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BONNY TERMINAL INTEGRATED PROJECT

PIPELINE INSTALLATION SHORE APPROACH FOR WEST AFRICAN VENTURES

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Institution For Civilised Area

FACULTY CIVIL ENGINEERING

PIPELINE INSTALLATION SHORE APPROACH FOR WEST AFRICAN VENTURES

contribution to the project: Bonny Terminal Integrated Project

By Junyong TANG

Final thesis

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UTRECHT, 2006

PREFACE

After one-year hold of school due to bad luck, personal problems and lack of thesis opportunities, I miraculously found a wonderful opportunity to finish my last year of my studies Civil engineering at Hoge School Utrecht in a proper way. What began as a part-time job in November 2005, ended as a fulltime Internship in Lagos, Nigeria. The company West African Venture, who gave me this opportunity, is a brand new company that made the adventure of this final thesis even more challenging. When I arrived in Nigeria, there were no material and no books available at all! Internet was often offline and there was no Lead engineer in place, which made things even harder. Nigeria: a true developing country.

The circumstances weren't perfect, but the team was well experienced and very motivated to do the job. At this moment the majority of the engineering of the project is being reviewed or finished.

I would like to thank my mentors who contributed my development into a "junior" project engineer and for my final thesis. These are the following persons: Stefano Cecconi (Italian, former Saipem employer), TeeJee Erhunmwunsee (Nigerian, former Wilbros employer), Tony Adhumwansa (Nigerian, former Willbros employer), Han in het veld (Dutch, former Allseas employer) and Henk Vastenholt (Dutch, former Shell employer).

Waventures is a member of Sea trucks group which has a numerous of construction barges, supply barges and different type of vessels. During my stay in the guesthouse, I ran into a lot of engineers, captains and crew members who came and went. They supplied me with their experience, advice and books who made my final thesis more immersion.

This Final thesis is split up in the main and sub sections. This main section of this final thesis contains the project statement execution. From the tie-in till the end for the 36-inch water disposal line and 48-inch distribution line. The sub sections are more detailed calculations and drawings of the project.

The alternative appointed teachers to guide my final thesis came late due to unknown internal problems of hoge school

Utrecht, but at the end of the day the assigned teachers were very inspiring and helpful.

Finally not to forget my study career supervisor of the Hoge school Utrecht can not be forgotten. I couldn't wish for a better study career supervisor Mr Ir. H. Heerden. He is a very flexible, when I came at the last moment to change my subject for my final thesis. Thanks to him I could start with this final thesis. There rest nothing more to say as: Enjoy your reading.

JunYong Tang, Holland, 18 May 2006.

West African Venture Team 2006 (BTIP PROJECT).

TABLE OF CONTENTS

SUMMARY

- The Bonny Terminal Integrated Project is a project, where 2 new pipelines are going to be installed in Bonny Area of South coast of Nigeria. This Final thesis covers the mayor project execution statement.
- The Barge, which is used for this project is the Jascon-30, which can operate at depths of 3m or less. Beaching the barge at low tide is an option provided that the seabed and weather conditions are suitable.
- Onshore a turning sheave will be set up and sheet piles driven to protect the beach in the surf zone. The cable will be pre-installed from the beach offshore for immediate pick up by the Jascon-30 when it arrives on site.
- The Jascon-30 will be mobilized to the area and set up near shore over the pipeline route with its stern aiming to shore. Using her front anchors and pre-installed anchor pattern on the stern, bow and port side.
- Pipelaying of the 48-inch oil loading line will commence first and continue pipe laying till the PLEM location,
- The pipeline is produced on the barge and pulled to the shore, as the barge is moved forwards in steps on its anchors as a concurrent operation,
- The shore pull operation is considered complete when the pipeline end has been pulled inside the cofferdam. Barge has then laid approx. 1000 mtr of pipelines.
- The pull-wire will be disconnected and buoyed, together with the retrieving wire, to be both picked up by tugboat for re-installation the 36”line.
- The 36” line will be flooded from the sea-side with filtered water.
- The 36” line will be hydro-tested from the shore. The hydro-test spread will be demobilised.
- The barge will return to the 48”, retrieve the pipeline and the 48” line will be flooded from the seaside with filtered water and approved inhibitor. Then the 48-inch pipeline and spool piece are hydro-tested in one operation from the Barge,
- The pipeline trenching machine is mobilised, brought to site and 48” line is trenched to specification, that is from the cofferdam to kp 0.480 to a depth of cover of 2 m and flush with the seabed to kp 4.0. It is anticipated that the full depth of trench, especially close to the shore, will only be achieved after a few passes of the trenching machine. The Trenching machine will be demobilised.
- During pipelay X-ray will inspect the completed welds and the joints coated with field joint coating system.
- In addition to coating the exterior field joints of the 36” pipeline, also the inside of the field joint is coated using mortar-cement-type.
- Since the diffuser is an integral part of the pipeline it will be laid as a conventional pipeline. On completion of laying the pipeline and diffuser, the pipeline end will be terminated with a lay down head (with pig-launcher) and the pipeline laid on the seabed,.
- The 48-inch pipeline is then connected to the PLEM via a spool piece,
- The SBM is installed and afterwards connected with double hoses.

DEFINITIONS & ABBREVIATION

AHT	Anchor Handling Tug
A&R	Abandonment and Recovery
BOP	Bottom of Pipe
CD	Chart Datum (equivalent to LAT)
COG	Centre of Gravity
DAF	Dynamic Amplification Factor
DP	Dynamic Position
HHI	Heavy Hyundai Industries
HU	Hogeschool Utrecht
HW	High Water
LAT	Lowest Astronomical Tide
MSL	Mean Sea Level
MHWN	Mean High Water Neap
MW	Mega Watt
KP	Kilometre Point
NDT	Non Destructive Test
OPEC	Organization of the Petroleum Exporting Countries
PH	Pull Head
PLEM	Pipe Line End Manifold
ROV	Remote Operation Vehicle
SPECIFICATION	Technical and procedural specifications applied to this Work
SPDC	Shell Petroleum Development Company
SPM	Single Point Mooring buoy
SWL	Save Working Load
TOP	Top of Pipe
TDP	Touch Down Point
WAV	West African Ventures

REFERENCES

[1] Barge Mooring Volume 6

[2] American Petrol Institution

[3] Shell Design and Engineering Practices (Shell DEP)

[4] Offshore Pipeline Design, Analysis and Methods, Boyn 2005

[5] Kaldenbach W.P.; Vastenholt H.(1977) Inleiding in de aanleg van pijpleidingen

[6] Alignment sheet 48” E 09335-4385-PLD-003.01 Rev.2

[7] EA Metocean Design Report

[8] 48” Export line design E09335-4385-PLR-103

[9] DNV RP E305

[10] COORDINATION OF COFFERDAM E09335-43-00-4D-3202

[11] SEATRUCKS JACON 30 SPECS

[12] SEATRUCKS JASCON 17 SPECS

[13] SEATRUCKS JASCON 3 SPECS

[14] SEATRUCKS JASCON 4 SPECS

[15] AMERICAN HOIST 11320 SPECS WW.RODSON.COM

[16] James F. Wilson (2002) Dynamics of offshore construction

[17] Nigerian Tide Table “Bonny Town” Year 2006

[18] Tipler, Paul (1998). *Physics for Scientists and Engineers: Vol. 1*, 4th ed.,

INTRODUCTION

West African Ventures Limited has been awarded by Hyundai Heavy Industries Co Ltd as part of the Bonny Terminal Integrated Project the installation of a 36 inch water effluent line including diffuser and a 48 inch oil loading line, inclusive of pipeline end manifold (PLEM) and loading buoy (SPM). The pipelines are to be laid between the beach of Bonny Island, Nigeria and target points offshore. Near shore the pipelines are to be buried. The work will be carried out on behalf of Shell Petroleum Development Company of Nigeria.

WAVentures is to install the 48-inch oil loading line from the high water mark on the beach to its target offshore. The pipeline has a length of 32 km. Here the pipeline terminates at a PLEM. The PLEM is tied to the seabed with 4 piles. On top of the PLEM a SPM buoy is to be installed. The SPM buoy is held in place with 8 anchor lines, comprising cables and chains, which are connected to piles. The buoy is connected to the PLEM via submarine hoses. The SPM is further fitted out with floating hoses and hawsers.

The 36 inch water effluent disposal pipeline has a length of 7.5 km. The pipeline terminates in a diffuser.

The company WAV has a well-equipped fleet of offshore support craft from their base at Onne Port in Nigeria. The Jascon-30 construction and pipelay barge will be the main vessel to be mobilised for the work.

The project BTIP has been based on the assumption that all permanent materials are issued to WAV, such as:

- Pipe Joints, coated including pre-installed anodes
- Diffuser materials
- Flanges and bends required for the spool pieces.
- SPM buoy complete with PLEM, anchor piles, mooring cables and chain and hoses Installation of sheet piles for protection of the beach at the pipeline landfalls and their removal after the shore approach operations,
- Provision and installation of a 600 tonne foundation suitable for a 300 tonne turning sheave with double messenger wire,

All these permanent materials except of the SPM are assumed to be delivered at Willbros yard Port Harcourt on board WAV’s barges and sea fastened. Night sailing restrictions along Bonny River, will be considered in the logistical planning as well mooring at Bonny Terminal or WAVS yard in Onne.

SCOPE OF DOCUMENT

The project BTIP is a dynamic and very large project. This document starts with the project process. All the main items, which are involved in the project, are explained. Some parts of the project are handed over to subcontractors. This is because some of the elements in this project requires professional specialty, which this company doesn't have yet.

These are the main subjects, which is going to be explained in this document.

☑ Beach pull;

☑ Mooring;

☑ Plem Installation;

☑ SPM Installation;

☒ Planning of Pipe supply.

- Determination of boundaries, installation process, sea fastening, crane capacity, distance sailing, time sailing, ect

(This item is not incorporated in this thesis prior to lack of time, although this item is in practice conducted and finalised,)

☒ Cofferdam

- Soil investigation
- Redesign is executed (a re-design, but not incorporated into this thesis, but you can see them on the drawings)
- Dimension

☒ Pipe stress analysis and Offpipe (Important part of the scope, you could see this as another part of this project and not to divert to many part I stayed primarily to the installation of the pipe)

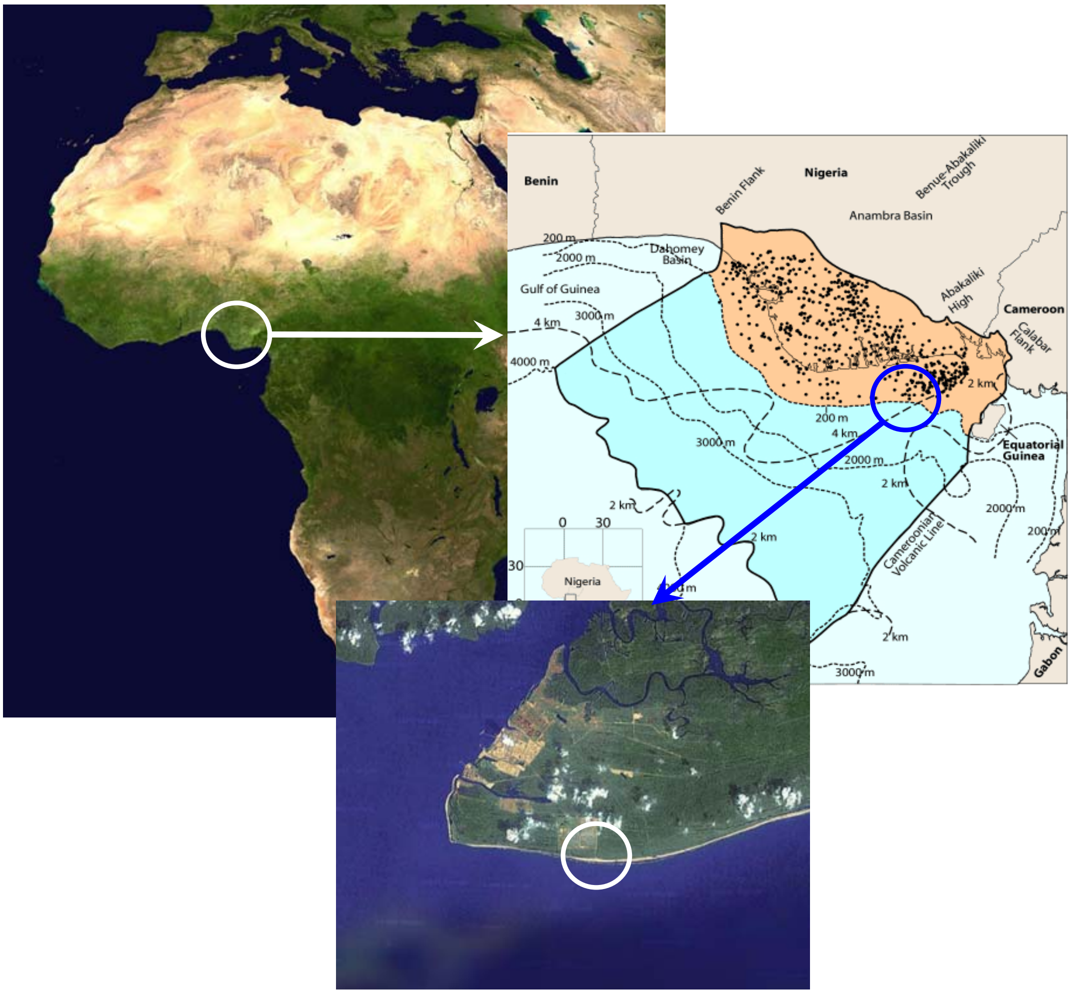
The lack of time and the project process resulted in some item changes, which made my final thesis different as proposed. Items like Offpipe calculations or Cofferdam calculations are no longer part of the scope. Instead of these items the project statement execution of the entire project are covered in this thesis and catenary's calculations, lifting analysis and drawings are added which are needed for the project execution statement.

The main target of this thesis was to find out what the best way was to install the pipeline. During this process the mooring analysis was an essential part of the scope. Since I was so focused to install the pipeline, I quickly realised that the pipe is only going to be finished when you install the SPM buoy and Plem. There for to finish the project I made a lift analysis for the PLEM.

1.0 LOCATION OF PROJECT

Nigeria's oil reserves are estimated at between 16 and 22 billion barrels. Its reserves make Nigeria the tenth most petroleum rich nation, and by the far the most affluent in Africa. In mid-2001 its crude oil production was averaging around 2.2 million barrels (350,000 m^3) per day.

