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Evaluation of the Valve-less Flooding System & Re-design of Hot Stab Guiding System

Mihar M. Ved
Internship Report
December 2015

Supervisors:
Prof. dr. ir. Andre de Boer - University of Twente
Mr. Alexander Huisman - Allseas Engineering
Mr. Martin Esselbrugge - Alleas Engineering

Applied Mechanics,
Faculty of Mechanical Engineering,
University of Twente
P.O. Box 217
7500 AE Enschede
The Netherlands

University of Twente

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Author:
Mihar Ved
Student No.: s1604015

Supervisor:
Mr. Alexander Huisman
Mr. Martin Esselbrugge

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Allseas Engineering B.V.

"*The capacity to learn is a gift; the ability to learn is a skill; the willingness to learn is a choice.*"

Brian Herbert

UNIVERSITY OF TWENTE

Abstract

Applied Mechanics
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Evaluation of the Valve-less Flooding System and Re-design of Hot Stab Guiding System

by Mihar VED
Student No.: s1604015

This internship is part of the requirement for my MSc. in Mechanical Engineering at the University of Twente and has been performed in cooperation with the Innovations Department and Pipeline Engineering Department at Allseas Engineering B.V..

After a pipeline has been installed on the seabed, it needs to be tested for client approval. During this procedure, an ROV (Remotely Operated Vehicle) is used to carry out the various steps that are necessary to ensure that the integrity of the pipeline has been maintained.

In this report, the two important aspects of this operation are researched; firstly, the time spent by the ROV to operate the valves on the launcher head and receiver head and secondly, the guiding system for the hot stab operations of larger pipelines laid down by Allseas. The shortcomings of using the ROV to operate the valves on the launcher as well as the present methods of guiding hot stabs are investigated and possible solutions are developed and their feasibility checked.

It is evaluated that the current methods of valve actuation on the launcher and receiver do not result in any unnecessary loss of time compared to the valveless flooding system. Furthermore, by implementing the valve-less flooding system into the current actuation methods, the system would be more complex, time consuming and expensive to maintain. Finally, a cone guide mechanism is designed for the hot stab system such that any impacts from the ROV do not compromise the integrity of the male stab and in turn the integrity of the seals on the stab.

Acknowledgements

I would like to thank Allseas Engineering B.V. for giving me this opportunity to work in an inspiring environment. I would like to use this opportunity to also thank my supervisors Martin Esselbrugge and Alexander Huisman for guiding me throughout the internship. I would also like to thank Lothar Wolthuis and Thijs Feijen for their quick responses and enthusiastic feedback. Finally, I would like to thank all those at the Enschede office for the wonderful support and company during the entire period of the internship.

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List of Abbreviations

A&R	**A**bandonment & **R**ecovery
DMA	**D**ead **M**an **A**nchor
DP	**D**ynamically **P**ositioned
FGT	**F**looding **G**auging and **T**esting
HPU	**H**ydraulic **P**ower **U**nit
OOD	**O**verall **O**uter **D**iameter
PIG	**P**ipeline **I**nstrumental **G**auge
PLEM	**P**ipeline **E**nd **M**anifold
PTFE	**P**oly**T**etra**F**luoro**E**thylene
ROV	**R**emotely **O**perated **V**ehicle

Chapter 1

Introduction

1.1 The Company

The Swiss-based Allseas Group S.A. is a major offshore pipelay contractor specialized in offshore and subsea constructions. It was founded in 1985 and is headed by Edward Heerema and employs around 2,500 people worldwide.

The company operates with specialized vessels which are designed in-house. At the moment, there are five main vessels in operation. These are the dynamically positioned (DP) pipelay vessels *Solitaire, Audacia* and *Lorelay*, the shallow water pipelay barge *Tog Mor* and the DP trenching support and subsea installation vessel *Calamity Jane.* Allseas recently acquired their sixth vessel, *Pioneering Spirit* as seen in Figure 1.2, which was delivered a few months ago. It currently holds the title for the largest pipelay, platform installation and decommissioning vessel in the world.

Figure 1.1: Allseas Fleet

1.2 Pipelay

There are several methods of installing pipelines: S-lay, J-lay, reeling and towing. The Allseas vessels use the S-lay method where the lengths of line pipe are welded onto the pipeline in a horizontal or near horizontal position. At the end of the vessel, the pipe is supported by rollers on a curved ramp known as the stinger, which guides it towards the seabed. The reason this method is called S-lay is because the shape of the pipe from the vessel to the seabed represents that of an "S" as seen in Figure 1.3. The overall outside diameter (OOD) of the pipeline ranges from 6” to 68”.

Figure 1.2: Pioneering Spirit arriving in Rotterdam

This method provides fast installation for all pipe diameters over a large range of water depths.

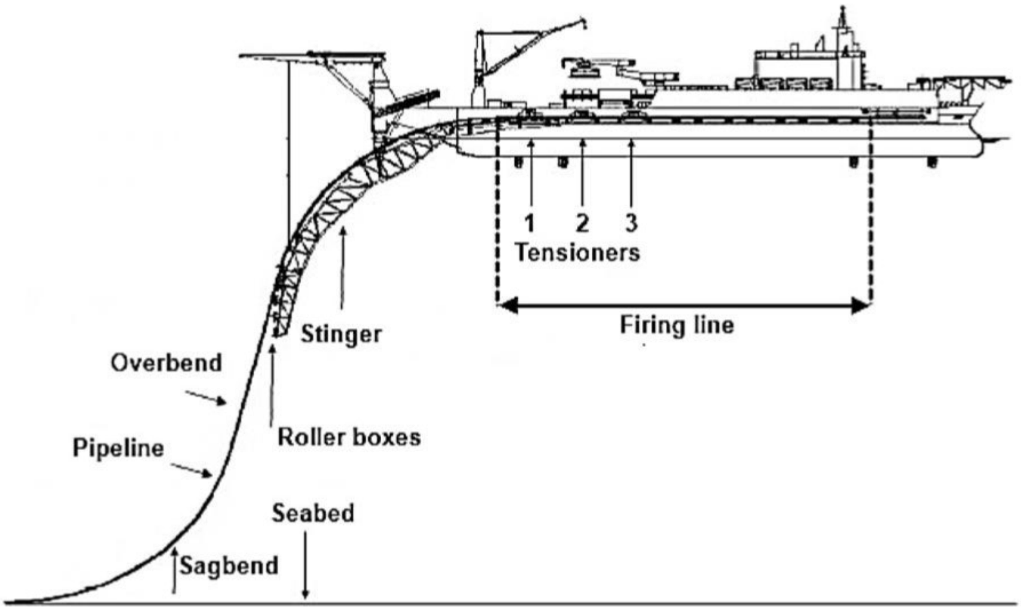


Figure 1.3: Overview of the S-lay pipelay method

The beginning of the pipelay process is carried out with either the dead man anchor (DMA) or pile while the end of the pipelay process is carried out with the assistance of an abandonment and recovery (A&R) cable. Generally, the dead man anchor (DMA) start-up method is used, where an anchor is placed on the seabed. This DMA is connected to the pipeline by a cable. Alternatively, a start-up pile is used, which is driven into the seabed. A cable runs via a sheave attached to the start-up pile back to the vessel. On the vessel, the cable is connected to the beginning of the pipeline and the other end of the cable is attached to a winch on the pipelay vessel. Finally, the beginning of the pipeline reaches the start-up pile, where a special mechanism catches the pipe and the A&R cable is cut by an underwater robot [1].

During the pipelay process, the pipeline is typically installed dry to reduce its submerged weight. This prevents unnecessary tensions in the pipe, high forces in the tensioners and on the thrusters. In some cases, when for example the pipeline requires more submerged

Figure 1.4: Male stabs

weight for installation or to reduce the amount of freespan, the pipeline can be installed flooded. However, this is not a normal practise. Before the client accepts the installed pipeline, depending on the contract, Allseas is required (by the client) to flood, clean, gauge and hydrotest the pipeline. This operation is commonly abbreviated as FGT (flooding, gauging and testing) and is known as the pipeline pre-commissioning process. It is either done by Allseas or sub-contracted to an external contractor. The procedure is explained in detail in the next section.

1.3 Flooding, Gauging and Testing operations

The flooding, gauging and testing process is typically carried out before a pipeline is ready to be used. During fabrication and installation, debris may be left inside the pipeline which can cause damage if not removed. At the same time, pipeline internal dimensions also need to be checked to make sure that no deformations have occurred during installation and that no internal restrictions exist. Furthermore, this test also verifies whether the pipeline is capable of withstanding the design pressure or not especially in the case of any leakage in the pipeline [2].

To enable flooding, gauging, high speed flushing and hydro-testing of pipelines, the pig launcher is fitted with a diver-less hot stab connection which allows a hose connection to be made between the pig launcher and the support vessel. The connection is made once the support vessel is set up on location over the subsea pig launcher. A flooding/testing hose fitted with a male hotstab (Figure 1.4) is then lowered from the support vessel. The head has the female receptacle attached to it as seen in Figure 1.5. The ROV then makes the hot stab connection such that pig launching operations can start. This is typically as seen in Figure 1.6.

FIGURE 1.5: Female receptacle mounted on the head

FIGURE 1.6: Launcher on the seabed [3]

The pig launching operation involves sending a number of pigs from a pig launcher head to a pig receiver head. The first pig is typically the contingency/dewatering pig which is used in the unlikely event of a wet buckle during pipeline installation; the second pig is the brush pig which is equipped with steel or polyurethane brushes, while the third pig swabs the dirt and debris out of the pipeline and the last pig measures the internal pipeline geometry with an aluminum gauge plate. Pigs are generally mounted with trackers such as pingers or electro-magnetic signalers which are used to detect the position of the pig within the pipe.

To flood, clean and gauge a pipeline, a flooding hose is deployed from a support vessel equipped with a FGT pumping spread and an ROV. Filtered seawater is pumped into the pipeline which is treated with chemical cocktails including biocide, corrosion inhibitors, oxygen scavenger as well as a fluorescent dye.

A controlled FGT operation (which includes pumping a pre-determined volume of water through the pipeline) typically consists of the following steps:

- The flooding hose is deployed from the support vessel close to the pig launcher head;
- The ROV is deployed and inserts the male hot stab into the subsea head;
- The ROV then operates the valves to allow water to launch the pigs;
- When the total volume of water is pumped, the ROV closes all the valves and removes the hot stab;
- The flooding hose and ROV are then recovered to the deck;
- The support vessel now sails to the pig receiver head location;
- The ROV is deployed to confirm pig arrival;
- The ROV closes valves on receiver head for hydrotesting;
- ROV is now recovered to deck.

The other type of flooding is free flooding. Once the pipeline has been flooded, cleaned and gauged, it is subjected to a hydrotest at a predetermined pipeline test pressure to prove the leak tightness of the pipe. Depending on the size of the pipeline, high pressure hoses are connected to the launcher head with the respective hot stab size. After a holding period of 24 hours, the pressurised pipeline is then depressurised to ambient pressure or slight overpressure. The whole operation typically consists of the following steps:

- High pressure hose is deployed from support vessel to pig launcher head;
- The ROV is then deployed and inserts the male hotstab into the subsea head;
- The ROV then opens the appropriate valves on the launcher head to pressurize the pipeline;
- Pressurisation steps carried out;
- After the hydrotest acceptance, the pipeline is depressurised;
- The ROV now closes all valves and disconnects the hotstab;
- The high pressure hose and ROV are finally recovered to deck.

1.4 Problem definition

From the above procedure, it can be seen that the FGT operations involve a large number of steps from maneuvering the ROV to the required positions to operation of valves, general visual inspection of the procedure and also carrying out the extremely delicate hot stab connection. The pre-commissioning phase of pipeline installation is of great importance since it determines the integrity of the laid pipeline.

Most of the steps listed in the procedure in the previous section involve the use of the ROV. In order to operate the ROV effectively, a great amount of training has to be undertaken such that all the operations are carried out within the given time frame. However, since the support vessel only has a video feed in two dimensions instead of three, this process may become slightly complicated. The first assignment therefore deals with finding a method of reducing the subsea tasks done by the ROV such that

FGT operations can be carried out within the best time frame possible. This will be explained in detail in Chapter 3.

Allseas installs pipelines of various diameters. As the size of the pipelines get bigger, the hot stab required for the FGT operations will also be bigger. The largest hot stab used by Allseas is the 6" hot stab. The male hot stab weighs about 200 kilograms while the female receptacle weighs around 360 kilograms [4]. As stated before, the hot stab operation is to be carried out by the ROV which maneuvers the hot stab into position. For a hot stab of this weight range, the connection normally leads to damage of components on the ROV and also breakage of seals on the stab due to misalignment.

1.4.1 Approach

To get a good understanding of how the FGT operations are carried out and to know how exactly the earlier mentioned problems fit in to the procedure, a detailed study is first done whereby the current methods of operations are looked into. Next, the possible ways of reducing ROV tasks are researched. Simultaneously, a literature survey is also done to find out the methods used by suppliers of the equipment. Then, conceptual designs to solve the first assignment are developed.

After completing the first assignment and having a deep understanding of the procedure, hot stab operations are then looked into in detail. New guidance methods are researched on and based on the requirements of the hot stab connections, a new concept will be developed to aid the existing system.

1.4.2 Goal of the research

1. To evaluate the use of the valve-less flooding system as a replacement for the current flooding procedure carried out during FGT operations;
2. To investigate new guidance methods for large hot stab connections.

Chapter 2

Process description

This chapter elaborates on the flooding, gauging and testing operations together with the various components involved. This is necessary for evaluating the concept design of the valve-less flooding system. An overview of the complete system can be seen in Figure G.1 in Appendix G. This includes the head launcher on the left side, the pipeline to be pigged in the center and the pig receiver on the right.

2.1 Pigging system

The FGT operations are also known as the pigging operations. *Pigging is the act of passing a fluid through a pipeline whereby the fluid is introduced into the pipe behind the pig propelling it forward under pressure [2].* These involve the following systems and components:

1. **ROV**: Allseas uses the Schilling Ultra Heavy-Duty ROV as seen in Figure 2.1. This has manipulators attached to it which can carry out the various operations such as opening and closing of the valves as well as grabbing on to the male hot stab to make the connection [5]. These manipulators act like human hands with control aboard the support vessel. The ROV is near-neutrally buoyant.

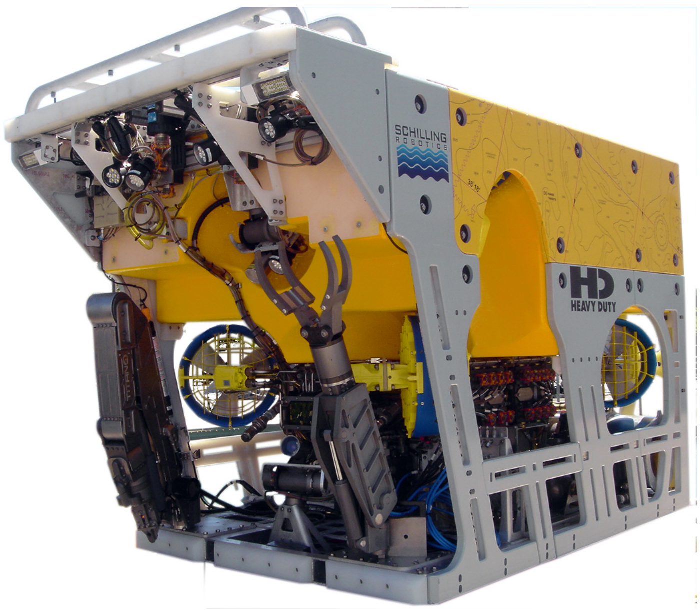


FIGURE 2.1: Schilling UHD ROV [5]

FIGURE 2.2: Brush and swab pigs

2. **Pigs**: This stands for **P**ipeline **I**nstrumental **G**auge. The pigs are enclosed in a pig launcher in the beginning or end of the pipe. They can be unidirectional or bi-directional, the latter implying that the device can be propelled from either end. Usually, a series of pigs is sent through the pipeline in a so called *"pig train"*. The pigs have different functions and are separated by pre-determined volumes of water.

   As mentioned earlier, a typical pig train consists of the following (as can be seen in Figure 2.2 and Figure 2.3a):

   - Brush pig - this pig contains nylon brushes to clean the inner pipe wall. It is also used as a contingency pig;
   - Swab pig - this pig sweeps out all the loose particles that are not removed by the brush pig and are not in suspension in the water;
   - Gauge pig - this pig verifies the internal bore of the pipeline.

(A) Gauge pigs

(B) Aluminum disc

FIGURE 2.3: Pigs and gauge plate

3. **Pig launcher**: The launcher as seen in Figure 2.4 is typically attached to the start of the pipeline. This may not be the case in some projects whereby the pig is supposed to travel from deep waters to shallow waters in which case the launcher is attached to the end of the pipeline. It is a section of pipe provided with valves and a manifold from which pigs are launched. It is also equipped with ROV operable valves and female stabs that are used during operation. The arrangement of pigs in the launcher can be seen in Figure 2.5.

