Evaluation and examination of temporary second line evacuation methods of the DolWin Beta

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Foreword

This thesis was written as a part of the Bachelor of Maritime Studies programme at Høgskolen Stord/Haugesund. The theme of the thesis was suggested by personnel at Aibel AS in Haugesund.

Several persons have supported us throughout the process of writing the thesis. Without their support it would not have been possible for us to produce it.

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As well as the people who were interviewed

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Summary

This project explores different means of temporary secondary evacuation that could be used for the wind platform the DolWin Beta during the towing from Haugesund to the German Bight. The platform is extraordinarily tall, 90 meters from top to bottom, and a secondary evacuation method for the personnel on board is needed if an accident would occur.

Based on reports from earlier tow operations, design drawings, interviews and research from manufactures this report focuses three different evacuation methods were found to be most suitable for the DolWin Beta platform: an evacuation chute, rappelling and ladders. These methods are evaluated in relation to technical design, simplicity, safety, how well it could handle injured personnel and how people would react when using it.

After evaluating the different temporary second line evacuations for the DolWin Beta the authors have concluded that rappelling is the most suitable system due to its capability of handling injured personnel, the flexibility of evacuation points and that personnel responsible for the evacuation will be provided.

1 Introduction

A large wind platform called the DolWin Beta will be outfitted in Haugesund by the company Aibel AS, (www.aibel.no). It will be towed from Haugesund to the German Bight in August 2014 where it is to be lowered to the seabed. During the tow the height of the platform will be significantly higher than when standing in its final position.

It was when preparing for the tow of the DolWin Beta wind platform the problem concerning the temporary second line evacuation of the 28 people that will be present emerged. During tow from Haugesund to the German Bight, the platform will have a height (90 meters from top to bottom) and a velocity (5 knots) that will disable the evacuation methods intended for the platform while seated on the seabed.

The lack of precise rules or regulations that state how a second line evacuation is to be carried out during a tow phase of a wind platform contributes to the present challenge and finding a temporary second line evacuation for this specific tow could be a great beginning in a process of evacuation standardization for similar operations in the future.

1.1 History of Platform accidents during tow operation

The history of accidents involving rigs that have sunk strongly suggests that the weather is the greater risk factor and the weather in the North Sea is infamous for being rough. The oceanographic phenomena called “freak waves” have also been recorded in modern times. One of these hit the oil platform Draupner in 1995, (Paul H Tylor, 1995), at a time when the significant wave height was 12 meters. Suddenly a wave with a height of 25.6 meters hit the platform. Even though the platform wasn’t damaged by the way such waves carry a tremendous force and one can only imagine the impact on an unprepared vessel or structure during a tow operation.

Rigs under towing are particularly vulnerable because they are not fixed to the bottom of the ocean. Normally the rigs are floating higher then their installation height for easier movement and transportation. This changes the center of gravity and the stability of the structure and the risk of capsizing increases, (Inge Tellnes, 2008).

During a tow operation the platform is connected to the towing vessels with heavy wires mounted from the rig to the stern of the vessels. There is a risk that these wires snap leaving the platform floating uncontrollably on the sea. This was the case with Key Biscayne that sunk outside Australia in 1983, (Australian Transport Safety Bureau, 1984), after being surprised by rough weather. This accident didn't result in any loss of life but the rig was lost.

In the case of Ocean Express in 1976, (United States Coast Guard, 1978), the outcome was less fortunate. Engine failure on the towing vessel resulted in loss of control over the rig and the personnel onboard were evacuated. But the weather was rough and unfortunately 14 lives were lost when one of the lifeboats capsized during the rescue operation.

An accident with particular relevance for the present project happened to the rig West Gamma on 21 August 1990, (Kvitrud A. & Kulander Kvitrud). The rig was being towed through the same area that the DolWin Beta will negotiate when it was surprised by a gale storm with waves up to 12 meters and winds gusting at 60 knots, (www.oilrigdisasters.co.uk). The rig first lost the helicopter deck when a large wave hit and then lost the tow wire between the rig and the towing vessel. West Gamma then drifted freely towards the German coastline. After several hours of trying to regain control without succeeding the crew decided to evacuate the rig. Evacuation with helicopter was not possible due to the damage to the helicopter deck and winching up to the helicopter was not possible due to the high winds. The lifeboats could not be launched due to the heavy roll and pitch so the crew had only one option, to jump directly into the sea. They tied themselves together in groups of 5 to 6 persons and jumped of the rig. Fortunately the two standby safety boats were able to form a horseshoe formation downwind from the rig and the crew there picked up by the safety vessels man over board boats, (West Gamma, Oil Rig Disasters). This accident happened on the same time of year and in the same area as it is planned for the DolWin Beta to be towed and no one was expecting this type of weather.