Nearly all of the country's primary reserves are concentrated in and around the delta of the Niger River, but off-shore rigs are also prominent in the well-endowed coastal region. (see figure 1.1) Nigeria is also one of the few major oil-producing nations still capable of increasing its oil output and unlike most of the other OPEC countries, Nigeria is not projected to exceed peak production until at least 2009. The reason for Nigeria's relative unproductively is primarily OPEC demands to cut production in order to regulate prices on the international market.



Figuur 1.1 Bonny Terminal and Oil Fields (black dots)

All petroleum production and exploration is taken under the support of joint ventures between foreign multi-national corporations and the Nigerian federal government. This joint venture manifests itself as the Nigerian National Petroleum Corporation, a nationalized state corporation. All companies operating in Nigeria obey government operational rules and naming. Six companies are operating in Nigeria and four out of the six companies have existence pipelines at the bonny terminal where they rendezvous at the same terminal (see figure 1.2).

These are the new pipelines (see figure 1.2);

① Blue	New proprosed 48″ Oil line;
② Red	New proposed 36″ Waterl line.

These are the excisting pipelines (see figure 1.2);

③ Orange	8″ Indiana Chevron Line;
④ Green	10″ and 12″ Oslo Mobil Line (50 m offset);
⑤ Black	32″ OGGS Shell Line;
⑥ Yellow	48″ Crude Shell Line;
⑦ Grey	24″ Amanam Total Fina Line;
⑧ Light Blue	Nitel Fibre Optic.

Bonny Terminal has been in operation for over 32 years. The facilities are currently being upgraded under a contract between SPDC and HHI. As part of BTIP, SPDC intends to install a new offshore oil export pipeline and produced water disposal pipeline. These pipelines commence at the onshore facilities and run over a few kilometres, over the beach and continue towards target areas offshore. The offshore section 48-inch oil export pipeline has a length of 32 km. The pipeline terminates at a Single Point Mooring (SPM) loading Buoy. The 36 inch water disposal line has a length of 7,5 km.

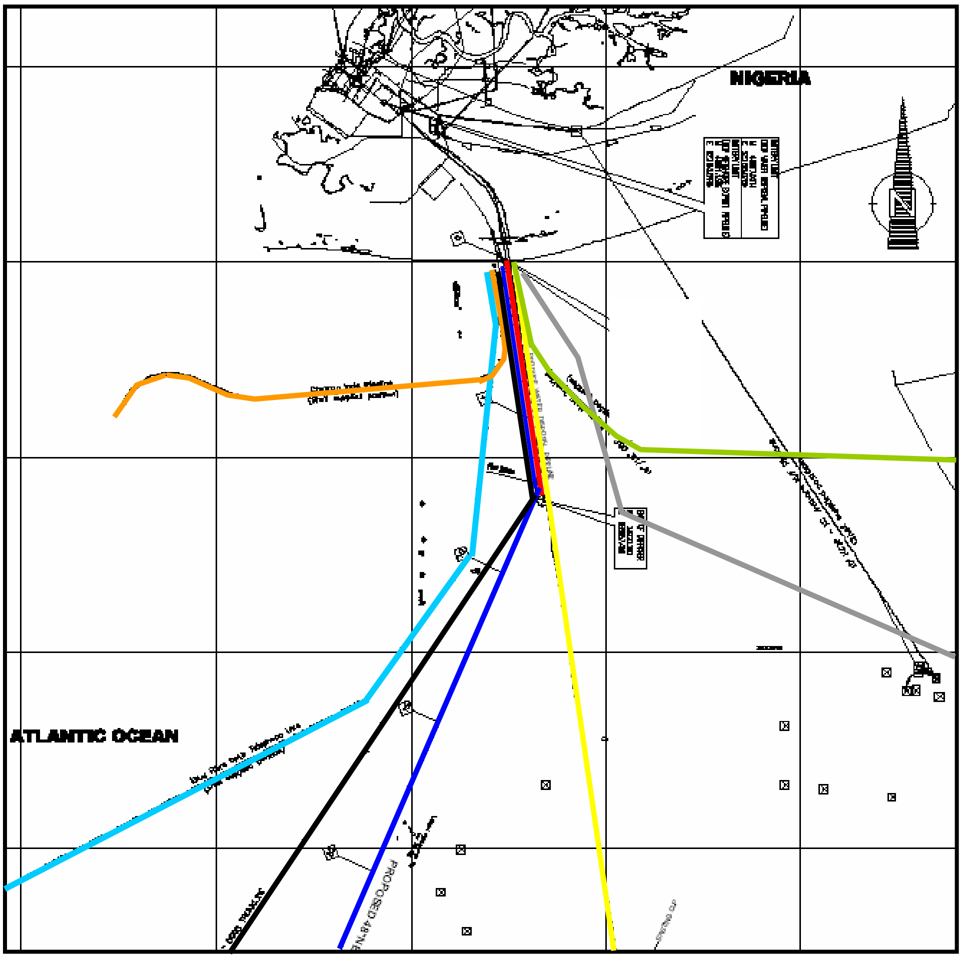


Figure 1.2 : Technical overview map.

Geodetic parameters:

Horizontal Datum:	Minna 1950
Projection:	Transverse Mercator Nigerian Mid Belt
Central Meridian (CM)	8º 30′ E
Latitude of Origin	4º N
False Easting	670553.98 m
False Northing	0.000 m
Scale Factor at CM	0.99975

2.0 PROJECT OVERVIEW

2.1 General

Waventures is the installation contractor and responsible for:

A) Installation of 48" diameter offshore export pipeline from KP 0.0 to KP 32.0 including spool and 36" water disposal pipeline with a diffuser from KP 0.0 to KP 7.5 including;

1. Beach preparation;
2. Pipe laying;
3. Pre commissioning

B) Installation of the PLEM and SPM and the related accessories like piles, chains, hoses etc. The SPM shall consist of 8 Anchor Piles, submarine hoses, floating hoses, chains, mooring hawsers and 4 Plem Piles

C) Trenching the Pipelines from KP 0.0 till KP 4.0

2.2 Description

According to Literature study and communication with various numbers of professionals in the field, it appears that there are various methods of submarine-pipeline installation including the lay-barge, reel, bottom-pull, tow and other methods. Some of the methods are suited for small-diameter pipe installations; others are particularly suited for deepwater installations (+1000m) A description of the most comment methods are state below;

[1] **Laybarge Method.** Pipes are delivered to the lay barge. A deck crane transfers the pipe to storage racks on the lay barge. When the pipe is laid, the crane transfers the pipe to a automatic rack for feeding pipe to the line up table. The line up table is the first workstation for welding the pipe and NDT. Afterwards the pipes are coated. Pipe-laying operations continue, with the pipe supported by the barge rollers, tensioner and stinger before moving to the seabed. See attachment for full details of the vessel.

Figure 2.2.1 typical low draft Laybarge

[2] **Reel Barge Method.** The reel-barge method of laying submarine pipeline uses a continuous length of pipe coiled onto a reel. Assembly is done onshore and NDT is completed before coiling the pipe. Barges goes to site and uncoil its pipe and goes through a pipe tensioner an pipe lay commence.

Figure 2.2.2 Vertical reel barge (Horizontal are available)

[3] **Tow Method.** Tow methods offers the advantage of pipe assembly on shore, but is also possible to assemble from Laybarge and use pontoons or buoys to support the pipeline at the water surface. Once in place the pipeline are lowered by removing the pontoons.

Figure 2.2.3 Controlled Tow method

To bury the pipe at a save depth at shore it is common to use dredgers or trenching machine.

"The Shore approach" as a unique and challenging part of the project is analyzed and studied in detail. Following a list of the main aspects which led to this conclusion:

1. Route corridor: the route for both lines is very narrow, because of existing adjacent pipelines. The new pipelines have to be laid between the existing 32-inch OGGS pipeline and the 48-inch Mobil oil loading line. Both lines are approx 100-110 m apart
2. The foreshore of the beach is very shallow. The seabed drops from the beach inwards the sea to 3,3m and goes to 4m till around 2.5km. This requires a special anchors pattern set up and handling procedure.
3. The shallow foreshore forbids the use of deep draft lay barges and narrowness of the available corridor.
4. Big pipeline Diameter and heavy weight require special pull in installation facilities.

The definition problem: What is the pipeline installation?

Method statement:

The use of concrete pipe, forbids method [2]. The minimum radius of the pipe bend to avoid any cracks would be too large to use any conventional reel barge.

Method [3] would be in theoretical way achievable, but the reason not to use to method is:

- The size of the logistical problem to bring the heavy pipes onshore, because there is no space to stock the pipelines.
- Very unsafe and unstable area to work onshore, which is often attacked by the local people.
- Very expensive, because you need to install roller boxes at the beach.

The use of deep draft lay barges in combination of towing with buoys and narrowness of the available corridor in effect prohibits the use of conventional cutter suction dredgers. Therefore this thesis is based on method the use of a shallow draft lay barge and trenching the pipelines with a purpose built post-lay pipeline trenching machine.

3.0 BEACH PREPARATION

The setup of the beach preparation consists of using sheet piles (to balance the pull force), the yokes (to direct the force equally and balanced to the sheet piles) and using cables and grommer to connect the sheet piles, yokes and sheave together (see figure 3.0.1 and 3.0.2).
To pull the pipe to KP 0.0 you can use different types of pull-installation;

[1] A winch. You connect the winch to the pipe and pull it onshore. The pipe property indicates a large pull force. This requires a powerful winch.

[2] A sheave. A sling is connected from one side to the end of the barge and goes trough the sheave and back to the direction of the barge and connected to pulling head of the pipe. This requires the use of the winches of the barge

The reasons of the use of the sheave is as follow:

- Cheaper
- You don’t need as much personal onshore when you are using a sheave.

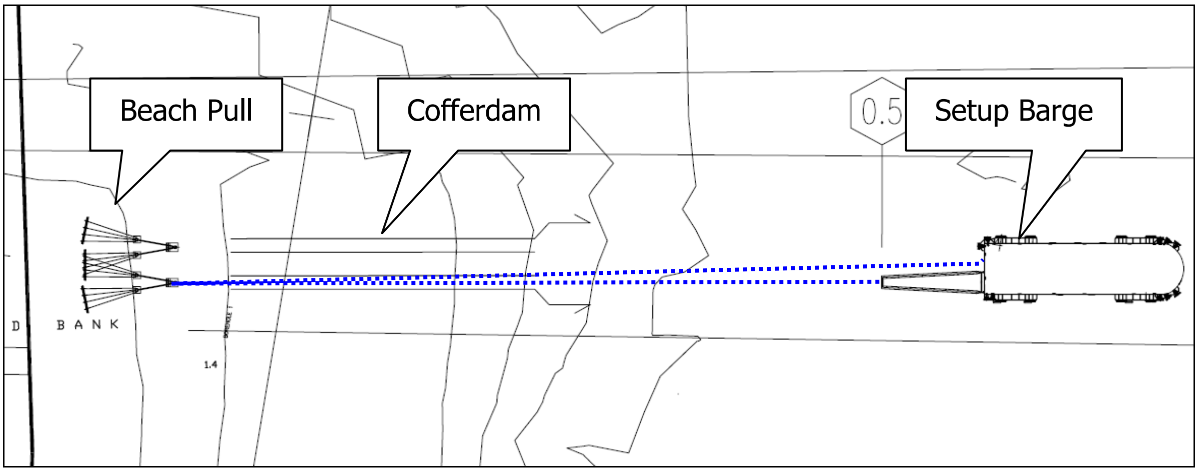


Figure 3.0.1 Overview

This would be a similar setup for the winch. The main difference is that the winch is pulling the pipe instead of the barge. The use of the 2 sets of anchoring is to prevent over dimensioning of the components of the beach pull.

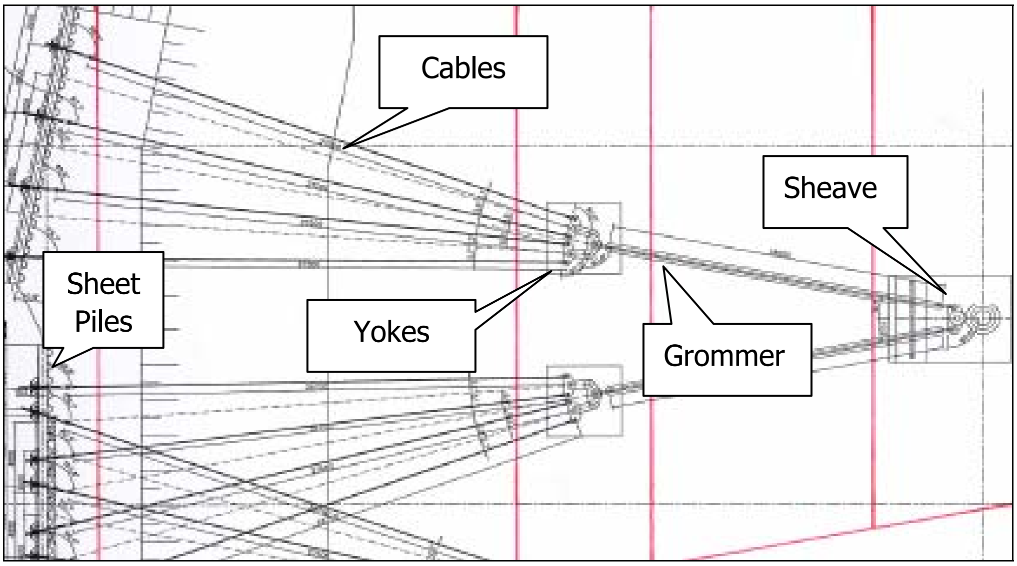


Figure 3.0.2 Setup Beach Preparations.

<u>The sheave</u>

By using the sheave you don't have to put any mechanical driven machine onshore to get the pipe on the beach. Presuming that the barge can maximum pull 300 mT(see further on in this thesis) which is only reached when the total force which need is for pipeline will result in a 600 mT opposite force.