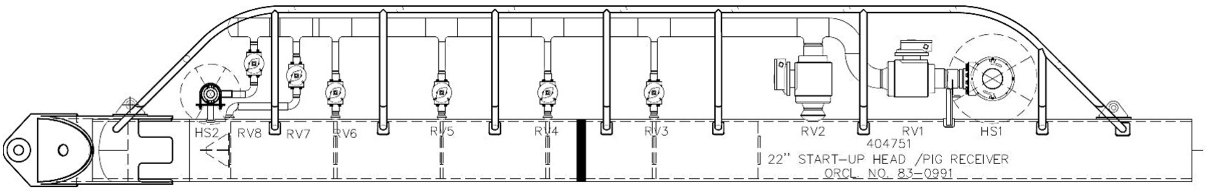


FIGURE 2.4: Head drawing of a pig launcher

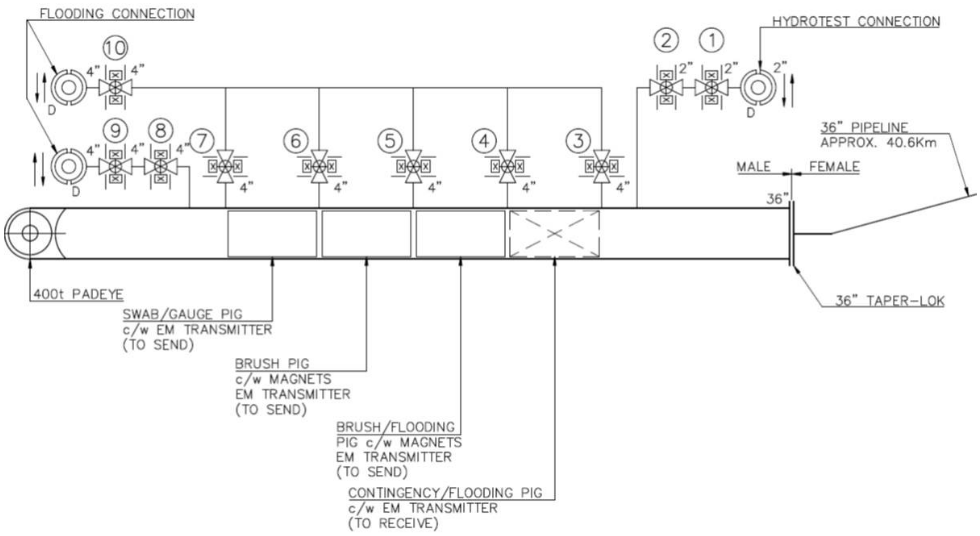


FIGURE 2.5: Schematic of a pig launcher

4. **Pig receiver**: This is installed at the end of the pipeline whereby the pigs arrive once the FGT operations have completed. A pig signaler is placed on the head to indicate the arrival of pigs (as mentioned in Section 1.3). A typical pig receiver can be seen in Figure 2.6 and its components in Figure 2.7.

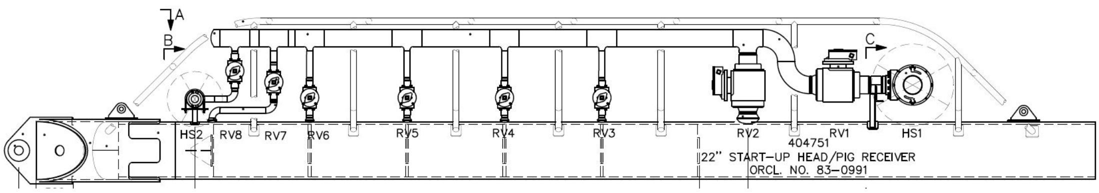


FIGURE 2.6: Head drawing of a pig receiver

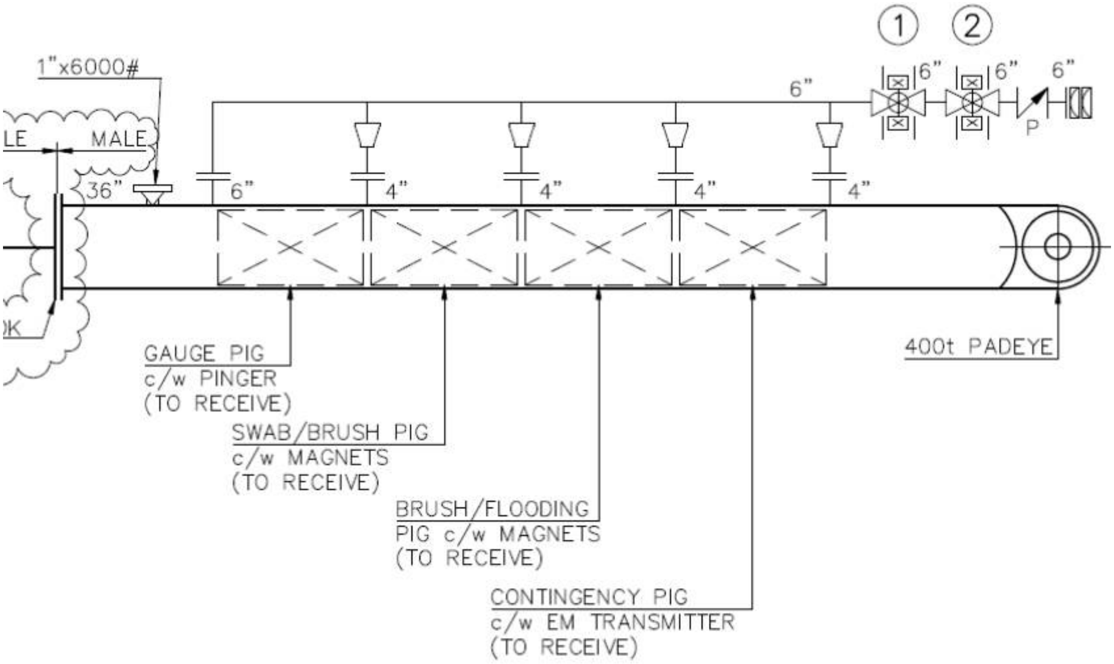


FIGURE 2.7: Schematic pig receiver with the various components

5. **Hose connection**: The hose is attached to a tugger wire and deployed subsea. It has a male hot stab at its end which makes the connection to the head launcher. A clump weight is attached to the tugger wire which is laid on the seabed (as seen in Appendix E). Some slack is then paid out to compensate for heave. A 20 meter tail hose then runs from the clump weight to the hot stab which is laid on the sea bed. This ensures that the vessel motion does not influence the tail hose or the hot stab. Hose deployment is typically done in four stages. The first three are seen in Figure 2.8.

   (a) Hose overboarding - this is where the downline is deployed from the vessel towards the seabed;
   (b) ROV holds one monkey fist (explained in point 6) and the ROV handle on the male hot stab;
   (c) ROV guides hot stab and hose towards the female receptacle;
   (d) ROV makes hot stab connection as seen in Figure 2.9.

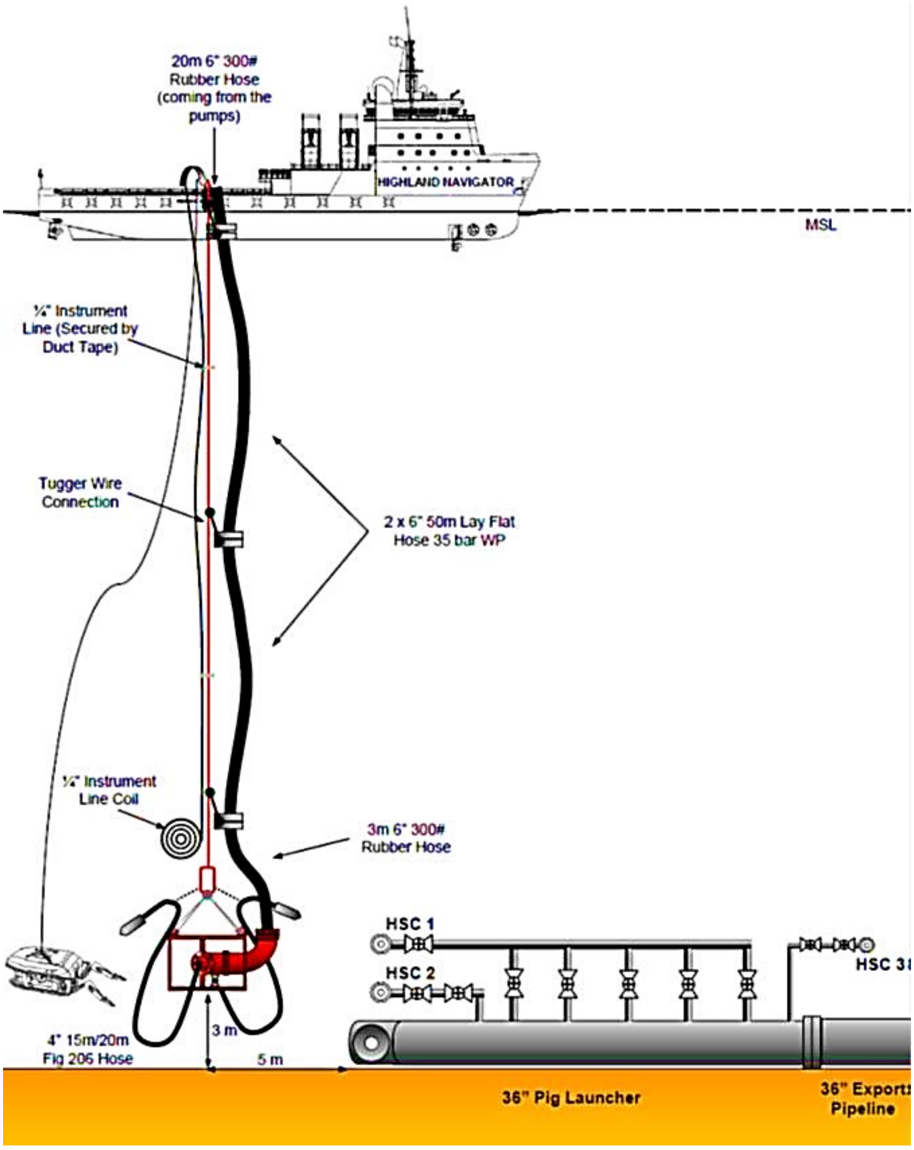


Figure 2.8: Overall view of the hose deployment process

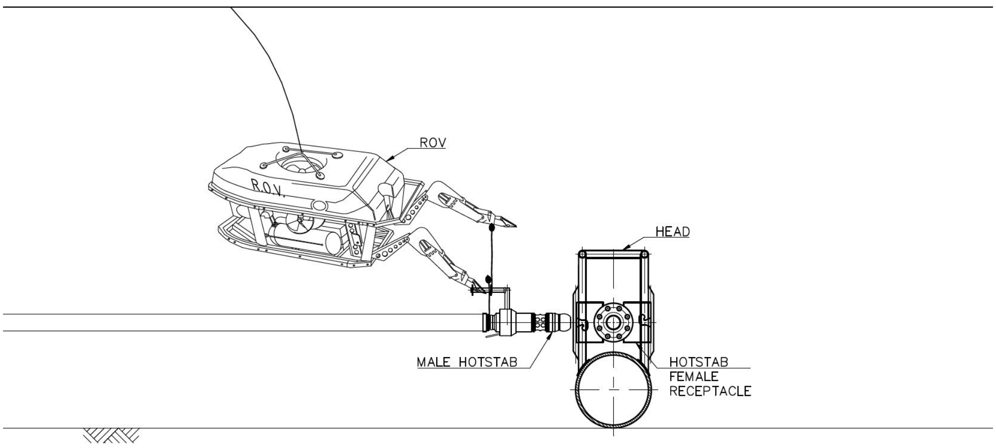


Figure 2.9: Step 4 of the hose deployment process

6. **Dummy hot stab**: Before the launcher is installed, the dummy hot stab is inserted into the female receptacle. This is so that during installation, there is no risk of contamination of the female receptacle i.e. so that sand or any other debris does not get stuck in it. A monkey fist is attached to the dummy hot stab to enable the ROV to pull it out. A monkey fist is a knot that looks like a small clenched fist. It is tied at the end of the line to add weight and can be used as an underwater float in poly prop lines to enable easy grabbing by an ROV manipulator arm. An example can be seen in Figure 2.10.

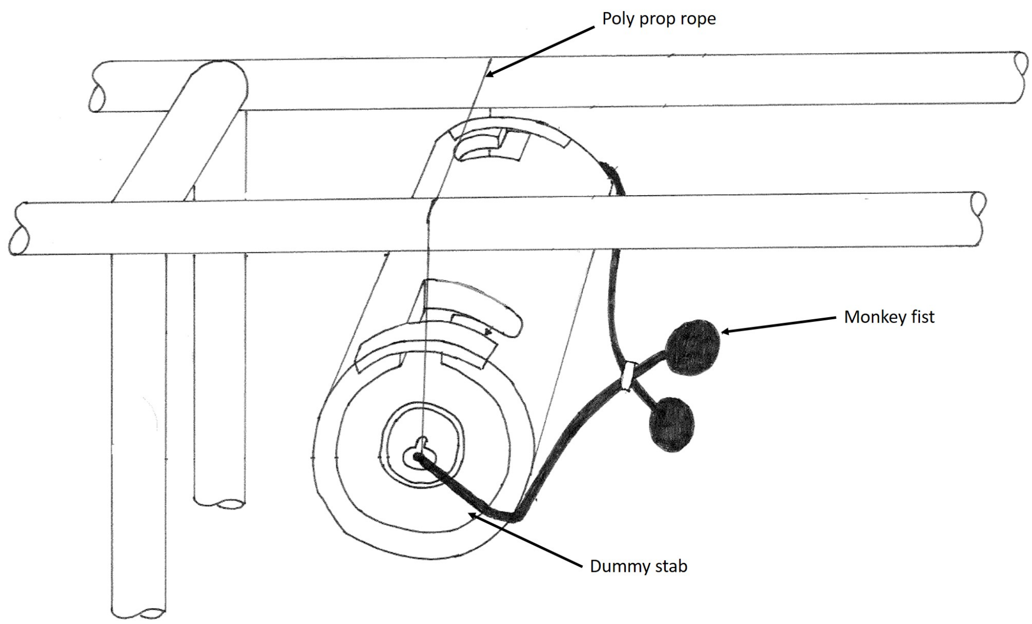
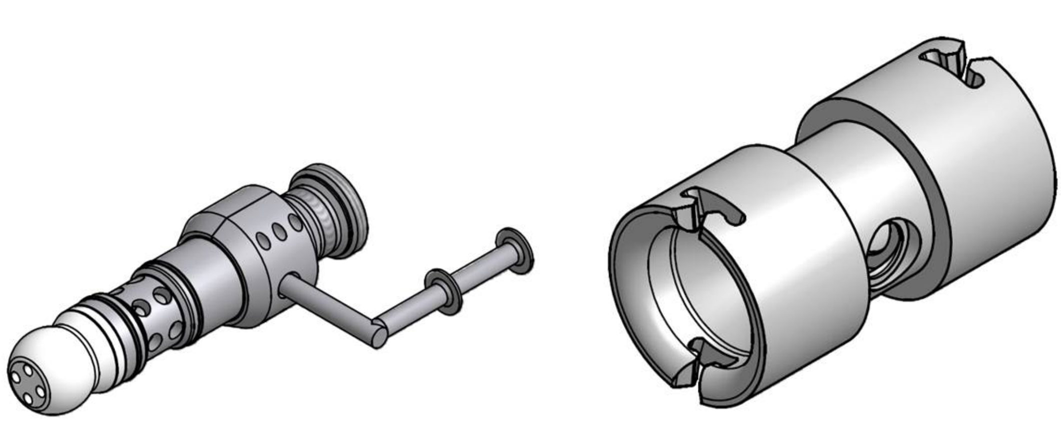


FIGURE 2.10: Dummy hot stab

7. **Hot stab - male**: This is attached to the hose. As seen in Figure 2.11a it has an ROV handle for the ROV to grab onto to guide it. The dimensions vary according to the size of the pipe, the largest that Allseas has used is 6-inch.



(A) Male hot stab (B) Female receptacle

FIGURE 2.11: Different parts of the hot stab assembly

8. **Female receptacle**: The female receptacle is attached to the launcher head. There are two provided 180° apart for contingency purposes. The female receptacles are fitted with a dummy hot stab which is to be removed by the ROV before the male hot stab connection can be made. A typical female receptacle is seen in Figure 2.11b.

9. **Pumping spread**: The pumping spread consists of the various pumps required to carry out the FGT operations. Monitoring of the pressure is done aboard the vessel for operations such as pressure testing. An example of such a spread can be seen in Figure 2.12.

FIGURE 2.12: Pumping spread aboard a support vessel

2.2 Details of the individual operations

This section provides details of the individual operations carried out during the FGT procedure.

2.2.1 Flooding

The main purpose of flooding is to allow subsea tie-ins to be performed and to provide a suitable medium for pressure testing. In some cases flooding may also be necessary to provide the pipeline with temporary "on bottom" stability. The two alternative methods of flooding a subsea pipeline are to inject water using temporary water injection spread (pump flooding) or to allow the pipeline to flood with seawater using natural hydrostatic pressure as the driving force (free flooding) [6].

Allseas typically carries out flooding by pumping seawater through a hose into the pipeline at one end. Some pre-water is usually provided for lube. To avoid air bubbles in the pipeline, a pig precedes the water flow and pushes the air out. Complete air removal is carried out to minimise the risk of corrosion, to dissolve the air in water and to be in accordance with the requirement of pressure testing. Secondly, during this process, there is a risk of hose collapse when the internal pipeline pressure is less than the external ambient pressure. This is prevented by using a suitable back pressure valve or by pre-pressurising the pipeline with a suitable gas.

The flooding operation is known to be complete when the pipeline pressure is equalised with or marginally greater than the external ambient pressure [7]. When pigs are used during the flooding operation, the arrival of all the pigs in the pig receiver signify the completion of the flooding operation.

2.2.2 Cleaning

The cleaning operation is carried out simultaneously as the pig train travels in the pipeline. The main purpose of cleaning is to remove any residual debris that has the potential to interfere with safe and efficient operation of the pipeline. The interference can be in the form of large quantities of debris causing a blockage in the pipeline or pig receiver during the initial pigging operation or it can also be if debris is to interfere with future pigging and internal inspection activities.

The cleaning is complete when all the pigs have arrived in the receiver head. The debris carried by the first and subsequent pigs supports the interpretation that the pipeline is clean.

2.2.3 Gauging

The main purpose of gauging a pipeline system is to verify the internal bore of the system and to confirm that no significant damage has occurred during or after the pipeline installation and the pipeline is within the client specifications. A pipeline is gauged by a gauge tool after the completion of the pipe-lay activity [2]. Figure 2.3b shows a gauge plate.

The last pig in the pig train contains an aluminum disc known as a gauge plate which fits the pipe with a pre-determined tolerance. If the pipe is too deformed or if too many penetrations of welding material occur, the edges of the aluminum disc will show this once the pig emerges at the end of the pipeline.

In case of excessive weld penetrations, a concession will be requested from the client and a gauging pig which is smaller in diameter will be deployed to repeat the process. If a major defect is detected somewhere in the pipeline, a repair is necessary.

When the gauging plates have been recovered and do not indicate the presence of any unacceptable dents, buckles or reduced bore or other obstruction or defect, the gauging procedure is complete and the integrity of the pipeline maintained. An example of a damaged plate can be seen in Figure 2.13.

FIGURE 2.13: Damaged gauge plate

2.2.4 Pressure testing

The main purpose of the hydro test is to confirm the overall integrity and leak tightness of the complete pipeline system.

