CHALLENGES AND FUNCTIONAL REQUIREMENTS FOR SUBSEA LAUNCHING INTO LIVE GAS PIPELINES

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Subsea pig launching may be a necessity in the operation of multi-phase production tie-backs and gas export pipelines systems and their design is critical to their operability. This paper discusses the challenges involved, basic launcher layout and Functional Requirements. The features required for effective launcher operation over the life of the pipeline are presented. Operational pigs, inspection tools and possible intervention tools such as plugs need to be considered. The launching method is discussed with a focus on the use of hydrocarbon gas to deploy the pigs in comparison with the use of nitrogen or Mono Ethylene Glycol (MEG) via a downline. The ability to safely launch pigs into the pipeline and the pros and cons of each launch method are discussed. A comparison between launching with a downline or with hydrocarbon gas from production is made and a guide as to how a decision could be made is provided.

INTRODUCTION

Subsea pig launchers are commonly used in the pre-commissioning of pipelines and frequently considered for production scenarios. Pigging during pre-commissioning and commissioning often involves launching pigs via a downline from a vessel. The most common mediums are water, MEG and Nitrogen. To ensure that the operation is successful, it is important that each pig is launched at the right time and that two pigs are not pushed into the line simultaneously. On the practical side, sufficient deck space on the vessel for the equipment, non-return valves to avoid back flow of fluids and quick release from the vessel to the launcher in the event of an emergency must be considered.

Operational pigging with subsea launchers, can be used for special operations such as pipeline cleaning followed by inspection of the pipeline at agreed intervals. Routine maintenance pigging from a subsea launcher is becoming more essential due to long flowlines, subsea tie backs, increasing water depths and non-piggable risers. Round-trip pigging is less attractive since a dual flow line is required. Round trip pigging is more onerous as it requires shutting down one line to launch a pig and then re-routing for the return. It is therefore less likely that operational pigs will be launched. The life-of-field pigging requirement needs to be considered and if pigging is important to the success of the operation, then the ability to launch subsea in a controlled and reliable fashion is essential. Selection of the correct scenario (round trip or subsea launch) and operation of such a system needs to be considered carefully given that subsea launching is costly.

This paper describes factors involved in launching pigs into an operating gas pipeline system using one of three ways: -

1. Pushing pigs into the pipeline via a MEG downline;
2. Pushing pigs into the line via a nitrogen downline;
3. Using production gas from the host facility or from a producing well to push the pigs into the line.

The same arguments and discussion discussed below could also be applied to liquid systems but since gas (and gas dominated multiphase) pipelines are more common for this application, then the compressible case is considered primarily.

The main emphasis is on safety, effective procedures to ensure a successful launch and the need to avoid problems that might cause a mis-launch or multiple pig pushed into the line. Given the criticality and cost of the procedure, this must be avoided if the system is to be practical. The actual design of the pigs is not considered in this paper – it is assumed that the pigs used are fit for purpose.

SYSTEM SCENARIOS

The following scenarios for launching pigs subsea are considered and discussed in more detail in this paper: -

<u>Launching with a MEG downline</u>

The first option under review is to launch the pigs using MEG via a downline. This involves pushing the next pig in sequence as far as the production tee using MEG. The system is shown in schematic below: -

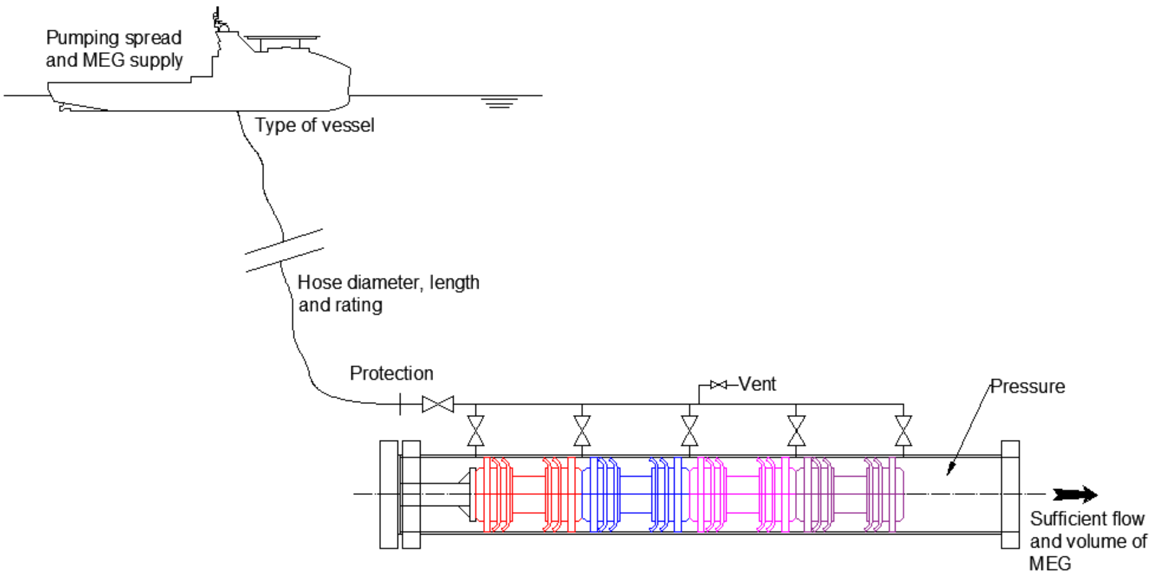


Figure 1 – Set up with liquid launch from a vessel and downline. This is typically with MEG. The aim is to push the first pig as far as the production tee, from where the gas flow will take over and drive the pig.

Launching with a nitrogen / N2 downline

The next option under review is to launch the pigs using a nitrogen downline. In outline, this is like the previous case using MEG launch from the vessel, but when the detail is considered, then there are many additional factors to consider. The aim is the same – to push the next pig as far as the production tee but this time using pressurised nitrogen from the vessel. The system is shown in schematic below: -

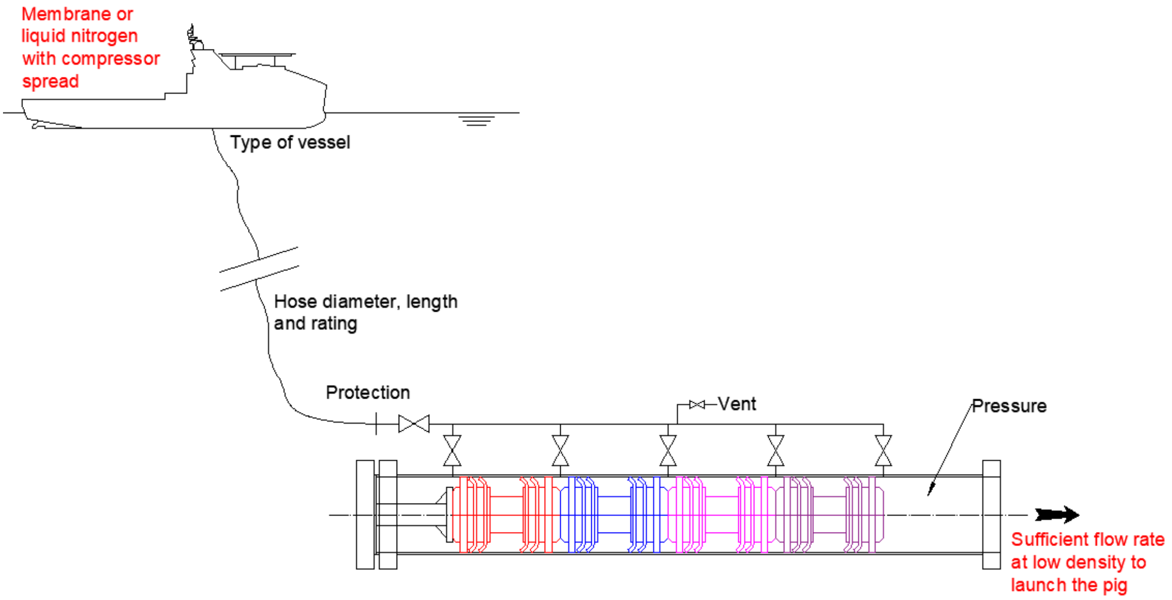


Figure 2 – Set up with nitrogen from a vessel and downline. This is less common but is a potential solution especially for deep water. The aim is to push the first pig as far as the production tee, from where the gas flow will take over drive.

Launching using Production

The final option considered in this review involves subsea launching using production. This may be optimal for deeper water developments where it could become impractical to deploy a down line from a vessel. Other examples of when such a launch may be the best proposition would be for remote operations with a long step from the host facility or if it is not possible to deploy a downline of sufficient diameter to achieve the necessary flowrate into the launcher. The method assumes that the system is designed to allow re-routing of production into the pig launcher.