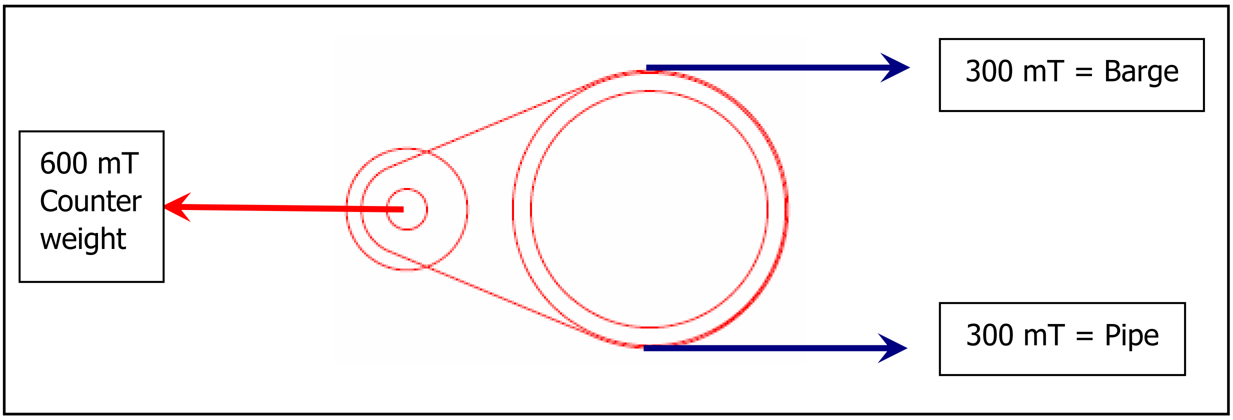


Figure 3.0.3 Overview of the Sheave

Yokes

The use of yokes. A mechanical device adapts to the pull force direction to divide the force equally over the anchor sheet piles

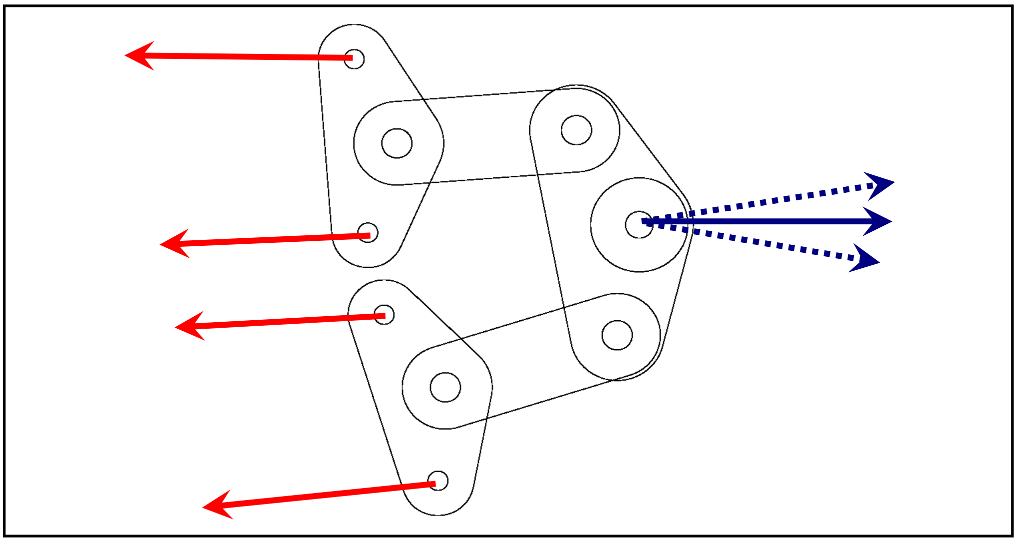
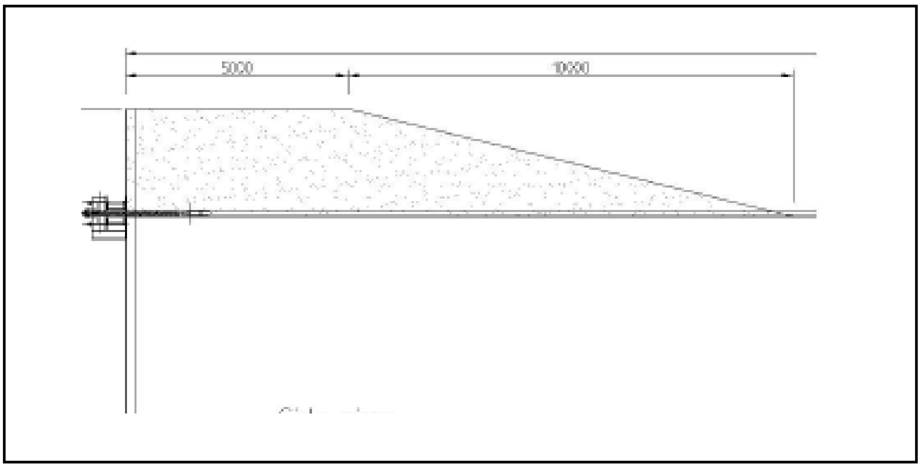


Figure 3.0.4 Overview of the Yokes

Sheet Piles

The function of the sheet piles is to take the load of the pulling force.



Grommer and Cables

The sheave is diverted into 2 forces. Each force will be 300 mT. In order to cope with this force it would be better to use a grommer instead of a cable. The Grommer is connected to the Yokes and from here on the force is spread out over 2 shackle connections which in turn is divided again across two yokes. As a result, only ¼ of the original force is being exerted on each connector. 75mT is well within the tensile strength of conventional cable wires.

4.0 METHODOLOGY OF PIPE-LAYING

4.1 S-lay

One of the methods most commonly used to install marine pipelines is the S-lay method, which consists of joining the pipe joints using conventional welding techniques, and testing the welds and field-joint coatings on the vessel. The near-horizontal ramp allows for several welding stations, tensioners, an X-ray station and some field joint stations to be placed on the deck. The stinger radius controls the overbend curvature and the sagbend curvature is controlled by the tension applied to the pipe by tensioners on the barge. The required tension depends on the water depth, the weight of the pipe, the allowable radius of curvature at the overbend and the allowable stress at the sagbend. This production process leads to a very fast laying rate. Even when handling large diameter pipes, from 2 up to 6 km per day.

The maximum depth at which a pipe can be laid in the S-mode is determined by the tension capacity, the stinger length, curvature and tip slope and the longitudinal attitude (trim) of the vessel. The maximum depth at which a given pipeline can be laid could be increased through increasing the tensioning capacity and the stinger length of the lay barge.

The Jascon 30 and all other (relative) undeep barges will be installed according to the S-lay method. Its name being derived from the shape in which the pipe will be laid. (see figure 3.3.2.2)

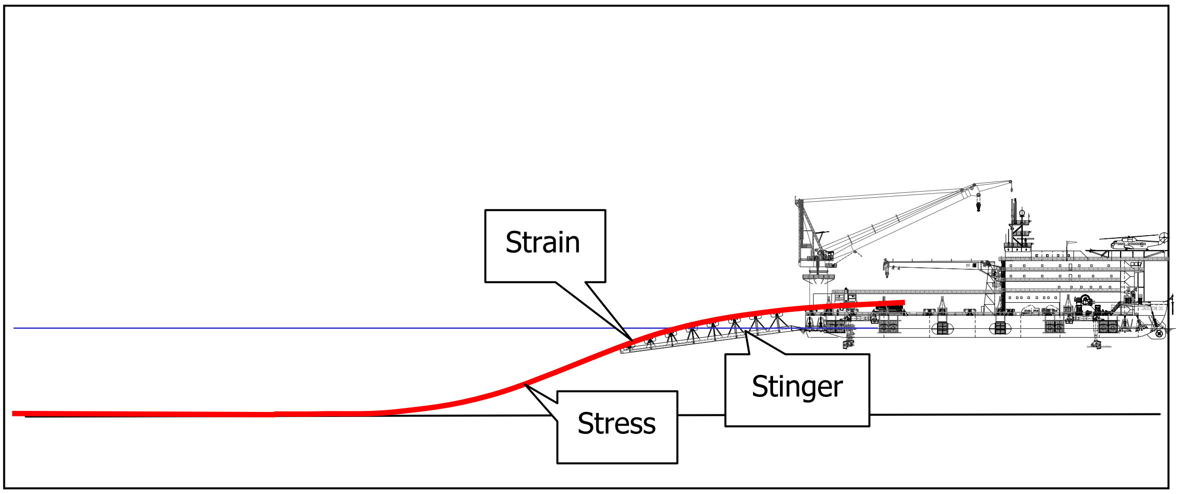


Figure 4.1.1 S-lay of the barge

4.2 J-Lay

The main alternative to S-lay for exceeding these depths with large diameter pipelines is the J-lay method. This technique is based on applying the axial force in a near-vertical direction, virtually eliminating any horizontal reaction on the vessel equipment. As the name suggest, the pipe originates from the lay vessel at a near vertical angle, hanging like a cable gently curving towards the horizontal as it approaches the seabed, following a J shape. The curvature required on the overbend is thus totally eliminated and only a very short stinger is needed, just to bring the pipe outside the vessel and to dampen the forces from the lay span. Only a relatively small amount of horizontal tension component is necessary to maintain a satisfactory curvature in the sagbend to control the stresses and prevent buckling, while in fact the major part of the tension requirement is simply meant to bear the submerged weight of the pipe. The near vertical pipe 'firing line' does not allow for more than one welding and NDT station, implying that the welding is much more time consuming than for S-lay. As a solution, stalks of 5-6 joints are first welded together horizontally, subsequently put in an upright position using lifting equipment and then welded in the near vertical to the previous one. Even if this situation allows for 5 welds rather than 6, which is highly preferable, the J-lay production process would still be slower than S-lay. This has to do with he available welding technology available for the thick pipes usually applied in these cases.

The applicability of J-lay method in deep and very deep waters requires barges with dynamic positioning capabilities, as positioning by means of a spread mooring with anchors would always be impractical and often unfeasible. This fact introduces new aspects in the evaluation of the safety of operations, particularly related to possible 'black out' conditions, such as the loss of thruster control during some emergency. Under such extreme conditions, vessel drift may induce an excessive curvature in the pipe catenary immediately outside the vessel. The development of special devices or remedial procedures is thus required. These should be capable of holding the pipe configuration at stinger exit within the envelope of the allowable configurations.

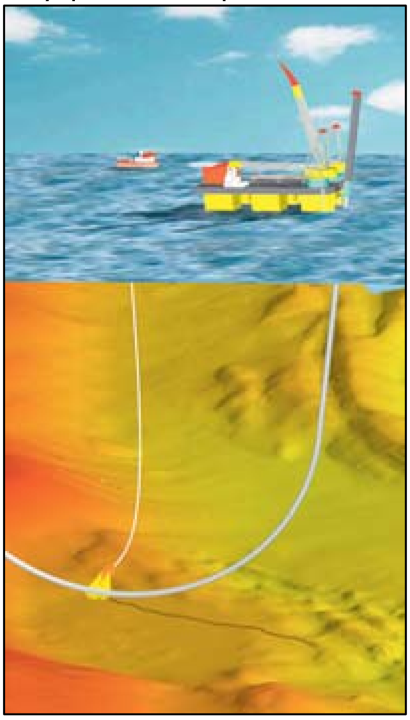


Figure 4.2.1 J-lay

4.3 Jascon 30

4.3.1 Background

The Pipe lay and Hook up Barge, Jascon 30, is a highly versatile multipurpose vessel of advanced hull design. The fire line/ pipe ramp, about 110m long, is located at an offset of 5.2m from the centre line of the barge towards the starboard side. Eight support rollers and one tension machine are installed inside the fire line. The firing line is divided into seven-work station for welding, NDT, repair and field joint coating. The abandonment and recovery (A&R) that is located on the deck above the firing line is capable of maintaining constant tension during the abandonment operation.

The barge is equipped with a truss and stinger system at the stern. The stinger with its rollerboxen is adjustable for the right S-curve in order not to buckle. The truss and stinger system is equipped with a hydraulic system and locking mechanism for attachment to the barge.

The Jascon 30 is a very shallow draft barge. Its operating draft is 2.8 m or less, including 10% filling of all fuel and water tanks, and 50 of the heaviest pipe joints on deck.

Length	111.00m
Breadth	30.48m
Depth	6.71m
Draft	5.00m
Transit Draft	2.7m

Table 4.3.1.1 Dimensions of Jascon 30

The barge is fitted with anchor handling winches. Therefore the barge requires at least 2 anchor handling tugs (AHT) to help the barge relocate the anchors when needed.

The main crane on Jascon 30 will be the American Hoist 11320

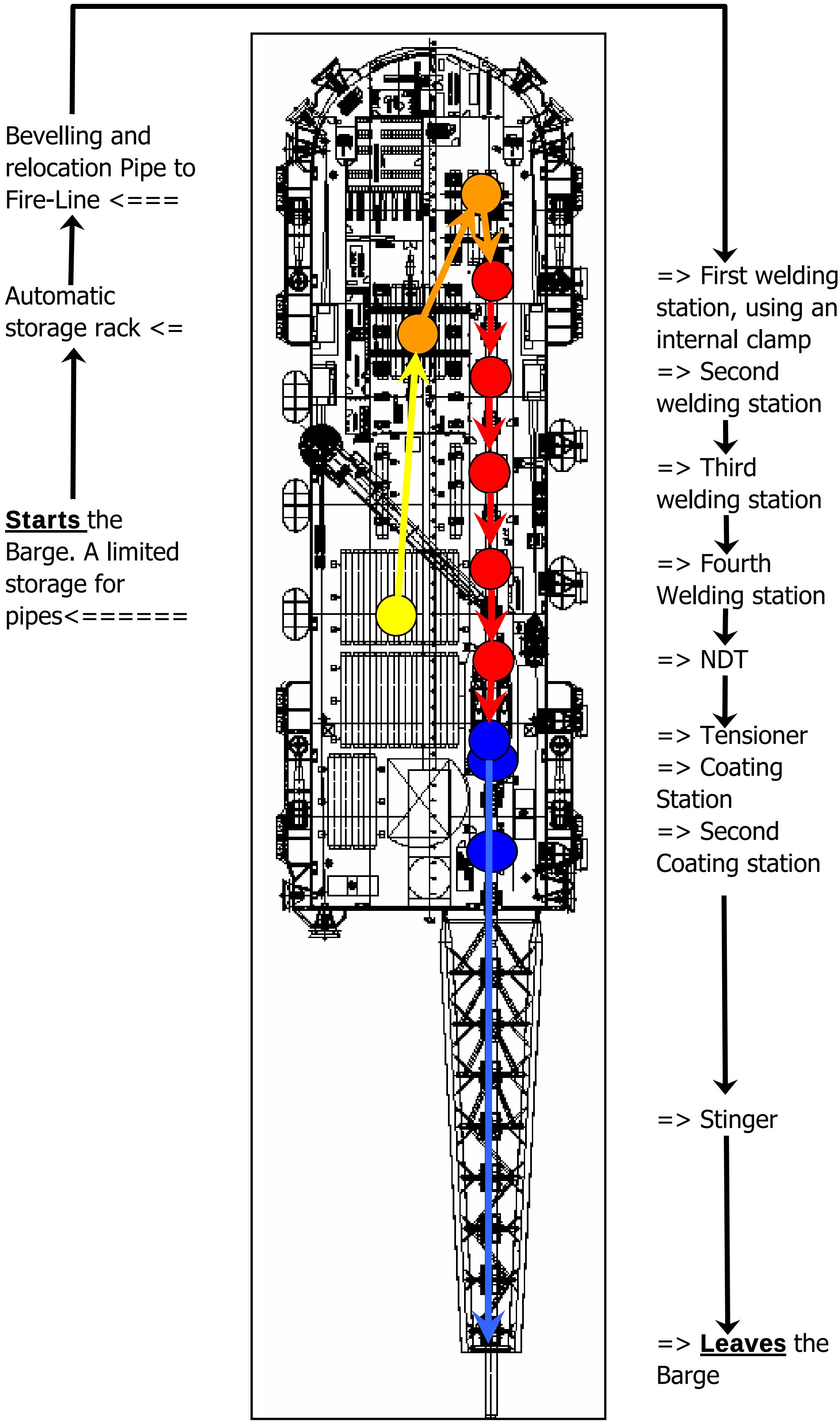


Figure 4.3.1.1 Jascon 30 layout and production sequence

4.3.2 Production Sequence

Pipe handling

When the pipe arrives at the barge it will be carried into a automatic storage rack. The pipe is going to be bevelled before its weld. This is to optimize the weld between both pipes.