Once the pipeline has been completely filled with water, it is subjected to a predetermined pressure. Sufficient hours must pass between flooding and testing of the pipeline for adjustment of the water temperature inside it. A percentage drop due to stabilisation of the pressure and temperature is allowed. A (large) change in the temperature of the water during the testing period can cause an unacceptable change in pressure. Once the pressure and temperature inside the pipeline have stabilised, the pressure is retained for about 24 hours and this should not decrease beyond a predetermined limit [2].

A pipeline is said to be safe to use for operations if the design code pressure testing acceptance criteria have been met.

2.3 Overview of pigging operations

The FGT operations therefore involve the following steps [7]:

1. The support vessel sails to the receiver head location. The ROV is deployed to place magnetic signaler on receiver head. The ROV then opens the valves on the receiver head;
2. The support vessel sails to the launcher head location. The ROV places the magnetic signaler near the flange assembly. The flooding hose is deployed and hot stab

connection made. The ROV operates the valves on the head to pump pre-flush and send pigs one by one. It stops flooding when 110% of the pipeline volume has been pumped. The flooding hose is then retrieved;

3. The vessel then sails to the receiver head location again where it confirms the pig arrival using the acoustic pinger and magnetic pig signaller. The ROV then closes the valves on the receiver head in preparation of the hydro-test;

4. The vessel again sails to the launcher head location. The high pressure hose is deployed and the hot stab connection made. The pipeline is pressurised and held for the required holding period. Once the client approval is obtained, the pipeline is depressurised and the high pressure hose recovered.

A detailed step-by-step procedure can be found in Appendix A.

Chapter 3

FGT Techniques

This chapter elaborates on the first assignment; it discusses the problems with the current system, gives an overview of what the offshore industry uses for FGT operations, provides an insight into the valve-less flooding system, possible integration of the new system with the old and finally a judgment on whether the new system would work or not.

3.1 Current system

As seen in Chapter 2, the FGT operations involve a number of steps that requires the support vessel to move from the launcher head to the receiver head. Other than this, the ROV is required to carry out a number of operations. This involves operating the valves on both the launcher and receiver, providing a visual inspection of the operations being carried out and performing the hot stab connection.

The first assignment looks into possible ways of reducing the tasks performed by the ROV. This is done so that (i) *the ROV can be used for other operations* and (ii) *to reduce the shortcomings of the ROV.*

Elaborating on the second point, the limitations include the workability of the ROV during bad weather conditions and the depth up to which the ROV can operate (due to tether and umbilical length). Other limitations of using an ROV can also include inexperienced ROV operators which can lead to damage of the ROV components as well as damage on the launcher and receiver due to impact from the ROV. The time taken to maneuver the ROV also depends on the experience of the operators which can influence the time to complete the FGT operations. Lastly, the launcher head may rotate when it is laid down subsea. This makes it difficult for the ROV to access the valves or hot stab connection.

These problems can be overcome by finding alternate methods of operating the valves on the launcher and receiver. This operation takes up the majority of the time of the ROV since the number of valves to operate depends on the number of pigs that are to be launched.

Keeping the above problems in mind, a literature survey is carried out and the findings are outlined in section 3.2.

3.2 Literature survey

Different methods of carrying out the FGT operations by various companies were examined. The findings are as follows:

1. **Kongsberg Nemo:** As seen in Figure 3.1, the pig launcher is fully automated. Its main features are launching pigs remotely from the mother platform, an option for the valve-less design and protection from dropped objects amongst others. This means that an ROV is not required to operate the valves and hence there would be no risk of impact with the launcher. It uses a pig cassette for easy replacement of pigs; it can be interfaced with PLEM/manifolds and it also includes pig detectors. For more details, refer to Appendix B.

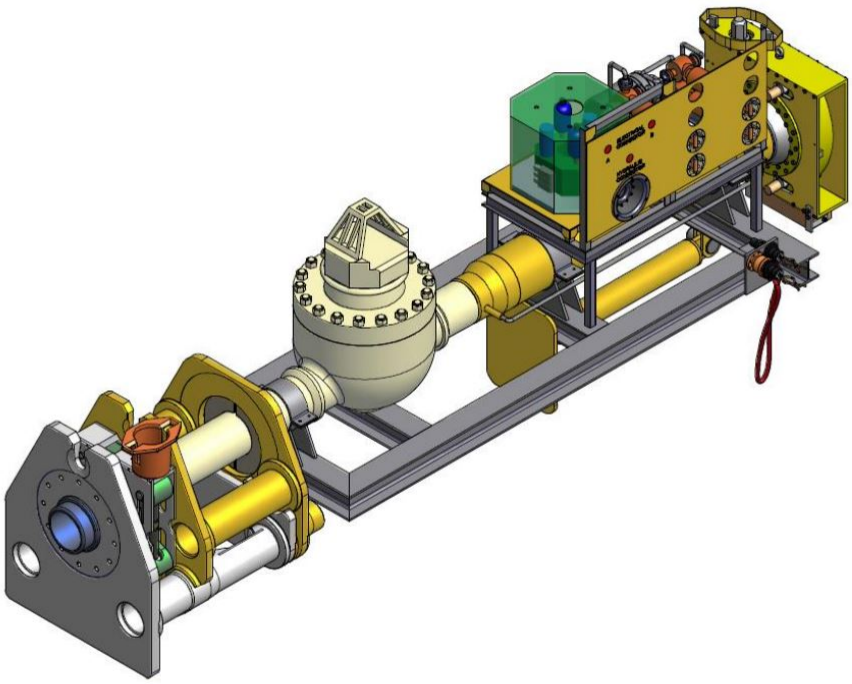


FIGURE 3.1: Kongsberg Nemo Pig Launcher [B]

2. **Kongsberg Subsea Automated Pig Launcher:** This launcher is capable of launching individual pigs subsea, remotely controlled from a platform. This remote launching removes the need of an ROV operating the valves on the launcher head. However, this can only be connected to a manifold or PLEM structure. For more details, refer to Appendix C.

3. **Automatic Multiple Pig Launcher:** This launcher allows independent launching of pigs without the need for launcher intervention every time. This means that the FGT crew does not have to continuously monitor the process. Launching is done by allowing the fluid inside the launcher to create a pressure differential which launches the lead pig. Appendix D provides a detailed insight on this.

4. **Balltec Pig Launcher:** The flangeless subsea PIG launcher facilitates the insertion of a PIG into a cut pipe during subsea operations and includes an ROV activated grip and sealing arrangement that negates the need for any additional fixings or flanges to be added to the pipe [8]. The Balltec launcher can be seen in Figure 3.2.

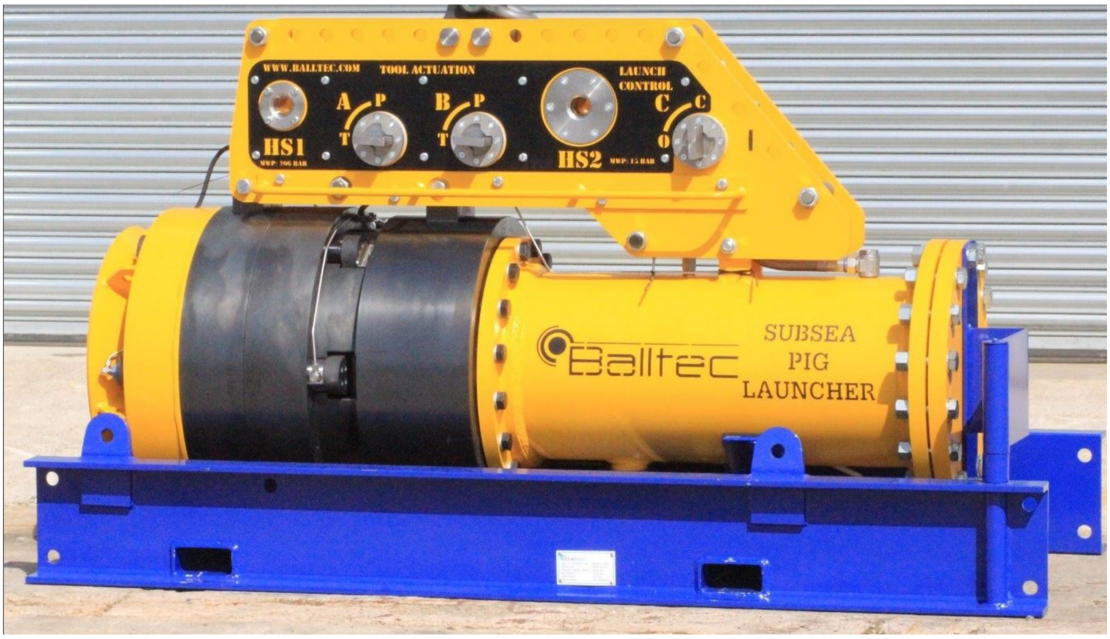


FIGURE 3.2: Balltec Pig Launcher [8]

5. **Rotork Subsea:** Rotork provides hydraulic actuation solutions to operate valves with ROV override options for contingency purposes and easy repairing of the valves. This again, is remotely actuated and does not require the ROV to be around to launch pigs.

6. **Sonardyne** provides acoustic actuation of valves which can also be used subsea.

7. **Halliburton pigging and hydrostatic testing unit:** Halliburton provides launchers that combine both pigging and hydrotesting operations. The set-up reduces deck space and as seen with Balltec, constant monitoring of the process by the crew is not required [9].

After carrying out the literature survey, possible remote valve actuation methods were researched. The following options were available:

1. **Hydraulic actuation**: For this to work, the system would have to be made redundant. That means that either the ROV is completely redundant or the ROV can still operate the valves in case the hydraulics fail.

   Another aspect to consider for this would be the fact that there will be added mass to the system. This mainly depends on where the hydraulic power unit is placed, i.e. either on the deck of the ship or the launcher. If it is placed on the deck of the ship, two hydraulic hoses and the pressure and return lines should be considered. Especially if greater depths are being tackled, the mass of the hoses themselves would increase considerably. Furthermore, pumping hydraulic fluid through, for example, a 2 km line would result in a substantial power loss. This can be overcome by installing more power since the HPU is on the deck. By adding the HPU to the launcher, the increase in mass of the head would be large. The source of power would have to be looked into as well; either using batteries on the ROV or a power cable from the vessel.

Finally, using hydraulic actuation would most likely require hoses and cables to be attached to the launcher for FGT operations. Since these cannot be left attached to the head during pipelay, an ROV would be required to make the connections. So in a nutshell, the tasks carried out by the ROV may not reduce by a considerable amount.

2. **Sleeve valves**: These are normally placed on the receiver head to operate the valves such that when there is a pressure build up behind them, they move to release the pressure [10]. A similar concept was used by Allseas when they used rupture plates to release the pressure. However, these were discontinued because the valves on the receiver head would have to remain open during pipelaying. Installation engineers laying the pipes found this to be risky.

3. **PLEM connections**: This concept is similar to what is observed in the *Kongsberg* pig launchers whereby pigs are launched from PLEMs automatically.

4. **Electric actuation**: This would increase the complexity of the system. Furthermore, in order to test if this worked, a whole system would have to be designed and tested. This would cost a lot more. Furthermore, the risk associated with using such systems subsea is great. The objective to find another solution to the actuation of valves was to reduce the complexity. Electric actuation conflicts this aim.

5. **Acoustic actuation**: This type of actuation has already been employed in A&R systems whereby acoustic release mechanisms are used [11]. Even though this has proven to be fairly useful, it cannot be applied to actuate valves. The reason is two-fold: the first is that the subsea environment is fairly noisy in terms of transmission of signals. Therefore, there may be a risk of the actuation not happening if the correct signal is not picked up by the actuator. This mainly occurs in shallow waters due to breaking waves. Secondly, it would require a complex system; this is something that is not desired.

6. **Electro-hydraulic actuation**: As mentioned above, large complex systems would have to incorporated in the current system which would increase mass therefore these systems are not considered.

After taking into account the above, a concept that was tested in the year 1995 - 1996 was researched on to evaluate whether it could be incorporated with the current pigging system or not. This concept is known as the valve-less flooding system. This is explained in Chapter 4.

Chapter 4

Valve-less flooding system

4.1 Overview

The valve-less flooding system concept was first designed in 1995 and used during the Shell Schooner project in 1996. The procedure involved the use of:

- Two 4-inch flooding hoses, each 50 metres long (one for the base case and one for contingency purposes);
- ROV for making the hot stab connection during contingencies;
- Ball operated flooding head;
- Three balls made of Teflon.

The base case flooding hose was to be connected to the ball operated pig launching system. This hose was laid down on the seabed and would be recovered with the help of the ROV and a tugger wire when needed.

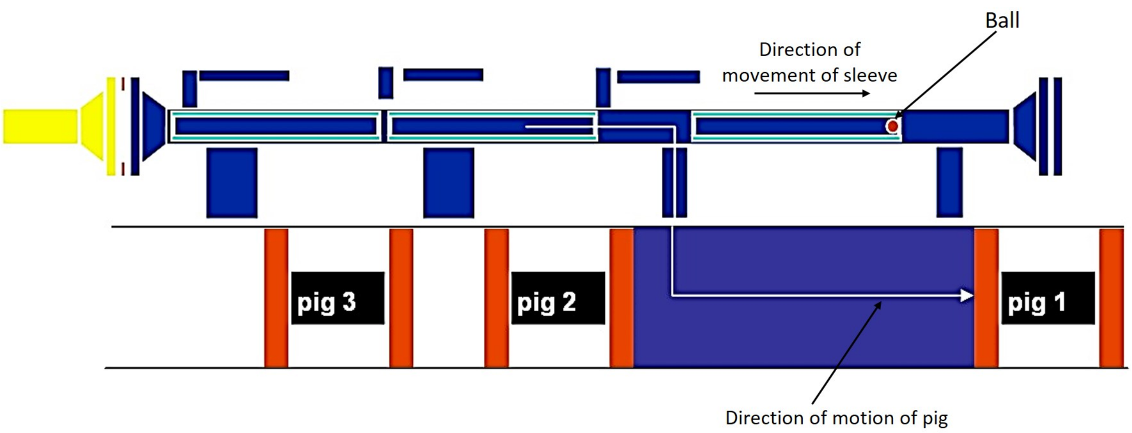


FIGURE 4.1: Schematic of the valve-less flooding system [12]

As seen in Figure 4.1, in this system, the ports to send the pigs away are blocked by sleeves (the ports are normally blocked by valves). Upon completion of inserting pre-water, the first ball is inserted into the system to move the sleeve away from the port. The first pig is then launched and this is continued until all pigs are launched.

The advantages of using such a launcher are:

1. For standard flooding operations there are no valves required;
2. A reduction in valves is a reduction in ROV operations, which is very favourable with poor visibility and high currents;
3. The ball launcher and hot-stab assembly can be re-used.

4.2 Ball operated flooding head

A test head was designed as presented in Figure 4.2.

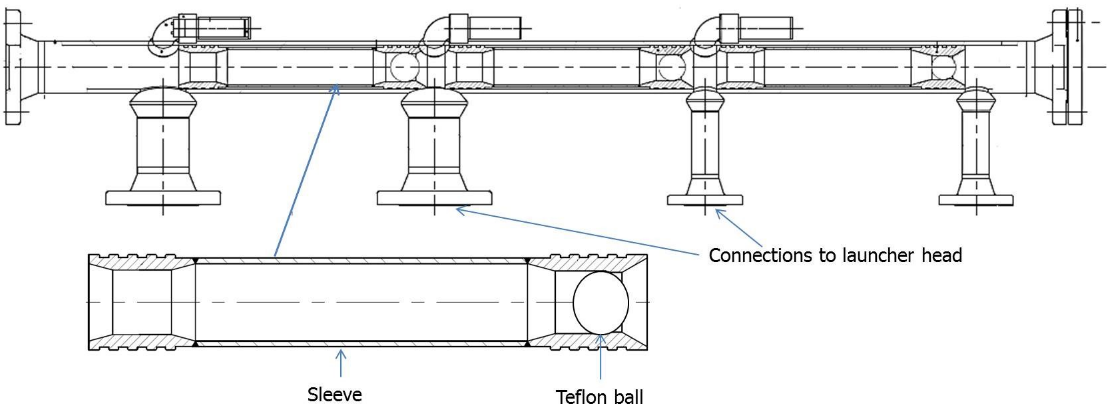


FIGURE 4.2: Test head for launching pigs [13]

In the design, the aft end and the front end of every sleeve was made of a different diameter [14]. The three Teflon balls used were also made of different diameters. This was done so that when the first ball was launched (which was the smallest), it could travel through the remaining two sleeves starting on the left and stop at the front end of the sleeve on the far right. This action would cause the sleeve on the right to slide along the groove and in the process uncover the opening so that water could be pumped behind the first pig to launch it. For reference, a design drawing of the launcher head that contains the pigs (not shown) is provided in Figure 4.3 [15]. The hot stab connection for contingency purposes can be seen.

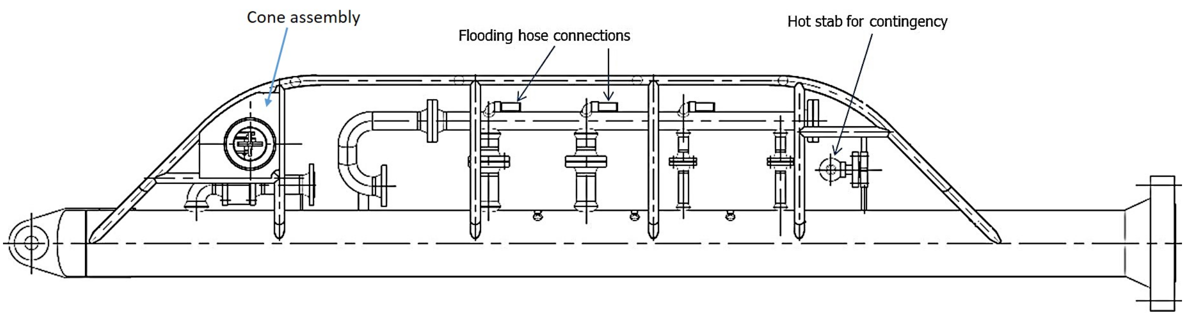


FIGURE 4.3: Head launcher with contingency hot stab port [16]

4.3 Procedure

1. Connect the 4-inch flooding hose to the flooding spread;
2. Pump water in front of pig 1;
3. Identify ball 1 (the smallest one) and insert in the ball launching system;
4. Launch pig 1 by pumping water behind it.