The system is shown in schematic below: -

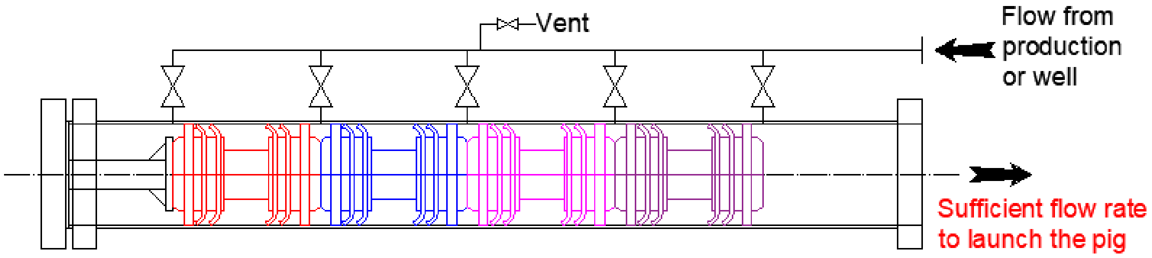


Figure 3 – Launching from subsea with production flow directed into the kicker line from process or direct from a well.

LAUNCHER LAYOUT AND FUNCTIONAL REQUIREMENTS

Preliminary subsea pig launcher layouts are set out below for the three scenarios under consideration: -

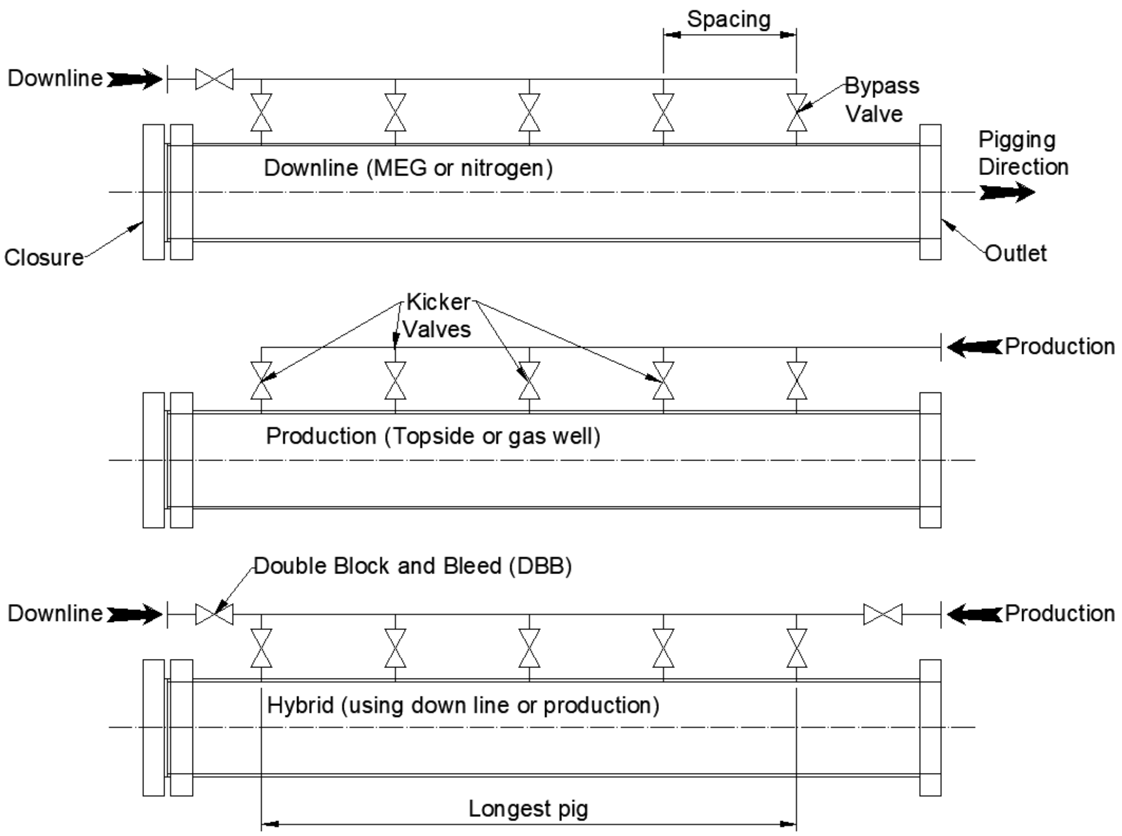


Figure 4 – Initial subsea trap layout. Note that only horizontal units for production pigging are discussed here. This paper discusses the operability of the unit and features required for successful operation.

The launcher consists of a major barrel, sized to suit the pipeline and the manifold or riser base to which it is connected. A kicker line with multiple valved connections allows each pig to be launched individually. The valves may be operated manually by a diver, by Remotely Operated Vehicle (ROV) or remotely. The spacing between kicker lines is set to contain one operational pig. The overall length between the first and last inlet allows a longer pig such as an inspection pig to be launched.

The following Functional Requirements are set out in respect of sizing and layout of the unit: -

1. The pigs must be capable of being loaded into the correct position within the launcher. Kicker spacings are not necessarily equal depending on the project;
2. The pigs must not move during deployment, installation or operation except when required to be launched. It must be possible to launch each pig separately;
3. The kicker line sizing must allow the pigs to be pushed forward effectively even when bypass pigging is considered (A bypass pig requires a higher flowrate and a percentage of the gas or liquid will pass through the pig);
4. The major barrel Internal Diameter (ID) must allow the pigs to be held positively but not over-stress the discs or cause them to be ineffective during the pig run;
5. The following operations must be possible: -
    - Deployment and recovery of the launcher;

   - Connection and disconnection to the manifold or riser base;
   - Kicker lines to launch pigs individually;
   - Venting;
   - Purge air or seawater;
   - Chemical injection (for example, MeOH for hydrate control);
   - Pressure test of the connections and / or the unit;
   - Drain and purge hydrocarbons before recovery.

   Care must also be taken to avoid excessive connections which are possible leak paths and can add risk;
6. A protection or temporary cap could be provided for the connector downstream of the pigs.

These key requirements will be examined further in detail in this paper but several aspects can be discussed at this stage. Pig loading can be provided in many ways using hydraulic rams (push) or winch (pull). The main concern is that the pigs should be positioned precisely between the kicker lines. This can be done by measuring into the launcher against the target location. A loading cone may also be required to ensure the pigs enter the launcher in a controlled and centralised manner.

To avoid taking the closure off, it can be considered in some cases to back load the pigs (i.e., push them in backwards from the outlet of the launcher). The closure is likely to be a blind flange (since it does not normally require to be opened regularly) and such a loading operation would negate the necessity to remove it. This depends on the design and type of pigs to be deployed and should be assessed for each case. In general, it would be preferable to push the pigs in from the closure end in the direction of travel. Removal of the closure flange would also allow checking of the closure seal.

To avoid uncontrolled movement of the pigs and to make it suitable for operations, the following steps can be taken as this stage: -

- Install a backstop at the rear of the launcher to stop the pigs moving back towards the closure. If this is not included, then the pigs will move backwards when the first pig is launched. The backstop can be bolted to the blind flange at the closure;
- Ensure that the pig design is compatible with the launcher and the bumper-to-bumper length is equal to the centreline spacings of all the kicker lines. This ensures that there is a kicker line immediately behind each pig;
- Longer pigs can be accommodated but the kicker line is still required to be positioned behind the pig or the drive module (inspection tools or multi-module pigs);
- If the launcher is to be designed for a new project, then the barrel ID should be based on consideration of the full pipeline bore map (not just the local riser base or manifold pipework) to avoid over stressing the discs on the pig. This is especially important in dual and multi-diameter pipelines (Note that consideration of the full pipeline design should also be considered for the receiver design at the other end and not just the local topside or arrival pipework). A holistic view should be taken;
- Include a high point vent on the launcher to avoid air getting trapped in the unit for pressure testing and during deployment. It is possible that the inlet valves could be used for this purpose but often the kicker line pipework is complicated by the need to keep the unit compact and this aspect is forgotten;
- Ideally, a low-point drain both at the front and back of the launcher with a separate receptacle should be considered. This way the launcher can be filled from the bottom as well as "back-flushed" in cases where MEG is used to launch into a gas system.
- A low or high-pressure cap at the outlet of the launcher to allow hydrotest and / or protect the connector. However, depending on the connector type, a test cap will add greatly to the

cost. Usually, the launcher can be leak tested once connected to the system by pressurising against the closest header valve.

Note that at this stage, the need for a mechanical pig stop has not been included. The launcher is horizontal and from a gravity point of view, there is no need to mechanically hold pigs in position. This will be discussed later in the paper to determine if such a device is required to physically stop the pigs moving within the launcher during deployment and operation.