2 Context for research focus

All offshore structures are designed with evacuation structures and procedures as integral parts of both the 'hardware' and operational programs. The first line of evacuation is always by helicopter but when it can't be used for any reason; there is a need for second line evacuation. The second line evacuation methods installed on the DolWin Beta are designed for when the structure enters into normal operation in its permanent position. However, when offshore structures are being moved the second line evacuation systems which are intended for the structure when it is in its permanent position may not be appropriate and a need for temporary second line evacuation systems emerge. Considering that the development of ever larger offshore structures is not likely to stagnate in the near future new challenges concerning the safety of the people onboard these structures are also likely to emerge. Troll A, a gas platform on the Troll field has a total height of 472 meters, (Teknisk Ukeblad, 1999).

2.1 Research Question

In this thesis we present an examination and an evaluation of possible temporary second line evacuation methods during the towing operation of the wind platform "DolWin Beta" from Haugesund to its destination on the German Bight. Our objective is to determine which evacuation method has the fewest obstacles and present the safest escape. In line with this objective our research question is: *Which temporary second line evacuation method would be most suitable for this specific platform during this specific voyage?*

2.2 Limitations and assumptions

In this project we restrict our attention to the temporary second line evacuations system on the DolWin Beta. Our investigation and evaluation of possible temporary second line systems for this platform rests on the following assumptions:

That weather and sea conditions will be adverse

That the platform is sinking and possibly listing

That first line evacuation by helicopter is impossible

Possible injury and/or fear reactions among crew that could make evacuation more difficult.

3 Theory

Presently there are a considerable number of theories about safety, some of which aim to explain why and how accidents occur, (e.g. Reasons 1990), others aiming to outline how to prevent accidents, (e.g. Flin et al. 2000). For the purpose of this project two theories have proved to be particularly useful. The so called “Swiss cheese model”, (Reason 1990), provides a toolbox for identifying factors and developmental paths (trajectories) which breaches safety barriers and could lead to an accident. Barriers can be categorized in many ways - one way is suggested by Hollnagel (2004). The second theory is called “Event Tree Analysis” and is used in order to get a visualisation of the temporary second line evacuation events.

3.1 The Swiss Cheese Model and barrier theory

The Swiss Cheese model is a way of seeing an organizational accident as a breach in several layers of defenses. Together creating what is called an “accident trajectory”, (Reason 1997 s. 12). A breach in only one defense will not cause an accident but when all defenses are breached it is likely that an accident soon will happen.

As shown in figure 1.1 , each defense can be seen as a slice of cheese where every hole represents a flaw in the defense.

Avoiding accidents would be easy if it was this simple, with fully understood, at all times controlled potential flaws in static barriers, or metaphorically; known holes in lined up slices of cheese. This is not the case since flaws, or holes, as well as the barriers, are constantly moving and shifting in size as opposed to being static.

The Swiss Cheese model postulates that a key factor in understanding and preventing accidents has to do with awareness about when it is likely that a defense may be breached. There are two types of failures, called *active failures* and *latent conditions*, (Reason 1997). An active failure most often lasts for a short time and has its origin in actions taken by workers and operators during the execution of an operation. A latent condition, on the other hand, often has its origin further back in time, arising from the decisions made prior to the operation taking place and possibly by other people than those involved in the operation, (e.g. the management, the board of directors). Examples of latent conditions are: poor training, bad equipment, lacking supervision, cumbersome procedures. A latent condition is often a more serious problem than an active failure in the sense that it is harder to predict its outcome, or even to know that it is present. Latent conditions may lead to failures and accidents in many separate parts of the organization thus causing the organization a lot more harm than an active failure. An active failure often stems from a latent condition, so being aware of possible latent conditions is a way of decreasing the risk of active failures.

There are two types of defenses, hard and soft, (Reason, 1997). The hard defenses are all the technical devises in a system that is used to prevent an accident; this could be alarms and equipment. The soft defenses are everything else; regulations, procedures, training and so on.