The remaining two pigs can be launched in a similar way. The ball launching system was placed on the deck [17]. The above mentioned procedure is presented in graphical form in Figure 4.4.

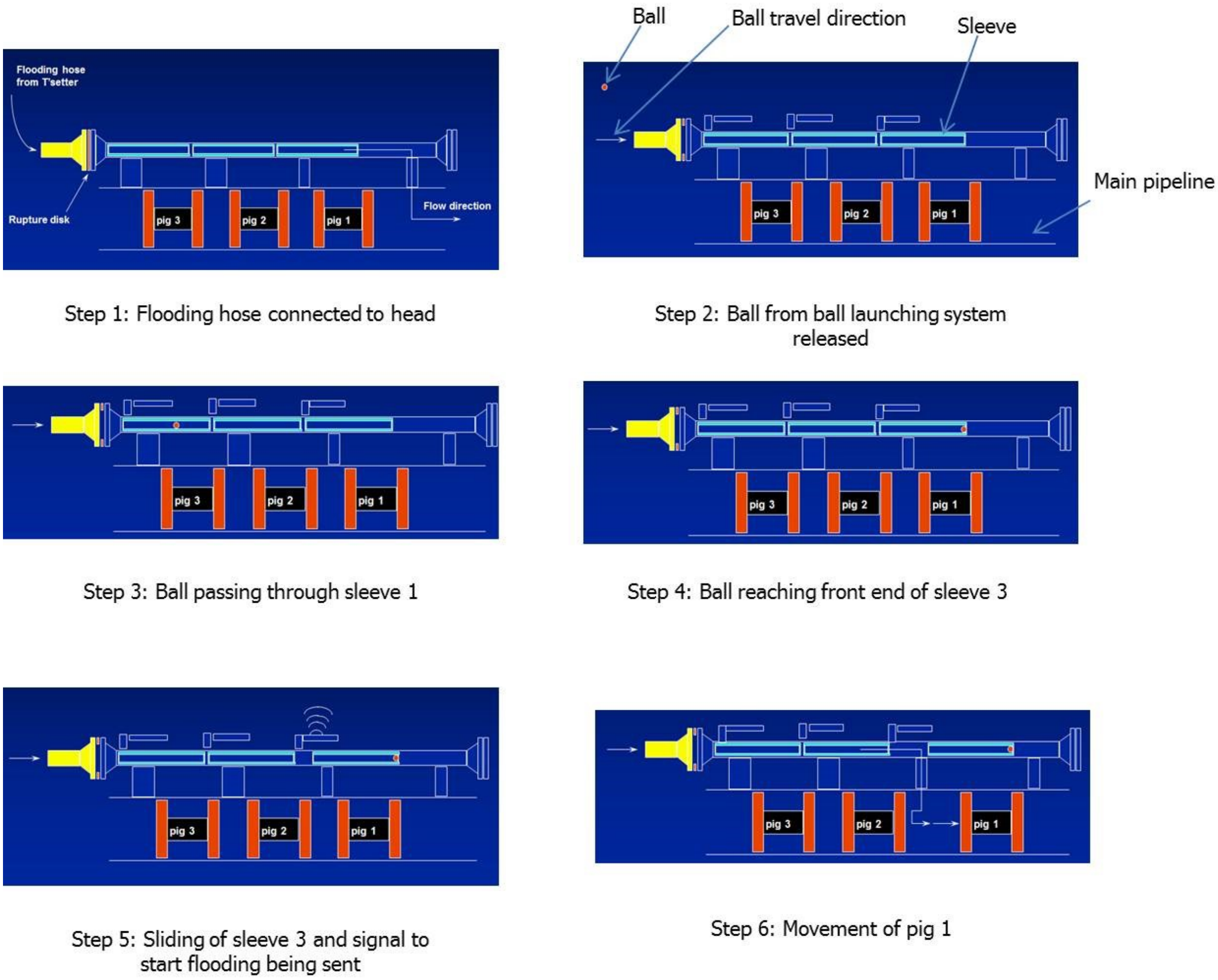


FIGURE 4.4: Graphical representation of the valve-less flooding procedure

4.4 Test results

Offshore trials were carried out using the valve-less flooding system in 1996 for the Shell Schooner project. The close out report indicated two main problems faced:

1. The Teflon balls blew through sleeve 3 and blocked the two inch pre-water port. This caused the three pigs to be launched together. In order to overcome this,

a recommendation to test the set-up with steel balls was made. However, upon further research, only a memorandum for budget approval was found whereby the launcher was to be tested with steel balls coated with Teflon. No other documentation was found on whether the test was actually done or what its results were.

2. Efforts to retrieve the flooding hose using the ROV caused it to break in to two parts due to inexperienced ROV crew causing significant downtime. The recommendation made then was to have experienced ROV personnel present during such operations.

Further research related to the Shell Schooner project revealed that the flooding hose that was to be retrieved using the ROV had indeed proven difficult to retrieve since it was caught under the main pipeline during installation [**.**] Eventually, the hot stab connection had to be used to carry out the flooding operation.

No other documentation other than detailed specifications containing drawings and procedures was obtained.

4.5 Evaluation

On carrying out an extensive internal and external search for this type of launcher or any information related to it, the closest results obtained were patents on sleeve valves and their modifications which were used on receiver heads in order to release the pressure build up behind them. Recent developments in launcher heads all indicated the use of ROVs in order to carry out the various tasks during the FGT operations with slight variations in design to meet the client's requirements.

The following information was established at the end of the evaluation:

1. There was no knowledge of the valve-less flooding system that was to be used for the Shell Schooner project within the FGT department at present;

2. A possible explanation as to why the concept was developed in 1995 was because ROV operations could not be carried out with ease at that time. However, this is currently not the case, whereby, FGT operations and especially opening and closing of the valves is carried out using the ROV which is more efficient because of experienced ROV personnel;

3. If the valve-less flooding system concept were to be applied in the current system, the ROV would still have to be present to carry out the hot stab operation during contingencies. Furthermore, the ROV would be present for visual inspection as well as pig tracking. By using the valve-less flooding system, the time saving is close to zero compared to the current system. The current system sends a pig at given intervals which gives the ROV enough time to move to the next position to operate the valves;

4. The complexities would increase in case there was a problem with the valve-less flooding system especially if the sleeve would not be able to move. In that case, the ROV would still be present for contingency purposes therefore the purpose of carrying out the FGT operation without using the ROV would not be possible;

5. There would be a significant increase in investment if this concept was implemented; pumps, steel balls, ball launchers and ball launch-able hot-stab assemblies would all have to be designed and manufactured. Testing would then have to be done and modifications made if it did not work as expected. This would only be advantageous if there was a significant amount of time saving. However, in the current system, when the ROV opens the valves on the launcher, by the time the pig reaches the receiver, there is enough time for the ROV to sail to the other side and be on standby to operate the valves. Even with a slight delay, this would not cause any problems in terms of downtime.

   However, if the valve-less flooding system was implemented, it would prevent the need of stock-piling of the various valves used on the launchers which would save a considerable amount of money;

6. By using the valve-less flooding system, the possibility of reverse pigging whereby the pigs are received at the location of launch is not possible which is a slight disadvantage;

7. During laydown, if the launcher rotates then the possibility of launching pigs using the valve-less flooding system may not be possible while in the current system, contingency procedures are in place to ensure that launcher orientation does not interfere with FGT operations;

4.6 Conclusions and recommendations

The valve-less flooding system was an innovative concept that would have made the pigging operations simpler and easier to carry out considering the state of the ROV technology in the years around 1995. Operating the valves with the use of the ROV is not a very time consuming task especially with the ROV having sufficient amount of time between the subsequent launches of the pigs and hence implementing the valve-less flooding system will not particularly be an advantage. Finally, the current system is more robust when something goes wrong compared to the valve-less flooding system.

In order to implement the valve-less flooding system, more research needs to be done for contingency procedures, reversible pigging and finally the robustness of the entire system.

Chapter 5

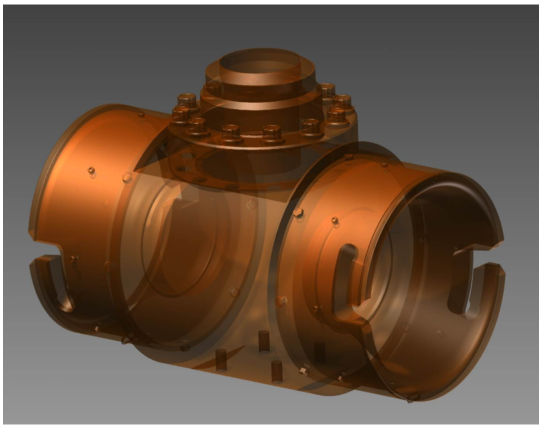
Hot Stab Guide System

The second assignment involved looking into the hot stab operations that are carried out during pigging. A subsea hot stab is a high pressure connector used to connect to launchers for fluid injection; it is designed to typically be ROV operated.

A hot stab assembly basically consists of two parts; a male stab, and a female receptacle which has a check valve on top of it which is used to operate it. A hose can be connected to the hot stab, which connects it in turn to the pipeline. The valve in the hot stab assembly now controls the flow of liquids from the hose to the pipeline.

Since Allseas lays pipelines of different diameters, hot stabs of different diameters are used. The 6-inch hot stabs are a particular case whereby they are used for very large pipelines ($\geq$ 22-inch) [18]; there can be exceptions when the client specifies that a 6-inch hot stab be used on a smaller pipeline. A typical 6-inch male hot stab and female receptacle are shown in Figure 5.1a and 5.1b.

(A) 6-inch male hot stab



(B) 6-inch female receptacle

FIGURE 5.1: 6-inch hot stab assembly

The male hot stab weighs approximately 200 kilograms [Appendix H]. Maneuvering this during high current situations has proven to be difficult in the past and generally takes a significant amount of time. Secondly, when a hot stab connection is made, there is a chance of impact of the ROV on to the launcher head. This causes damage of seals on the stab. Hence, the objective of the second assignment is to research a new guide mechanism that can make the hot stab operation easier and save time. By doing this, the problem of broken seals could be solved simultaneously.

The assignment will be tackled by first taking a detailed look at the current hot stab procedure. Following this, a literature survey will be done to look at the different types of available hot stab guides, general requirements will then be listed out and finally a few concepts drawings developed and evaluated.

5.1 Current System

As mentioned in Chapter 2, the hot stab operation basically involves the following steps [2]:

1. Determine from which side the dummy plug is to be removed;
2. ROV to move to the opposite side of the head where the dummy plug will be pulled out and cut the polyprop rope with the monkey fist from the dummy plug. This is done to prevent snagging of the monkey fist (Figure 2.10) inside the female receptacle;
3. ROV to move to the side of the head where the dummy plug will be pulled out;
4. ROV to remove dummy plug from the 4-inch female hot stab receptacle by pulling on the polyprop rope;
5. ROV to place dummy plug in tooling basket or ROV loading tray;
6. ROV to insert male hot stab into female hot stab receptacle;
7. ROV to align male hot stab locking pin with female receptacle longitudinal locking slot;
8. ROV to rotate male hot stab clock-wise to lock the locking pin in the circumferential locking slot;
9. To remove the male hot stab from the female locking receptacle, ROV to rotate the male counter clockwise from the circumferential locking slot;
10. ROV to pull out the male hot stab from the longitudinal locking slot.

This is a simple operation. The ROV operators are required to make the connection based on their own judgment which can be a big challenge for less experienced ROV pilots. A graphical step-by-step procedure can be seen in Appendix E.

5.2 Guiding

As mentioned section 5.1, the stab operation is straightforward. In order to aid this procedure, the female stab has a guide cone built into it. This is seen in Figure 5.2. However, it still depends on the ROV operator to maneuver the stab close enough to this cone guide to be able to carry out the stab operation even when the pipe has rotated. This is the motivation for designing a new guide system that can make the hot stab process easier.

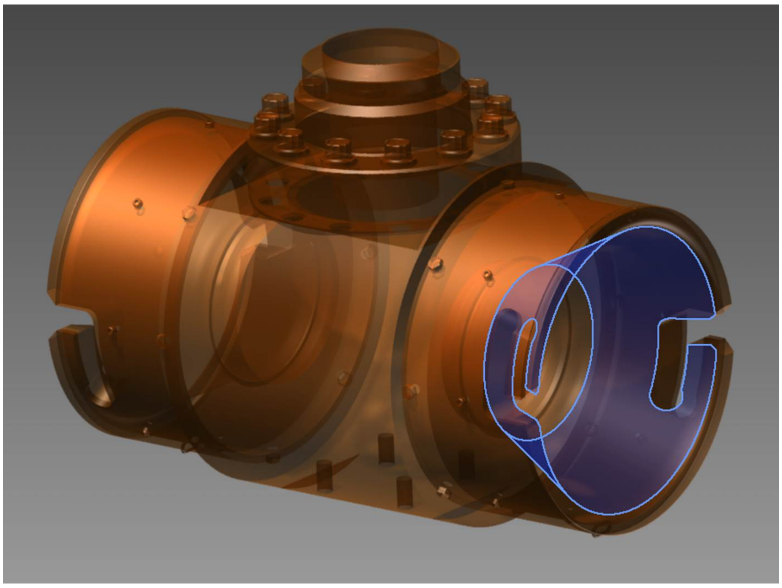


FIGURE 5.2: Cone on the female receptacle

5.3 Hot stab requirements

When considering the design requirements of a hot stab, the main requirements are:

- The hot stab should be installable by the ROV;
- The hot stab should be able to seal in the required pressure. The maximum pressure is 700 bar for 1-inch and 2-inch stabs, 130 bar for 4-inch stabs and 50 bar for 6-inch stabs.

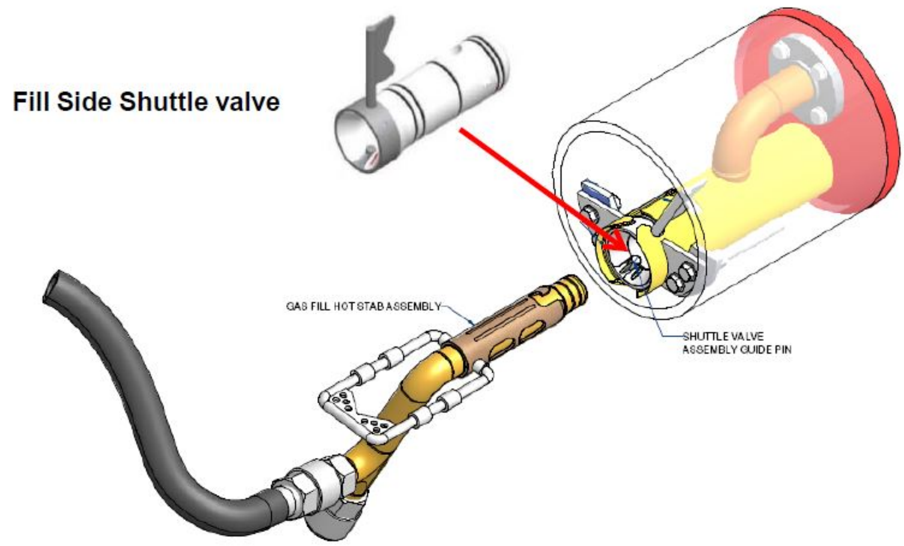
Other than this, when considering the whole stab system, its key features should be:

- **Ease of use:** It should be easy to carry out the hot stab operation;
- **Pressure balanced design:** No net force should act on the axis of the stab or the retaining mechanism;
- **Rotating handle and collar:** The collar should be allowed to rotate around the stab;
- **J-slot locking mechanism:** This should be provided for two purposes:
    1. To show visually that the stab is correctly located inside the female receptacle;
    2. To provide a physical restraint against any axial force on the hose.
- **Ease of maintenance:** The assembly should be robust and if need be, the male stab seals should be easy to replace;
- **Double sided solution:** The pipe may rotate subsea therefore for contingency purposes, two receptacles should be provided.

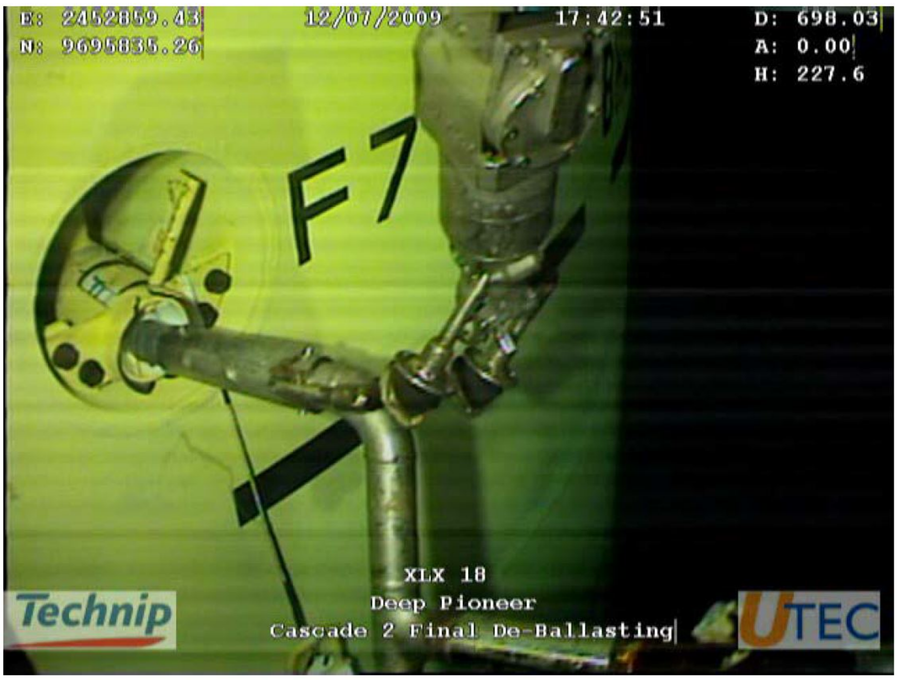
5.4 Literature survey

Hot stab designs of various companies (including suppliers of hot stabs and excluding Piper and Deepstar Limited) were researched to check the trend in the industry. The following was obtained:

1. **Technip:** Technip uses a gas fill hot stab assembly to de-ballast. The procedure simply involves inserting the hot stab using a guide pin and pumping nitrogen until bubbles escape from a vent. This can be seen in Figures 5.3a and 5.3b.