The launcher is configured as follows (using the hybrid case to demonstrate for all): -

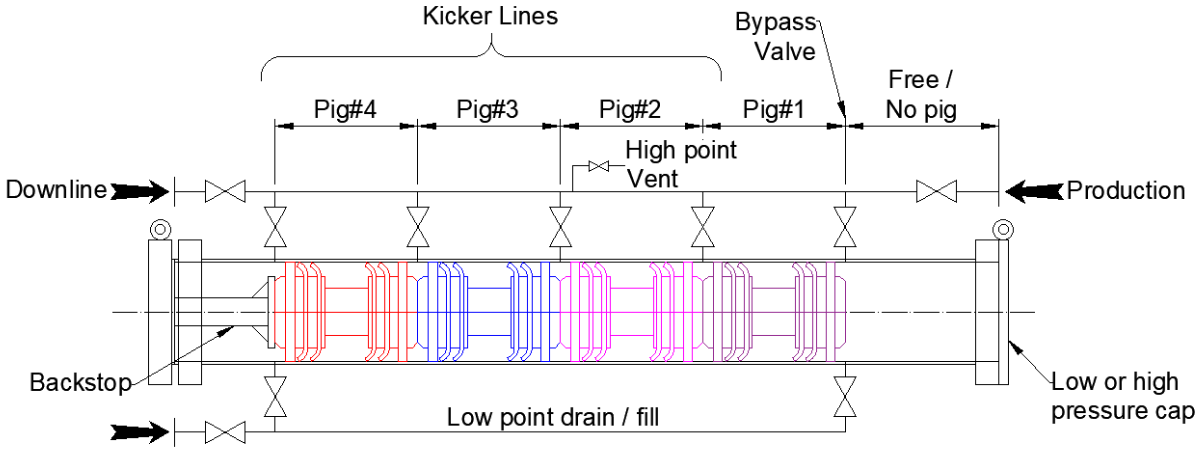


Figure 5 – Updated launcher design. Note that the inlet line closest to the launcher outlet is termed a bypass line (not a kicker line). This is an important valve connection and should be easily operable during any pigging campaign (by diver, ROV or remotely as required).

Assuming that the launcher is deployed from a vessel, it will contain raw seawater which must be removed before introducing gas into the launcher. By including drains front and rear of the launcher barrel, with a separate receptacle it will be possible to introduce MEG from the low point, with discharge through the top header or vent.

For inspection tools and pigs with bypass, the low point connections will enable flushing from the front low point, over the tool and discharge through the rear kicker. Some pig seals or discs will not hold liquid when the tool is stationary, hence MEG filling of the cavities is not possible after loading the tool.

CHALLENGES AND APPROACHES

The challenges involved in each of the launching scenarios is discussed in detail in terms of the equipment involved and the launch methodology.

OPTION 1: MEG LAUNCH VIA DOWNLINE

The schematic highlights several aspects that must be considered: -

- To move the pig as far as the production tee, then there must be sufficient MEG volume available (including the hose volume, the distance to the production tee and any losses due to pig bypass) and pressure to overcome gas back pressure, losses in the kicker lines and hose resistance. This is considered in detail below. For a new system under design, the kicker lines and header pipework should be sized to avoid excessive pressure losses in the system;

- Prior to opening the production line valve that is connecting the launcher to the pipeline, the launcher pressure should be taken to just below that of the confirmed pipeline pressure. If the liquid head is greater than the pipeline pressure, then this is not possible and there is a risk that when the valve is opened, the pigs could move – due to the sudden movement of liquid into the launcher. This places one constraint on using this approach in deep water;
- Since the hose and vessel are connected to full pipeline pressure, some safeguards must be put in place to avoid hydrocarbons migrating to the vessel. These typically include: -
    - Non-return valves at the launcher end of the hose or as part of the launcher design. This helps avoid reverse flow of gas to the vessel. A double non-return system could be considered for safety along with a quick operating valve to provide redundancy. Note that specific local requirements may apply;
    - Emergency disconnect coupling to allow the vessel and hose to be detached safely in an unplanned vessel drift-off scenario. Typical designs include self-sealing capabilities and tension-based release functionality.

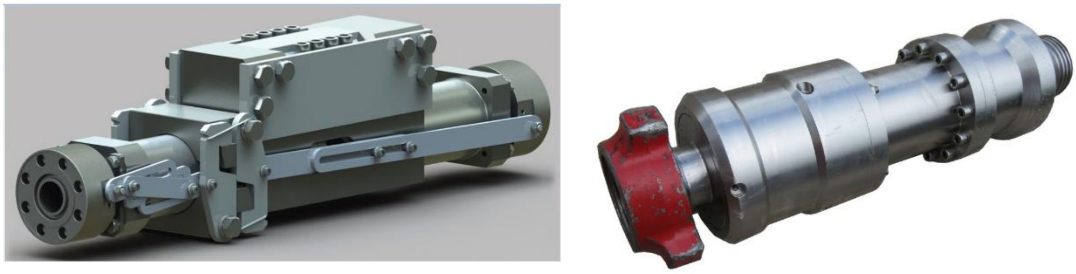


Figure 6 – Examples of emergency disconnect couplings, Left: SECC, Right: Flint Subsea.

- The type of vessel to be utilised needs to be considered. Hydrocarbons are not expected on the vessel but there is some risk of this and a decision needs to be made as to whether the vessel is hydrocarbon rated or not.

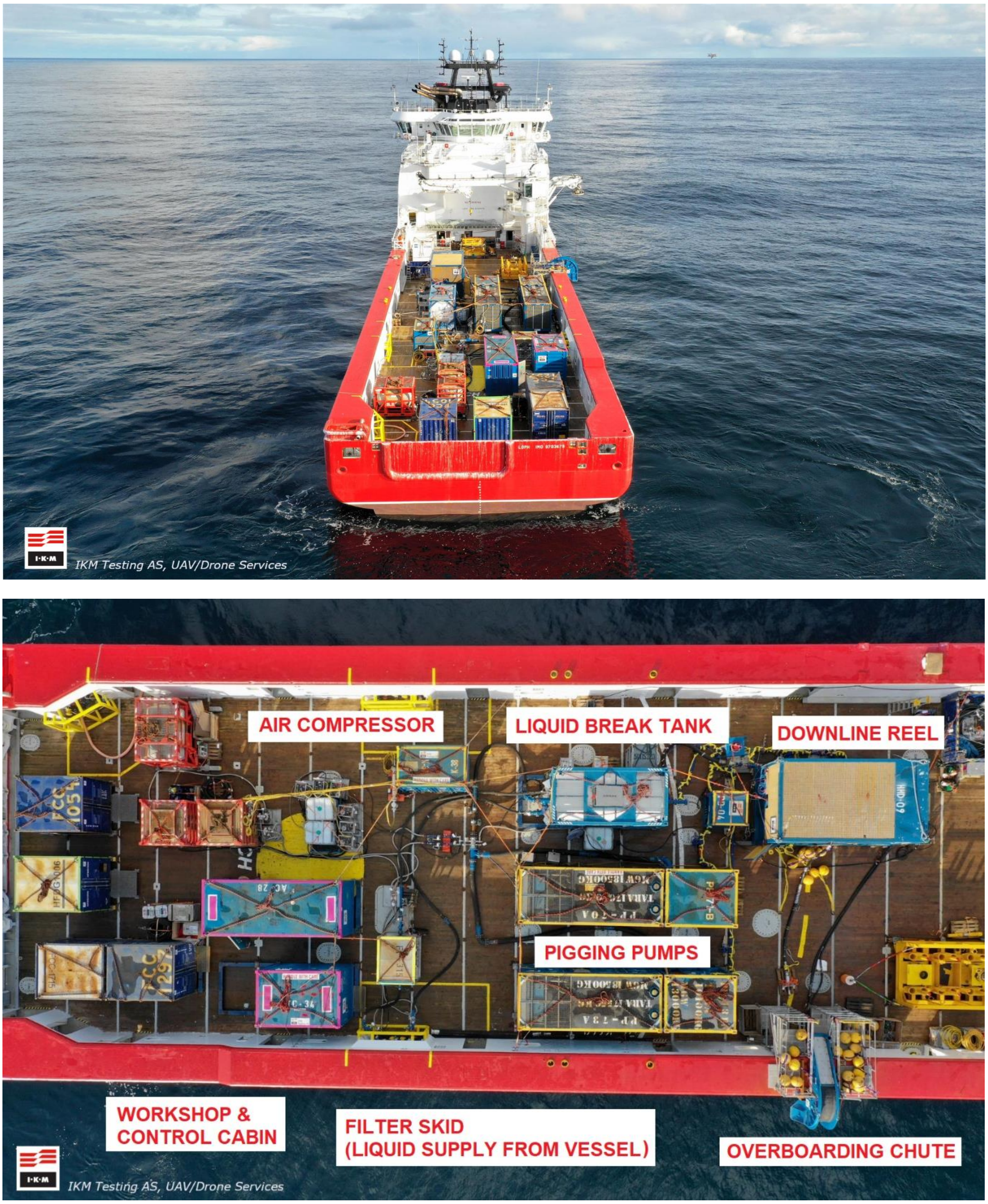


Figure 7 – Views on typical offshore campaigns with vessel and downline (IKM).

