PRE STUDIES OF MASTER THESIS

Design of ROV Launch and Recovery System

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Foreword

This is a pre study report for my Master Thesis project at the University of Stavanger, department of Mechanical Structural engineering and Material Technology. The project task is from Oceaneering AS.

In this pre study report of my Master Thesis I take a basic look at already existing concepts for Launch and Recovery of Remote Operated Vehicles (ROV). I will try to highlight the main design problems that might occur when designing a new and improved launching system for an offshore rig. The objective of the thesis work is to design a specific launch system that potentially can be used on the rig Deep Sea Delta (DSD). The Deep Sea Delta rig is unique and the new launch system will have to guide the ROV safely through both the lower and the upper moon pool. The system will include a Guide Structure, Hydraulic Rotary Table and a Guide Beam.

The obtained advantage of such a system will be a reduced pendulum behavior of the umbilical, and less human interference due to the Hydraulic Rotary Table and the Guiding Structure. Other benefits might be a more efficient launching and increased Operating Window (Less waiting on weather).

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1. Introduction

Oceaneering`s experience with the use of heavy weather launching systems began in the 1960's when the concept was first applied to manned diving bells. The purpose then as well as now was to increase the weather window for launching. This reduces the "Waiting On Weather" time. A great deal of knowledge was gained from these early experiences and applied to ROV operations in the early 1980's. In past years, Oceaneering would typically install approximately two cursor systems per year on drilling rigs and dive support vessels. Since that time, a number of variations and enhancements have been developed. These variations and enhancements allow Oceaneering to suit any vessel from a dive support vessel to an ultra-deepwater drill-ship or offshore rig. Twenty new-generation ROV curser systems have recently been installed on vessels worldwide. Some of these systems are installed on older vessels during refit, but the majority of these systems are installed on new ultra-deepwater drilling rigs and drill ships. These vessels are designed to work at 3000meter depth, and stay operational in rough weather. The combination of the vessel's capabilities and those of the heavy weather launch system provides the ROV entrepreneur with more operational time and less "waiting on weather".

However, some of the older offshore rigs do not have the new-generation ROV cursor system. The “old school” ROV launch system has no guiding structures. When launching, the ROV is carefully winched from the workshop, through the rig moon pool and into the sea 15-20meters beneath the moon pool. During this operation, the ROV is manually guided through the moon pool. Throughout launching, the 4ton ROV can swing and rotate freely with absolutely no guiding. The pivot point of the pendulum behavior of the umbilical is actually all the way up on the A-frame. This pendulum behavior is one of the reasons for a very complicated launching and recovery. The other reason is that the ROV is constantly rotating/spinning without any form of restriction. The ROV operator has to rely on decent weather to be able to launch or recover the ROV. These older systems cause a lot of hazards to both the ROV personnel and the ROV itself.

With the above-mentioned challenges as a basis, the objective of this master thesis is to develop a launch system that will partly guide the ROV when it is being deployed. The launch system will have to be robust, easy to install and a fairly compact solution.

In this pre study report, I will attempt to make a survey of the launch system and explain the challenges with designing such a system. The Time Schedule for execution of the project will be included as an attachment. [1, 2]

2. Heavy weather Launching Systems

In general, the main purpose of the heavy weather launch system is to stabilize and centralize the ROV and cage with a device that restricts horizontal movement and uses its weight to speed the transition time through the splash zone. The air-sea interface presents the greatest risk of damage to the ROV, cage, and potentially the vessel. Large waves and high winds can cause the ROV and cage to swing wildly, potentially hitting vessel structure. As the ROV is raised, this motion is amplified many times similar to shortening the string on a pendulum. The greatly amplified swinging can make it difficult if not impossible to recover the ROV. This might cause excessive side loading on the A-frame, which will cause it to fail. The A-frame comes in different sizes and configurations. A typical A-frame is shown on figure 1.