(A) Male stab and female receptacle



(B) Hot stab attached to ROV arm sub sea

FIGURE 5.3: 6-inch Technip hot stab

2. **Depro:** Depro has a variety of stabs from hot stabs to pressure and protection stabs. However, the receptacle did not have any guiding system; it was the same as the current Deepstar system.

3. **Oceaneering/ Fugro:** These companies had a variety of stabs with the same concept of stab and receptacle. However, none of these were 6-inch stabs; the 1-inch and 2-inch stabs are available.

4. **SECC Oil & Gas:** SECC has four main types of stabs:

   (a) Hot make hot break - this is designed to enable efficient pumping/transfer of fluids while providing a reliable safety system in the event of a vessel losing its dynamic positioning. This is ROV operated and can be operated by actuators or winches;

   (b) Max flow hot stab - this is suited to high flow operations and incorporates SECC's zero head-loss technology. Again this is ROV operated and offers a variety of ROV handles and has a full pressure balanced design;

   (c) ISO stabs - this is used to supply hydraulic power to subsea equipment. It features a flexible handle that makes connection and disconnection easier even after long periods of subsea exposure.

   (d) Triple S stabs - these are self sealing stabs however are only offered in 1/4-inch to 1-inch bores;

   In summary, the stabs provided by SECC feature 1-inch to 6-inch full bore, they can be connected or disconnected under full pressure, offer emergency disconnect, can be used at a depth of 10,000 feet and are ROV operable.

5. **Schilling:** On searching for newer technologies, Schilling intends on using vision guided techniques for carrying out peg-in-hole tasks such as installing and retrieving hot stabs. For this task, Schilling is developing a system that uses a manipulator-wrist mounted camera capable of recognizing features on a panel that allows the user to simply tell the system which receptacle they would like the hot stab to be inserted into, and the control system simultaneously flies the ROV and positions the manipulator to make the hot stab go into the hole.

   For example, in a successful peg-in-hole maneuver, the ROV pilot must align five of the six possible degrees of freedom; three of the possible rotations - pitch, yaw and roll - and two of the three translations. According to Schilling, what inexperienced operators generally do is focus on getting the tip of the hot stab into the receptacle, which requires three degrees of freedom; lining up the other two degrees of freedom to make the axis of the hot stab and the axis of the receptacle aligned is more difficult. In their new system, the computer does all this work for them.

6. **Velocius:** This company supplies hot stabs of 6-inch that are machined from a single piece of material to reduce the risk of leakage whilst providing mechanical strength. However, no special guide mechanisms are used for the stab operation. Velocius does feature another product known as the *ROV Operable Stabplate* that reduces installation time due to misalignment capability.

   Velocius also features a particularly interesting product - the *buoyancy sphere* that compensates for heavy products. This can be useful when designing concepts to overcome the 6-inch stab problems.

5.5 Concept Design

In order to solve the problem of guiding and connecting the male stab to the receptacle, possible concepts are:

1. **Vertical frame with horizontal stab:** This concept assumes the head to be oriented in the correct manner (i.e. no rotation should have taken place). In this, a frame is lowered using winches on the support vessel. The frame has in it integrated the hot stab. Once the frame is positioned correctly onto the head, the hot stab connection can be made using a hydraulic actuator. In order to disconnect the stab, hydraulic ejection can be used. However, this concept cannot be applied since the head is almost never in the correct orientation. Furthermore, it would make the system heavy and complex.

2. **Male cones and female funnels:** This concept involves using funnels as a guidance method to make the hot stab connection. It is a simple design that does not involve complex actuators as mentioned above. A variation of this can be using male funnels and female cones. A disconnection method for this is simply ROV pull-out.

3. **Guide wire:** This involves using a guide wire to guide the male stab and using hose tension to disconnect the stab. However, by using a rope, there would be a risk of the rope getting stuck in the female stab. Furthermore, there is a risk of tangling of ropes and cables from the support vessel.

Since the principle problem with using the 6-inch hot stab is weight, a simple solution to tackle this is by using buoyancy modules. These have previously been implemented on 6-inch hot stabs in order to carry out the stabbing operation vertically. Figure 5.4 shows the buoyancy modules.

FIGURE 5.4: Buoyancy module on a 6-inch stab

However, it is not possible to integrate the buoyancy modules as shown in Figure 5.4 for all orientations of the head launcher. Therefore, distributed buoyancy modules can be used whereby the buoyancy modules are clamped on to the hose that extends from the clump weight to the male stab. The reason for doing this is twofold:

1. The hose remains slightly raised off the seabed which makes it easier for the ROV to maneuver;

2. There is less weight that the ROV has to support/carry while handling the male stab.

If the buoyancy modules were to be attached as seen in Figure 5.4 then the ropes would interfere with the stab operation. The main idea behind using buoyancy modules is that, depending on the orientation of the launcher, they can be placed along the hose at specific points such that the hot stab can attain a given orientation to be able to easily engage with the female receptacle. This can be seen in Figure 5.5.

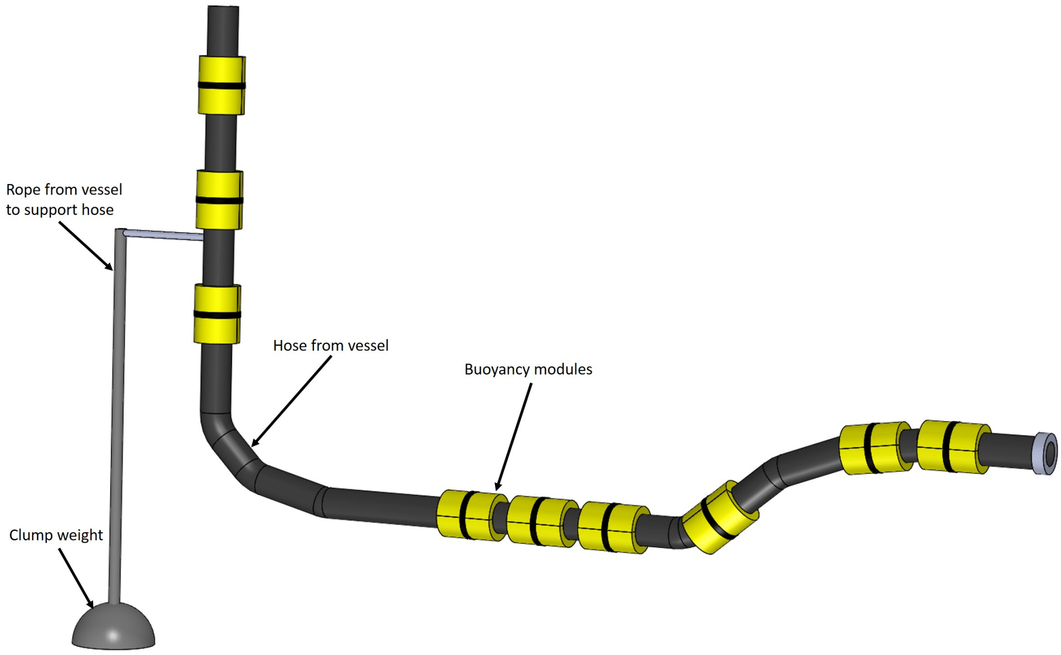


Figure 5.5: Bouyancy modules placed along the hose

These modules are widely available. Allseas uses buoyancy modules from *Balmoral Offshore Engineering, Lankhorst* and *Trelleborg*. For example, *Fendercare Marine*, provides buoyancy modules for three configurations of hoses. These allow the hose to have a reasonable range of movement without putting it under great tension and thereby risking it being damaged. The buoyancy modules consist of the various parts as seen in Figure 5.6. The fasteners clamp the whole set-up together while the rubber fingers provide friction which prevents the buoyancy module from sliding over the hose.

A datasheet for the above mentioned buoyancy modules can be found in Appendix F.

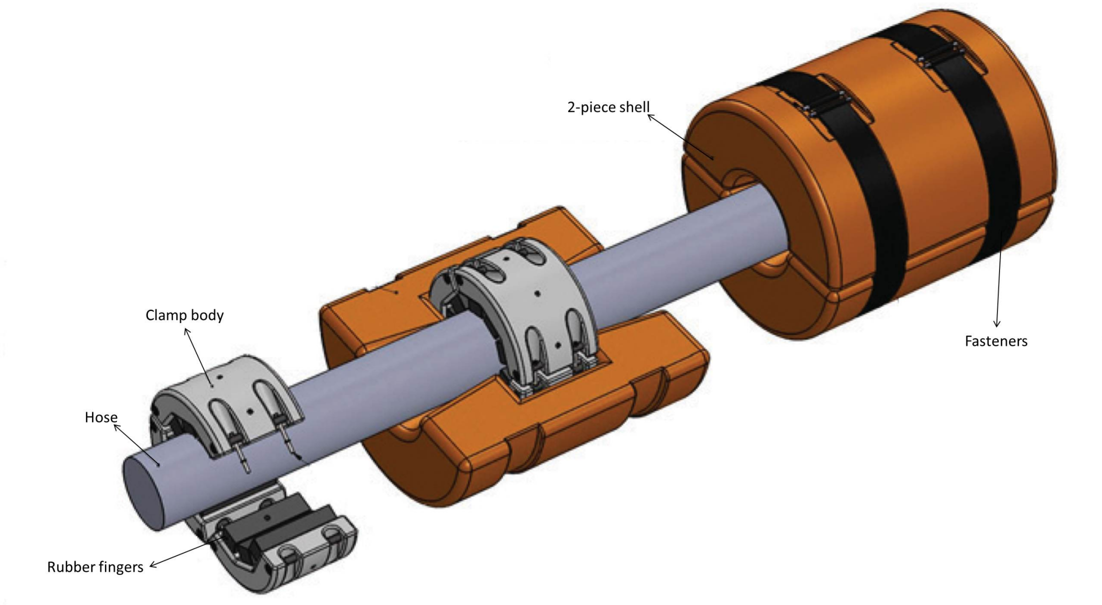


Figure 5.6: Hose with the different parts of the buoyancy module

Secondly, the use of cone guides can be made. This is illustrated in Figure 5.7. In this case, the two cones on either side of the female stab (as shown in Figure 5.8) are used to guide the male stab straight into the female stab such that the seals engage in the correct orientation. Failure to do so would lead to the stabbing operation being done at an angle which would engage the seals in a way such that they can be damaged. In a situation where the launcher has rotated, the stab operation can either be carried out from the opposite side or at an angle. In this way, if there were any initial misalignment, the cone guides would take the impact instead of the male stab experiencing any damage. Furthermore, the female guides can easily be reinforced on to the protection frame or the launcher itself such that they are held properly in place.

Finally, the guides on the male stab are made of different lengths such that one guide is used to align the stab along the horizontal direction while the other is used to correct any difference in angle during the stab operation.

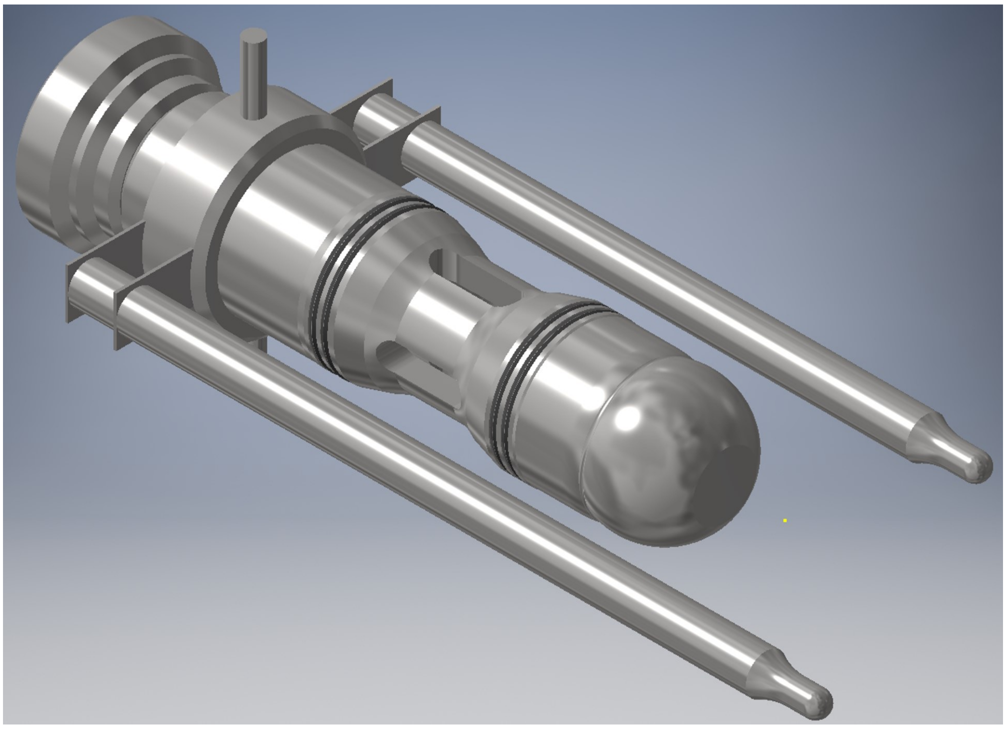


Figure 5.7: Male stab with guides

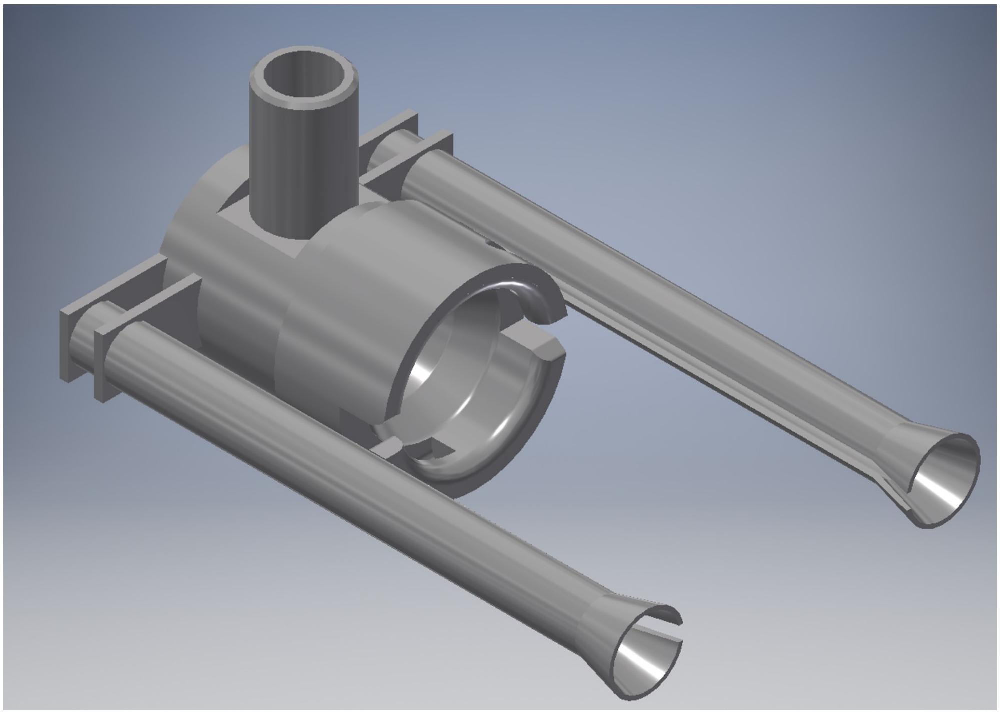


Figure 5.8: Female receptacle

The guide can be made from a stronger material than that of the stab itself since it takes most of the impact during contact. Suitable materials can be researched and tested to see if they can withstand the force during the stabbing operation.

Possible variations of this design are:

1. The cone guides are replaced with roller guides which would allow some freedom along the lateral direction of stabbing. This can be tested and compared to the cone guide design;

2. Hinges can be used on the guide to compensate for rotation of the head and a feasibility study done to see whether it would work or not.

5.6 Force required to engage and disengage the seals

During the hot stab operation with 6-inch hot stabs, the amount of force required to engage and especially disengage the seals is large as observed from experience. Currently, there are two sets of seals on the male stab; a softer Nitril o-ring underneath and a harder PTFE seal on top. Generally, an impromptu solution is thought of when faced in a situation whereby the seals do not engage or disengage. For example, during the *Wheatstone Trunkline* project, the hot stab operation was carried out in the vertical position due to rotation of the launcher. While disengaging the hot stab, a wooden wedge was used which was forced between the body of the stab and nose of the female to force out the stab. Therefore, a method had to be devised whereby the engaging and disengaging of the seals could be done with ease. Possible methods are:

1. Elongating the male stab to include an eye on the nose:

   This has the following explanation. A rope should be attached to the nose of the stab. The dummy stab should first be removed from the female in the same way as the current system. Then, using the guide, the male stab should be inserted into the female and the rope threaded. The ROV then flies to the other side of female and pulls the rope such that the seals engage. In a similar way, the ROV uses the eye to push out the stab when disengaging of the seals is required. The drawback of using such a system is that during threading of the rope, the monkey fist that the ROV uses to hold on to may get stuck (snag). Therefore, in order to use this concept, a fail-safe method of threading should be devised.

2. Using hydraulic stabs:

   The second concept uses hydraulic stabs to solve the problem. However, as seen in Chapter 3, using hydraulic actuation would make the system complex and heavy; this is something that would not be feasible. If hydraulic actuation were to be used, the system can be mounted on to the female receptacle whereby when the engaging of seals is required, enough force would be generated to pull the stab in and engage the seals. The hydraulic actuator can also be mounted on to the male stab whereby it would be used to insert the stab in. The drawback of mounting it on to the male stab would be that the weight would increase which is not desired. An alternative would be to use the hydraulic circuit mounted on the ROV in order to engage the seals.

3. Using inflatable seals on the stabs:

   The final concept is to use inflatable seals on the male stab. The inflatable seals would be employed in place of the soft Nitril o-rings whereby once the stab has been pulled in completely, the seals can be inflated which will engage the seals and prevent any leakage from taking place. However, a risk of leakage of the inflation system remains which would not make the system fail safe.