Pipe lay assembly

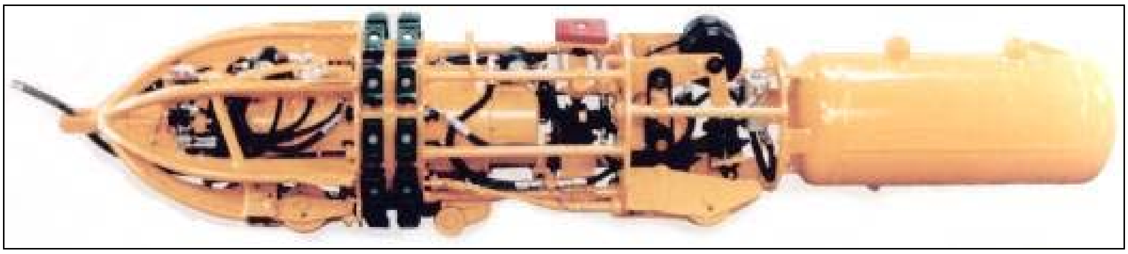


Figure 4.3.2.1 Typical Internal Line-Up Clamp

Before the pipe is pre heated, an internal Line up clamp (see figure 4.3.2.1) will expand internallyl so the pipes will align next to each other. The 36 as wel as the 48-inch pipelines, will be welded together through an automatic welding process. Welding occurs at four welding stations.

NDT Inspection

The welds in the pipeline will be inspected using an automatic ultra-sonic NDT process. Nondestructive testing is accurate, reliable, and repeatable. Testing can be performed by transmitting ultrasound or inducing eddy current into a material from one side, making it unnecessary to cut or destroy parts. Hidden internal flaws can be identified in engineering materials like metals and composites. Wall thickness of pipes, tanks, and a wide variety of manufactured parts can be measured from one side. Material, time, and labor can be saved in many applications where the internal structure is invisible and the opposite side is difficult or impossible to reach.

Coating

Upon completion of welding, the field joint will be coated externally with shrink wrapping and foam infill will be applied. Anodes are pre-installed. Cement-mortar will be plastered on the field joint of the water effluent line only.

End of the Pipe, pipeline Lay Down

Pipeline lay down is conducted as follows: The last pipe joint to be welded on the pipeline is fitted with a lay down head. For the 36″ the laydownhead will be expoxy coated and anodes attached. For the 48″ pipeline, this lay down head is flanged onto the pipeline end. This allows divers to remove the head. The 36-inch pipeline will only be flooded and tested on pressure.

The lay down head for the oil pipeline is designed to take the full pipeline test pressure. Note that the 48″ lay down head is fitted with valve and check valve. This arrangement will allow air from the pipeline to escape. However, it will prevent seawater from the outside to enter the pipeline. During lay down of the pipeline the valves are closed.

From the abandonment and recovery winch on board of the barge, a pulling cable is attached to the pipeline lay down head. The pipelay tension is transferred from the pipe tensioner to the abandonment and recovery winch. When maximum tension is applied, the pipe tensioner will dis-engage.

The barge moves forward and the pipeline end is allowed to leave the barge and stinger. The barge continues to move forward over a predetermined distance, after which the tension of the winch is gradually released. The pipeline is then allowed to be lowered onto the seabed. When the pipeline has been laid down the pulling cable will be disconnected.

For the 36-inch effluent line the diffuser openings will remain sealed during this lay down operation to avoid premature flooding of the pipeline. Note that the seals will have been opened and greased on the barge before laying, and will have a suitable padeye to ease opening by divers later in the program.

Commissioning (Pipeline Flooding, CLEANING and Gauging)

Offshore, the lay down cable is disconnected from the pipeline lay down head. A forerunner wire will remain attached to the offshore pipeline end to avoid diving operations. The lay down head is filled with a flooding pig and fitted with valve and check valve.
The gauging pig (48-inch pipeline only) will have a diameter, which is 95 percent of the nominal internal diameter of the pipeline. Filtered and inhibited water is pumped into the offshore end of the pipeline, which will drive the pigs out to the other end of the line. At the onshore end the excess air will escape from the pipeline via the check valve. A sudden pressure increase will indicate the arrival of the pigs.

Chemicals are mixed with the injected water, for the purpose of corrosion prevention, oxygen scavenging and to stop biological activity (SRB). When the water is to remain in the pipeline only for a short duration of time one may consider to use no chemicals at all. Biocides could be used only when the water is to remain in the pipeline for longer period. Note: that on the 36-inch water effluent line no chemicals will be used.

When the pig has been run through the 48-inch pipeline, the gauging pig is recovered onshore and inspected.

Shore approach Trenching works

The project requires that the pipelines are trenched from shore to KP 0.480 to a cover depth of 2 metres. Further out to KP 4.000 the top of the pipeline will be flushed with the seabed. Conventionally, the lines are pre-trenched using a cutter suction dredger. However, since the existing lines lie close together, conventional dredging would present a serious risk to these lines, as offshore class dredgers can only prepare large access channels. Trenching will be conducted using a self-contained pipeline-trenching machine. Near shore and at low tides the trench is made and backfilled with land based excavators.

The 2 MW trenching machine is a powerful self-contained jetting and dredging machine, which runs on rollers on top of pipeline. The machine fluidises the soil around and under the pipe and removes it using strong dredge pumps. From here, only a narrow trench is formed under the pipeline, with the resulting limited impact on the environment. The pipe and large buoyancy tanks support the machine. These can also be lowered by remote control to act as skids in the surf zone. The machine is bi-directional enabling it to make multiple passes between the beach and the support barge without being turned around.

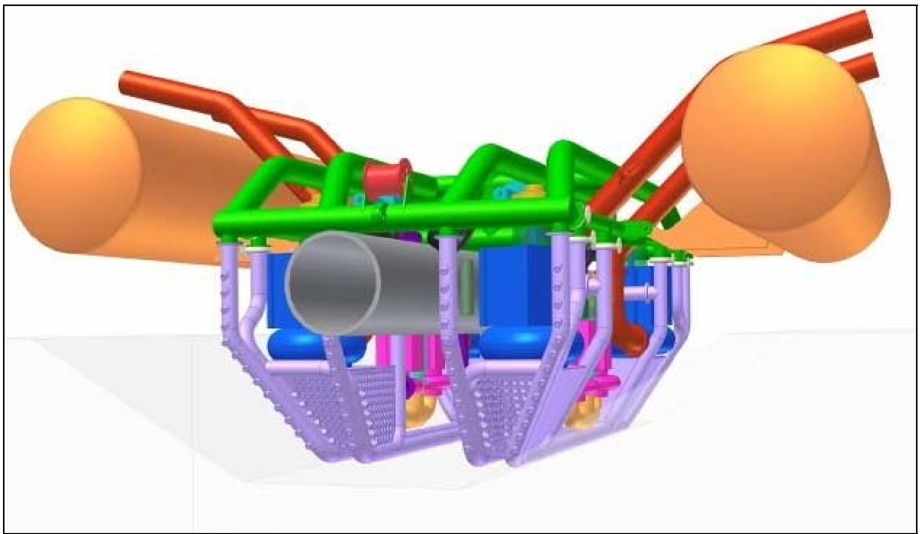


Figure 4.3.2.2 Trenching Machine

The machine travels along the pipeline on a set of instrumented rollers. Ballast/floatation tanks are fitted to the machine to ensure that the submerged weight of the unit is controlled to avoid overstressing of the pipeline.

The machine receives its electric power through an special cable wire. The unit will be towed back and forth between the beach and the work barge offshore using a winch on a barge and the return sheave on the beach. Trenching the pipeline in several passes, avoids the pipeline to become overstressed as it curves via an S-bend from the seabed into the newly made trench.

Plem and SPM Buoy

The 48" Line ends into a PLEM, which is attached to the bottom with 4 anchor piles to hold the Pipe at the same place. The Plem is connected with 2 hoses to the Plem to divert the Crude Oil. The SPM Buoy is attached to 8 anchors to prevent any movement during load or unload of crude oil.

Figure 4.3.2.3 SPM Buoy connected to Anchors and Plem

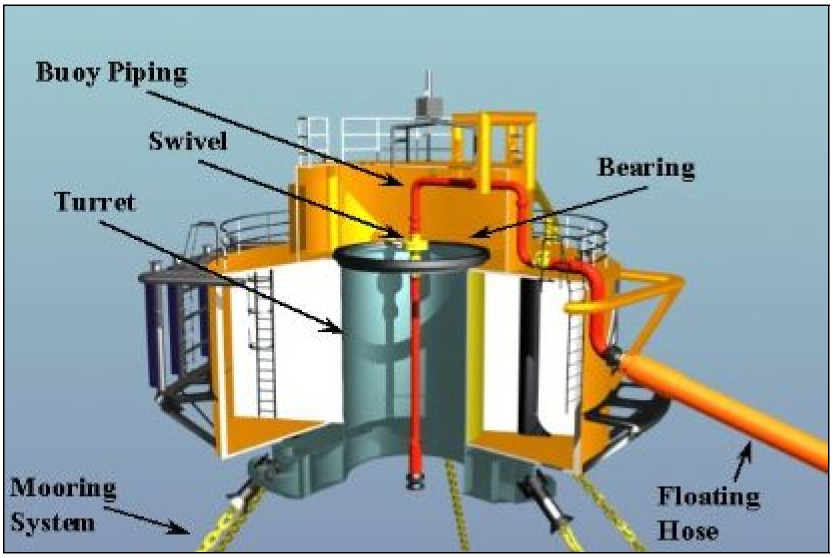


Figure 4.3.2.4 SPM buoy

Main components of a buoy mooring system are:

- Buoy Body - The buoy body serves to provide buoyancy and stability to the unit and to accommodate various components
- Mooring and Anchoring Components - An anchor arrangement connects the buoy to the seabed and a hawser arrangement connects an (off)loading tanker to the Buoy.
- Product Transfer System - A product swivel provides the interface between the geostatic and weathervaning part of the Buoy product piping.
- Auxiliary components - Boat landing, lifting and handling equipment, fendering, navigation aids and power provisions.

Pipeline End Manifold (PLEM) is a gravity structure located at the end of the 48" export pipeline, 32km from the shore (see figure 4.3.2.5).

It is designed to:

- Provide a secure connection point at the seabed for the spool piece.
- Provide a fixed termination point for the 48" export pipeline from the shore.
- Provide valving to isolate the 48" pipeline from the Flexible Hoses for maintenance, operational and safety reasons.

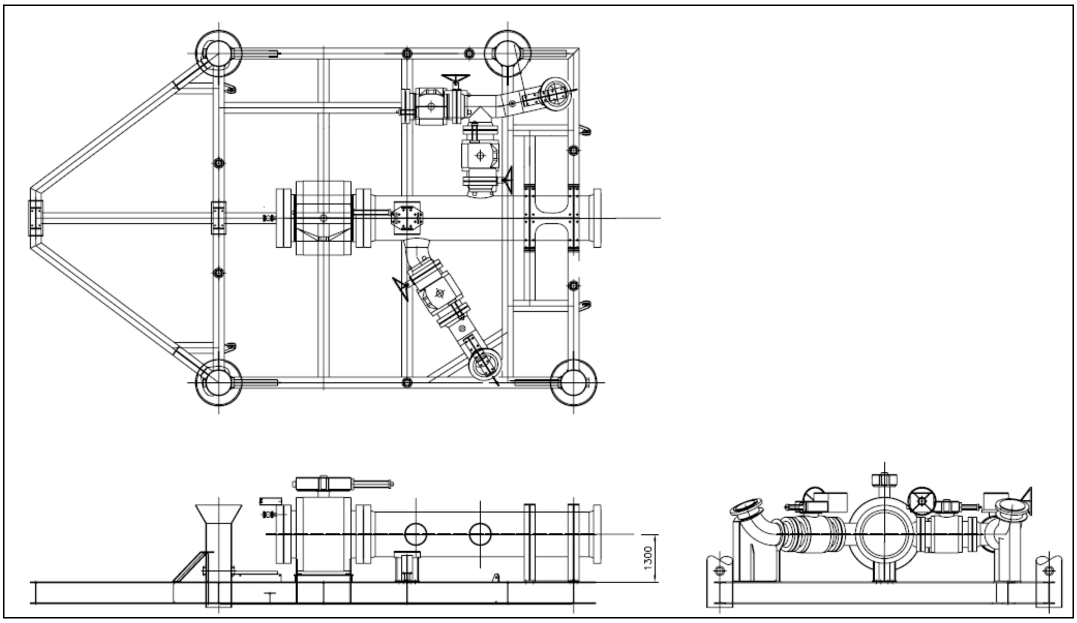


Figure 4.3.2.5 Plem Details

PLEM Tie-in and Pressure Testing

When the 48-inch pipeline has been flooded, cleaned and gauged, it will be tied in via a rigid spool to the Pipeline End Manifold.

A metrology is conducted to ascertain the dimensions of the tie-in spool. The spool is fabricated on the barge. Upon its completion it is lowered in place and connected by divers. The spool tie-in is achieved with flanged connections. For tie-in it may be required that the spool is fitted with pipe bends. Upon tie-in and after near shore trenching, the pipeline and spool are pressure tested. It may be decided to perform an initial pressure test prior to testing, but this may not be required.

The 36-inch pipeline will be pressure tested, and then 60% of the seals of the diffuser openings removed.

4.3.3 Project Boundaries

The pipe-pull to onshore is achieved by moving the Jascon 30 forward on its bow anchors. The pull wire is connected from the barge stern over the return sheave on the beach and back to the pipe pulling head, which is on the stinger. As the barge moves forward the pipe is pulled off the barge and towards the beach. As the shore pull progresses the line tension in the main pull cable will increase. Note that the two bow anchors will take the load of the shore pull.