Figure 1. *The A-frame is shown inside the red circle*

The A-frame is a basic structure designed to bear a load in a lightweight efficient manner. Due to having only two legs, A-frames are usually set up in rows so that they can have good stability. The structure is a solid and stabile structure often used for rising or lowering heavy loads such as the ROV cage. The ROV cage is a solid pipe construction built to carry and protect the ROV and all necessary equipment. It is often referred to as the ROV-garage. The cage contains the ROV, umbilical, tooling and necessary equipment needed to carry out the operation. Extra tool basket might be added for carrying extra tooling. Less time spent in the interface in between air and water is preferable for the ROV equipment. This is because damage to the ROV and the cage is most likely to happen in the transition zone/splash zone. This is due to hesitation. "Hesitation" is the second or two that a standard system seems to float at the interface while the ROV and cage become flooded and begin to sink. [1, 2]

2.1 The Main Heavy weather Launching Systems

We have three heavy weather launch systems. The Guide Wire Cursor System, The Rail Cursor System and the Cursor Moon Pool System (Boat). They are all shown in figure 2, 3 and 4. The main objective of the launch system is to assure a safe and efficient launching of the ROV. As long as the ROV is secured in the Cursor, the Guide Wires or the Rail System will safely guide the Cursor and ROV up to the workshop or up on deck. The main objective of the Cursor is to encompass the top half of the ROV and to connect the ROV with the Guide Structure. The Cursor is connected with Guide Wires or Rail Structure.

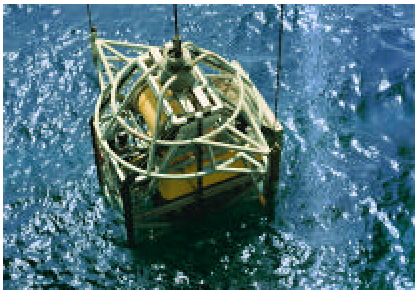


Figure 2. *Guide Wire Cursor System*

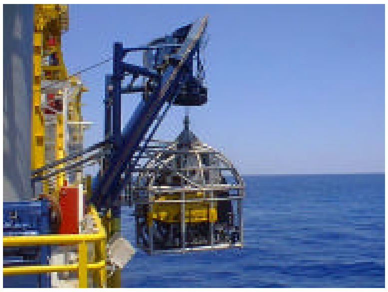


Figure 3. *Rail Cursor System*

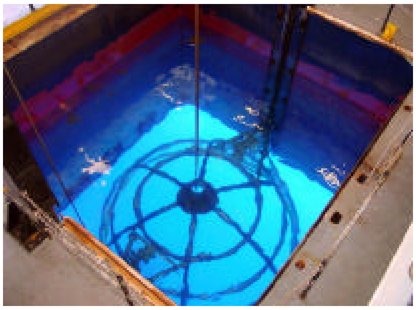


Figure 4. *Moon Pool System (boat)*

The heavy weather launching system allows the ROV to be deployed in a sea state where we have a significant wave height of 9 meters (Fig.6 page 7).

Fig.5 and Fig.6 Illustrates the allowed significant wave height when launching the ROV with or without the Cursor Guide System. When launching without the Cursor Guide System (Fig.5 page 7) the risk level of damage to the cage/ROV will be low until we reach a significant wave height of 5 meters. When launching with a Cursor Guide System, (Fig.6 page 7) the risk level will be low even at 9 meters significant wave height. The Cursor System reduces the "Waiting On Weather" time substantial and allow for a more efficient ROV operation. [1, 2, 3]

2.1.1 ROV Weather Tolerance Diagram

The ROV Tolerance Diagram illustrates allowed significant wave height when launching the ROV. The allowed significant wave height might vary depending on the launch system that is being used. The two figures underneath illustrates the difference in use of launch system. Figure 5 shows allowed significant wave height when using a launch system without Cursor Guide System. Figure 6 shows the allowed significant wave height when launching with the Cursor Guide System. The column on the right illustrates the maximum allowed heave on the cage. Since the cage is connected to the rig, the heave will be the same as the heave experienced by the offshore rig/boat. Usually the heave of an operating rig will be approximately half of the wave height. This will off course depend on the rig design and rig mode. [1, 2, 3]