A model of the subsea launch with liquid will suffice to estimate the pressure required at the pump on-board the vessel and the volume of MEG required for one pig launch: -

These can be estimated as follows to establish the pumping pressure: -

$$P_{pump} \quad = \quad \left(P_{pipeline} + \Delta P_{pig} + \Delta P_{hose} + \Delta P_{kicker} - P_{head}\right) \times (1 + Margin)$$

and for the volume of MEG required: -

$$V_{liquid} \quad = \quad \left(Vol_{pipeline} + Vol_{hose} + Vol_{kicker} + Bypass\ loss\right) \times (1 + Margin)$$

10% margin is used for the pressure to account for unknowns and 20% for the volume of MEG to account for additional pipework at the pump.

The following graph shows a typical output for a 20-inch pipeline with 220 bar back pressure in a 350 m water depth. In this case, it is required to push a bi-directional bypass pig, 15 m to the production tee with MEG at 100 m^3/hr. The output shows the pump pressure and the volume of liquid used: -

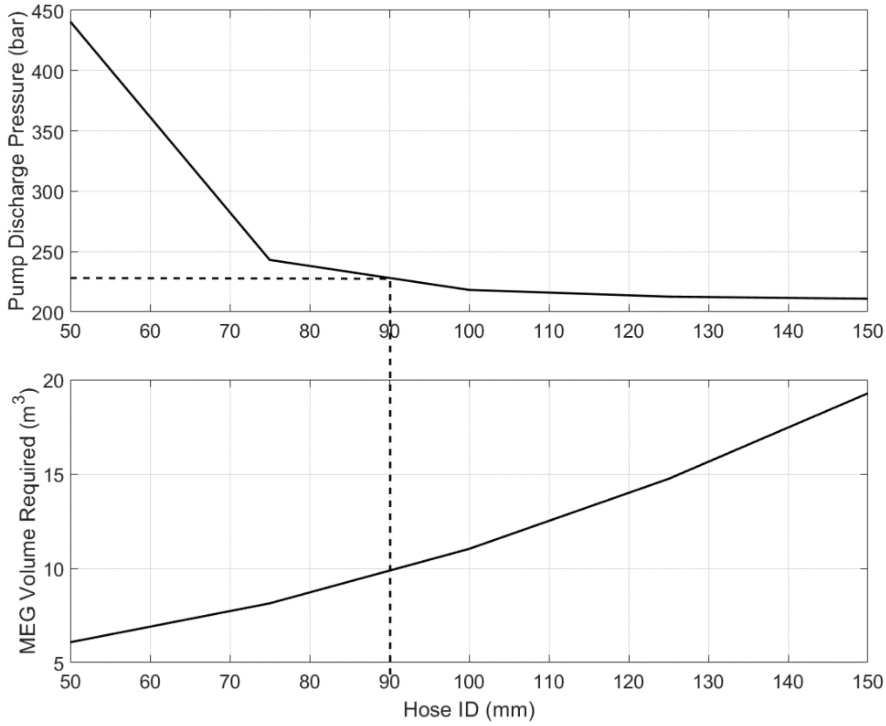


Figure 8 – Output for the subsea launch with MEG showing inlet pressure to the hose on the vessel and the volume of MEG required.

There are diminishing returns in terms of inlet pressure reduction as the hose diameter increases. The volume of MEG required also increases with increasing hose diameter. A downline with ID of circa 90 mm has been used in the case above (or the closest available hose size). Any larger does not reduce the pressure significantly and uses more MEG volume. Note that bypass can lead to a large loss of MEG during pig deployment and can limit the feasibility of launching the pig via a MEG downline. If bypass is necessary for the pigs (for example with a multiphase line where bypass pigging aids liquid control), then robust checks on the required flowrate and the ability to pump sufficient MEG to launch the pig is required. As a rule of thumb, it is best to run the pig out with less than 50% bypass by flow of MEG through the pig.

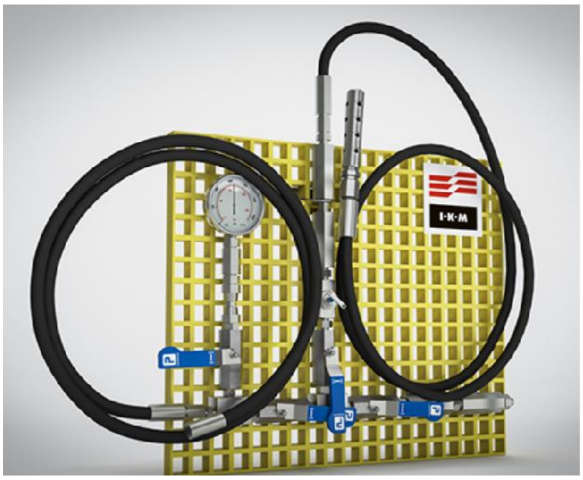
Launching the pig involves aligning the valves such that only the kicker line behind the pig is open to flow. The pump is then started and the production pig is pushed to the flow tee. It is normal when deploying cleaning pigs to continue to produce gas via the tee while the pig is passing the inlet gas flow. For inspection tools, this would have to be discussed with the vendor to establish if sensors, joints or the seals could be damaged by the gas flow at the tee.

Two pig signallers are recommended to record a successful launch. One is placed at the exit from the launcher barrel and one after the production tee to indicate that the pig has both left the launcher and is pigging through the line. Pig tracking could also be included for initial pig runs if there is any doubt or a risk of a lost pig in the line.

OPTION 2: LAUNCHING WITH A NITROGEN DOWNLINE

Several aspects that must be considered: -

- The volume of liquid nitrogen required is based on the pressure in the line, the length of the hoses, kicker lines and distance that the pig needs to travel to the production tee. The need to overcome any bypass in the pigs is also a consideration as this will require more nitrogen;
- Membrane nitrogen may allow more volume of gas but the ability to pump at a higher rate is limited. This may then limit the ability to get a pig to the production tee in the event of bypass or through leakage past the pig;
- If the pig has bypass – which is often the case for cleaning pigs and inspection tools with speed control (even when the valve is closed there may still be leakage) – then there may be difficulty getting sufficient flowrate to move the pig forward. The velocity of the bypass pig depends on the size of the bypass opening, the density of the fluid pushing (which can be low in a gas system compared with MEG), the nitrogen flowrate and the pig differential pressure;
- The downline must be adequately sized with regards to flow capacity. There is a possibility of choking the flow from the compressor in the downline if it is not sized properly. It is important that the diameter for a given hose length maintains the gas velocity below a critical level. This is considered in the simulations below;
- A system for measuring pressure in the launcher prior to the downline opening is recommended. This can be performed with a Subsea Pressurization and Monitoring Manifold (SPAMM) unit connected to the permanent structure. Due to the risk of hydrates during venting or depressurization of the High Pressure (HP) cap cavity (prior to removing blind for connection of launcher) the discharge should be routed away from the valves using a vent hose. The SPAMM should also be designed such that MEG could be injected if necessary;



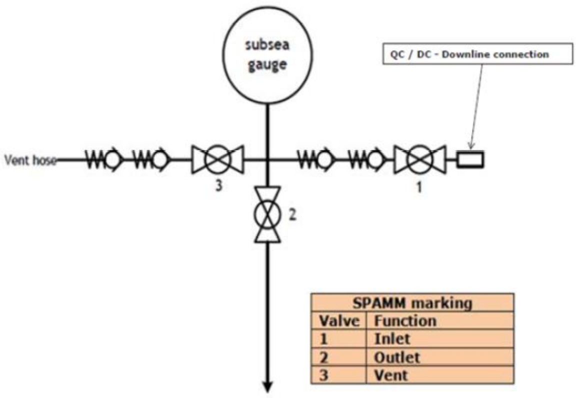


Figure 9 –SPAMM unit and example schematic allowing measurement of pressure in the launcher and venting pressure.

- The same issues on non-return, double block, quick release couplings and the type of vessel to be utilised is also required to be considered as per the MEG discussion.

The potential risk of hydrocarbon gas migrating to the vessel must be carefully considered and mitigations put in place.

A simulation of the system has been set up using PIGLAB, an inhouse model for compressible flow pigging. A 2-inch, Class 5000 rated, downline is used to take nitrogen to the launcher. Care must be taken to avoid choking this line if the required gas flowrate is high. This will be part of the analysis. The launcher is a 20-inch section of pipe with kicker and bypass lines as shown. To keep the model as small as possible, just two pigs are modelled but this can be increased in number if required. One aspect that is important to check is that the second pig does not move during the deployment of the first pig. The launcher is connected to the pipeline using a 20-inch ball valve.