5.7 Conclusions and recommendations

From the above, it is seen that even though the cone on the nose of the male stab and the cone on the female provide a good enough guiding mechanism for the stabbing operation to take place, it may lead to damage of the hot stab and/or the seals. Since the hot stabs can be re-used for other projects, it is important to maintain their integrity. The conceptual design in section 5.6 gives a guiding mechanism which ensures that the seals remain undamaged as well as the hot stab body. The impacts during such a procedure cannot be avoided and hence are taken up by the cone guides. Furthermore, the distributed buoyancy modules on the hose help to reduces the total weight the ROV has to deal with therefore making it easier to maneuver.

Further recommendations for the guiding mechanism include carrying out tests with different buoyancy modules as well as the designed guiding mechanism to validate the above concept. This can be modeled using software such as Orcaflex.

Lastly, due to time constraints, a concept choice could not be made on how to effectively engage and disengage the seals on the hot stab. Therefore, recommendations to do so include finding out the force required to engage and disengage the seals, checking the feasibility of the concepts mentioned in 5.6 given the force and lastly giving a concept choice and method of implementation.

Appendix A

FGT Procedure - Example

TASK PLAN CALAMITY JANE

Summary flooding operation	**CHECK**
1. Set up on DP at start-up head location	X
2. Preparation of start-up head by ROV to receive pigs	X
3. Set up on DP at laydown head location	X
4. Preparation of laydown head by ROV to launch pigs	X
5. Deployment of 4-inch flooding hose	
6. Launching of three pigs	
7. Flooding the pipeline with 110% of pipeline volume	
8. Recovery of 4-inch flooding hose	
9. Relocate vessel to start-up head	
10. GVI on rupture discs on start-up head and determine pig train arrival	
11. Set valves on start-up head for hydro test upon confirmation of pig train arrival	

Notes:

1. *Start-up head is located in the A12 platform 500 m zone*

Reference drawings:

300STD/A-19-10-01 REV B - Hose deployment

300STD/A-19-11-01 REV A- Abandonment rigging FGT operations

401840/A-12-01-01 REV B – Schematic launcher and receiver 16-inch pipeline

401840/A-12-10-01 REV D – 16-inch start-up head

401840/A-12-10-02 REV D – 16-inch start-up head protection frame

401840/A-12-11-01 REV C – 16-inch laydown head

401840/A-12-11-02 REV C– 16-inch laydown head protection frame

Ad 2 – Preparation of start-up head by ROV	**CHECK**
1. Deploy ROV with valve key and 2x valve locker at start-up head and perform GVI of valve status (all valves should be in closed position)	X
2. Open valves 1 and 2	X
3. Install valve lockers at valve 1 and 2	X

Ad 4 – Preparation of lay down head by ROV	**CHECK**
1. Deploy ROV with valve key, 3x valve locker, acoustic receiver and reference beacon tripod at laydown head and perform GVI of valve status (all valves should be in closed position)	X
2. Remove 4-inch dummy hot stab	X

Ad 5 – Deployment of 4-inch flooding hose	**CHECK**
1. Deck to prepare deployment of four lengths of flooding hose (5x20 meter) using the winch wire and 4-inch hose clamps	
2. Deploy hose to 15 meter above seabed (water depth is 44 meter). ROV to monitor deployment with sonar	
3. Move in ROV and lower hose to 5 meter above seabed while having visual contact by ROV camera’s	
4. ROV to grab hot stab/monkey fist on hot stab	
5. Deck to deploy remaining hose until clump weight is 5m above seabed	
6. Move in vessel/clump weight to 15 meter from start-up head	
7. Lower clump weight on seabed (approximately 15m off 4-inch receptacle)	
8. Deck to connect hose to deck outlet	

9. Start pumping and flush the hose
10. ROV to insert 4-inch hotstab
11. Pressurise flooding hose slowly by regulating the ball valve on TOP deck to maximum pump capacity and observe for 5 minutes and check for leaks
12. Depressurise flooding hose, by opening overboard valve in flooding room
13. Reset flow meter

Ad 6 – Launching of three pigs **CHECK**

1. ROV to open valve 2, 6 and 7
2. ROV to install valve lockers on valves 6 and 7
3. Flooding room to pump 22 m3 of filtered seawater and stop pumps
4. ROV to close valve 2 and open valve 3
5. Flooding room to pump 22 m3 of filtered seawater (launching brush pig) and stop pumps
6. ROV to close valve 3 and open valve 4
7. Flooding room to pump 22 m3 of filtered seawater (launching swab pig) and stop pumps
8. ROV to close valve 4 and open valve 5
9. Reset flow meter
10. ROV to check if acoustic pinger on gauge pig has engaged

Ad 7 – Flooding the pipeline with 110% of pipeline volume **CHECK**

1. ROV to inspect layout of flooding hose from hot stab to as close as possible to the first WECO connection below the waterline
2. ROV to install valve locker at valve 5
3. Flooding room to pump 196 m3 of chemically untreated water, stop when flow meter reads <u>196 m3, reset flow meter</u>
4. Start adding corrosion inhibitor and dye to filtered seawater
5. Stop adding dye when flow meter reads <u>100 m3</u>, continue adding ONLY corrosion inhibitor
6. Notify A12 platform approx. 2 hours before chemical discharge is expected
7. Flooding room to continue pumping chemically treated water (no dye, only corrosion inhibitor) until flow meter reads <u>2496 m3</u>
8. Stop pumping after complete volume is pumped (2496 m3)
9. ROV to close all valves, retrieve valve lockers and tripod

Ad 8 – Recovery of 4-inch flooding hose **CHECK**

1. ROV to remove 4-inch hotstab
2. Flush hose to wash out the chemicals
3. Deck to recover flooding hose
4. Recover ROV to deck

Ad 10 – GVI on rupture discs on SUH and determine pig arrival **CHECK**

1. Deploy ROV with valve tool and acoustic pinger receiver
2. GVI on rupture discs (discs should be opened)
3. Confirm pig train arrival by detecting acoustic pinger

Ad 11 – Set valves on SUH for hydro test upon confirmation of pig train arrival **CHECK**

1. Remove the valve lockers
2. Close all valves on SUH after confirmed arrival of pig train
3. Perform GVI of SUH and fill-in "as-left valve status sheet" with client as witness

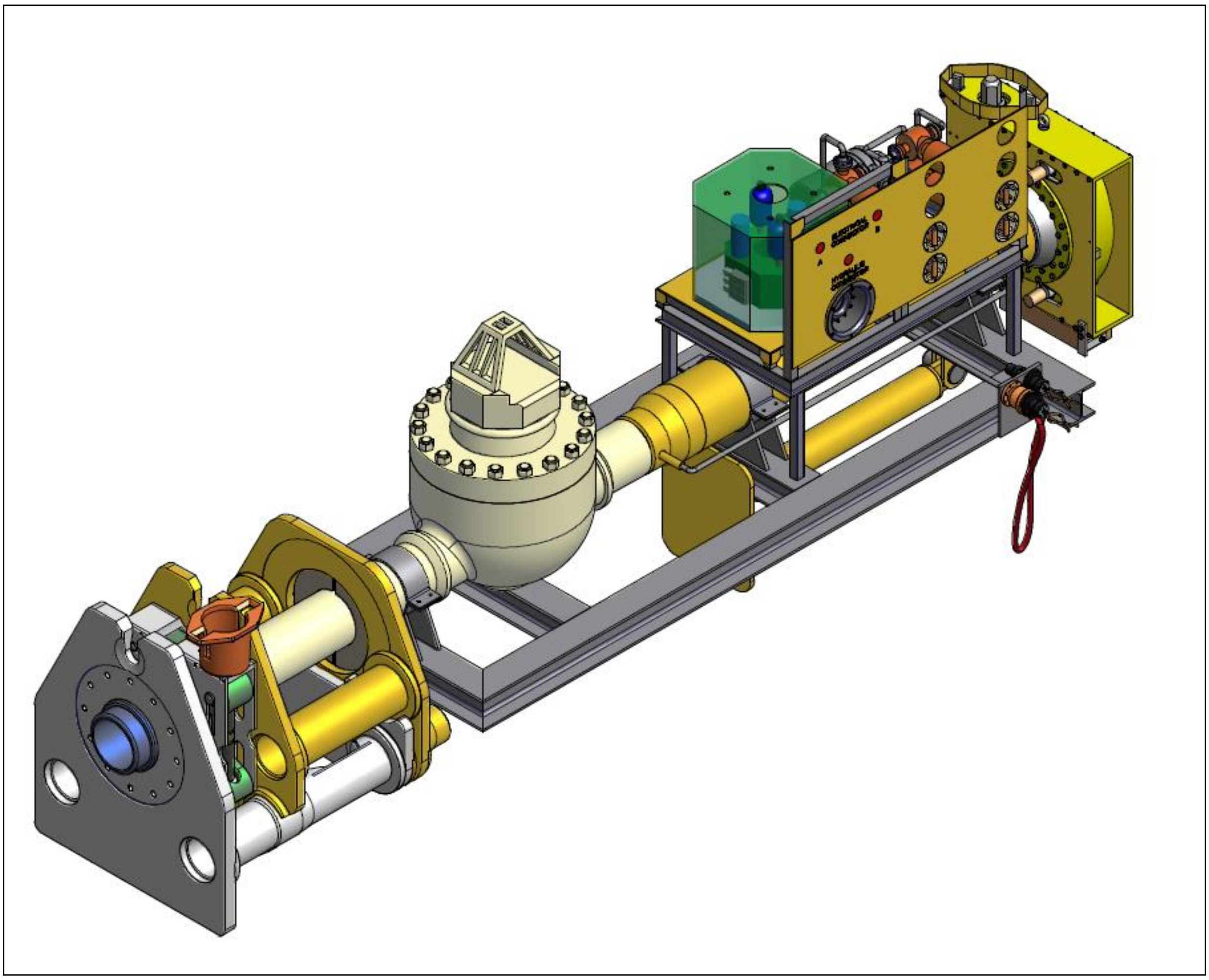
Appendix B

Nemo Automated PIG Launcher

NEMO AUTOMATED PIG LAUNCHER

Product Data Sheet

KONGSBERG



Kongsberg Nemo Automated Pig Launcher with our proprietary tie-in system, Thor

References

A version of Kongsberg Nemo Automated Pig Launcher has been procured by Statoil for the Fram Vest Field. It is designed to remotely launch 4 off 10” ID wax removal pigs and will be delivered spring 2013. It will interface with a production template manifold.

Features

The Kongsberg Nemo Automated Pig Launcher is designed to launch pigs remotely from the mother platform. It will reduce the need for dual pipelines with pigging loops and it allows production with arrival temperatures into the wax formation range. Its main features are:

- Individual launching of pigs, remotely controlled from mother platform
- Suitable for wax pigs with internal by-pass
- Internal pig cassette for easy replacement of pigs, can be designed to handle
    - Pre-commissioning and commissioning pigs
    - Wax removal pigs
    - Inspection pigs
- Interfaces with:
    - Client PLEM or manifold, new or existing. Pipe size, design pressure and connection system
    - Electrical power and signal from Client (SPS) control system. Electrical and hydraulic flying leads
    - MEG / Methanol as initial driving medium. The wellstream will take over once the pig has entered the manifold. Connection to Client PLEM or Manifold by flying lead or jumper bridge connection
- Diverless
- Monitoring, including pig detectors
- High reliability. E.g. dual redundant electronics, based on components proven in subsea production systems (SPS)

Description

As a reference case the following main system elements are:

- Subsea connector for makeup to existing or new PLEM or manifold
- 10" ID pipe
- 4 pigs
- ROV operated ball valve
- Pig cassette receptacle
- Pig cassette for subsea installation of pigs
- Small bore methanol injection valves
- Integrated control pod and sensors
- Electrical and hydraulic flying leads

Connector

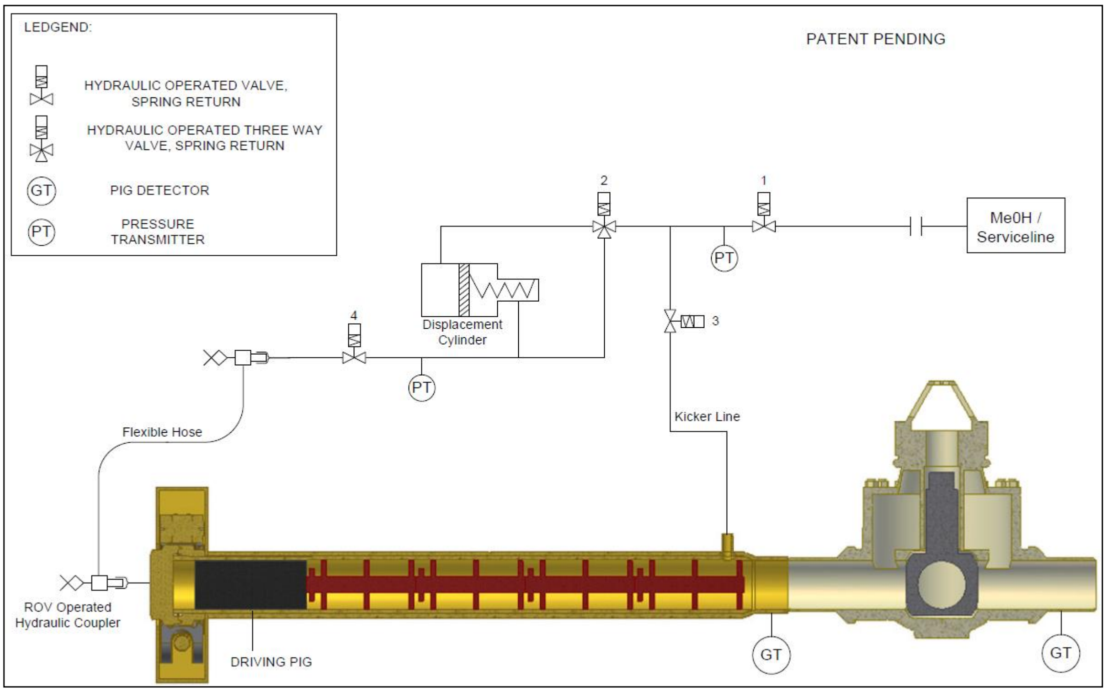
The Kongsberg Nemo Thor tie-in system as shown in the figure above is proposed.

Pipe, valve and pig cassette receptacle

Kongsberg Nemo Automated Pig Launcher matches the mother pipe; typically 10" ID. An ROV operated ball valve is incorporated to allow replacement of pig cassette while producing. The pig cassette receptacle houses the pig cassette. It consists of a pipe welded to the ball valve and has an ROV operated clamp connector at the rear.

Pig launching and control system

The pig launcher control system will interface the platform control system using standard communications interface. It will use the existing infrastructure for communication and power to the subsea system.

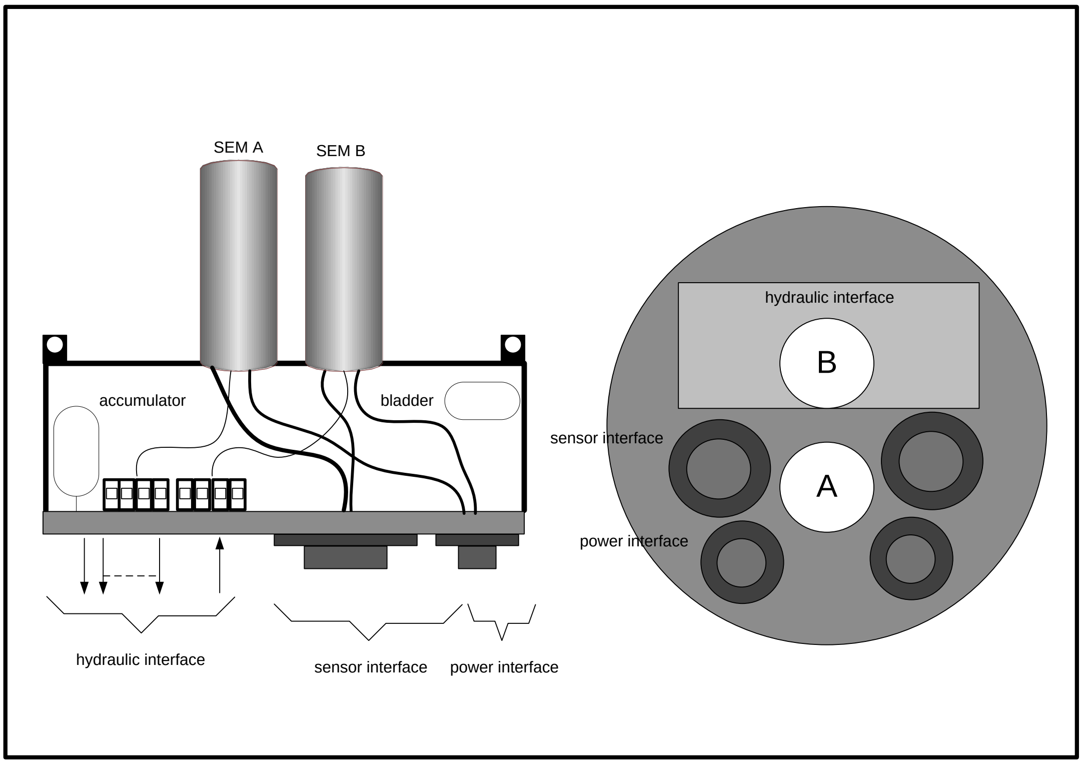


Kongsberg Nemo Automated Pig launcher, pipe and valve schematic

The ball valve is ROV operated and normally open during operations. At the hub end of the pigging cassette there is a "kicker line" enabling injection of methanol behind the driving pig. The displacement cylinder acts as a dosage valve, moving the driving pig a pre-determined distance forward.

Kongsberg Nemo Automated Pig Launcher will be instrumented and e.g. have a pig detector for detecting that the front pig has reached launching position, and another pig detector for detecting that the pig has passed the ball valve.

Control equipment for controlling and operating Kongsberg Nemo automated Pig Launcher will be located in a subsea control module, integrated with Kongsberg Nemo Automated Pig Launcher. The control module will consist of three separate units integrated into one module, two electronic canisters for redundancy, and one electro-hydraulic container. The electronic canisters are filled with nitrogen at 1 atmosphere, while the electro-hydraulic container is pressure compensated and filled with a dielectric fluid.



Kongsberg Nemo Automated Pig Launcher Control Module

There is one Directional Control Valve (DCV) for each function. For each function line there is a pressure transmitter which is used for indication of valve position. In addition flowmeters are included in the hydraulic supply and return line, which are used for confirmation of valve travel, and hydraulic leakage detection.