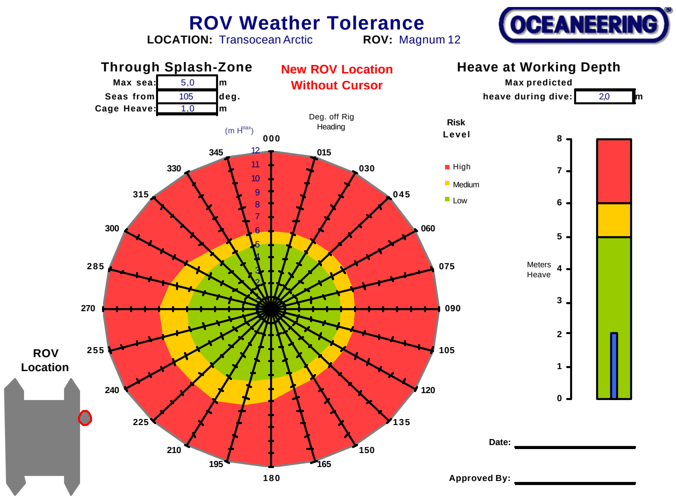


Figure 5. *ROV Weather Tolerance Diagram for ROV launching without Cursor Guide System, Transocean Arctic*

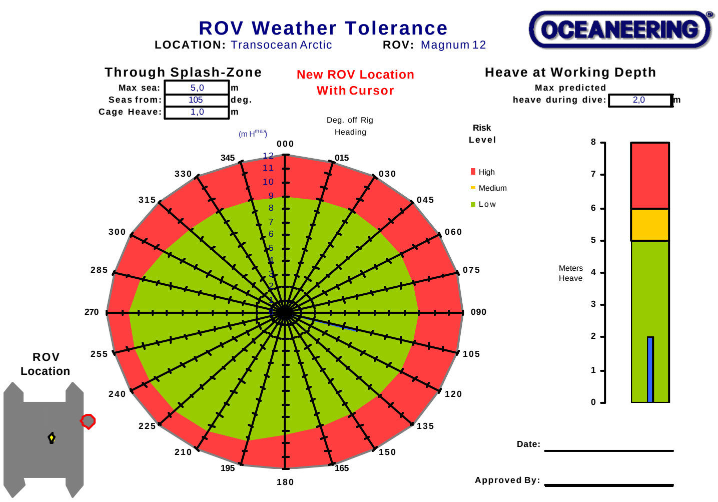


Figure 6. *ROV Weather Tolerance Diagram for ROV launching with Cursor Guide System, Transocean Arctic*

2.2 Cursor

Oceaneering has several different types of heavy weather launch systems, but they all have one piece in common. This piece is called a cursor. The cursor is the essential piece of equipment that allows the heavy weather launch system to safely deploy and recover the ROV. The cursors are fabricated from stainless steel pipe with very few moving parts and almost no maintenance. It is in the shape of an upside down bowl that encompasses the top half of the ROV and cage. The cursor travels a constrained path down the side of the vessel on guide wires or rails. The cursor travels with the ROV and cage until the cursor stops at the point where the wires or rails are terminated sub sea. The wires or rails are terminated at the deepest possible level on the vessel structure. The cursor is also perforated with 1" holes to allow it to flood as fast as the winch can lower it. This combined with the weight of the cursor helps transit the cage through the waves as quickly as possible to reduce "hesitation". [1, 2]

2.3 Guide Wire Cursor System

The most commonly used cursor system in Oceaneering's fleet uses guide wires. This method for constraining the cursor's path is well known technology. The guide wire system is typically used on drilling rigs, tension leg platforms, and other similar installations. This method is useful when some horizontal movement is acceptable and there is no structure present to attach rails too. Cursor guide wire lengths range from 45-50 meters. The guide wire system includes a pair of 2” parallel wires, strung from the fixed a-frame on deck to the lower cursor arms. The cursor arms are either bolted or welded to the pontoon. A specially designed and tested breakaway joint connects the wires to the lower cursor arms. This breakaway joint prevents damage to the a-frame, vessel, and most importantly personnel in case a wire becomes overloaded. Turnbuckles are used to tension the wires. The turnbuckles are then connected to the A-frame. The guide wire system enables Oceaneering to offer a heavy weather launch system with excellent operational characteristics for semi-submersible drilling rigs, and other similar vessels. [1, 2]

2.4 Design Considerations for a Heavy Weather Launching System

A number of factors need to be considered when selecting a configuration best suited for a specific application. Environmental conditions, vessel type, and the vessel limitations should serve as the base line for the selection. Space limitations and access to attachment points on the vessel lower hull or pontoons must be considered as well. On an offshore rig, these considerations normally result in the selection of one of the following configurations, the Guide Wire Cursor or the Rail Cursor System. [1, 2]