A production tee is 10 m further along in the riser base as shown below: -

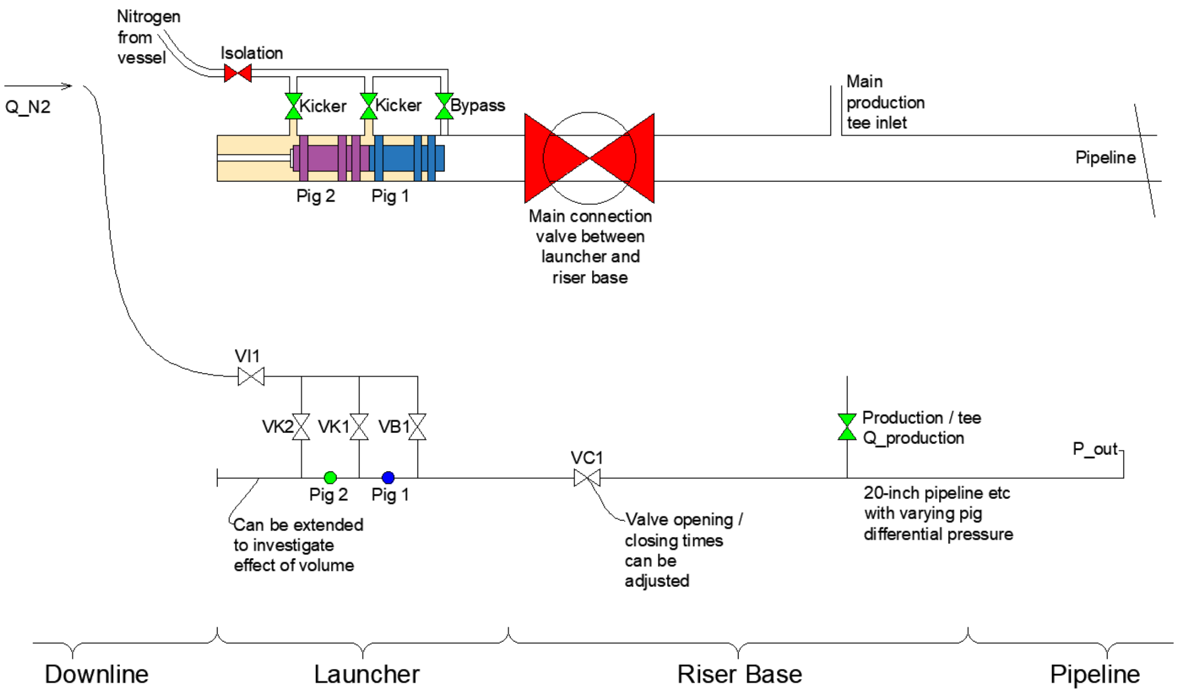


Figure 10 – Schematic of the subsea launch with gas down line. It is assumed that all liquid has either drained out or is at a low level within the launcher and that there is mainly gas present.

Initially, the downline is at a nominal 10 bar pressure. The pipeline is operating at 110 barg with 10 mmscmd flowrate entering at the production tee. For the sake of sensitivity, the launcher is set at 130 barg (high pressure case).

Not all valves are shown and only essential valves for function are included. Many valves will be double block type and it is also required to have a non-return valve at the connection to avoid hydrocarbon gas going back up the downline.

The kicker and bypass valves are normally open. This is to provide pressure balance across the pigs and minimise the chance of movement. Once these valves are closed, then pressure can build up and the pigs can be pushed into the line.

The PIGLAB model is used to check the launcher procedures and to optimise the design to ensure that the pig can be launched and sent to the production tee. The following base case launch procedure is used: -

1. Hook up the downline to the launcher;
2. Pressurise the downline to the same pressure as the launcher;
3. Open the main inlet valve between the launcher and the downline;

4. Pressure in the launcher should be equalized over the main system valve to avoid pressure surge which could cause the pigs to move prematurely. The SPAMM unit used for checking the launcher pressure is designed with a bleed valve and the launcher can be depressurized if necessary. Alternatively, if the launcher is designed with a separate drain / bleed line this could be used. Note: If HC gas is present in the launcher there is a risk of hydrate formation during depressurization, it is therefore advisable to route discharge away from the bleed valve using a vent hose.
5. Stop the inlet flow;
6. Confirm launcher pressure using the SPAMM unit and adjust downline pressure accordingly. Open VC1;
7. Close VK2 and VB1;
8. Open VI1 and start nitrogen flow into the launcher to push the pig to the production tee. A signaller on the end of the pig trap will be required to show that the pig has passed out of the launcher. A second signaller downstream of the production tee will show that the pig has been launched successfully and sent into the pipeline.

The analysis examines ways to make the launch fail as a “stress test” on the procedures and determining what caused the problem. Two cases are outline here: -

- Case A: Launcher at 130 barg, and equalised with that of the pipeline with kicker valves closed;
- Case B: Launcher at 130 barg, and equalised with that of the pipeline with kicker valves open.

The aim is to establish if the pigs move prematurely. There is also a potential problem opening the large VC1 valve between the launcher and the pipeline without equalising before doing so. Such valves are normally not opened with a large differential pressure across them and this must be checked with the supplier. The launcher or SPAMM unit should be designed to provide a way of removing this differential pressure.

The output for cases A and B is shown below. The pigs move when the kicker line valves are shut and the pressure is equalised with that of the pipeline. This is since the line pressure is also behind the pig and with the kickers closed, there is no way of equalising this pressure fast enough. The result is movement of the pigs.

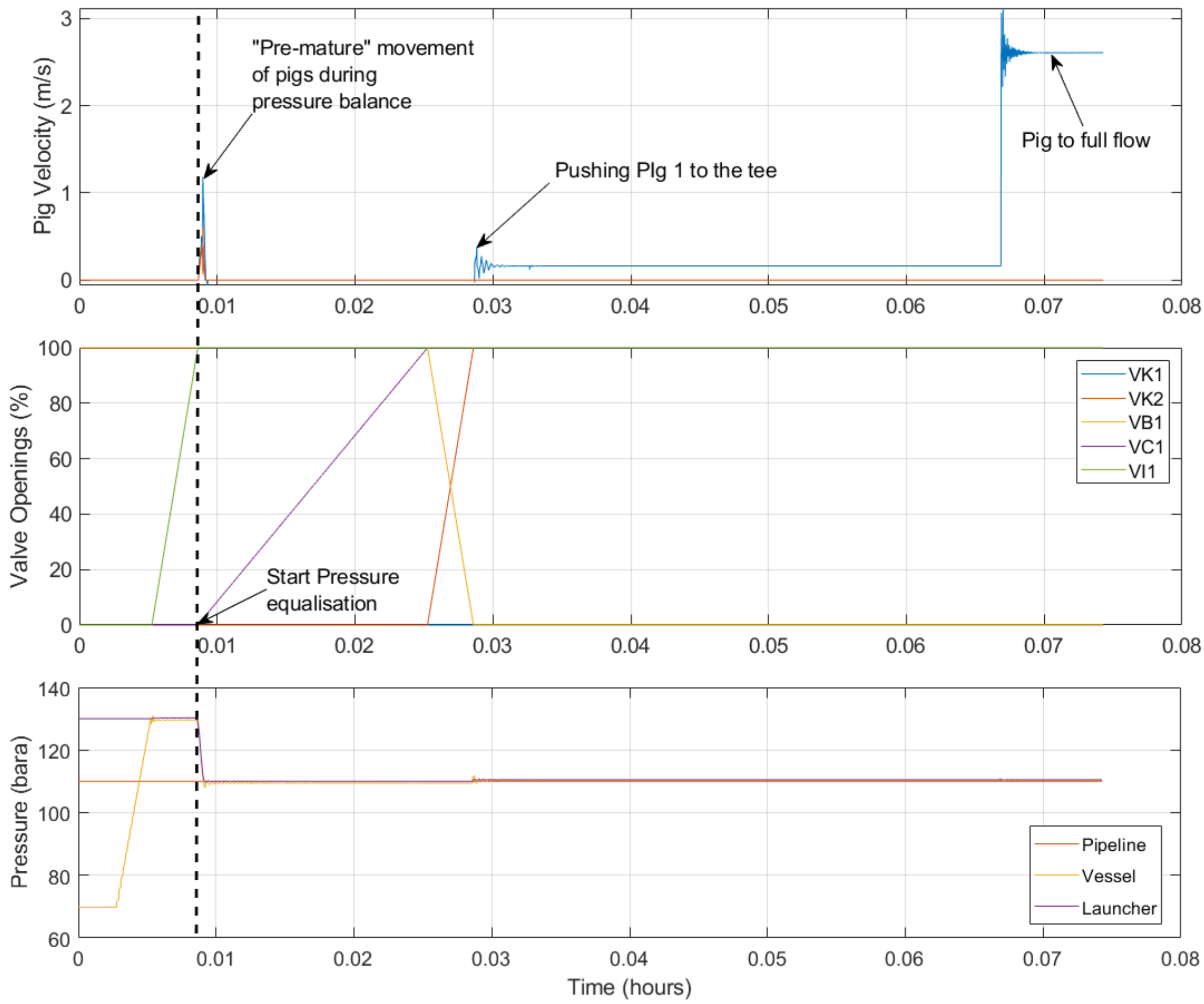


Figure 11 – Case A output with 130 barg launcher pressure but with kicker lines closed. Since the kicker lines are closed, there is less chance for the pressure to equalise over the pigs and a velocity is recorded for a moment. There is a potential for this to move both pigs resulting in the two pigs launching simultaneously.