The winches are certified to achieve a pull of 300 tonne total. *Note: that the barge will set up with its stern at KP 0.500. The mouth of the cofferdam is at KP 0.250. When the pipe head is pulled to KP 0.200 (which is well inside the cofferdam) a pipe travel of 450 m is achieved.*

The shallow water depths at the fore shore restrict anchor-handling tugs to HW operation only. Therefore smaller crafts have to be used here for the anchor operations. The vessel is the Dolphin Worker. This vessel covers 34 x 7.25 m and has a draft of 1.9 m. The vessel would be fitted with a winch and A-frame to allow it to handle buoys only.

The barge itself does not have space to accommodate enough pipes. A cargo barges will be moored along the side during the whole operation (see Figure 3.3.2.4). Till the time that the cargo barge becomes empty, there will be another cargo barge standing by to replace the empty cargo barge.

To supply the pipelay barge with enough pipes, there will be continues a cargo barge moored a long side the Jascon 30. When the cargo barge is empty it will go back to collect more pipes. Meanwhile there is already another cargo barge with pipes standing by to offload the pipes to the barge.

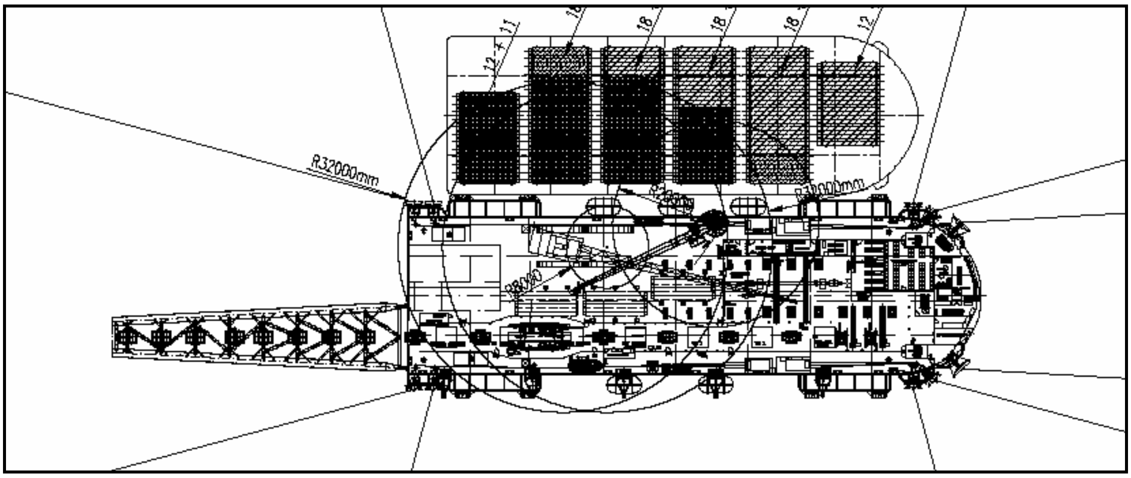


Figure 4.3.3.1 Jascon 17 moored along side of the Jascon 30

The Jascon 3 and 4 are anchor handling tugs. To run the anchors down it will need 2 tugboats. (see figure 4.3.3.2.)

Figure 4.3.3.2 Tugboat Jascon 3 and 4

Total number of vessels needed on this project according to the pipe supply planning and Pipe installation is displayed in the table below:

Pipelay Barge	1
Construction Barge	2
Anchor Handling Tugs	2
Cargo Barges	4
Cargo Barge Tug	4

Table 4.3.3.1 Overview of vessel use.

Since the barge has an off centre lay ramp on starboard side, the 48 inch line will be laid first. This avoids that the barge will lie over the first line when the second is being laid.

On board, the barge pipeline production of the 48-inch pipeline will commence and the produced pipe string pulled off the barge to shore. The pipe tensioner is engaged on the pipeline and will maintain a constant tension in the pipeline.

After securing the pipeline end, the laybarge will now continue laying the pipe by moving forward parallel to the production of the pipeline in the lay ramp of the barge. During pipe laying, a buckle detector will be inserted in the pipeline and towed along. The buckle detector will be recovered only before the pipeline end is laid down on the seabed. If it turns out that during normal pipelay operations, it becomes hard to tow the buckle detector along, it may be recovered and inspected.

5.0 SHORE APROACH

The pipe has to land approximately at the end of the Cofferdam KP 0.0 (see photo 5.1). This means that the pull, which is pulled to the shore, has to travel from the barge on to the stinger and goes into the sea and sliding ontop of the sea bottom and arrives out of the sea and stranded on the shore of Bonny Terminal. To meet the requirements of the sheave and the boundaries of the barge a pull force has to be calculated.

Pic.1. is as build location of the cofferdam. Pic.2 is the preliminary design. Pic.3 is the re-design of the cofferdam. More space between the cofferdam is added. This is to ease the working space during the pull of the pipeline and because of the configuration of the barge.

Photo 5.1 cofferdam

5.1 Pull force calculation

The classical approximation of the force of friction known as **Coulomb friction** is expressed as: $F_f = \mu N$, where μ is the coefficient of friction, N is the force normal to the contact surface, and F_f is the force exerted by friction. This force is exerted in the direction opposite the object's motion.

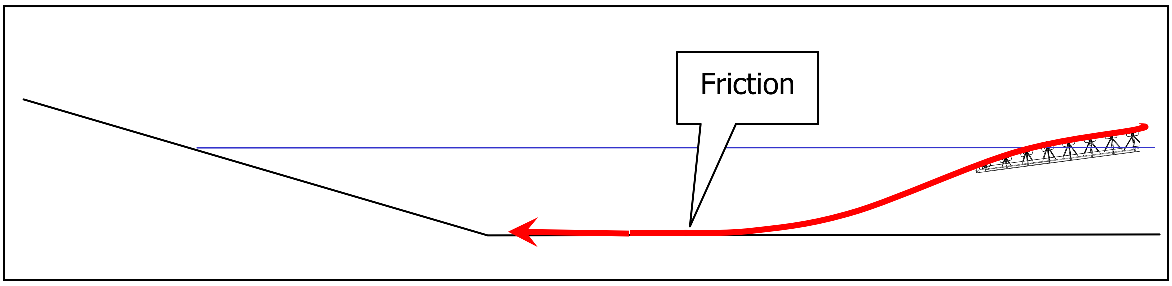


Figure 5.1.1 Friction

5.1.1 Static friction

Static friction occurs when the two objects are not moving relative to each other (like a pipe on the ground). The coefficient of static friction is typically denoted as μ_s. The initial force to get an object moving is dominated by static friction. The static friction is in most cases higher than the kinetic friction. That is why you feel a jerk when starting to move and when stopping. Rolling friction occurs when one object "rolls" on another (like a car's wheels on the ground). This is classified under static friction because the patch of the tire in contact with the ground, at any point while the tire spins, is stationary relative to the ground. The coefficient of rolling friction is typically denoted as μ_r. Limiting friction is the maximum value of static friction, or the force of friction that acts when a body is just on the verge of motion on a surface.

5.1.2 Dynamic friction

Dynamic (or kinetic) friction occurs when two objects are moving relative to each other and rub together (like a sled on the ground). The coefficient of kinetic friction is typically denoted as μ_k, and is usually less than the coefficient of static friction. From the mathematical point of view, however, the difference between static and kinematic friction is of minor importance: Let us have a coefficient of friction which depends on the displacement velocity and is such that its value at 0 (the static friction μs) is the limit of the kinetic friction μ_k for the velocity tending to zero. Then a solution of the contact problem with such Coulomb friction solves also the problem with the original μ_k and any static friction greater than that limit.

5.1.3 Calculation method

Calculation have been made according to:

$$F_p = \mu . L . W$$

Where:

F_p = Pull Force
W = Pipe Weight
L = Length of the pipe to be pulled
μ = Longitudinal friction factor

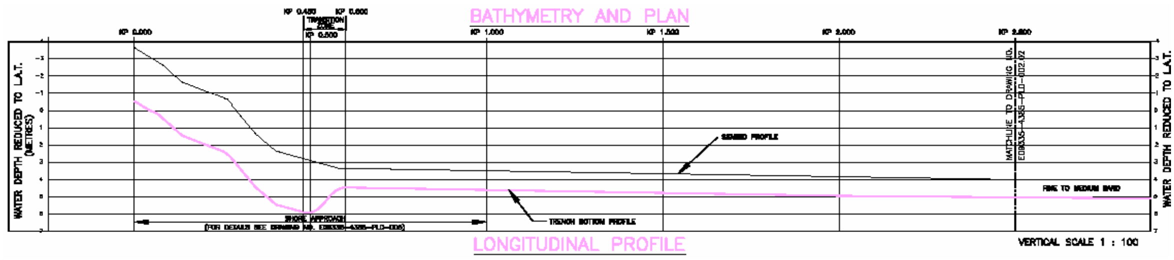
According to DNV RP E305 "simplified method" ref [9] the design of the pull force is based on a seabed friction factor of 0.7. [Typical for sandy seabed]

According to this formula, it means the more pipe you have, the larger the pull force will be. A fully pipe or half pipe in submerged condition is always lighter as dry pipe. To achieve a lighter buoy you can trench the cofferdam. The best combination to lower the pull force is a trenched cofferdam and HW.

5.2 Boundaries

5.2.1 Beach profile

The beach profile of Bonny Terminal is very shallow. The foreshore of the beach is very shallow. The seabed drops from the beach inwards the sea to 3,3m and goes to 4m till around 2.5km.



5.2.2 Water level - tide and surge information

This data are according to ref: EA Metocean Design Report

	Ref LAT (m)
HAT	1.9
MHWS	1.8
MHWN	1.5
MSL (Mean Sea level)	1.17
MLWN	0.8
MLWS	0.5
LAT	0.0
Chart Datum	+0.2

Table 5.2.2.1 Water boundaries

- According to ref: [6] "General Notes No. 2" All bathymetric soundings are reduced to CHART DATUM which is the LAT at Bonny.

In order to achieve the most reliable result the pipeline length to be pulled on shore was divided in three sections addressing a proper weight for each of them:

Zone	Description	Weight	Unit
Dry Zone	Weight of pipe in air when Empty	19952	N/m
Transition Zone	Average of Dry and Submerged Weight	11574	N/m
Pre-trenched Zone	Weight of pipe in air minus Buoyancy given by a semi-submerged pipe Height of submerged pipe @LAT 1m	7761	N/m
Submerged Zone	Pipe submerged Weight when Empty	3196	N/m

Table 5.2..2.2 Boundaries

Note;

- *Transition Zone begin where the BOP start going in the water and finish where TOP is completely in the water.*
- *Height of submerged pipe 1 meter*

TOP and BOP a represented in the Attachment C as a shaded line on top of the landfall profile. Overall O.D. of coated pipe is 1456 mm. Both cases of pre-trenched cofferdam and natural landfall profile where analysed. In order to have a complete overview of the situation the shore pull force was calculated in three different situations:

- Water level at LAT
- Water level MSL
- Water level MHWN

Each of these water levels analysed under the following hypothesis:

Case A and B is a conventional way of install the pipe. See attachment C.

CASE A - Continuous pipe laying

Pipe lay and pulling of pipe will occur at the same time, meaning that pull force will increase proportionally to the length of pipe laid till the head is at target position.

- Stinger tip is supposed to be located at the 3m-water depth contour line at LAT, which according to Ref [6] is at Kp. 0.315. To make calculation a bit more conservative stinger tip was positioned at KP 0.350;
- TDP according to pipe lay analysis is 60 m behind the stinger tip.
- Weight and dimensions of pipe line as per Attachment C

CASE B - Continuous pipe laying plus extra buoyancy

Extra buoyancy will be added on pipe in order to reduce the weight of the submerged pipeline section. The minimum buoyancy required was calculated to be 126 Kg/m.

- Stinger tip is supposed to be located at the 3m water depth contour line at LAT, which according to Ref:[6] is at Kp. 0.315. To make calculation a bit more conservative stinger tip was positioned at KP 0.350.
- TDP according to pipe lay analysis is 60 m behind the stinger tip.
- Weight and dimensions of pipe line as per Attachment C

Case C and D is a very unusual way of to install the pipe. Instead of the continues pipelay you are going to stop welding, when you welded aprox. 50 meters of pipes(4 Pipes) Than all fabrication stops. The barge is going to move forward by 25 meters. By that time the open pipe is located at the tensioner of the barge. The barge moves back till the pipe is at welding station 1 again. Fabrication starts and an another 50 meters of pipe is going to be weld. This exercise continues till the pipe is at KP 0.0 See appendix C for the yo-yo installation

CASE - C Yo-Yo pulling
The pulling exercise will occur after laying a fix length of pipe. Minimizing the pipe string length will reduce the maximum pull force required to slip the pipe head at target position.

- Stinger tip is supposed to be located at the 3m water depth contour line at LAT, which according to Ref:[6] is at Kp. 0.315. To make calculation a bit more conservative stinger tip was positioned at KP 0.350
- TDP according to pipe lay analysis is 60 m behind the stinger tip.
- Weight and dimensions of pipe line as per Attachment C
- Pipe string length is 270 meters

CASE - D Yo-Yo pulling plus extra buoyancy on Pipe.
Extra buoyancy will be added on pipe in order to reduce the weight of the submerged pipeline section. The minimum buoyancy required was calculated to be 126 Kg/m

- Stinger tip is supposed to be located at the 3m water depth contour line at LAT, which according to Ref:[6] is at Kp. 0.315. To make calculation a bit more conservative stinger tip was positioned at KP 0.350.
- TDP according to pipe lay analysis is 60 m behind the stinger tip.
- Weight and dimensions of pipe line as per Attachment C
- Pipe string length is 270 meters

Cofferdam location

The first investigation was made in order to assess where the pre-installed cofferdam was located with reference to the Alignment sheet drawing. Details can be found on Attachment C.

Drawing clearly shows that locating the cofferdam as per HHI coordinate Ref. [6] the far end of the construction is extending approximately till the 2m-water depth contour line @ LAT. The cofferdam looks like running from Kp. 0.050 to Kp. 0.250. Based on Ref. [6] attachment B represents the most suitable configuration for shore pull arrangement. According to drawing <Pipeline approach turning sheave general arrangement of anchor points>,

Then considering the cofferdam fully trenched from the mouth [Kp 0.250] to sheet pile start [Kp 0.05] a 31-meter length remains free to allow a transition slope from trench to anchoring yard Ref. [1]. That lead to the conclusion that the pipe can be pulled to Kp. 0.019 at last.

5.3 Analysis results Pull Force

Pull Force Calculation

The pulling force was calculated assuming the Pipeline head target to be at Kp. 0.05.exactly at the cofferdam sheet pile start. Calculation also shows pulling force distribution against pulling head position based on 12.2 m steps.

The first table illustrate pulling force required to slip the pipeline along the shore approach profile assuming that no pre-trench occurs inside the cofferdam. This means that position of the cofferdam mouth does not affect the calculation.