3. General Hazards with Launch and Recovery

Hazard that might occur on some vessels, when launching and recovery of the ROV, is the close proximity of the ROV to vessel thrusters. Many of the new deepwater vessels are dynamically positioned using thrusters rather than held in place by anchors. Due to the size and power of these thrusters, ROV systems can easily be destroyed during launching and recovery. The main task of a heavy weather launch systems is to move the pivot point of the umbilical from the a-frame to the bottom of the vessel. This minimizes the risk of the ROV and cage being pulled into a thruster or slammed into the rig structure, destroying the ROV and cage and causing major damage to the thruster and structure.

However, at some older rigs the pivot point has not been moved at all. The point is actually all the way up on the A-frame. When executing launching and recovery from these systems there will always be a risk of damaging the ROV or cage. Extensive limitations have been made. Launching systems without guide wires or a cursor system does only allow launching when we have a fairly calm sea state. Significant wave height should not exceed 5 meters (Se Fig 5 and Fig 6 page 7).

A slow speed winch might also cause a lot of launch and recovery problems. A slow launch through the sea state and a slow recovery out of the sea state is not ideal. During recovery, heavy waves might lift the ROV while it is being pulled through the surface. When the wave passes, the buoyancy disappears and the ROV might drop several meters before it again is restrained by the umbilical. This will cause extensive loads to the a-frame and umbilical, as well as an enhanced chance of damage to the ROV and cage. This behavior might also cause the ROV to swing uncontrollably and increase the chances of hitting rig pontoons and lower rig equipment. To eliminate this type of "hesitation" during launching, the ROV operator might be able to "sink" the ROV a little faster by controlling the ROV into a full throttle dive. This will help reduce the hesitation. To reduce hesitation during recovery, the ROV can be kept under water till the sea state is calm and allows for a controlled recovery of the ROV. To be able to avoid these hazards, it is at its most important that the pilots operating the ROV has experience with this kind of launching system.

The single most disruptive failure that can occur to an ROV system is the failure of the umbilical. This is due to the long period of down time to repair the failure, and the time it takes to transport and change out a new deepwater umbilical offshore. If heavy wave action or high currents should drive or push the cage onto its side, the umbilical termination on the top of the cage can be bent at a severe angle resulting in this type of failure. For this reason, another important purpose of the heavy weather launch system is to maintain the vertical orientation of the ROV cage. [1, 2, 3]

4. Background for Master Thesis

The main part of the master thesis will be to evaluate and design a smart ROV launching system that is cost efficient, easy to install, safe to operate and most of all a system that will improve the ROV Pilots work situation substantially.

When launching through a rig moon pool, a special Guide Wire System or a Rail Cursor System is usually used in combination with a Cursor. Both the Guide Wire System and the Rail Cursor System are used to lower the ROV safe into the sea. The two systems are well known and widely used all over the world (Shown on figure 2. and 3. page 6). Nevertheless both systems are complex and cannot be installed while the rig is offshore. This consents for a new system to be developed. Due to cost of "rig down time" the new launching system has to be installed offshore, while the rig is in production/drilling mode. The new system has to be a robust and simple system that is cost efficient and easy to install. Due to lack of space the system has to be compact and smart. One of the main goals will be to implement health and safety issues and improve the work condition for the ROV pilot.

The new launching system will not be a "Full Cursor System", but it will lower the pivot point of the umbilical from the A-frame to the lowest point of the moon pool. The ROV must have full guiding from the moon pool and all the way up to the A-frame. This will allow for less pendulum behavior of the ROV, as well as a guided and smart launch and recovery through moon pool. Since there will be no guiding beneath the moon pool, a special system has to be developed to be able to align the ROV before it is being pulled through the tight moon pool.