The problem can be solved or the effect reduced by leaving the kicker lines open during the pressure equalisation process to allow a balance of pressure across the pigs: -

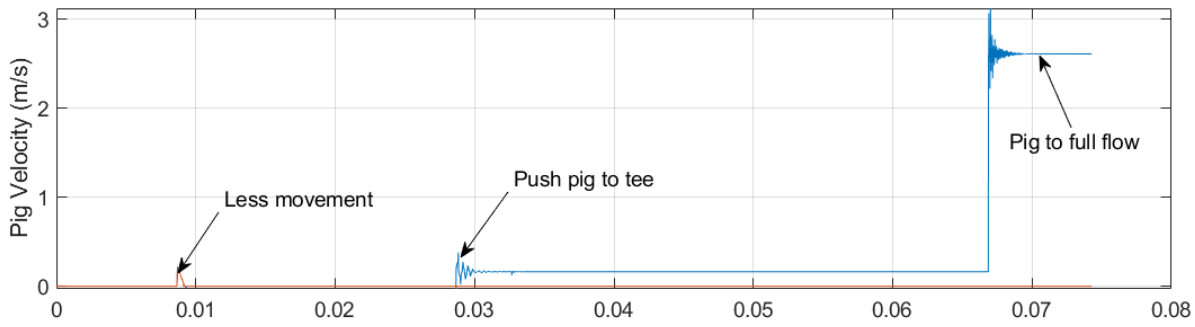


Figure 12 – Case B output with 130 barg launcher pressure but with kicker lines open. The velocity and movement are less. This can be further corrected with a larger kicker line diameter.

The following observations are made: -

1. If the pressure is larger in the launcher than the pipeline, it is not obvious how this can be equalised (as there is a non-return valve at the downline) and the only route to the pipeline is via the main isolation valve VC1. A smaller bypass valve across the VC1 would help to equalise slowly but could be considered as a potential leak path. The SPAMM unit could also be used;
2. To help avoid movement of the pigs during pressure equalisation, it is necessary to have the kicker lines on the launcher header open to act as a pressure balance. This also means that the launcher header must be large enough to avoid pressure drop developing when the valves are open. If this is the case, then it appears that the pigs will not move and there is no need for a physical pig stop. Engineering design and simulation can ensure that this is the case;
3. Care must be taken when first pressurising the downline as the velocity could be high. This may lead to choked flow but can be managed by stepping up the flowrate gradually and choosing a suitable hose ID;
4. If the pressure in the launcher is less than the pipeline, then the launcher pressure can be increased to line pressure using nitrogen from the vessel. Knowledge of the pressure in the launcher is important to understand which strategy to use. A pressure transducer can be included on the pig trap or using the SPAMM unit;
5. The requirement to shut down or reduce production when the pig approaches the main production tee is a decision based on the type of pig to be deployed. It is often recommended to reduce the production flowrate close to, or corresponding to the target launch velocity just before the launch. The production could then be ramped up once the pig is launched and past the production tee. This way there will be less risk of flipping the seals as the pig passes into the production flow. As a positive effect this will also reduce the system pressure and thus the flowrate or pressure required to launch the pig.

<u>OPTION 3: LAUNCHING USING PRODUCTION</u>

From a pigging point of view, launching with production flow allows potentially higher flowrate of gas into the launcher which is useful when the pigs have high bypass. On the other hand, there can be less control once a well is opened into the kicker line – high flow may enter the launcher rapidly and cause pressure fluctuations which could move the pigs in an unplanned manner.

An additional connection is required to the subsea manifold or riser base and this can be viewed as a potential leakage path. Selection of a multi-bore connector is preferable if the size is available and qualified. The advantage of this method of launch is that a vessel is not necessarily required except for deployment.

Remote operability must be available for the valves. The kicker lines and the bypass valve need to be remotely operable or by using an ROV. This allows flow to be introduced via the bypass and a steady flow established before the pig is launched – like a normal pig launcher with kicker and bypass lines. The pig can then be launched into this stable flow by manipulation of the valves.

A simulation of the launch has been set up with the following PIGLAB model but this time the launcher is a smaller diameter than the pipeline (a decision made elsewhere for this project): -

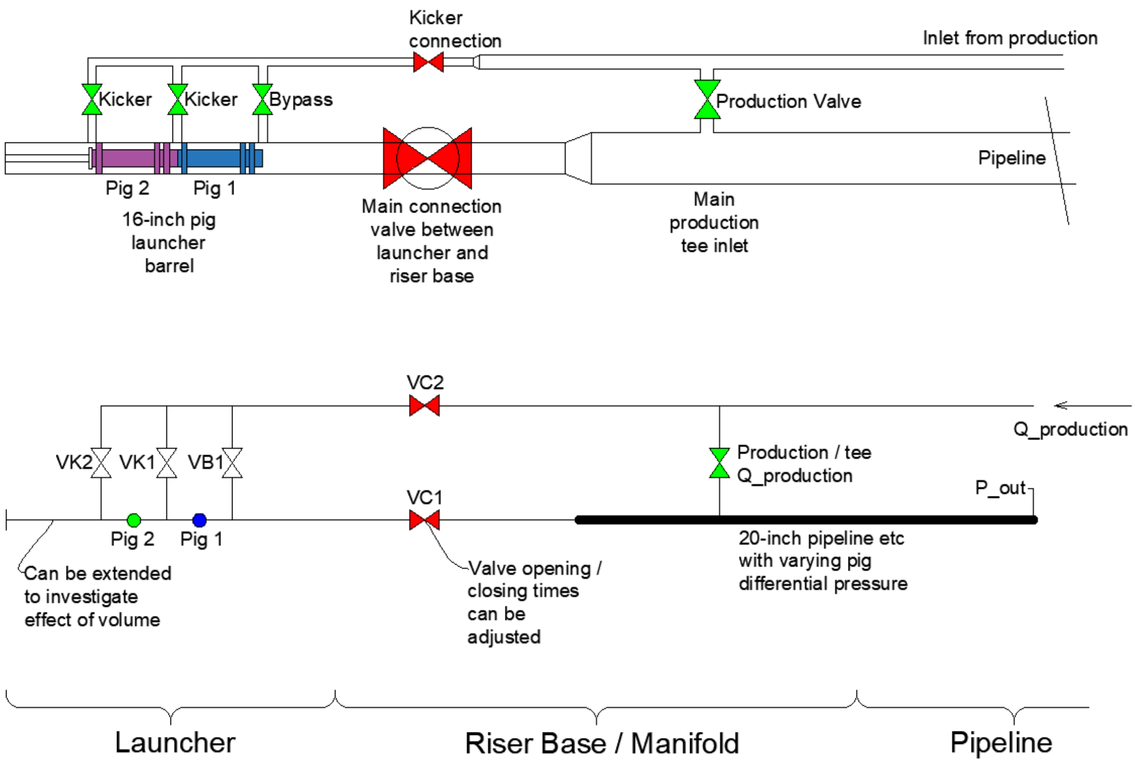


Figure 13 – Schematic of the subsea launch using production from well or local installation riser. Note that the launcher is 16-inch and the pipeline is 20-inch – a decision made on available qualified valves at the time of construction.

The PIGLAB model is used to investigate different methods of launching the pigs. One aspect of the remote subsea launcher without a downline is that the pressure in the launcher can neither be increased nor reduced prior to opening to the pipeline. Note that the pressure equalisation issue discussed previously remains and for this case, there could be a higher or a lower pressure in the launcher prior to opening the small equalisation valve, VC2. A controlled opening – slow opening time – should be determined and all the kicker lines and bypass lines should be open to avoid pig movement during equalisation. VC2 should also be a control type valve, not a quarter turn valve.