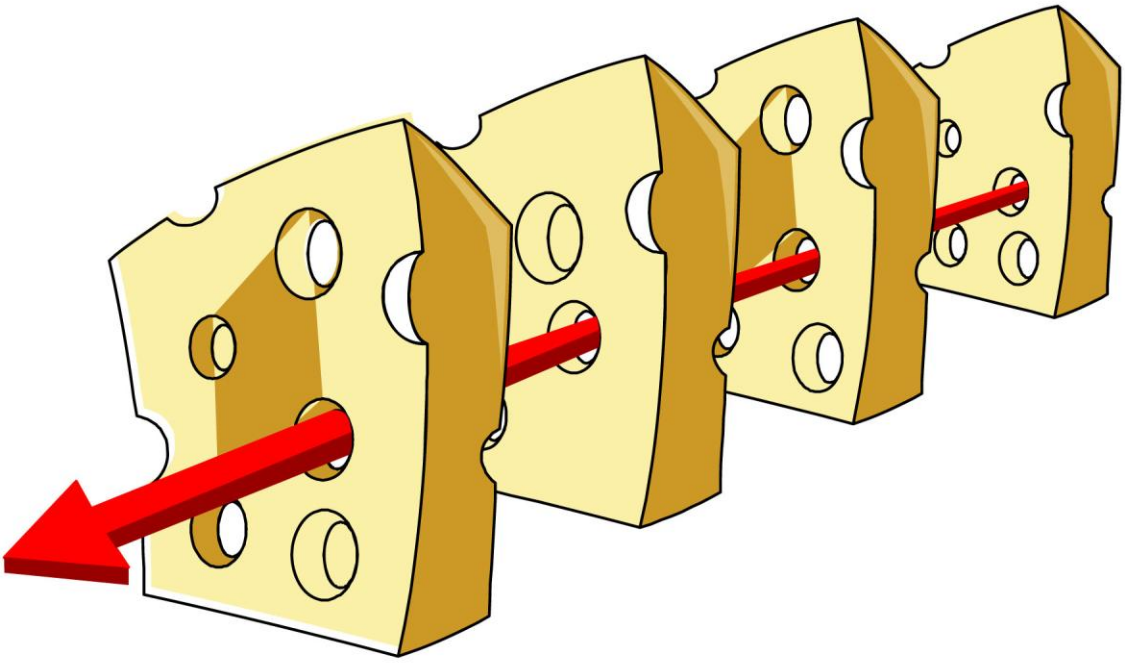
Defenses, or barriers, can be further categorized. According to Hollnagel (2004) they can be separated into the following categories:

Physical Barriers are material hindrances with the function of physically preventing an unwanted event or action to take place, (e.g. railings, walls, fences).

*Functional Barrier*s are obstructions for an event to happen or an action to be carried out. It is defenses put in place so that an action cannot be carried out unless one or more pre-conditions are met. It can be an automated system or require human involvement, (e.g. passwords, locks, airbags).

Symbolic Barriers are defenses which call for a person to voluntarily abide to carry out an action in a certain way. It requires a person to actively adjust his behavior according to the message that the barrier carries in order for it to work, (E.g. warning signs, reflective posts along a road).

Incorporeal Barriers are immaterial barriers which carry no physical function. It can be rules for actions and regulations, attitudes and safety cultures, laws and so on.



[1]

3.2 Event tree

The Event Tree (called ET in this thesis) is a tool to provide a visual display of possible outcomes in a physical system (Clemens 1990). It can be used to identify critical sequences of a system and logically shows the possible steps leading to either positive or negative outcome. It has its start at an initiating event (e.g. an evacuation), from there every event in the Event Tree represents a phase in the physical system it's easy to visualise the different possibilities in the event. It is common to add probabilities to the success or failure of each sequence, so called "failure rate data" (Sutton, 2003), which is based on the statistics for every possible outcome.

A schematic display of the events for each temporary second line evacuation method was created for this thesis. It is not strictly an "event tree" but is inspired by it and shows different possible outcomes when the temporary second line evacuation is used.

[1] Fig 1.1, Swiss Cheese Model Illustration: http://www.dfwhcfoundation.org/wp-content/uploads/2012/09/Swiss-Cheese-3.jpg

4 Method

4.1 Research design

Three methods have been used in order to gather data. When collecting data using different methods or sources concerning the same subject it is called triangulation (Guion, L, Diehl, D, McDonald, D). This enhances the validity and accuracy of the data.

Informal discussions and meetings with personnel involved with the project at Aibel AS have been held; Aibel AS is the company building the platform. A literature study was conducted were relevant data concerning the project was examined and reviewed. When a framework had been worked out semi structured interviews were conducted.

The study began with a review of the platform design and premises for the voyage in order to get an overview of the problem. Relevant documents were available from a database for the DolWin Beta platform at Aibel AS's network, these documents are considered confidential and are not available for the public. In this database there were drawings of the design and structure of the platform, HAZIDS and HAZOPS, relevant rules and regulations and the Tow manual to name some. Also the internet has been used as a source of data. The findings from this review are presented in chapter 5 and 6.

When an overall understanding of the problems regarding the research question had been established, further work focused on finding and evaluation possible evacuation methods that would have the fewest obstacles and present the safest escape. Different methods for temporary second line evacuation were examined, discussed and evaluated between the authors as well as between the authors and personnel at Aibel AS. Some were dismissed rather quickly by the authors and/or personnel at Aibel AS as technical issues would make them impossible to apply on the DolWin Beta platform.

Based on the information collected by employing the above methods interviews were carried out.

Together with a representative from Aibel AS the authors visited the chute manufacturer Viking-Life in Bergen, Norway, for further information.

Three evacuation methods (evacuation chute, rappelling and evacuation ladders) were evaluated in-depth. The data needed for this evaluation was gathered by interviewing people both in regards to technical detail and the human aspect in an evacuation using the suggested methods.