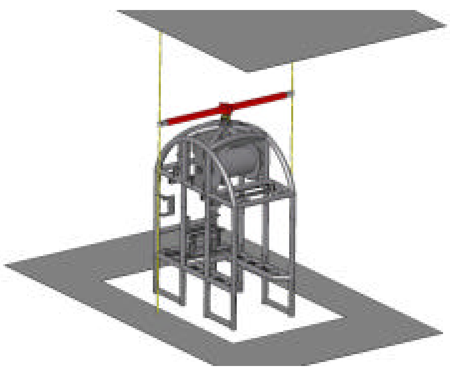
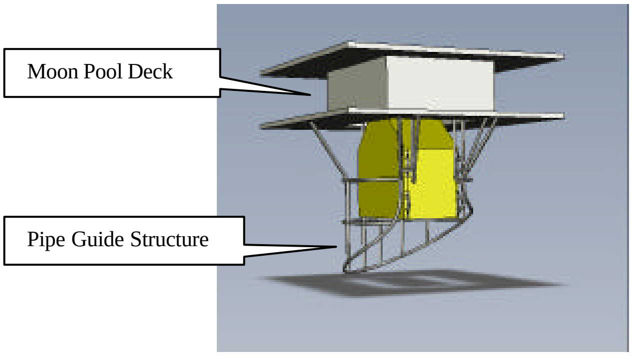


Figure 7. *ROV Launch System with Hydraulic-Rotary Table*

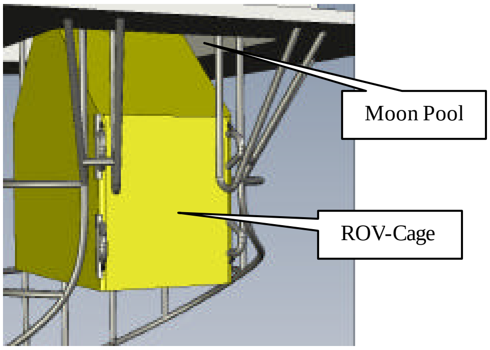
The DTS (Deep Water Technical Solutions) department at Oceaneering is currently developing a similar full mechanical system that allows for easy launch and recovery of the ROV. The system is based on a pipe guiding structure that twists and guides the ROV-cage accurately and safe through the moon pool. Due to the twisting, the ROV-cage will always be aligned and parallel to the edge of the moon pool while being recovered.

This ensures a safe and simple recovery.

There will be some friction force acting between the pipes and the ROV-cage while pulling the cage through the pipe configuration. However the friction force will be less than the force pulling the ROV through the moon pool. In case of deploying the ROV-cage, the cage will be able to deploy straight down, without twisting, and into the sea. When deploying, barley any contact will be made between the ROV-cage and the pipe guiding structure. The Pipe Guiding Structure will be installed on several oilrigs during spring 2008.



Figur 8. *Oceaneerings Pipe Guiding Structure*



Figur 9. *The ROV is twisted and aligned before it enters the Moon Pool.*

Due to concerns about, if the Pipe Guiding Structure will be efficient and tough enough to deal with the 4 ton ROV-cage, and its acting forces, Oceaneering have decided to look into developing a Hydraulic Rotary Table System that allows for a similar, but more robust deploying and retrieving of the ROV.

Developing the Hydraulic Rotary Table System will be a part of my Master Theses. The system will be without Guide Wires and without a Cursor. The ROV-cage will be pulled up from the sea and through the rig moon pool, which is located 16-20 meters above sea level.

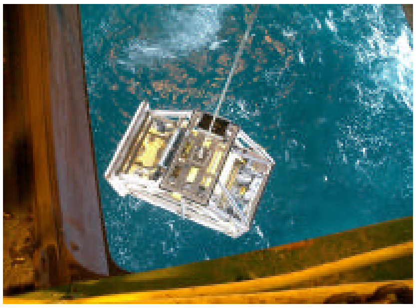


Figure 10. *Free pendulum from rig*

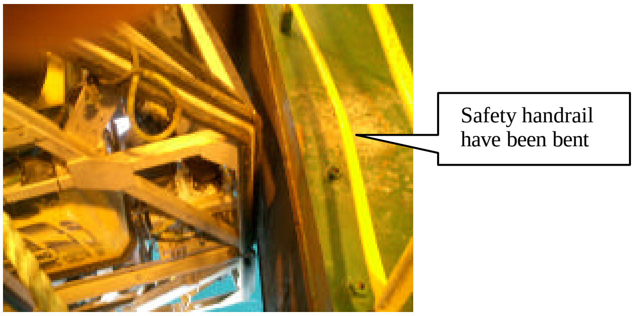


Figure 11. *ROV-Cage collides with moon pool. Safety handrail is bent from earlier impact.*

The great height from the sea level to the moon pool allows for pendulum behavior of the umbilical and the ROV-cage. Waves acting on the rig and the ROV, when it runs through the interface, and wind acting on the ROV, will all have an impact on the ROV-cage pendulum behavior. Some movement of the ROV-cage must be expected. A special hydraulic Rotary Table System will be designed for steering and correcting the ROV-cage before it enters the moon pool. To be able to rotate and correct the ROV-cage, the cage has to be connected to the rotary table. Docking the ROV-cage into the rotary table does this. The docking must happen before the ROV-cage enters the moon pool.