The pipeline is operating at 110 barg with 10 mmscmd flowrate entering at the production tee. The launcher is set at 90 barg (lower pressure case). Not all valves are shown and only essential valves for the launching function are included. To understand the criticality of valve opening times, some method of measuring the pressure in the launcher would be useful: -

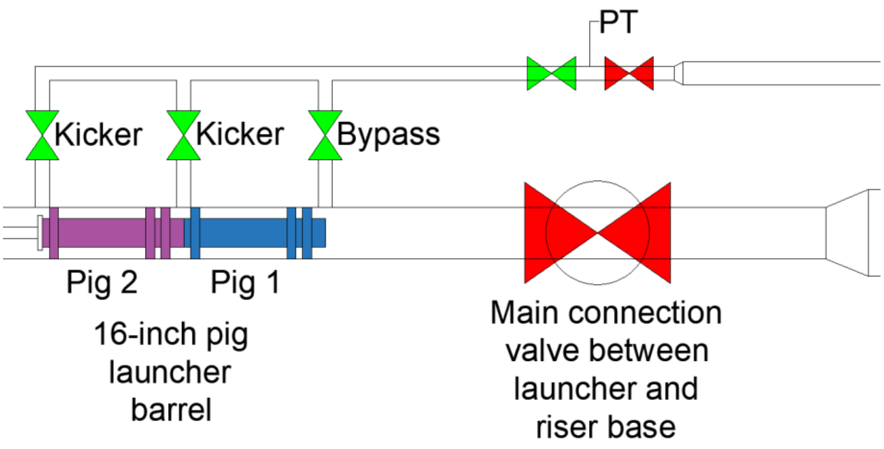


Figure 14 – Checking the pressure in the launcher prior to opening the connection to the riser base using a double valve arrangement and a pressure transducer between the valves.

The model is used to check the launch procedures and to optimise the design to ensure that the pig can be launched properly with confidence. The following launch procedure is used with a demonstration of two launch methods: -

1. The launcher is hooked up to the system with pigs installed but isolated from the pipeline;
2. The bypass line and all kicker lines are open to avoid problem with potential pig movement as noted previously during pressure equalisation;
3. Reduce production (a necessary consequence of running the pigs in this manner) to allow the flow to be routed via the kicker line. It is not possible to route all the production via the kicker line as the velocity will be too high. In such a case, only one well could be used to launch the pig;
4. Open the small isolation valve VC2 on the kicker line between the launcher and production at a slow rate (the rate of pressurisation can be modelled for safest operation);
5. Once the launcher is equalised with the pipeline, then open the main connection valve, VC1, between the launcher barrel and the pipeline;
6. Then either: -
    - Case C: With all kicker lines open, close the valve in front of pig to be launched to kick it off or…
    - …Case D: Close all kicker lines (leaving VB1 bypass open), then open the kicker line behind the pig to be launched and then close the bypass line (a more traditional launch method directing flow in behind the pig to be launched).
7. The pig is pushed into the pipeline. Once the pig is safely past the production tee, full production can be re-established and the pig taken to full speed.

The PIGLAB model allows a walk-through of the launch procedures and the simulation enables various options to be tested and the final method checked and verified. This provides confidence in launching only the next pig (no movement of other pigs in the launcher) in what can be an expensive exercise – even if it goes well. Two cases are examined here to show how the correct valve movements can make a difference: -

- Case C: Launcher at 90 barg, pipeline at 110 barg. The launcher is equalised with the pipeline (all kicker and bypass valves open). Production is lowered and routed through the launcher. The pig is then launched by closing the bypass valve (leaving the kickers open);

- Case D: Same as above but both kicker valves are closed prior to launch. To launch the pig, the kicker behind the first pig is open and the bypass is closed (following a more traditional launch method).

The output for the two cases is shown below. Due to the dual diameter nature of the system, there is a transient event when the pig enters the 20-inch riser base and manifold. In the 16-inch line, the pig differential pressure is 2 bars but in the 20-inch this falls suddenly to 0.3 bar. This causes a pressure shock which can propagate back and move the next pig.

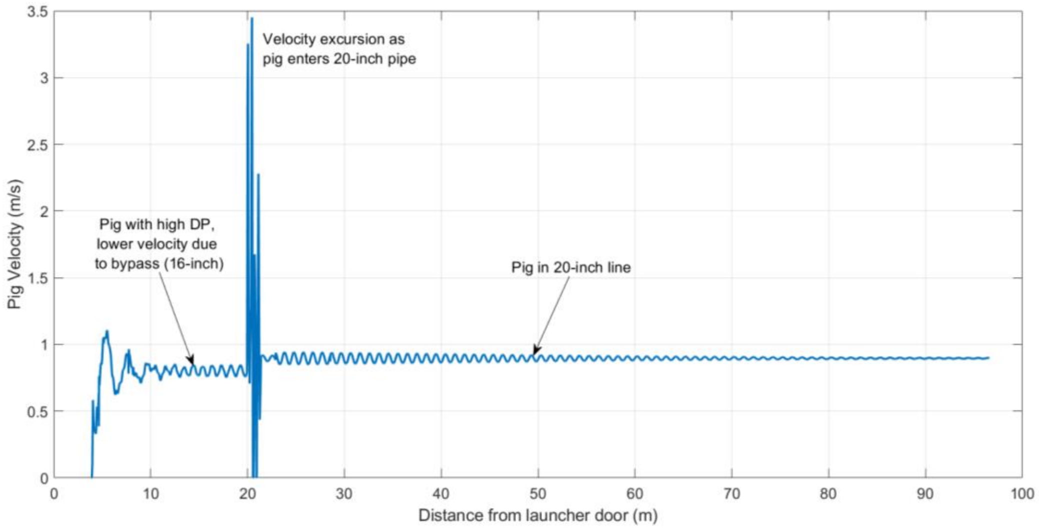


Figure 15 – Output for Case C showing velocity of Pig 1 against time. Since the pig has bypass, it travels slower in the 16-inch section where friction is high. The velocity excursion at the reducer to 20-inch causes a pressure transience which can lead to movement of the other pigs.

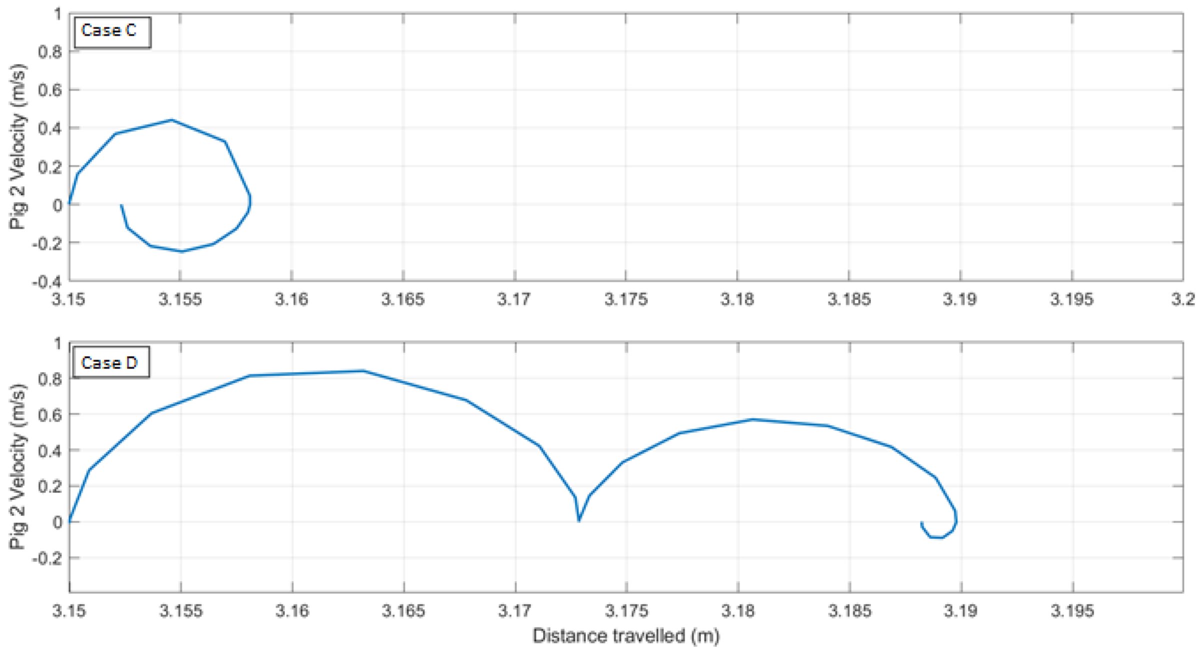


Figure 16 – Movement of Pig 2 for both cases due to the pressure transience while pig 1 traverses the reducer to 20-inch. Although there is a small movement of pig 2 for case C it is much safer than case D where the pig is not pressure balanced and more movement can occur potentially leading to a premature launch.

Both procedures will work but it is shown to be safer to use the first method – but this is a less common approach. It may also be possible to further optimise the kicker line size. The method appears to be always safer since the other pigs in the barrel are pressure balance and are less likely to move.

In summary: -

- The pressure in the launcher should be monitored prior to pressure equalisation;
- The connection valve on the kicker line should have a slow opening time to avoid any sudden surge of gas into or out of the launcher;
- The kicker and bypass lines should be open during pressure equalisation;
- The launch method that appears to cause the least chance of premature pig movement, is to have all valves open, establish the required flowrate through the bypass and then close the valves downstream of the next pig. The fact that the other pigs are pressure balanced via the kicker lines reduces the chance of these pigs moving at any stage.

EVALUATING AND SELECTING LAUNCH METHOD

In many cases the correct selection between MEG downline, nitrogen downline, processed gas or well-stream production will be determined by the circumstances and selection of the correct option will be obvious. For example, a remote well in deep water will most likely use the unprocessed well flow to launch a pig. For a shallow water case where, pigging frequency is low or is based on 5 yearly inspection intervals, then a MEG downline may be the best choice. In other cases, the choice is not clear cut.