Relevant data from the interviews will be presented in the findings chapter and will be referred to as Interview1, Interview2, Interview3, Interview4 and Interview5.

Datasheets from suppliers of relevant evacuation equipment were also examined.

4.1.1 Interviews

Semi structured interviews has been a substantial part of the data collection related to this thesis. This method was used in order to obtain information from several experts in their respective field, with the added benefit of enhancing the depth and scope of the data material. Information from a user perspective as well as the experience of the suppliers could not have been obtained otherwise.

Two categories of people were interviewed. The first category consists of people directly involved in the DolWin Beta project - as an employee at the Marine Department at Aibel AS, a technical manager at Tristein AS and a business developer at AAK AS. From them we have gathered information about how the temporary second line evacuation can be carried out and possible problems that might occur with different methods of evacuation.

The second group of interviewees are not affiliated with the project but who have experience with working on platforms and/or experience with life saving and/or evacuation. They provided a "user perspective" on whether they would rely on the suggested methods for the temporary second line evacuation and problems they thought might occur.

Two interviews were conducted with personnel from the company ResQ AS in Bleivik in Rogaland who work with safety training for ship and offshore personnel. The first interview was a group interview with two employees, one of whom had 30 years of experience working on platforms and the other person had 30 years of experience as a sea navigator. Both now work as safety training instructors for offshore personnel. Because both of them have extensive experience concerning evacuation- situations and training we wanted to get their view on how well different methods of second line evacuation would work and what was needed for them to work (03.04.2013).

The second interview with “non-involved” people was with a person that was working with emergency training for offshore personnel. This interview focused primarily on questions concerning what preparations needed prior to the tow operation in regards to the temporary second line evacuation; what the subject imagined that the crew would expect and so forth (04.04.2013).

The third interview was with an employee of Tristein AS, the company that would be in charge of the tow of the platform. We wanted to know what responsibility they would have and what aid they had to offer if an evacuation had to take place. We also wanted to know what parts of the voyage they considered to be the most dangerous (04.04.2013).

The forth interview was with an employee of Aibel AS who was involved with the DolWin Beta project. The purpose of this interview was to obtain information on the possibilities and difficulties of implementing the different suggested temporary second line evacuation methods for the DolWin Beta (26.04.2013).

The fifth interview was with an employee of AAK AS who has been hired by Aibel AS to construct a temporary evacuation solution using rappelling for the DolWin Beta platform. The purpose of the interview was to gain knowledge of how this was to be done and what potential problems that could occur (29.04.2013).

4.2 Limitations

4.2.1 Literature review

The biggest problem concerning the literature review has been to evaluate the reliability of the sources. Technical datasheets from manufacturers of evacuation methods and also their internet web pages has been used in order to present and evaluate the different evacuation methods and it has not always been possible to verify certain data. An example being the time stated it would take to perform an evacuation by chute. It was not stated how this information was obtained, if the time it would take was referring to descent when the chute was already released or yet had to be, or what conditions that were present.

4.2.2 Interviews

A possible weakness in the data collection of this thesis concerning the interviews is that a lot of technical information about the platform design, the tow operation itself and also a lot of information about the rappelling evacuation method was gathered from people that were involved with the DolWin Beta project. There is a possibility that these interview subjects could have been biased and as a consequence were not fully objective as sources of information. We do not have any specific evidence to support this in our case however we assume this as a general rule. When asked about the possible problems in certain parts we got what seemed to be true and honest answers.

Another problem, concerning the other group of interview subjects who were not involved in the problem was the sample size and the lack of own experience with a crisis situation on a platform. The purpose of these interviews was to get a subjective view of what evacuation method that would be most suitable. It is possible that there could have been limitations to these subjects knowledge concerning any one method. This means that had the sample size been bigger, it is possible that the other views than those presented in this thesis would have been expressed. The reason for not conducting more interviews was limitations in time as well as the unavailability of suitable subjects to interview.

5 Findings

5.1 Conditions, platform design, POB

The findings from the various methods used will be presented thematically rather than for each method used.

5.2 Platform design

The DolWin Beta is a submersible floating platform that will be towed to its intended position where it will be lowered to the bottom (DolWin 2 – Hazid report) (TRI-AIB-HZD-22-2010-12-01).

The platform has a height of 90 meters, a length of 100 meters and a width of 75 meters (Tow Manual). The DolWin Beta has three decks at different heights; the weather deck is at the top, the intermediate deck is the middle and the main deck is the lowest. A helipad located on the weather deck and on the main deck there is a free fall life boat as well as a davit to lower a mob boat (006026-AI-N-XD-0002-01_04). Helicopter and the two types of lifeboats make up the permanent first and second line evacuation methods when the platform is in its final position and is resting on the seafloor (interview4).