This will be a more intricate design structure compared to the "Pipe Guiding System". The rotary table docking system might contain hydraulic power components and maybe a special Docking and Lock in System similar to the docking system used when launching the ROV-cage through a moon-pool from a boat. This system is already known and will be partly adapted into the rig launching system.

The Hydraulic Rotary Tables main objective will be to straighten/correct the ROV-cage before it runs through the moon-pool. This will be a great improvement compared to the older system, where the ROV pilot had to adjust the ROV-cage manually by hand (stick, rope or chain), while launching or recovering the ROV through the moon pool. The new system must allow for a safer operation. Personnel should not need to be in physically contact by guiding/rotating/adjusting the ROV-cage while it runs through the moon-pool. This will improve the human environmental safety factor substantially.

5. Main objectives with Master Thesis

- Designing Hydraulic Rotary Table
- Designing Guide Beam
- Designing Guiding Structure

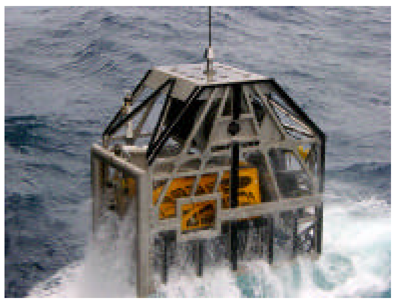
5.1 Hydraulic Rotary Table

To be able to align and pull the ROV through the moon pool of the rig, the ROV cage has to be rotated before it is winched up or down through the moon pool. The ROV Pilot crew usually does this manually, using sticks ("Båtsake") and rope. In this new system a Hydraulic Rotary Table will be designed to relieve the ROV Pilot and his crew. This will improve the Health, Safety and Environmental issues of the Pilot/Crew.

The Hydraulic Rotary Table will have to be integrated into the Guide Beam, similar to the one shown in figure 10. The Hydraulic Rotary Table will have to rotate the 4ton ROV in a maximum of 90degree angle, and in both directions, to be able to enter or exit the moon pool. If it is desirable to be able to point the ROV in one certain direction, the Rotary Table will have to be designed so that it can rotate the ROV in a maximum of 180degrees in both directions. This will assure a safe and easy entering of the moon pool.

5.1.1 Rotary Momentum of the ROV

If we estimate/chose an angular acceleration of $\alpha = 0{,}034 \,{}^{rad}/_{s^2}$, the torque ($\tau$) generated while rotating the ROV can be estimated as follows.



Figur 12. *ROV Cage: L=3m,H=3m, W=1,5m*

I = Mass Moment of Inertia

τ = Torque

α = Angular Acceleration (chosen to be $0{,}034 \,{}^{rad}/_{s^2}$)

$$I = m \cdot r^2 \qquad (1)$$

$$I = 4000\ Kg \cdot (1{,}5m)^2 = 9000\ Kgm^2$$

$$\underline{\tau = I \cdot \alpha = 9000Kgm^2 \cdot 0{,}034\ {}^{rad}/_{s^2} = 306\ Nm}$$

5.1.2 Time that elapses when rotating the ROV 180 degrees

If we assume that the maximum angular velocity is reached after 2 seconds of constant acceleration, the maximum speed of angular rotation will be:

V_{max} = Angular Acceleration· Time of Angular Acceleration (2)

$V_{max} = 0{,}034\,{}^{rad}/_{s^2} \cdot 2\text{ seconds} = 0{,}068\,{}^{rad}/_{s}$

The time that it will take to rotate the ROV 180 degrees when we have an Angular Acceleration of $0{,}034\,{}^{rad}/_{s}{}^{2}$ for 2 seconds, and after maintain a constant Angular Velocity of $0{,}068\,{}^{rad}/_{s}$.