Natural land fall profile *μ = 0.7*	Pull Head Target	LAT Transition Zone start @ KP 0.176- end @ 0.269	MSL Transition Zone start @ KP 0.135- end @ 0.221	MHWN Transition Zone start @ KP 0.128- end @ 0.209
CASE A	PH at Kp.0.019	372 [Ton]	319 [Ton]	286 [Ton]
Continues	PH at Kp.0.05	311 [Ton]	259 [Ton]	225 [Ton]
CASE B	PH at Kp.0.019	346 [Ton]	290 [Ton]	262 [Ton]
Continues buoy	PH at Kp.0.05	289 [Ton]	233 [Ton]	204 [Ton]
CASE C	PH at Kp.0.019	315 [Ton]	261 [Ton]	250 [Ton]
Yo-Yo	PH at Kp.0.05	280 [Ton]	226 [Ton]	215 [Ton]
CASE D	PH at Kp.0.019	309 [Ton]	251 [Ton]	239 [Ton]
Yoyo Buoy	PH at Kp.0.05	271 [Ton]	214 [Ton]	201 [Ton]

Table 5.3.1 Results

From the table above we can state that the pulling exercise can be done at LAT only using extra floaters or by the Yo-Yo method, which should be relegated to a contingency solution as far as is possible. Anyway in the eventuality that the pipe has to be pulled till Kp. 0.019 that can only be done at MSL or MHWN remaining the pulling force below the 300 Ton.

The following table is a summary of the pulling force calculation in the hypothesis of a pre trenched cofferdam.

Given the pipeline inside the cofferdam not completely flooded, extra buoyancy (as far as concern that section) would not add any benefit to calculation.

Pre-Trenched Cofferdam	Pull Head Target	LAT Transition Zone start @ KP 0.176- end @ 0.269	
		μ = 0.7	*μ = 1.0*
CASE A	PH at Kp.0.019	204 [Ton]	291 [Ton]
	PH at Kp.0.05	175 [Ton]	251 [Ton]
CASE B	PH at Kp.0.019	181 [Ton]	258 [Ton]
	PH at Kp.0.05	155 [Ton]	222 [Ton]
CASE C	PH at Kp.0.019	146 [Ton]	208 [Ton]
	PH at Kp.0.05	138 [Ton]	196 [Ton]
CASE D	PH at Kp.0.019	142 [Ton]	203 [Ton]
	PH at Kp.0.05	131 [Ton]	188 [Ton]

Table 5.3.2 Results

Note:

Since no data are available on the pre-trenching inside the cofferdam, the following hypotheses are assumed:

1. Trench is supposed to start from KP 0.05
2. Cofferdam is supposed to be trenched at 4 meters depth below the landfall profile meaning 1 meter below LAT.
3. Transition of trench start from Kp 0.019 [BOP on ground] to Kp. 0.05 [BOP at 4 m depth underground]

6.0 MOORING

6.1 Anchor calculations

Conventional anchor deployment as well as pre-installed anchors are placed to keep the barge in position. The anchor will be dropped on the soil and will remain there (or due to the weight it will sack into the seabed). As the anchor is pulled by the winch to initiate penetration and burial, the soil in front of the anchor blades (know as flukes) becomes disturbed. Maximum penetration is reached when the front layer becomes so hard that the anchor blades cannot penetrate further and if pulling on the winch continues the anchor may continue to drag rather than penetrate (see figure 6.1.1 and 6.1.2).

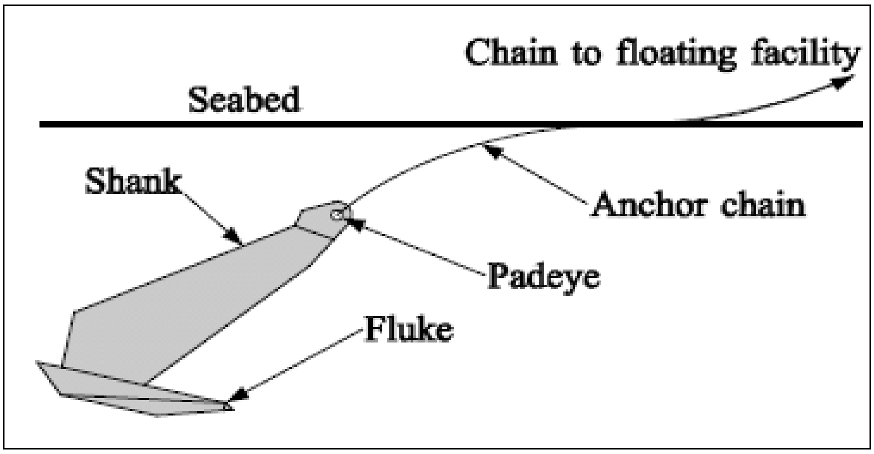


Figure 6.1.1 Anchor burried

The Jascon 30 is quipped with Delta Flippers. (See figure 5.1.1)

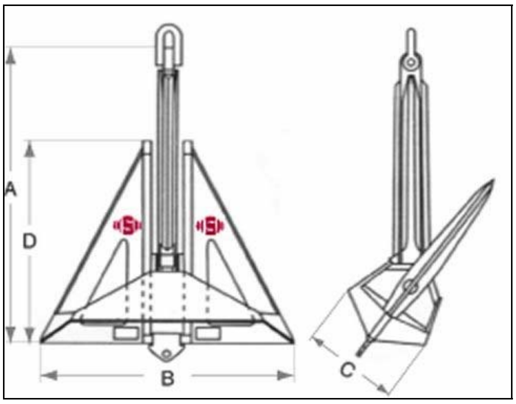


Figure 6.1.2 Typical Delta Flipper

In a mooring system, part of the mooring line will be in contact with the seabed. The ground leg portion of the mooring line contributes to the holding power of the anchor, due to the frictional resistance of the line in contact with the soil. The amount of the holding power depends upon the construction of the line, chain or wire. Its weight per unit length and the type of soil it is in contact with. Wire rope contributes little to the holding power and due to practical reasons neglected because of its smooth cross sectional area. Chain however can provide considerable extra holding power especially in dense sticky ground like clay.

The amount of holding power that the ground leg can impose is readily calculated using generalised friction factors. (See attachment F)

The table shows these factors for both starting and sliding in various ground types. Starting factors are used to compute holding power and sliding factors are used during anchor deployment when the chain is being dragged across the seabed.

The anchor-holding power is calculated with this formula Ref. [1]:

$$H_M = H_R \times \left[\frac{(W_A)^b}{9,81} \right]$$

Where:

H_M = Anchor holding capacity in tonnes
W_A = Anchor weight
b = Soil factor
H_R =Kip factor

H_M = 105 mT. This means that the anchor won't shift position, because the maximum survival pull force is 30mT.

6.2 Catenary Calculation

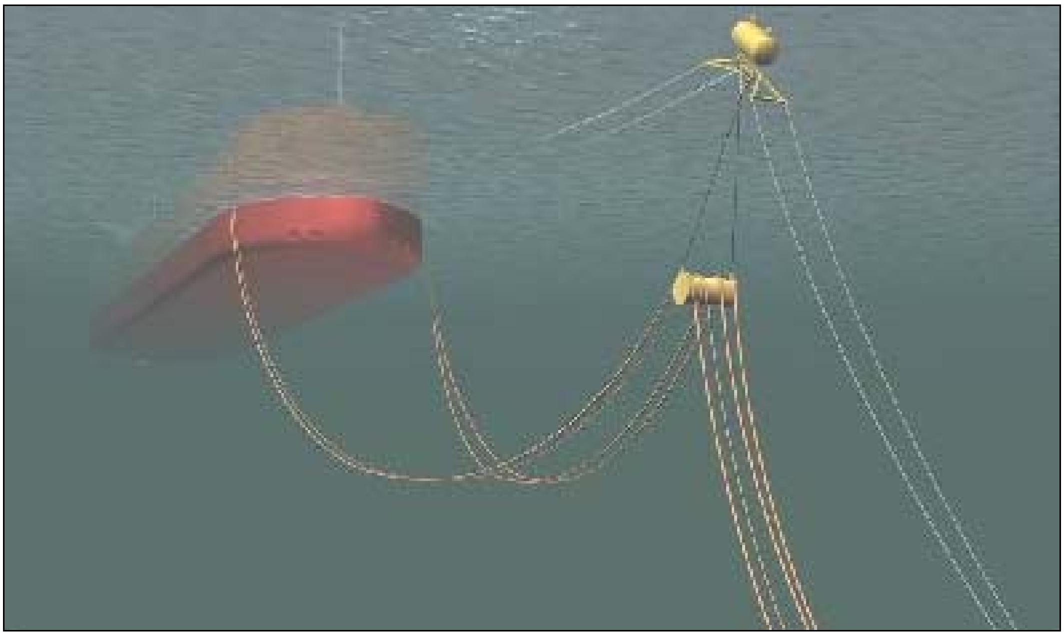
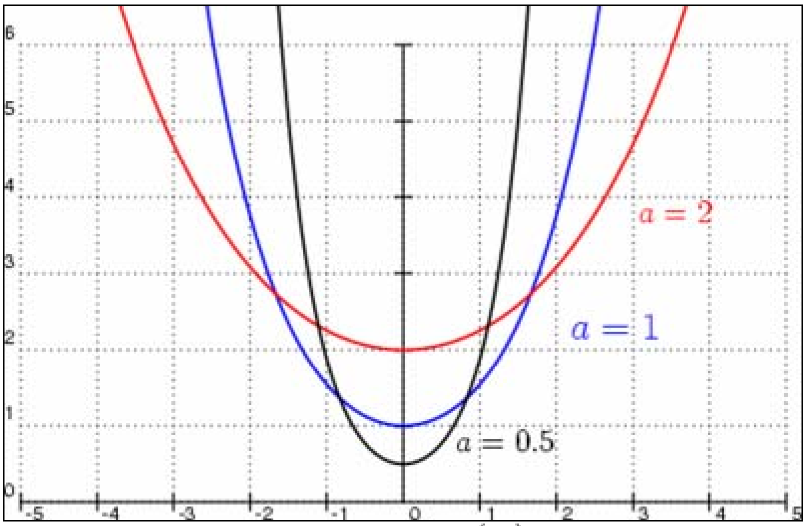


Figure 6.2.1 Catenary of an anchor line

The anchor line of the Jascon 30 has a slightly different concept as shown in figure 6.2.1. This type of anchoring is for usually used in deeper waters. When you have a water depth of from 3 till 7 meters you cannot use this type of configuration. The anchor wire will simply touching the ground and may damage existing constructions. Pendant wires will not be used until KP4.0.

The sag bend is caused by the length of the attachment points (the longer the wire, the deeper the sag bend it gets), type of wire and the tension. The criterion of the sag bend is not the most extreme condition (very bad weather condition), but the power of the AHT. The AHT can never match up with the survival configuration. The survival configuration has a smaller sag bend as the AHT.

In mathematics, the catenary is the shape of a hanging flexible chain or cable when supported at its ends and acted upon by a uniform gravitational force (its own weight). The angel of the chain is largest near the points of suspension because this part of the chain has the most weight pulling down on it. Toward the bottom, the angel of the chain decreases because the chain is supporting less weight.



$$y = a \cdot \cosh\left(\frac{x}{a}\right)$$

The word catenary is derived from the Latin word catena, which means "chain.". Square wheels can roll perfectly smoothly if the road has evenly spaced bumps in the shape of a series of inverted catenary curves. The wheels can be any regular polygon, but one must use the correct catenary, corresponding correctly to the shape and dimensions of the wheels.

The method to calculate the sag bend and the touchdown point is used by a Cosines Hyperbolic Ref [1].

$$D = \frac{T}{W} - d \times CosH^{-1}\left[\frac{\frac{T}{W}}{\frac{T}{W} - d}\right]$$

Where:

D = Horizontal distance
T = Tension
W = Weight per unit in water
d = Depth between suspension and seabed

6.3 Boundaries

Horizontal Clearance:

- The distance of anchor restrictions behind the pipe has been set on 200m, because bad weather conditions or any other factors might drag the anchor towards the direction of the barge. This is to ensure a save working distance between the barge's anchor and the existing (buried) pipelines.
- A certain distance is required in front of the pipeline, this is to avoid damage to the pipeline when a miss drop of the anchor accurse. Therefore a min distance of 100 meter is required.

Vertical clearance:

- Due to the low water operation, the vertical clearance is small. For this thesis a minimum of 1 meter is taken.

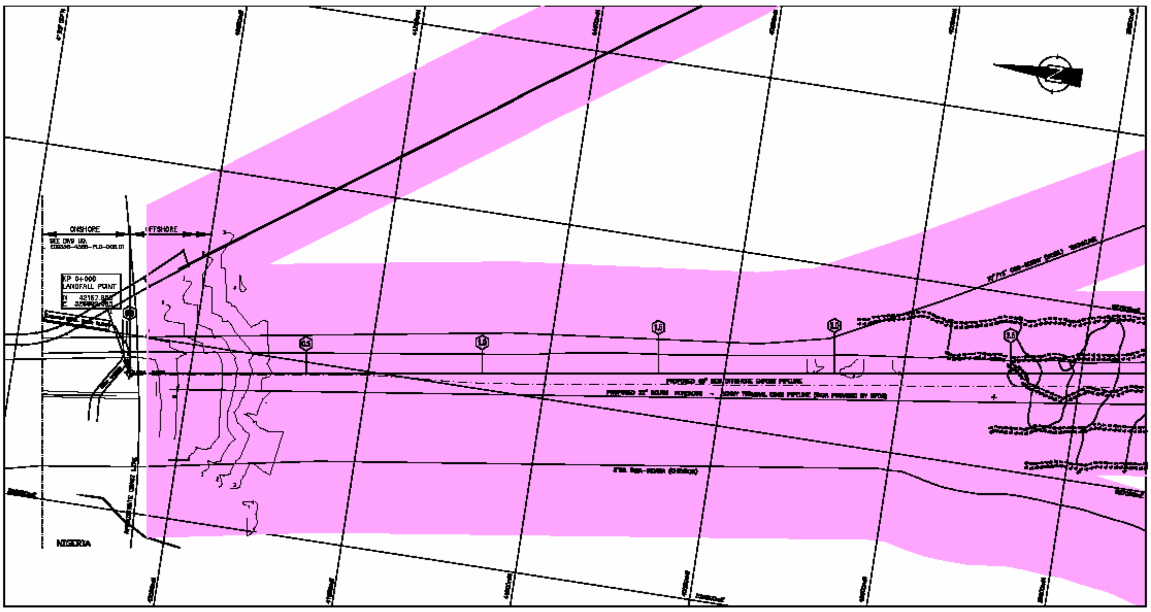


Figure 6.3.1 Beach profile. The raster is 500 x 500m

The pink section indicates no anchor deployment at all. This is to avoid damages on existing pipelines, although they are buried under the ground.

