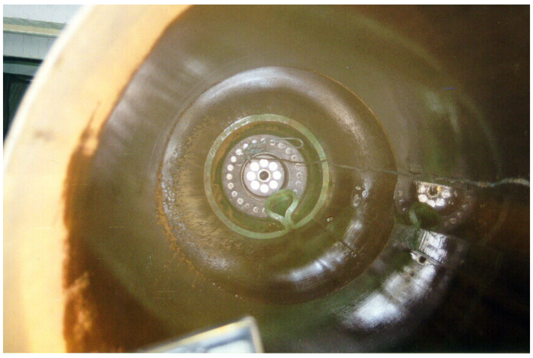


External, pipeline pressure acting on a trapped cavity

To avoid this all cavities must be pressure balanced. If a cavity is required then it should be designed as an externally pressurised container and subject to qualification.

24. Tearing seals out of boltholes

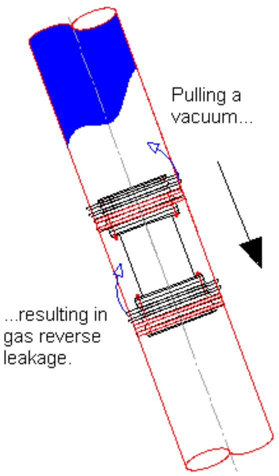
Highly oversized sealing discs are at risk to being pulled out of their boltholes on the pig. This is especially true in dual and multi-diameter pigging: -



The oversize needs to be carefully selected and the bolting arrangement such that the disc is properly clamped to the pig.

25. Pigs in Free Fall

Large diameter pigs are heavy and they can free fall in steep sections such as risers: -



This can lead to high velocities and damage to the pig. During flooding of the line for hydrotest, this can also result in gas ingress into the test water.

There are various methods for slowing the pig down and avoiding this scenario.

26. Environmental Issues

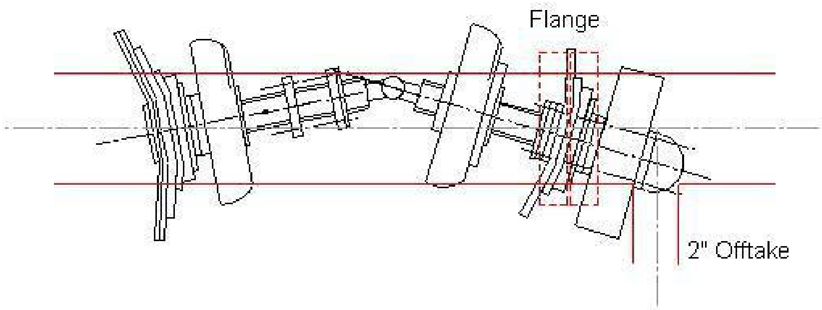
The main environmental issues to consider are: -

- Line Temperature (Degradation of the seal material, expansion of metallic parts, etc);
- Line pressure (Cavities, explosive decompression etc);
- Line contents (Incompatibility with the seal materials etc);
- Immersion Time.

Such aspects should be checked with the pig suppliers.

27. Unusual Damage to 10” x 16” Pig during testing

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



An imprint of the 2” offtake was observed on the pig nose!

Thorough design and checking of each line feature along with an appreciation of (a) how flexible polyurethane can be and (b) the magnitude of the forces involved can aid in avoiding these problems. In addition, if the line is perceived as being difficult to pig, then good representative tests can show up any such problems.

As a rule, pig differential pressure or friction should be minimised. High differential pressures result in large forces acting on the pig. These forces can either damage the pig or act to pull the pig off-centre and lead to leakage or loss of drive.