The muster station for the DolWin Beta when positioned on the sea bed will be on main deck. That is where the crew would gather if an evacuation were to happen. According to Aibel AS data (evacuation routes version 2) the travel time for the crew to the muster station is 8 minutes 33 seconds during the day and 8 minutes 44 seconds at night.

When towed the DolWin Beta will have a draft of 7.8 m in normal weather, this is called “pontoon draft”. If pontoon draft is not acceptable due to bad weather it is possible to increase the draft to 15m. This mode is called “survival draft” (Evacuation_Tow_to_field_1_2). At pontoon draft the distance from weather deck to the sea level is 62 meters and from main deck to the sea level the distance is 42 meters (DolWin 2 – Hazid report). Consequently the distance in survival draft is 69 meters from weather deck to the sea level and 49 meters from main deck to the sea level.

The platform is to be considered “dead” during the tow operation, which means that no system onboard containing hydrocarbons (e.g. generators) will be active. Therefore there is little risk of explosion or fire (interview4).

5.3 The Tow

The tow is planned to start in August 2014 from the docks at Aibel AS, Haugesund to DolWins location in the German North Sea (The German Bight). The tow is planned to take 75.5 hours at a speed of 5.5 knots with 28 personnel onboard (POB) (TRI-AIB-TMA-22-2010-12-01_Towing Manual, Rev.01). Four of these will be employees of the company AAK AS. They have been hired by Aibel AS to develop and be in charge of the temporary second line evacuation method of the DolWin Beta. They are planning to use rappelling as the temporary second line evacuation method. To use this as the temporary second line evacuation method for the DolWin Beta was decided during the time this thesis was still being written and prior to the conclusion was presented. Although the decision was taken the authors continued to look into different possibilities for a temporary second line of evacuation as it could have importance to future projects.

Aibel AS has hired Tristein AS to carry out the tow and be responsible for the platform and the safety during the operations. Tristein AS was founded in 2007 and according to their website they "deliver high standard performance at all levels, based on our vast knowledge and experience installing offshore wind turbines and floating production units, complex and heavy lifting, marine management and rig-moves, as well as vessel/rig surveys and quality surveillance" (www.tristein.no). Tristein AS will supply two vessels for the tow and will make sure that the vessels are fully certified in accordance with rules, regulations and owner requirements.

The tow will be divided in three different parts, the inshore tow, the offshore tow and the installation phase. The inshore tow phase is from the docks in Haugesund to the pilot disembarkation point. During this phase two additional tugs will be provided by Aibel AS to help with maneuverability and control. This will take about 13 hours. The offshore tow phase is approximately 344 nautical miles and will take 62.5 hours. It will take the DolWin Beta from the pilot disembarkation point directly to the installation site. During this phase the DolWin Beta will be vulnerable to the weather and other vessels in the area. The DolWin beta will cross the large shipping route of Skagen the Norwegian trench with depths to 700 meters. Upon arrival at the DolWin Beta location the tow will rendezvous with 2 installation tugs that will help with the positioning of the platform while it is lowered to the sea floor.

Tristein AS has appointed a Tow Master for the operation. One of his responsibilities is to maintain safety during the whole operation after the DolWin Beta has been handed over at Aibel AS:s quay.

The Marine operation department at Aibel AS has chosen the departure date on the basis of the stable weather that August usually brings. A meteorological service will be used to provide meteorological data continuously during the tow. If this data shows that the weather exceeds the weather limits the Tow Master will steer the platform to shelter.

"The weather criteria for the installation operations are governed by referenced DNV rules and Offshore Standards, Ref./2/ to Ref./6/" according to the Tow Manual.

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5.4 Rules and regulations

In this chapter the existing rules and regulations concerning the evacuation of a platform such as the DolWin Beta will be presented. The following are directly quoted from the documents specified in the headlines.

IMO MSC/Circ.884 GUIDELINES FOR SAFE OCEAN TOWING

Chapter 13, Towed Object.
"13.15 Boarding facilities should be rigged on each side of the towed object."(s. 9)

Chapter 13, Towed Object.
"13.17 Life-saving appliances in the form of lifejackets and life buoys shall be provided whenever personnel are likely to be on board the towed object even if only for short periods. When personnel are expected to remain on board for longer periods of time, liferafts should also be provided. If the freeboard is more than 4.5 m, liferaft davits should be provided, unless rendered impractical due to the design or conditions of the towed object." (s. 9)

Offshore Substations for Wind Farms (DNV OS-J201)

G. Evacuation.

G 100 General

"101 Arrangements shall be made, to the extent necessary, for provisions on the offshore substation or with suitable persons beyond that will ensure, so far as is reasonably practicable, the safe evacuation of all persons. Persons shall be taken to a place of safety or to a location from which they can be recovered and taken to such a place." (s. 57)

"102 Means of evacuation offer protection from the hazard and have their own motive power to enable persons to move quickly away from the installation. Such means may include:

- davit launched or free fall lifeboat
- rescue or transfer vessel (possibly used with winch and crane transfer)
- helicopter" (s.57)

“103 Arrangements shall be made to ensure, so far as is reasonable practicable, the safe escape of all persons from the offshore substation in case evacuation arrangements fail. This may involve entering the sea.” (s.57)

“104 Several locations on the installation should enable persons to escape to the sea. Means of escape which assist with descent to sea, such as davit launched or throw-over life rafts, lifebuoys, chute systems, cargo nets or ladders shall be provided.” (s.57)

“105 All offshore substations shall have at least one launchable life raft which can take the maximum number of persons on the installation. In addition, the following applies:

- **unmanned installation**: When the offshore substation is manned, an emergency response and rescue vessel (ERRV) shall be in the vicinity of the installation. The ERRV shall be equipped with fast rescue craft.
- **manned installation**: At least one launchable lifeboat with the capacity of maximum manning shall be available. Should manning ever exceed the boat’s capacity, additional provisions shall be made.” (s.57)

H. Rescue and Recovery

H 100 General

“101 Arrangements shall be made to enable persons who have to evacuate an installation to be recovered or rescued to a place of safety. Such arrangements are:

— facilities and services external to the installation, such as vessels, public sector and commercially provided search and rescue facilities
— facilities on the installation such as installation based fast rescue or man-overboard craft.” (s.57)

“102 Arrangements shall be made to rescue persons from the sea or near the installation. Incidents to be considered shall include a person falling overboard or a helicopter ditching on landing or take-off.” (s.57)

“103 Arrangements for recovery and rescue should take into account:

— the numbers of persons who may need to be rescued or recovered
— the capacity, remoteness and response times of the rescue and recovery services
— potential limitations on availability, daytime, weather conditions and sea states
— the need to cover all stages of the operation
— the nature of work activities being carried out (e.g. over side/under deck work would require a dedicated rescue craft).” (s.57)

“104 Arrangements shall be regarded as being effective if they secure a good prospect of persons being recovered, rescued and taken to a place of safety, onshore or offshore, where medical treatment and other facilities for care are available.” (s.57)

5.5 Non-suitable evacuation methods

Several methods of possible temporary second line evacuation were indentified by interviewees, and the authors. A number of these methods are not suitable for the DolWin Beta but are still presented here in order to demonstrate the variety of possibilities that needed to be examined.

5.5.1 Davit launch able life rafts

A common method of evacuating offshore structures is by life-raft or boat while still on the vessel and then to lower the raft down to sea level by a davit. In this way the people onboard don’t have to enter the sea before getting to safety in a life-raft or boat and you can get a controlled evacuation.

This method was soon dismissed because the wire was to short and the manufacturer suggested that a longer wire would make the life raft very vulnerable when being lowered from the main deck where the davits are placed. The distance which it would have to be lowered is more than 40 meter which could give it a large pendulum motion due to the wind as there is little sheltering in the platform design. This could render the evacuation uncontrolled and in worst case fatal. Installing a longer wire would also require a new certification for the davit.

5.5.2 Slide

The slide system is built up on the same way as you can se on all commercial airplanes today. A slide is released from the vessel down to the sea where a life raft is inflated. All people onboard the vessel can slide directly down to the life raft. This method is quick and easy, but there is no product on the market which can be launched from the heights needed for the DolWin Beta platform (Viking-Life Evacuation Slide, Product Guide).

5.5.3 Freefall lifeboat

A freefall lifeboat is installed on the DolWin Beta which is intended as a second line evacuation when the platform has been lowered on the installation site. Having this as the second line evacuation during the tow would not be recommended for several reasons. The freefall lifeboat installed on the DolWin Beta is certified for a 34 meter drop, when being towed it will have an altitude that exceeds that.

Another reason is that there is only one freefall lifeboat installed, on one side of the platform; if the platform would start to tilt to any one side that is not the one where the lifeboat is placed, it might not be possible to launch it. The problem could be solved by installing one freefall lifeboat on each side of the platform. This would however require extensive reconstruction of the platform and would only serve the transit state as having more than one freefall lifeboat would be redundant when the platform is standing in its final position on the sea bed. When the platform is in its final position there is little or no risk of it getting list or lean and therefore little or no risk that the one free fall lifeboat installed would ever fail to launch.

5.5.4 Chute and rappelling from boat landing platform

Both chute and rappelling from main deck are methods that will be discussed more in depth later. Initially we thought that these methods could be used and executed from the boat landing platform, which only has a height of approximately 20 meters above sea level at pontoon draft. Evacuation from the boat landing platform was discarded for the following reasons: It would take longer time for the people on board to muster at the boat landing platform as one has to climb a ladder down to it from main deck, and if someone would be injured it could prove to be very difficult for that person to climb down the ladder to the boat landing platform. Also, in the event of an emergency it could prove difficult to organize an evacuation on the boat landing platform because it is not very big (interview4).