KP	Depth to L.A.T
0.5	3
2.5	4
7.5	7
32	37

Table 6.3.1 Water Depth

Anchor Patterns:

- Pipelaying barges have anchor patterns which are designed to enable the vessel to move progressively along a chosen path with the maximum pulling force working against the pipeline as its laid out.
- The pattern is set up by 30/60 degrees angels (see figure 6.3.2)

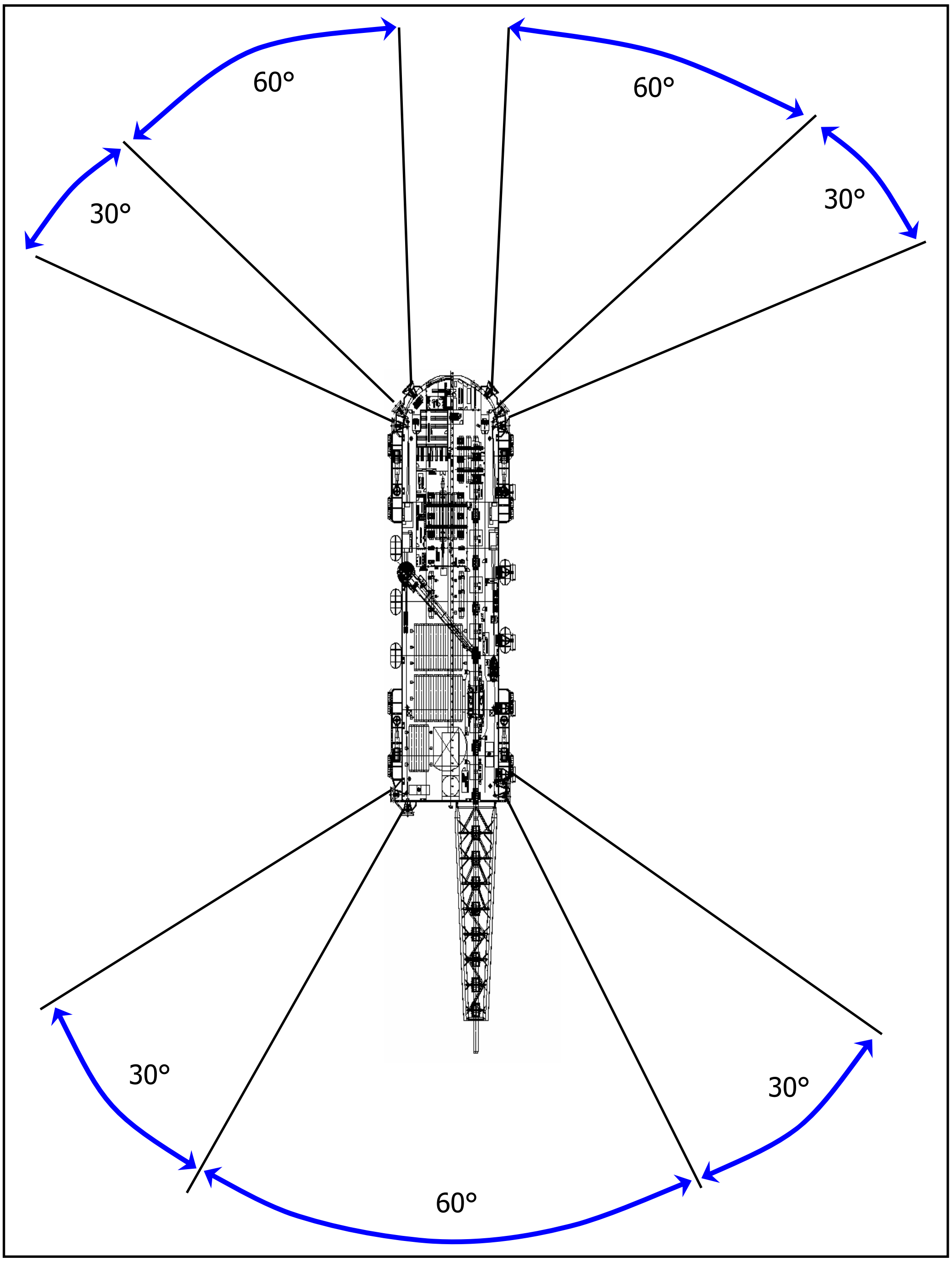


Figure 6.3.2 Typical mooring pattern

6.4 Installation Methology

The barge will deploy its stinger and set up with its stern facing the shore in a minimum water depth of 3.0-3.5 m (relative to LAT) or 4.5-5.0 m (at MSL) at KP 0.500. The anchor lines will be attached to the pre-installed anchors to position the barge (see figure 6.4.1) The two bow wires have a length of 1800 m. The anchors of the bow winches can thus be dropped in deeper water some 1500 m ahead of the Jascon 30.

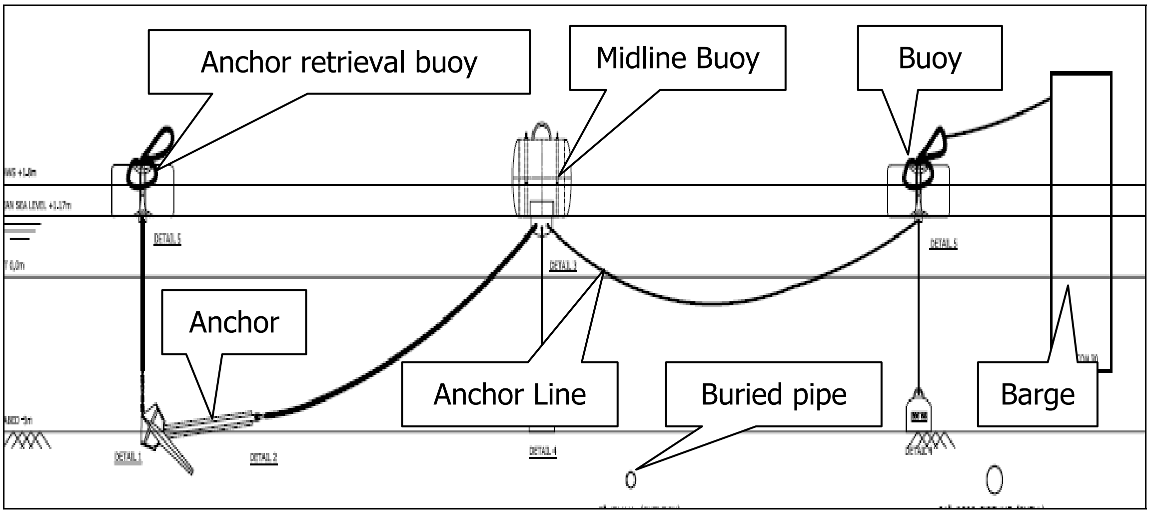


Figure 6.4.1 typical anchor setup.

The setup has six preinstalled mooring points and will be prepared and along the pipeline route at 200 m away and on both sides of the pipeline routes anchors and 150 m in front the pipelines with buoys and anchor lines will be pre-installed. These pre-installed anchors will ensure an efficient set up of the Jascon 30, because it reduces the time to set up the Lay Barge. Detailed anchor running calculations and drawings are (attachment C) to make sure that anchor wires will not rest on existing pipelines during barge movement.

The lay barge will fit in between the two existing pipelines (32 inch OGGS and 48 inch oil loading line). Because of the limited storage capacity onboard the Jascon 30, the lay barge is to be supplied continuously with pipes during pipe laying. It is therefore important that the barges supplying the Jascon 30 will have limited draft to avoid touching any of the existing (buried) lines.

The lay barge will recover both ends of the pre-installed pulling wire. One end will be attached to the barge, the other end to the first pipe in the firing line. A messenger wire from a winch on board will be connected to the shackle of the runningwire, connected to the first pipe. This to retrieve the running cable.

Slack in the pull cable is picked up by moving the Jacon 30 forwards on its anchors. Then the Jascon 30 commences the shore pull by moving forward and concurrently it will start pipe laying. When the pipelines has been pulled ashore and well into the cofferdam, the pipeline end is dogged off. The pull wire will be disconnected by barge. The pull heads will be pulled as close as possible to the return sheave at KP 0.0

When the first 2500 m of pipe has been laid, somewhat more water depth is available. Now the mooring procedures can be more conventional with the seagoing anchor handling tugboats. Also the draft of pipe supply barges is now less critical and fully laden barges can be brought to the Jascon 30.

Should the weather roughen, whilst the lay barge is still in the very shallow water area, conventional emergency procedures can still be followed: The cargo barges can always be cast off and towed to deeper water. The pipeline can be capped and abandoned temporary and the barge moved ahead on its anchors. The forward anchors, which are deployed well ahead of the lay barge, will allow that this barge can be moved well clear of the beach, from where it can even be picked up by tugboat and taken under tow.

7.0 PLEM INSTALLATION

7.1 Installation Mythodology

Before the installation of the PLEM the diver will examine the PLEM installation area and transponders (two) will be installed on the pipeline end. One will be on the pipeline end and the other at 20-metre distance along the pipeline allowing Survey to obtain a 90 degrees angel on the pipeline heading. See figure 5.2.1

Lifting slings will be pre-installed. The PLEM will be sea-fastened prior sailing to offshore installation site. Two transponders are to be used and these would be fitted on two opposite corners together with an underwater gyro.

A dead man anchor connected to the PLEM will be deployed from one of back stern anchors to prevent twist of the PLEM during deployment and manipulate the heading of the PLEM when suspended in the water.

Slings will be connected from the PLEM to the main hook and an anti-twist device (fixed-length sling) will be connected to the PLEM lifting slings (on the lift shackle). The use of the anti-twist wires is to stop rotation of the PLEM during lowering and set down and positioning of the PLEM within tolerances. During hooking of the slings cutting of sea fastening will start. When all sea fastening has been cut the crane will lift the PLEM of deck. When above the deck the level of the PLEM will be checked. When level of PLEM is out of tolerance the rigging will be adjusted.

The PLEM will be lift from a cargo barge deck, which is located at the stern of the barge and connect the fixed sling to dead man anchor. The PLEM will be lowered after all has been cleared and checked.

The PLEM will be lowered to seabed into the final position and a final survey of the orientation will take place.

Divers will be deployed and will disconnect the lift rigging and the anti-twist wires. The slings and wires and will be recovered to surface. Divers will recover the transponders on the PLEM as well the transponders on the pipeline end.

The first foundation pile will be rigged together with the follower. After piling the first pile with a hydraulic hammer to the right depth. The pile will be connected to the Plem. The same procedure for the other three piles.

Divers will perform metrology for the spool fabrication. The spool will be fabricated on deck of Jascon-30 and after completion it will be NDT inspected.

The spool will be rigged with slings and shackles and lowered by crane towards the sea bottom. Divers will be deployed and will be witnessing the lowering of the spool piece to the sea bottom.

By using air bags be filled with air on the spool piece makes the spool piece neutral buoyant. The Plem will now be install the spool piece between the pipeline and pipeline on PLEM.

The first connection will be on the PLEM. The boltholes on the side of the PLEM will be aligned and all bolts will be installed but not tightened.
The spool piece and pipe on PLEM will be shifted towards the pipeline using air bags, which will be installed on the PLEM and Pipeline end, and using cum-a-long, which will be installed on the pipeline. The boltholes will be aligned on both flanges and bolts will be installed. When correct aligned all bolts to will be hydra-tightened.

7.2 Lifting Analysis

Due to the lift offshore instead of onshore there will be extra forces on top of the object, which has to be lifted and lowered. This extra force is a result of the waves in combination with lowering the object, which generates the extra force.

The Slam forces:

By lowering an object into the water, you have to take slam forces into consideration. These extra forces will be added on top of the dynamic factor. These slam forces are horizontal members in the wave splash zone which a structure may experience. These nearly vertical forces are caused by the local water surface rising and slapping against the underside of the member as a waves passes. This force can be calculated by the Morison equation.

Offshore lifting rate.

The offshore lifting rate table included the Design Safety factor. These ratings comply with ANSI B30.5. They are applicably only when the crane is used in accordance with good operating practice. Ref [5]

Onshore into Offshore

The use of the onshore lifting rate table is more a conservative calculation.
The lift of the PLEM consist of the dry self-weight of all the components by a "Design Safety factor" SF Value and the rigging material. The design safety factor SF shall be calculated in accordance with guidelines in Ref. [1] as follow:

SF = Dynamic Amplification Factor (DAF) x Skew Load Factor x Weight Contingency Factor x Centre of Gravity (COG) Uncertainty Factor.

Where:

- Dynamic Amplification Factor = 1.10-1.40
- Skew Load Factor = 1.05
- Centre of gravity Uncertainty Factor = 1.00

$$SF = 1.10\text{-}1.40 \times 1.05 \times 1.00 = 1.155\text{-}1.470$$

Offshore rate = Onshore rate x SF

According to the ref [2] the slam forces have to be taken in consideration as an extra load. These nearly vertical forces are caused by local water surface rising and slapping against the underside of the member as a wave passes.

The rigging weight is not unspecified and there for in this calculation I assume a 7% weight on top of the PLEM for the rigging material.

Specification American Hoist

The crane boom consists out of different parts of modules. These are the available modules:

Inner and Outer	70 feet	1 piece
Centre Section	10 Feet	1 piece
Centre Section	50 feet	2 pieces

The available combinations of lengths are:

70 ft	80 ft	120 ft	130 ft	170 ft	180 ft

The Crane is supplied with an offshore and onshore lifting rate.

In order to lift the PLEM in the most efficient way, the crane is positioned towards the end of the stern. This is a consequence of the limited range of the crane boom reach. Each of the following length will be analysed under the following hypothesis:

Case A-1

- Crawler's heading is stern side.
- Boom length 120 ft.

Case A-2

- Crawler's heading is stern side.
- Boom length 130 ft.

Case A-3

- Crawler's headings stern side.
- Boom length 170 ft.

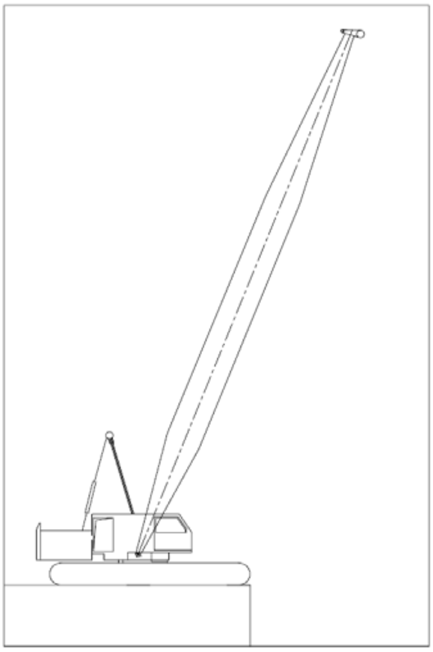


Figure 7.2.1 Case A arrangement

Case B-1

- Crawler's headings 90 deg of the stern side.
- Boom Length 70 ft.