Options

The Kongsberg Nemo Automated Pig Launcher will be designed to meet Client requirements. For a final design the following options can be considered:

- Higher number of pigs;
  Application studies indicate that the number of pigs can be increased to 10
- Larger or smaller pipe size;
  Typical applicable pipeline sizes are in the 6" to 16"ID range
- No ball valve;
  The ball valve is required for pig cassette replacement and can be integrated with its interfacing PLEM or manifold
- DPE ball valve should «block and bleed» test function be required
- Vertical arrangement;
  Where vertical connection system, combined with no requirements to over-trawlability, exists, the pig launcher can be arranged vertically
- SPS proprietary pig launcher connector;
  The Thor tie-in system can be replaced with a connection system from an interfacing SPS supplier
- No pigging cassette;
  If a recovery of Kongsberg Nemo Automated Pig Launcher for pig replacement is preferred, the pigging cassette can be avoided
- Kongsberg Nemo Automated Pig Launcher support;
  A landing cradle might be required. Also if the bending moments onto inboard hub becomes excessive, a support foot at the rear end of the structure might be required
- Protection against dropped objects and requirements to over trawlability can be incorporated

For interested parties please contact

Arne Roar Holden,
Business Area Director, Subsea Process
Arne.Roar.Holden@nemo-group.com

Tel.: +47 9184 0837

Eirik Archer
Snr Specialist Engineer, Subsea Process
Eirik.Archer@nemo-group.com

Tel.: +47 9207 0524

Kongsberg Nemo AS
Fornebuveien 1-3,
1366 Lysaker, Norway
www.nemo-group.com

Appendix C

Subsea Automated PIG Launcher

SUBSEA AUTOMATED PIG LAUNCHER (SAPL)

Patented Technology

The Subsea Automated Pig Launcher (SAPL) is a system designed for individual launching of pigs from subsea, remotely controlled from a platform. The pig launcher control system will interface the platform control system using standard communication interface. It will use the existing infrastructure for communication and power to the subsea system, and hydraulic power and return.

The internal pig cassette, which enables easy replacement of pigs, can be designed to handle:

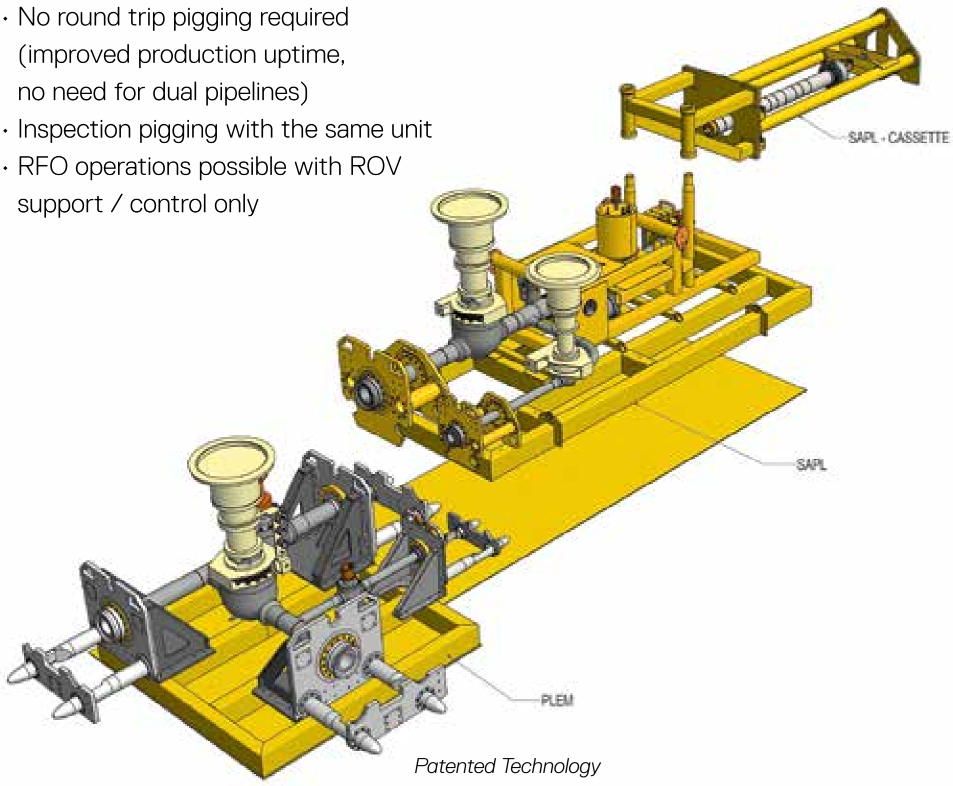
- Pre-commissioning and commissioning pigs
- Wax removal pigs
- Inspection pigs

An ROV operated ball valve is incorporated to allow replacement of pig cassette while producing. The pig cassette receptacle houses the pig cassette. It consists of a pipe welded to the ball valve and has an ROV operated clamp connector at the rear.

Some of the benefits offered by SAPL:

- Subsea launching (no platform required)
- Remote launching (no vessel or ROV required)
- Multiple-pig cassette (reduced number of trips by service vessel)
- No round trip pigging required (improved production uptime, no need for dual pipelines)
- Inspection pigging with the same unit
- RFO operations possible with ROV support / control only

Base case interface for the SAPL is a PLEM structure. However, the SAPL may be installed directly onto a manifold structure. It can also be connected to a manifold via a spool.



Patented Technology

Europe, Africa, Middle East
Kongsberg Oil & Gas Technologies
Drengsrudbekken 12
1383 Asker
Norway
Phone: +47 67 80 48 00
Fax: +47 67 80 48 30
kogt.sales@kongsberg.com

Americas
Kongsberg Oil & Gas Technologies, Inc.
10777 Westheimer Road, Suite 1200
Houston, TX 77042
United States of America
Phone: +1 713 808 6800
Fax: +1 713 266 8611
kogt.sales@kongsberg.com

Asia Pacic
Kongsberg Oil & Gas Technologies Pty Ltd.
Level 5 189 St Georges Terrace
Perth WA 6000
Western Australia
Phone: +61 8 6141 3350
Fax: +61 8 6141 3101
kogt.sales@kongsberg.com

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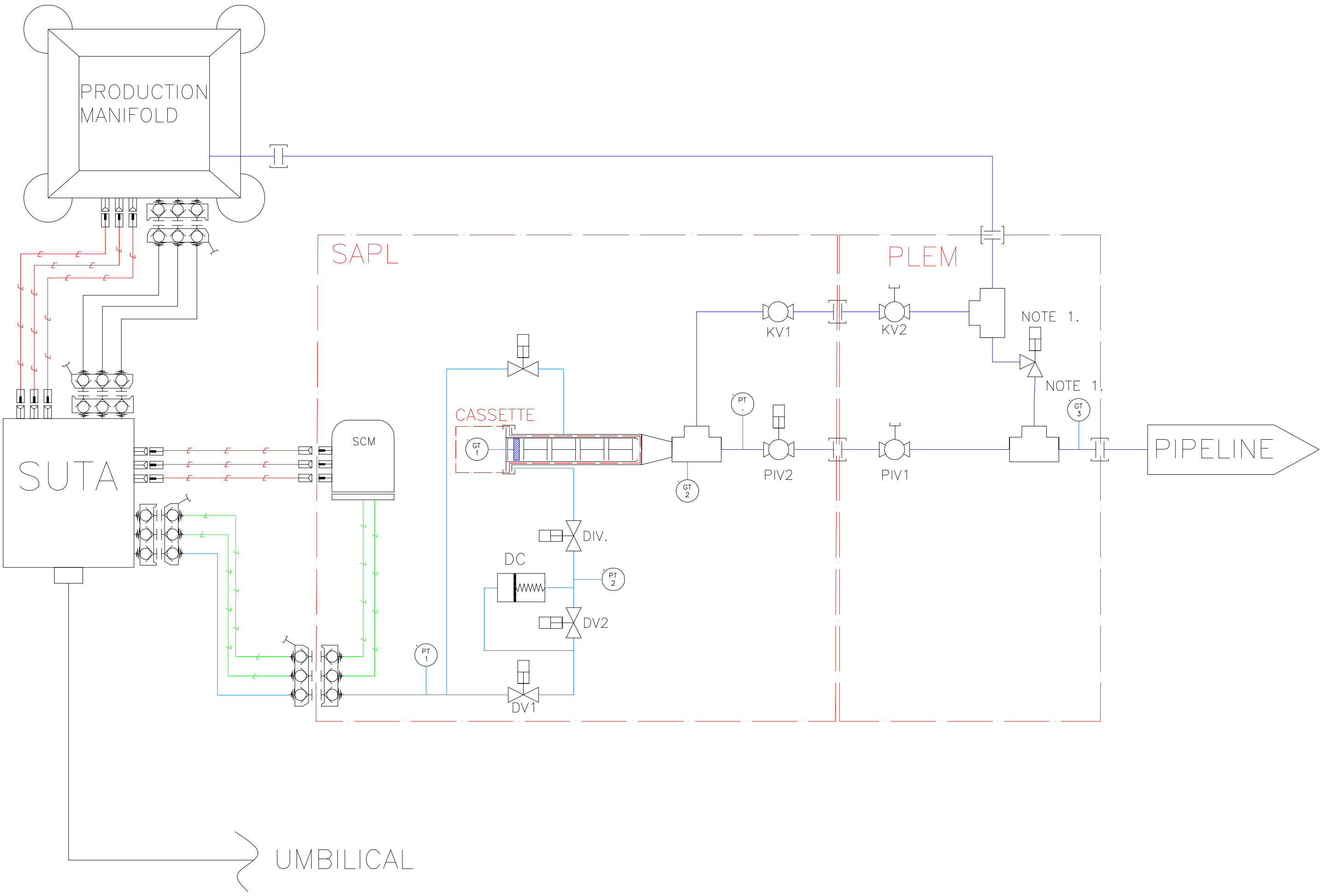
SUBSEA AUTOMATED PIG LAUNCHER (SAPL)

The SAPL comprises the following key elements:

- Insert cassette for pigs to be launched. It is inserted into the SAPL in a “pipe in pipe” arrangement, having a pressure retaining connector in its rear end and a hydraulic stab for fluids to the drive pig.
- A drive pig (or piston) is arranged at the rear end of the cassette, pushing the pigs to be launched stepwise forward.
- A displacement cylinder feeding a predefined volume behind the drive pig.
- Piping, valves and actuators.
- Pig positions sensor, one to verify that the first pig in line is in a launch position and a second to verify that the pig has passed the production Tee and is in the wellstream. One drive pig position sensor may also be considered. Additional sensors might be incorporated for redundancy.
- Retrievable subsea control module.
- Electrical and hydraulic flying leads with associated connectors and MQC plates.



Patented Technology

Europe, Africa, Middle East
Kongsberg Oil & Gas Technologies
Drengsrudbekken 12
1383 Asker
Norway
Phone: +47 67 80 48 00
Fax: +47 67 80 48 30
kogt.sales@kongsberg.com

Americas
Kongsberg Oil & Gas Technologies, Inc.
10777 Westheimer Road, Suite 1200
Houston, TX 77042
United States of America
Phone: +1 713 808 6800
Fax: +1 713 266 8611
kogt.sales@kongsberg.com

Asia Pacic
Kongsberg Oil & Gas Technologies Pty Ltd.
Level 5 189 St Georges Terrace
Perth WA 6000
Western Australia
Phone: +61 8 6141 3350
Fax: +61 8 6141 3101
kogt.sales@kongsberg.com

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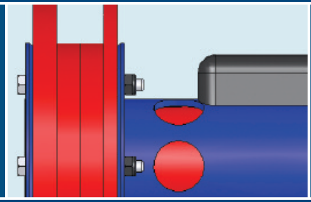
Appendix D

Automatic Multiple PIG Launcher

Video Link: https://www.youtube.com/watch?v=KMoCbqOT7yU

Automatic Multiple Pig Launcher - AMPL

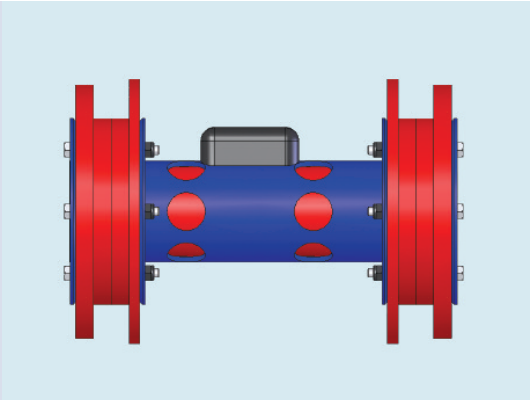


Multiple pig launching capability with minimum trap intervention

Product Description & Function

AMPL is a multiple pig launching system that allows the independent launching of one or more pigs for either a regular or irregular pigging programme, without the need for launcher intervention every time.

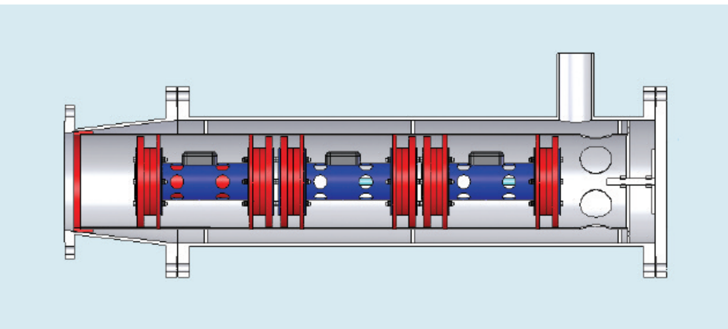
AMPL operates in a similar way to standard pigging equipment. The pigs are either pre-loaded into a specially designed cassette, which is then inserted into the standard trap, or they are loaded into the trap in which the cassette has already been fitted. The number of pigs in the cassette is predetermined by the length of the trap.



AMPL pig set for launch

Features

- Uses proven engineering components
- Incorporates a fail safe mechanism that only allows the control mechanism to operate when the launcher is depressurised after the previous launch
- Uses a specifically designed pig launching control mechanism
- Once launched, the pig behaves as a standard bi-directional pig
- Can be fitted with all the equipment that can be mounted on standard pigs, such as brushes, magnets, isotopes & pingers etc
- Internal profiles within the cassette are used to locate pigs correctly and enable preset pressure for successful pig launching
- The cassette has segmented / perforated supports to allow circulation of fluid and control flow rate / fluid bypass
- The number of pigs in the AMPL is determined by the length of the launcher
- To allow planned pig launches, AMPL is mechanical / hydro mechanical and does not require an external power supply



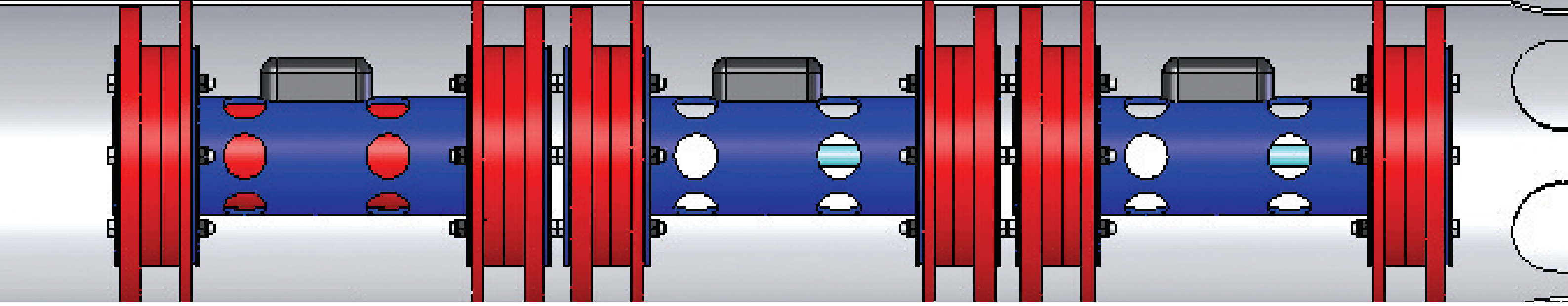
A series of AMPL pigs loaded and ready for scheduled launches

AMPL is particularly suitable for:

- Remote land based locations such as desert pigging stations
- Unmanned platforms
- Subsea launchers for commissioning and tie-ins
- Standard pipelines that require frequent pigging

PIPELINE ENGINEERING

"Engineered Solutions for the Pipeline Pigging and Flow Assurance Industry"



Benefits for Operators

PE's AMPL provides many benefits:

- Increased levels of safety
- Reduction in spillages due to the reduced number of line interventions
- Lowering of polluting emissions, as the amount of flaring is reduced
- Less manpower required for pigging
- Can be easily removed for non-routine pigging
- Reduced number of launcher interventions required to launch a series of pigs
- Can be retrospectively fitted to most pig launchers, with no costly adaption to the configuration or the addition of extra valving or control systems
- Pigging specialists are required less and installation staff have more time to focus on other requirements
- Designed to be more cost effective and quicker to install than current multiple pig launching systems available
- More effective use of traps designed with extended barrels
- Requires no extra personnel intervention, other than that required for a standard pig launch after loading of cassette
- Utilises line pressure to arm itself for launch, resulting in no external power source or batteries
- Suitable for a wide range of pigging requirements

Operation of AMPL

Loading - Pigs are either pre-loaded into a specially designed cassette, which is then inserted into the launcher, or they are loaded into the trap with a cassette fitted.

Launching – The interlinked pigs allow fluid to bypass the pigs until the lead pig is reached. On the lead pig the bypass mechanism is not engaged, which allows the fluid to create a pressure differential to launch the lead pig.

The launcher is then depressurised and the system reset with the bypass mechanism on the new lead pig disengaged. This allows the new lead pig to launch the next time the launcher is pressurised.

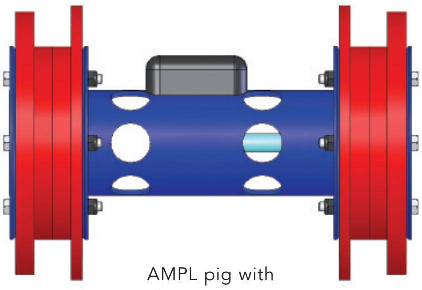
All pigs can therefore be launched independently without accessing the launcher.

On-site Services

Our Engineering Team is available to provide support services worldwide. All our engineers are fully certified and trained for onshore and offshore operations.