In short, the boat landing platform is less suitable to use for these two evacuation methods, regardless of the lesser height, than the main platform is.

5.6 Chute, rappelling and ladder

In this chapter evacuation methods that have been found to be the most suitable will be discussed. How they work and what challenges there is in using them will be presented. A fault tree analysis diagram is presented beneath the text for each evacuation method.

5.6.1 Why these methods?

Having an evacuation chute (www.viking-life.com) as the temporary second line evacuation method was one of the first methods considered. It is a system that "everybody" knows of and it is a basic element in safety training for offshore personnel (Interview1).

Using rappelling as a temporary second line evacuation method was considered as it had been used as an evacuation method during the tow of the Troll A platform (Aibel AS, verbatim).

Both rappelling and the chute were chosen based on the fact that main deck is so high above the surface of the sea.

Installing ladders down to sea level was discussed by personnel at Aibel AS (interview4) but dismissed (interview4). The evacuation method was once again suggested and discussed in interview1 and therefore it was decided that the method would be examined closer.

5.6.2 Evacuation method #1: Evacuation chute

The evacuation chute is a method by which the personnel onboard the platform descends through a cylindrical tube to reach a boarding platform at sea level where life rafts are fastened. The chute is located inside a shielding structure on a suitable location on deck and it is lowered by a winch. It is gravity based meaning one only has to release a break for it to be lowered. Once the chute reaches the sea level a boarding platform is inflated. Life rafts are connected to the boarding platform. Inside the "tube" there are slides running at an opposing angle in a zig zag pattern so a person descending it does so in a controlled manner (Viking-Life product guide, Chute).

5.6.3 Review of the Chute

The release mechanism of this construction is simple and there is very little chance of it failing (Viking-Life product guide). Though releasing the chute is simple, it might not successfully land in the water if the platform is subjected to list or lean and if it lands in the water it could still become non-functioning if the platforms list or lean is increased later on (interview1). The platform needs to be standing more or less still for a chute to work since velocity of the platform will make the chute drag in the water (Interview1).

When the chute has reached the sea level two persons will descend the chute in order to inflate and prepare the life rafts connected to the platform at the lower end of the chute. If these two persons successfully manages to descend the chute and reach the platform at sea level it is unlikely that they would fail to inflate the life rafts, given they are familiar with how it is done (Verbatim, Viking-Life personnel). There are 4 life rafts connected to the platform which means there is redundancy if one of the life rafts were to malfunction. It is however unlikely that any one of them would (Verbatim, Viking-Life personnel). The next step is for the rest of the crew to descend the chute. If no one is injured and everyone performs the descent as intended the chute has the capacity to get 140 persons down in 10 minutes according to a producer of life saving equipment (Viking-Life product guide). Interviews estimated the time for an evacuation using a chute, from that the alarm is raised to when all persons has made the descent to be approximately 25-30 minutes (Interview1).

It is unlikely that someone gets stuck in the chute, but if it would happen, people above him can climb past him the on the outside and re-enter under him, as the chute has openings in every cell (Interview1).