The following sets out advantages and disadvantages of each option that could help make the optimum choice: -

METHOD	ADVANTAGES	DISADVANTAGES
Launching using nitrogen downline	o Independent of production flow and may not require production turndown; o Only a single main connection to the manifold required (less leak paths); o Other than the main connection, the launcher is independent of the production manifold; o Helps avoid hydrocarbons from entering the launcher making recovery easier (but some level of hydrocarbons should be expected in the launcher following launch); o No liquid is pushed into the pipeline compared with the MEG case and nitrogen as a drive medium is benign; o Downline diameter can be smaller compared with MEG due to lower density (calculations are required to make the right choice); o Pressure can be increased or reduced using the SPAMM unit for instance (build into the launcher design).	o Risk of choking the flow in downline, if the hose diameter is not correct. Sizing of the line is important; o There can be high differential pressures across the main connection valve; o There is a possibility of high-pressure hydrocarbon gas migrating to the vessel with associated risks; o A more costly vessel may be required with flare; o If hydrocarbon gas is a risk on deck, then equipment may need to be zone rated; o Lower flowrate and density available to launch pigs; o The volume of nitrogen required may be large; o The nitrogen downline method appears to be less popular in the industry; o Potential large equipment footprint on the vessel.

METHOD	ADVANTAGES	DISADVANTAGES
Launching using MEG downline	o Relatively small equipment footprint on board the vessel compared with nitrogen and could be performed using a support vessel; o Lower pressure at the pumps due to the head of liquid compared with the nitrogen downline case; o Helps keep hydrocarbons from entering the launcher making recovery easier; o Since liquid is already in the launcher from deployment, then complications with multi-phase flow is avoided; o Source of MEG to counter potential hydrates issues; o Less likely to stall the pigs as higher density flow; o Independent of production flow and may not require production turndown; o MEG is required for leak tests.	o Sizable volume of MEG entering the production flowline; o May require large bore, dedicated downline to get required flowrate into the launcher; o MEG volumes enter dry gas pipeline and cause problems; o Increased weight of the hose potentially; o Risk of hydrocarbons to the vessel is present due to line between production system and vessel; o Potential for pressure from liquid head to be higher than pipeline pressure making launch difficult to control; o High pressure across the equalisation valve is possible; o Liquids entering the pipeline may affect some inspection techniques and Inline Inspection (ILI) tools.
Launching using production (from process or using well)	o No side loads at the tee as it is closed or the flowrate is reduced considerably; o Hydrocarbon gas cannot migrate to the support vessel; o Use of a ready store of energy; o No liquid into the line or not introducing additional fluids into the system; o Bypass pigging more feasible due to higher flow potential.	o Requires a reduction in production to get necessary differential pressure to push the pigs due to the small size of the kicker line; o Hydrocarbons enter the launcher making recovery more difficult; o Hydrocarbons may contact seawater in the launcher and hydrate mitigation is necessary; o Downline may be required for venting, purging, testing during installation and for a one-off pig run (inspection), it may be easier to use the downline to launch the pigs; o Possible mixing of gas and water which will require MEG injection to avoid hydrates; o Additional connection required for launcher (design issue, leak path); o Unknown pressure in the launcher if left for time or after a number of pig runs; o Possible requirement to open valves subject to high differential pressures; o High differential pressure between launcher and production which could move pigs. This can be investigated by simulation and by getting valve sequence correct; o More suited to system where a single well can be diverted to launch a pig while the other wells produce as normal.

Table 1, Selection of optimal launch method.

SUMMARY

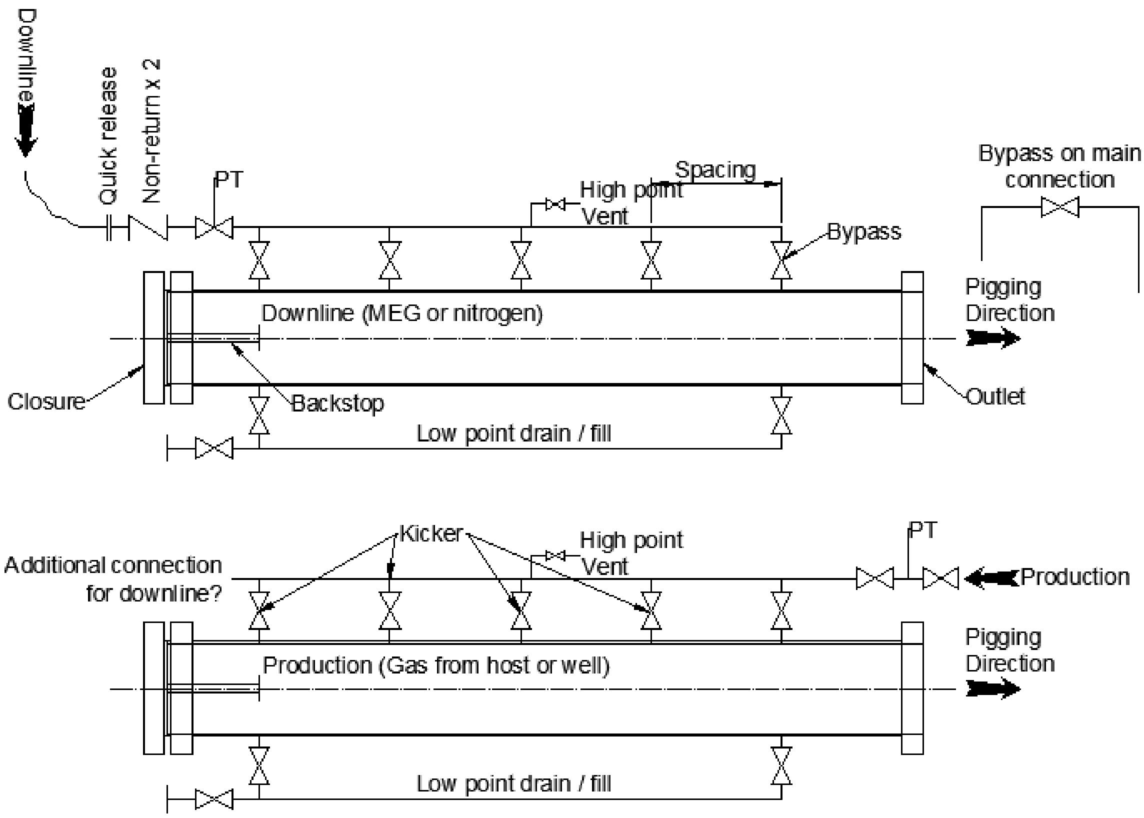
Deciding the correct and most appropriate method of launching pigs with a subsea launcher involves consideration of (a) vessel and downline using liquid such as MEG or gas such as nitrogen or (b) using production gas from process on an installation or from local wells. In many cases, the choice may be clear cut due to practical (e.g., water depth, proximity of installations) or economic considerations (cost of pig launch against frequency required).

This paper shows that in many cases it is possible to simulate the various options and simulate pigging procedures to highlight the feasibility of pigging or not. Bypass pigging can result in higher flow requirements than is practical with one method compared to another. The requirement to balance pressures between the production flowline and the launcher can result in premature pig movement if the procedures are not adequate. The ability to simulate and step through the launching process and valve sequencing can help to anticipate and avoid problems and fine tune the procedure. It is a very expensive process and if the pigs are not launched correctly or are mis-launched, then this can be very costly indeed.

Such simulation and engineering can also aid with the design of the launcher to make it as suitable as possible for the operation.

Finally, selection of the correct safety equipment, downlines and vessel layout for the MEG or nitrogen case is very important and equipment such as non-return and quick release couplings can be critical for the success of the operation.

The following figure summarises the main features that should be considered for a subsea launcher.



Notes: -

1. All valves operable remotely or via ROV;
2. Manifold to kicker and bypass sized to allow good equalisation;
3. Ability to determine pressure in launcher as well as pipeline;
4. All downlines and connections sized to avoid restrictions and possible choked flow;
5. Reverse / back loading for single diameter lines or large bore / dual diameter launcher, forward loading for small bore / dual diameter;
6. SPAMM unit / method of monitoring pressure and reducing pressure in the launcher;
7. Diameter of barrel to avoid un-necessary stress on seals;
8. Mechanical pig stops may not be necessary if pigs are pressure balance but may be a preference for the operator;
9. Pig signalling to confirm pigs have left the launcher and left the manifold / riser base;
10. Slow control of pressure equalisation is an advantage with bypass and kicker valves open;
11. Kicker and bypass valves open during deployment, isolation and launching if possible;
12. Vent on high point to allow all air to be removed prior to test and deployment;
13. Low point drain and fill incorporated.

Figure 17 – Summary of main points in this paper for input into subsea launcher design.