AMPL Operating Conditions

Nominal Line Diameter:	12" – 56"
Minimum Bend Radius:	3D
Line Pressure:	Up to 300 BarG
Pipeline Medium:	Can be used in lines containing hydrocarbons of all types including sour service, any type of liquid or gas.
Length of run:	As per standard pigs
Flow rate:	As per standard pigs
Temperature:	As per standard pigs


AMPL pig with bypass open

PL/AMPL/01

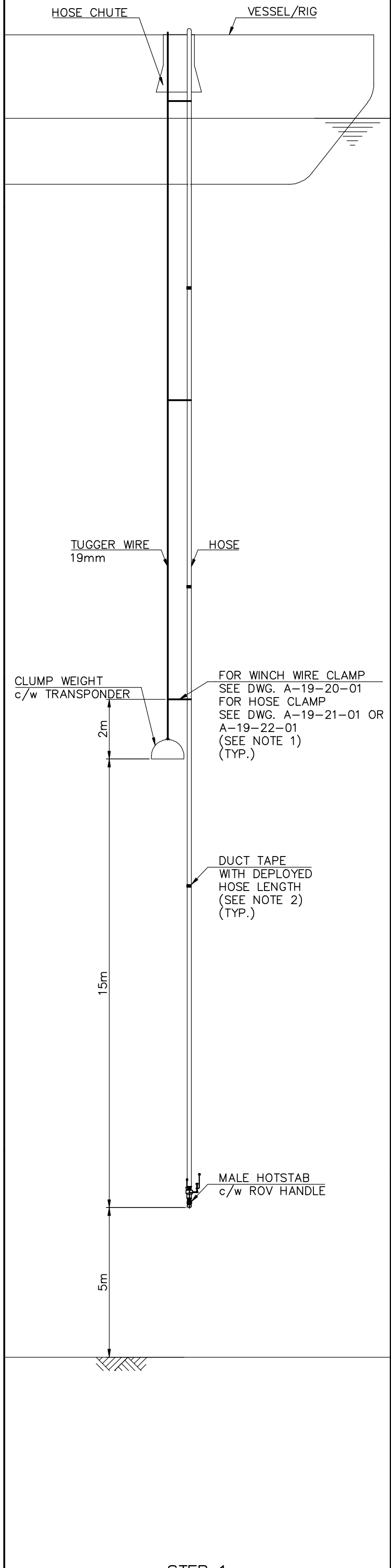
Pipeline Engineering
Gatherley Road
Catterick Bridge
Richmond, North Yorkshire
DL10 7JQ United Kingdom

Tel: +44 (0) 1748 813 000
Fax: +44 (0) 1748 813 501

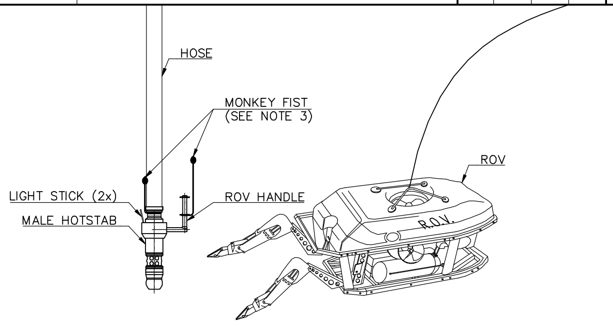
e: sales@pipelineengineering.com
w: www.pipelineengineering.com

Appendix E

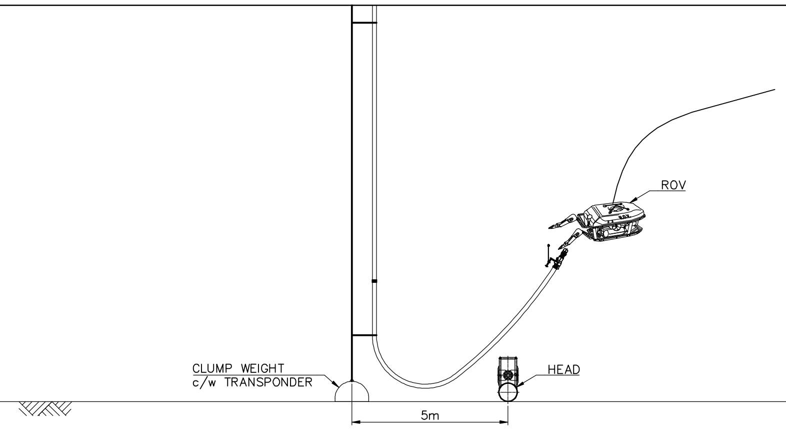
Hose Deployment



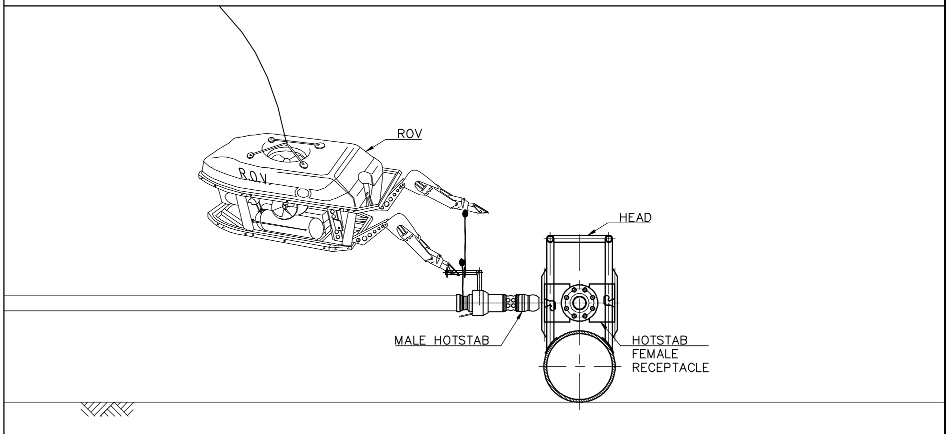
STEP 1



STEP 2
SCALE 1:20



STEP 3



STEP 4
SCALE 1:20

GENERAL NOTES

1. HOSE CLAMP BETWEEN HOSE AND TUGGER WIRE EVERY 10m ALONG THE HOSE. CLAMP TO BE FASTENED WITH FOUR M10 BOLTS.
2. DUCT TAPE WITH DEPLOYED HOSE LENGTH INDICATED TO BE ATTACHED TO HOSE EVERY 10m.
3. ONE MONKEY FIST, LENGTH AROUND 1m, CONNECTED TO HOTSTAB HANDLE AND ONE MONKEY FIST WITH LENGTH AROUND. 0.5m CONNECTED HOT STAB TO WECO CONNECTION.

REFERENCE DRAWINGS

A-19-20-01 WINCH WIRE CLAMP 19mm
A-19-21-01 2" HOSE CLAMP
A-19-22-01 4" HOSE CLAMP

GRAPHIC SCALE 1 : 20 — 0 500 1000 1500 2000 2500 mm
GRAPHIC SCALE 1 : 75 — 0 2 4 6 8 10 m

SIGNED ON ORIGINAL

REV.	DATE	DRAWN	DESCRIPTION	APPROVED ENGINEERING		APPR. PROJ.
B	19 Aug 2010	LRu	FOR INFORMATION	DTa	SfS	RvA
A	11 Jun 2007	DTA	FOR INFORMATION	PLam	LvdL	RB

PROJECT
STANDARD / FOR JOBS

SUBJECT
HOSE DEPLOYMENT

Allseas

ORIGINATOR	SIZE	UNITS	SCALE	PROJECTION
DTA	A1	mm	1:75 U.N.O.	

JOB No.	ACT. CODE	JOB DESCRIPTION

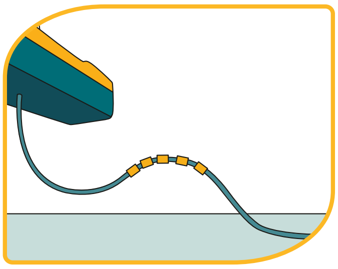
FILE No.	discipline / ident. no. / subject no. / sheet no. (ALLSEAS DRAWING No.)	revision
300STD	A-19-10-01	B

Appendix F

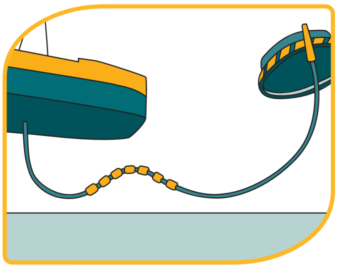
Distributed Buoyancy Module

Distributed Buoyancy Modules

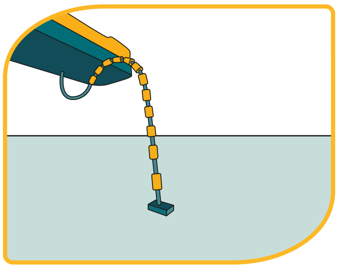
Distributed buoyancy modules are used in subsea floating production to prevent damage to the conduits such as flexible risers, umbilical and cables. Designed and manufactured under our Hippo brand, our modules are ideally suited for subsurface applications. These modules allow movement to maintain configurations, typically referred to as lazy, pliant and steep waves.



Lazy wave



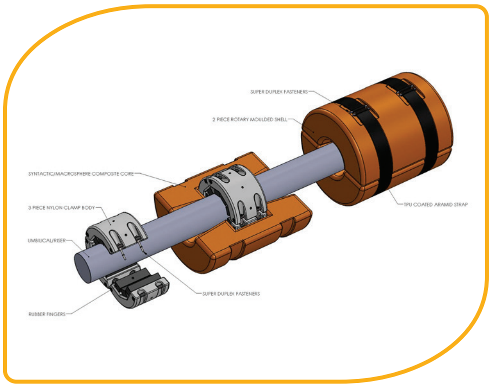
Pliant wave

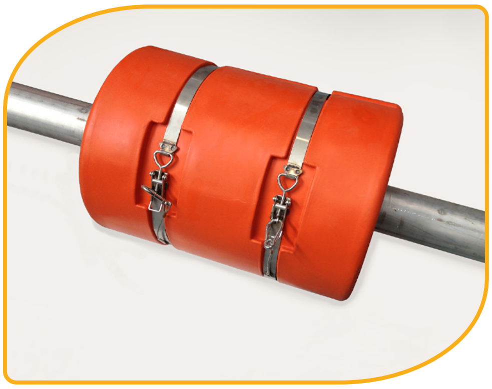


Steep wave

Design features include:

- Internal clamp acts as an interface between the conduit and flotation unit, securely locking it in position to resist axial movement of the conduit
- Rubber fingers create friction within the nylon clamp body
- All fasteners are made of super duplex stainless steel to ensure maximum tensile strength and resistance against corrosion
- Flotation element provides the required amount of uplift
- Syntactic foam core is encased with a polyethylene half-shell with an internal recess designed to accomodate the internal clamp
- At the end of the half-shell the opening widens into a bell-type configuration which reduces stress to the conduit





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15.11.13

Appendix G

Overview - Pipeline Setup

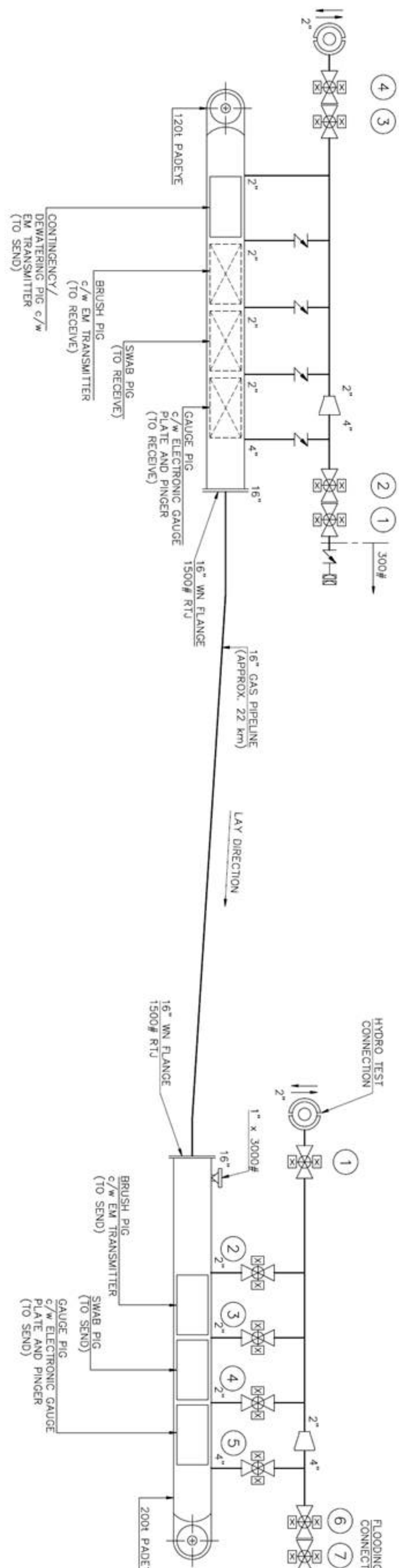


Figure G.1: Pipeline setup during pigging

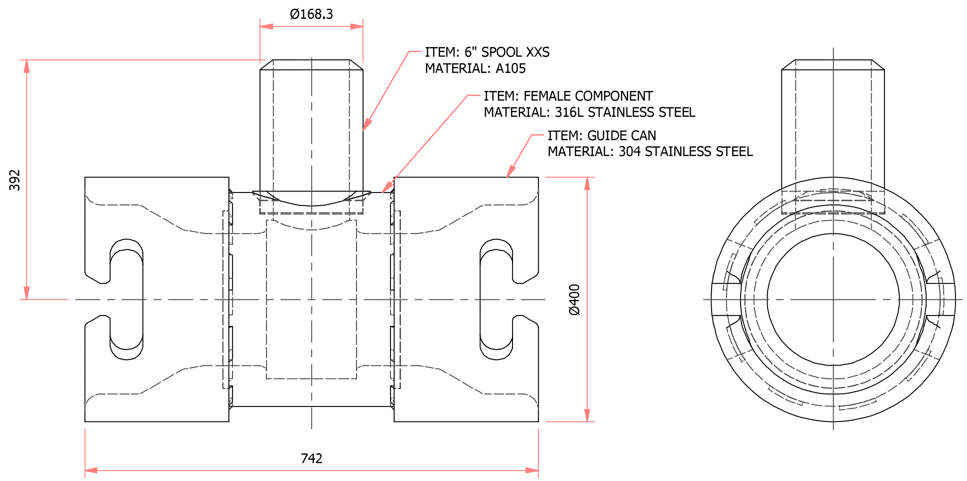
Appendix H

6-inch stab connection system

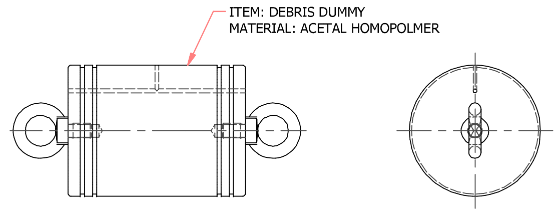
REV	DATE	DESCRIPTION	DESIGNER	CHECKED	APPROVED
A	05/03/14	ISSUED FOR APPROVAL	CJL	JSC	JSC
B	08/01/15	FLANGE INFORMATION CORRECTED	CJL	JSC	JSC

REVISION HISTORY

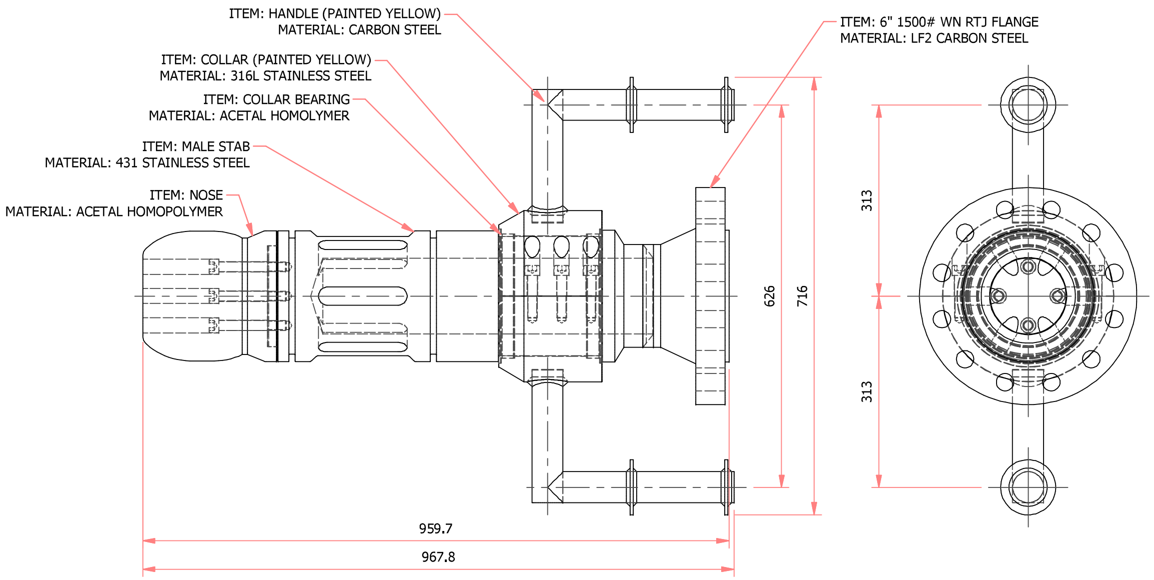
ITEM: FEMALE RECEPTACLE
APPROXIMATE WEIGHT: 361.7KG



ITEM: DEBRIS DUMMY
APPROXIMATE WEIGHT: 16.4KG



ITEM: MALE STAB
APPROXIMATE WEIGHT: 194.3KG



Deepstar Subsea Limited.
Unit 15 Victoria Industrial Estate, Hebburn, Tyne & Wear, NE31 1UB, England
Tel: +44 (0)191 4286770, Fax +44 (0)191 4286771, Website: www.deepstarsubsea.co.uk

Drawing Number: 57-0916
Title: 6" 1500# Stab Connection System
Material:
Weight:
Designed By: Chris Lilly
Scale: 1 : 8

Unspecified Tolerances:
Decimal (.0): ±0.1
Decimal (.00): ±0.05
Decimal (.000): ±0.010

IF IN DOUBT ASK

All dimensions are in mm unless otherwise specified.
Third Angle Projection:
Size: A3
Sheets: 1 / 1

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