Case B2

- Crawler's headings 90 deg of the stern side.
- Boom Length 80 ft.

Case B3

- Crawler's headings 90 deg of the stern side.
- Boom Length 120 ft.

Case B4

- Crawler's headings 90 deg of the stern side.
- Boom Length 130 ft.

Case B5

- Crawler's headings 90 deg of the stern side.
- Boom Length 170 ft.

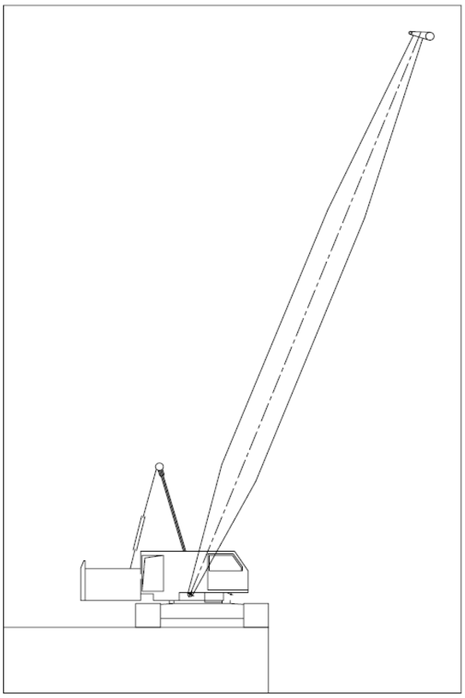


Figure 7.2.2 Case B arrangement

7.3 Analysis and Results

Case	Boom Length [Ft]	Heading	Clearance [m] Offshore Curve between object and crane.	Clearance [m] Onshore Curve between object and crane.
A-1	120	Stern	0.804	0.804
A-2	130	Stern	0.499	0.499
A-3	170	Stern	No lift	-0.11
B-1	70	Port or Star	2.79	1.87
B-2	80	Port or Star	2.63	1.72
B-3	120	Port or Star	2.02	1.87
B-4	130	Port or Star	1.78	1.41
B-5	170	Port or Star	1.12	1.11

Table 7.3.1 Analysis

The manual calculation for the SF and the simplified calculation for the offshore crane curve are almost the same output results in the most situations.
The differences between the lifting rates are to be found at the smaller length of boom and larger length of the crane boom. The smaller the crane booms the better offshore lifting rates will become. Manual calculations are preferable as the crane boom becomes longer.

8.0 SPM INSTALLATION METHODOLOGY

8.1 Mooring Anchor leg Installation (attachment A sheet 1,2,3,4)

All mooring components such as anchor piles, shackles and chain will be loaded in Onne (Nigeria) onboard a cargo vessel. The chains will be stored in a chain locker.

The barge Jascon-30 will be towed to the offshore installation site. At site the Jascon-30 will be running 8 anchors to set up for the mooring installation. The Jascon-30 will be positioned over the location of the first anchor and its position and heading will be checked.

The chain end will be retrieved from the chain locker and it is ensured that there is no twist in the chain. The anchor shackle will be installed between the enlarged link (end of chain) and anchor shackle.

The anchor pile will be lifted from deck and placed in the outrigger at the stern of the barge. A follower will be stabbed in the pile top to facilitate driving the pile below the sea bottom level. The hammer will be rigged and installed on top the pile-follower assembly. The assembly will be secured for installation. The chain will be guided through an over boarding ramp. This ramp ensures also that no twist will occur in the mooring leg.

After connection of the anchor pile to the mooring leg, the anchor pile (with follower and hammer) will be deployed in the water while paying out chain. The anchor pile will be lowered to +/- 2 m above seabed. The position of anchor pile will be checked and corrected when necessary.

After the check, the anchor pile will be lowered down onto seabed. After driving the pile to grade, the orientation and heading will be confirmed by the positioning surveyors with help from ROV. The hammer will be disconnected and recovered to deck. For this operation an hydraulic hammer will do the driving of the piles.

The Jascon-30 will move towards the buoy centre while paying out chain over the boarding ramp to avoid twist. At end of the chain, a pennant line with marker buoy will be connected. After connection this assembly will be deployed into the water.

For the remaining mooring legs all steps will be repeated.

8.2 Mooring Leg Pre-Tensioning (attachment A, sheet 5)

The mooring legs will be tensioned in four (4) pairs of two (2) mooring legs by using the Jascon-10 moored at the location of the centre of the SPM buoy.

A prefabricated pad eye / sheave assembly will be installed on center of the cargo barge tensioning winch will be properly sea-fastened to the deck of the cargo barge and the winch wire will be reeved through the pad eye / sheave assembly. The assembled configuration will have enough capacity to meet up of the project requirements.

The first mooring leg will be recovered by handing the pennant wire over to the crane of the cargo barge. The mooring leg will be connected to the pad eye at port side side shell. The Cargo barge will now be positioned above the end of the opposite mooring leg. The mooring leg will be recovered and connected to the sheave assembly on the deck of the Jascon30.

After connection of both mooring legs the tension in the sheave assembly can be increased and the slack will be taken out. By using the deck winch the tension will be increased gradually until the sheave assembly is close to the pad eye assembly. The mooring leg will be fixed and the tension for the sheave assembly will be released. Connect the sheave assembly to the next connection link and build up the tension to continue the tensioning.

The tension will be further increased until the required holding power is reached is reached. The tension will be maintained for 10 minutes. Upon acceptance, the tension in the mooring legs will be decreased gradually and disconnected from the tensioning assembly. A pennant wire and pick-up buoy will be connected and the complete arrangement will be abandoned.

The Jascon-10 will be repositioned and the above steps will be repeated for the remaining three (3) sets of mooring legs.

8.3 Buoy installation (attachment A, sheet 6)

The Jascon-30 will be positioned at the buoy location so that the SPM buoy can be moored on the Barge's lee side. The orientation of the SPM buoy will be ensured such that the numbers on the buoy body circumference below the bollards corresponds to the anchor chain layout. The buoy will be moored alongside the Jascon-30 using adequate mooring lines. A fender will be placed between the two to prevent damage to buoy and barge.

A pick-up line will be looped through the chain stopper hawse and both ends will be attached to the buoy body bollard directly above it. The anchor chain end will be retrieved on deck of the AHT via the chain pick-up arrangement and secured.

The AHT will be manoeuvred as close as possible to the SPM buoy and the top end of the anchor chain will be connected to the pick-up line protruding from the underside of the chain stopper hawser. The other end of the pick-up line will be attached to the crane block. The anchor chain tension will be transferred to the pick-up line by releasing the pennant into the water. Pull the chain through the chain stoppers. The pick-up line stays connected to the chain for re-use, but will be disconnected from the crane block. Repeat above steps for connecting the other mooring lines.

After all mooring legs are pulled through the SPM Buoy position will be checked versus base point and the number of links to be pulled or let out will be determined. Tension will be applied and the mooring legs will be fixed at their determined length.

On completion of anchor tensioning and positioning of the buoy above the PLEM, chain angle measurements will be taken. This is achieved by installing a temporary protractor as close as possible to the chain stopper in the buoy (normally installed in the next link). The other end of the protractor is hooked to a chain link further down the chain and the angle between the chain and the horizontal is measured. Each chain angle will be measured to ensure a uniform angle on all chains. A plumb line will be suspended from the centre of the underside of the buoy. A diver will check the buoy's position with respect to the target location point and ensure that the relationship with the PLEM is accurate in distance, bearing and rigid pipe alignment. The anchor chain tensions will be adjusted until the SPM buoy's position and the chain angles are within the allowable tolerance. After acceptance of the SPM buoy's position and the anchor chain departure angles, excess anchor chain lengths will be removed.

8.4 Floating and Under Buoy Hose Installation (attachment A, sheet 7 and 8)

The under buoy hose string is lowered and pulled down until the plem and hose are connected to each other. The top of the under buoy will be connected by using an airbag connected to the end. By mother nature it will raise to the bottom of the SPM and the divers will connect the hose to the PLEM.

CONCLUSION / RECOMMENDATION

General:

Working in very shallow waters, narrow corridor and the fact that a lot of buried pipes, makes this operation very specialised and delicate. Especially when there are so many stakes involved. A good preparation is already the half way of the job. If you can save a day of work, than you will save at least 80.000 dollar a day. This illustrates the amount of funding that is involved in such projects.

Timing is going be very essential during the setup and pulling the pipe to the shore. These kinds of operations are only suitable at good weather conditions. If the swell is larger than 1,5 meter, than the whole operation is not save to execute. The change of buckling the pipe is at that moment very large. The best time to install the pipeline will be in December till April, when the Sea is relatively calm.

Shore pull:

Considering the result of this first analysis at LAT there is no further investigation at different tidal condition required. LAT is considered to be the most conservative of the proposed 3.

On level 2 of this shore pull analysis a statement on the bending stress at begin of trench should be done also investigating the presence of free span.

With the above pull cable and sheave arrangement it follows that the barge has moved 450 m forward to KP 1.000. This means that a pipe string of 800 m has been laid with less than 700 m being in contact with the seabed. Assuming a friction factor of 1.0 and a submerged pipe weight of 326 kg/m for the 48-inch oil line, the pull force to overcome this friction is about 291 tonne. follows that enough pull capacity is available. Calculations see. Attachment C

The above means that the pipe can be pulled further than KP 0.200, because of the more favourable friction factor. The tide (high water) will also help to pull the pipe further into the cofferdam. Note that the onshore length cannot increase too much as during trenching the pipeline has to settle, that is the pipeline must be allowed to move axially. Because of the seabed profile, the trenching operation will cause that the pipeline end will move somewhat axially further inshore. If this axial move would not be permitted, the pipeline will not settle smoothly into its trench.

Plem Lift:

The American Hoist makes the operation of the Plem an unnecessary delicate operation. The limited radios due to the load and dynamic fac
tor, makes the free space between the Plem and Stern of the Barge very small. This operation can only done by very slow calm waters. Otherwise the Plem might be damaged with the Barge it self.

Normally distance requirement is 3 m. distance between the object and the crane. Ref. [1] In this situation we have maximum clearance of 2 meters with a boom length of 120 foot, which means:

- Very small clearance;
- Small protection fenders, due to the small clearance;
- The PLEM is located at the boarders of the cargo vessel, which means the sea fastening process and balancing the vessel is an important operation;
- All lifting operation with a boom of exceeding 130 ft Boom is not operational;
- The weather conditions have to be good. Swell larger as 1.2 meter is not operational;
- The Angel of the Slings, which the PLEM is going to be lift, exceeds the minimum required angel of 60 degrees.
- By using an extension Sling, the main block of the crane will be above the water by using the crane boom length of 120 or 130 Ft. In case using the 70 Ft or 80 Ft boom, the main block will enter the water.

Recommendations:

Option 1: Use boom length 70 Ft
Option 2: Lift the PLEM inshore
Option 3: Double crane lift
Option 4: Other crane.

APPENDIX A SPM INSTALLATION

SINGLE MOORING POINT BUOY SPECIFICATION

Water depth	36 m
CALM Buoy	Body diameter 12.0 m Including skirt: 15,3mtr Overall height 5.3 m Operational draft: 3.10 m (incl. chains & hoses connected) Weight 255 mT approx.
Anchor chains	8 No. 81.0 mm chain, each with a continuous length of approx 454 m (chain 81mm x 228m + joining shackle +chain 81mm x 207m + joining shackle + chain 95mm x 19m)
Anchor points	8 No. 48 inch anchor piles (1" WT), each with a length of 33 m. Anchor pile penetration 38 m. Weight 30 mton.
Submarine hoses	two strings of 20" hoses complete with body floats Chinese lantern configuration Length of each string is 42.8 m
Floating hoses	One string of 20" hoses with two 16" tails Overall length: 1e string 306m, 2nd string: 316m
Mooring hawser	Two floating 17" circ. Nylon hawsers, complete with end fittings. Length = 70 m.
PLEM	Dimensions: 14.7 m x 9 m Weight in air, 115 mT approx. Base plate anchoring: 2 x 24" x 32 m – 12 mton; 2 x 24" x 27 m – 10 mton
Bottom clearance	600mm

APPENDIX B AMERICAN HOIST LIFTING RATES

APPENDIX C SHORE APPROACH ANALYTICAL CALCULATION AND PIPE INSTALLATION

APPENDIX D CATENARIES CALCULATIONS AND DRAWINGS

APPENDIX E PLEM INSTALLATION DRAWINGS

APPENDIX F TABLE OF FRICTION FACTORS

Anchor Type (a)	SOFT SOILS (Soft clays and silts)		HARD SOILS (Sands and stiff clays)	
	H_R (kips)	b	H_R (kips)	b
Boss	210	0.94	270	0.94
BRUCE Cast	32	0.92	250	0.8
BRUCE Flat Fluke Twin Shank	250	0.92	*(c)*	*(c)*
BRUCE Twin Shank	189	0.92	210	0.94
Danforth	87	0.92	126	0.8
Flipper Delta	139	0.92	*(c)*	*(c)*
G.S. AC-14	87	0.92	126	0.8
Hook	189	0.92	100	0.8
LWT (Lightweight)	87	0.92	126	0.8
Moorfast	117	0.92 *(i)*	60 100 *(d)*	0.8 0.8
NAVMOOR	210	0.94	270	0.94
Offdrill II	117	0.92 *(i)*	60 100 *(d)*	0.8 0.8
STATO	210	0.94	250 *(e)* 190 *(f)*	0.94 0.94
STEVDIG	139	0.92	290	0.8
STEVFIX	189	0.92	290	0.8
STEVIN	139	0.92	165	0.8
STEVMUD	250	0.92	*(g)*	*(g)*
STEVPRIS (straight shank)	189	0.92	210	0.94
Stockless (fixed fluke)	46	0.92	70 44 *(h)*	0.8 0.8
Stockless (movable fluke)	24	0.92	70 44 *(h)*	0.8 0.8

(a) Fluke angles set for 50 deg in soft soils and according to manufacturer's specifications in hard soils, except when otherwise noted.

(b) "b" is an exponent constant.

(c) No data available.

(d) For 28-deg fluke angle.

(e) For 30-deg fluke angle.

(f) For dense sand conditions (near shore).

(g) Anchor not used in this seafloor condition.

(h) For 48-deg fluke angle.

(i) For 20-deg fluke angle (from API 2SK effective March 1, 1997).

Data from NCEL – Techdata Sheet 83-08R