180degrees = π rad

During the acceleration sequence, the ROV rotates a distance of:

$X = ½ \cdot a \cdot t^2$ (3)

$X = ½ \cdot 0{,}034\,{}^{rad}/_{sek}{}^{2} \cdot 2^2 = 0{,}068\text{rad}$

The angle that is left to turn: πrad –0,068rad =3,073rad

The total time that elapses when the Rotary Table is rotated from a standstill to an 180degree of revolution:

Total Rotating Time (180°) = 2 seconds of acceleration + (3,073rad)/(0,068rad/s) = 47,2 s.

Approximately 47,2 seconds will elapse when rotating the ROV 180degrees from a stand still.

However, the time it takes to rotate the ROV will not be of crucial importance. The important part of the design will be the Angular Acceleration. It is the Angular Acceleration and the Mass Moment of Inertia that creates the torque. The Moment of Inertia is non negotiable (ROV = 4ton), but we can freely chose the Angular Acceleration of the Rotary Table (see equation 1).

Another important part of the Hydraulic Rotary Table will be to connect the ROV with the rotating unit of the Rotary Table. The connection between the two units will have to be strong enough to rotate the 4ton ROV in both directions. A special coupling will have to be designed. The coupling will have to be strong enough to deal with a torque that is bigger than 306 Nm.

5.1.3 Safety Clutch

If necessary, a clutch will be designed to relieve the momentum in case of an emergency due to a collision with the moon pool structure. The clutch will be mechanical and friction controlled. If the momentum exceeds allowed torque, the clutch will free and structure/ROV will not be further damaged. The clutch will be designed similar to Oceaneering`s Mechanical Friction Torque Tool. This is a fairly easy design that consists of a certain amount of spheres on a rotating plate. The spheres are connected to a spring and sits in a half submerged hole in the rotating plate. When the torque exceeds the friction produced from the spheres to the rotating plate, the rotating plate will rotate and the torque will be zero. The size and number of spheres and the stiffness of the springs will decide the relive torque.

5.2 Guide Beam

To be able to rotate the ROV, we will need to set the Rotating Table in a ridged structure. This will allow us to transfer the torque from the Rotary Table to the ROV. The main objective of the Guide Beam will be to guide and hold the ROV Rotating Table stable so that the torque can be transferred. The Guide Beam will be guided trough moon pool and up to workshop by the guiding structure.

5.3 Guiding Structure

The ROV will need guiding through lower moon pool and all the way up through upper moon pool. I believe a pipe structure similar to the one used on Seadrills West Venture will be the template for this structure (Fig.10 and Fig.11). The structure will be ridged and fairly easy to construct/install. The pipes will guide the Guide Beam from the workshop area/A-frame and all the way down to the lower moon pool where the guiding ends. This will lower the pivot point of the umbilical pendulum behavior from the A-frame to the lower moon pool.

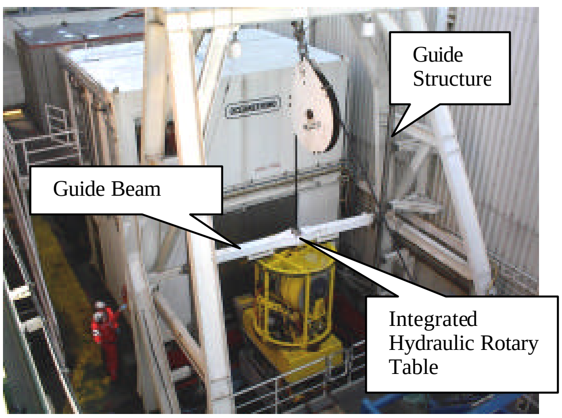


Figure 13. *Launching System Seadrills West Venture*

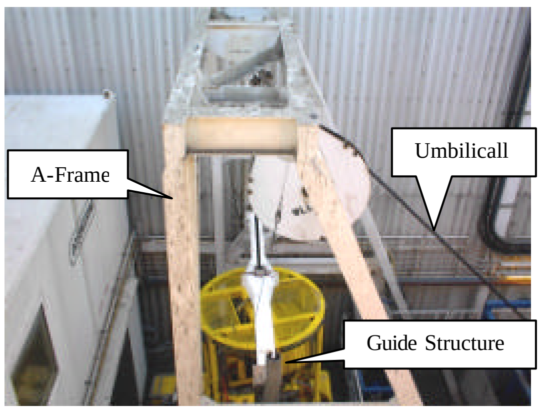


Figure 14. *Launching System Seadrills West Venture*

However the moon pool and workshop area is small and very complicated, and especially on the rig Deep Sea Delta. Due to the small space, a walkway/gangway is crossing parts of the lower moon pool. This combined with a small workshop and the necessary needs of running/launching the ROV through both lower and upper moon pool makes for a very complicated launching. A smart and compact solution must be designed.

The main challenges with the design will be to fit necessary equipment and Pipe Guiding Structure between and through upper and lower moon pool.

6. Design Problems that should be taken into consideration

- Size and weight of the guide structure will be a main problem when designing. Moon pool and ROV workshop is small on older rigs.
- The structure has to be strong and ridged, yet be able to fit inside the moon pool together with the ROV/ROV-cage.
- Older rigs do often have smaller moon pools, and in the last couple of years the ROV/ROV-cages with tools have been increasing in size (Bigger Tools/Tool Baskets).
- One of the main tasks with the design criteria will be to fit all components in their respected area. The design of a Guide Beam will be one of the main tasks.
- The Guide Beam will assure a ridged construction as well as perform as an integrated platform for the "Hydraulic Rotary Table" and all necessary hydraulic components. The Guide Beam will shorten the pendulum behavior of the ROV cage. The new pendulum will now terminate at the bottom-end of the moon pool instead of the A-frame. This shortens the pendulum with 5-8meters.
- The hydraulic components will be designed to both rotate and dock/lock the ROV-cage.
- The docking/locking system already exists on launching systems where the ROV is launched through a boat moon pool. Similar system might be used and adapted into the rotary table system.
- Other systems such as a Friction Coupling and a Torque Clutch will be considered. The Friction Coupling will consist of two "Friction Areas" facing each other, one on the ROV, and one on the Hydraulic Rotary Table. The two surfaces will engage. This will allow the momentum created by the Rotary Table to rotate the ROV into the preferred position. In the worst case the ROV has to be rotated 180° to be correctly aligned and ready for recovery through the moon pool. The Torque Clutch will act as a safety component that will allow the clutch to disconnect if the ROV rotary momentum exceeds maximum allowed Torque. This will assure improved safety for both personnel and ROV/Equipment. The clutch will be fully mechanical and a fairly easy and robust component.
- Design and structure have to be able to withstand loads from the 4ton ROV.
- Critical areas have to be determined and strength analyses and calculations have to be performed.

7. Attachments

A. Pictures (Figure 15, 16, 17 and 18)

B. Execution Plan Master Thesis

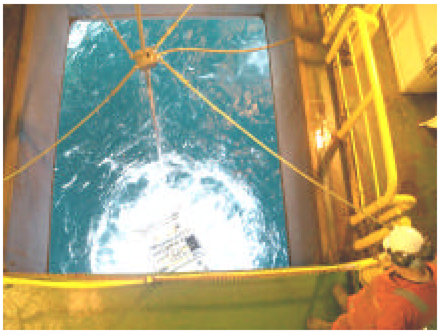


Figure 15. ROV being manually corrected with ropes during launching/recovery

Figure 16. *ROV launch/recovery with ropes and hooks through moon pool*

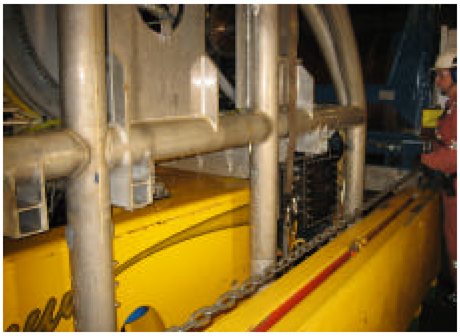


Figure 17. ROV is launching through a tight moon pool. Chains are used to guide the ROV manually through the moon pool

Figure 18. Launching ROV through moon pool on a boat

8. References

1. www.Oceaneering.no

2. ROV Handling Document, Oceaneering AS

3. Interview of ROV Personnel (24.01.2008) Oceaneering AS