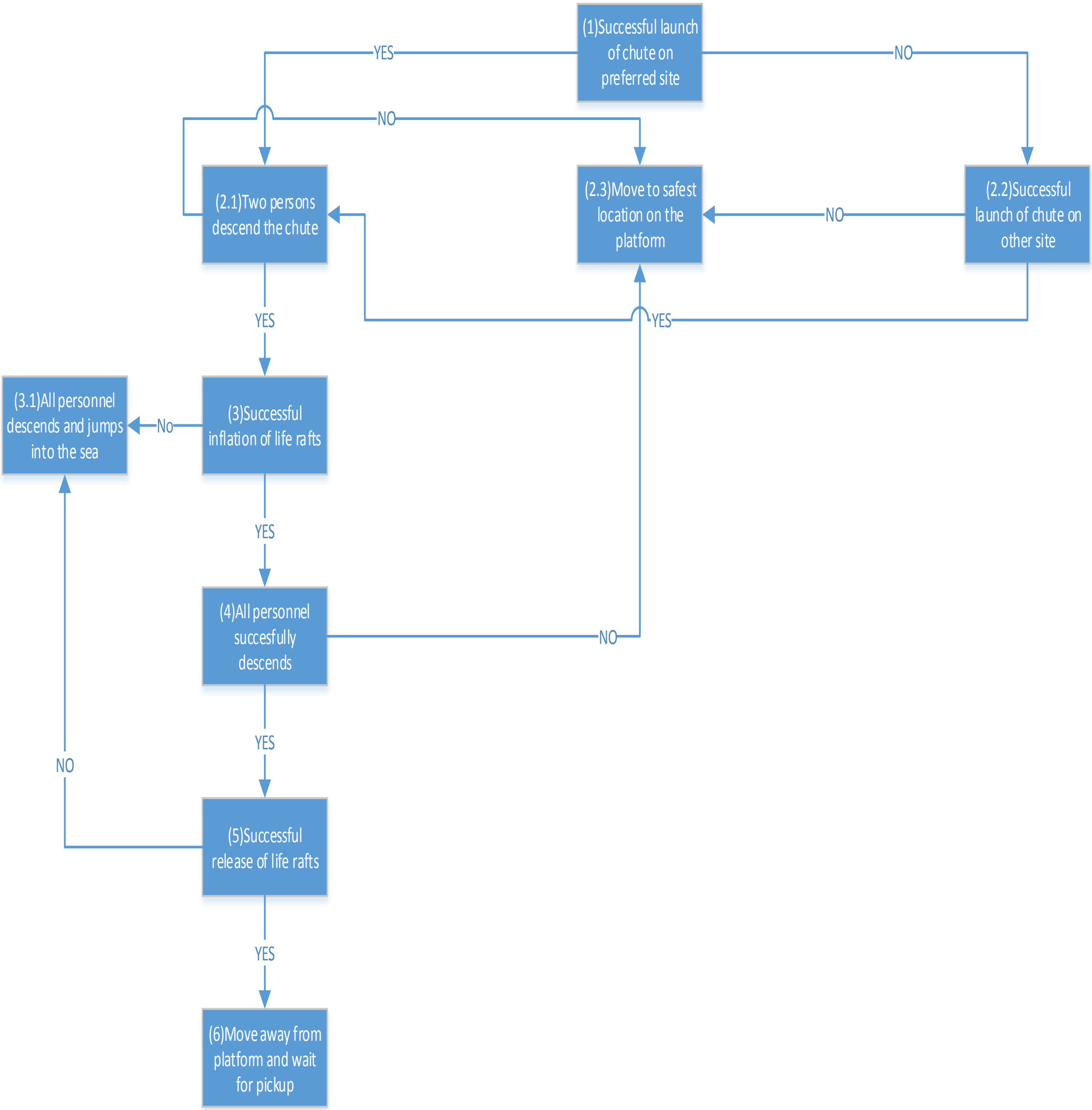
The chute is not suited for people who are injured. If a person has broken a bone or is in an unconscious state it is very hard to get that person down the chute (Interview1).

There are chutes that could be used on the DolWin Beta platform (Viking-Life product guide). A good placement of the chute would be on the backside of the platform, considering the front as the direction which the platform will be towed in. The reason being that the life rafts connected to the chute’s platform would have the biggest chance of drifting away from the

DolWin Beta from here. Another possibility could be to have two chutes installed; one in the right or left front corner and one diagonally on the back (Interview1). Having a chute installed in the front would not be wise since the towlines are connected in the front and also it is less likely that the life rafts would drift away from the platform than it is on any other side of the platform. This is because the platform is most likely moving in the direction it is towed (interview4).

It is not possible to install a chute on the DolWin Beta without making considerable reconstructions. An installation platform would have to be built on the side of the DolWin Beta so that the chute would gain free access vertically to the sea (Interview4). Possible locations to make reconstructions and install a chute on the platform are in the front on intermediate deck or on main deck on any of the other sides. Because the evacuation equipment would only be used in the towing phase it would have to be removed once the platform was standing on the sea floor. The crane on the DolWin Beta would not be able to reach an installed chute on the aft side of the platform, which would be the best place to install it. It would however be able to reach the other three sides (interview4).

5.6.4 Event Tree for evacuation by chute



5.6.5 Evacuation method #2: Rappelling

Rappelling is a rope based system used for descending from heights that are not safe for a normal descent. Rappelling was invented in Chamonix in the 1870s by a climber called Jean Charlet-Straton (Roger Frison-Rocheand and Sylvain Jouty, 1996). Then and now it is as a way for climbers to get climbers down from mountains. The same technique is used by climbers today and is proved to be a safe and reliable system.

Today rappelling is used in a lot of different industries where you are working at height. Every industry has adapted the concept of rappelling in different ways to suit their needs in their work areas. The military uses one way to get down from helicopters and a window washer on skyscrapers uses another.

5.6.6 Review of Rappelling

The system is based of different components, the rope, an anchor, pullies, a harness and a brake. This configuration can be set up in different ways so that either the descendant has the control over the descent or if it's controlled by a second person standing underneath or above.

On a single person system the rope is fixed on an anchoring point above the descendent. The rope then goes thru a brake on the persons harness which uses friction to slow down and stop the descendant on his way. The brake system can work in different ways, a climber can use a special knot that he fixes to the harness, by applying more or less force to the brake he controls his speed down the mountain. Another braking system is the automatic brake system where the descendant has to squeeze a leaver to release the brake and descend. If he lets go of the handle the brake closes and he stops.

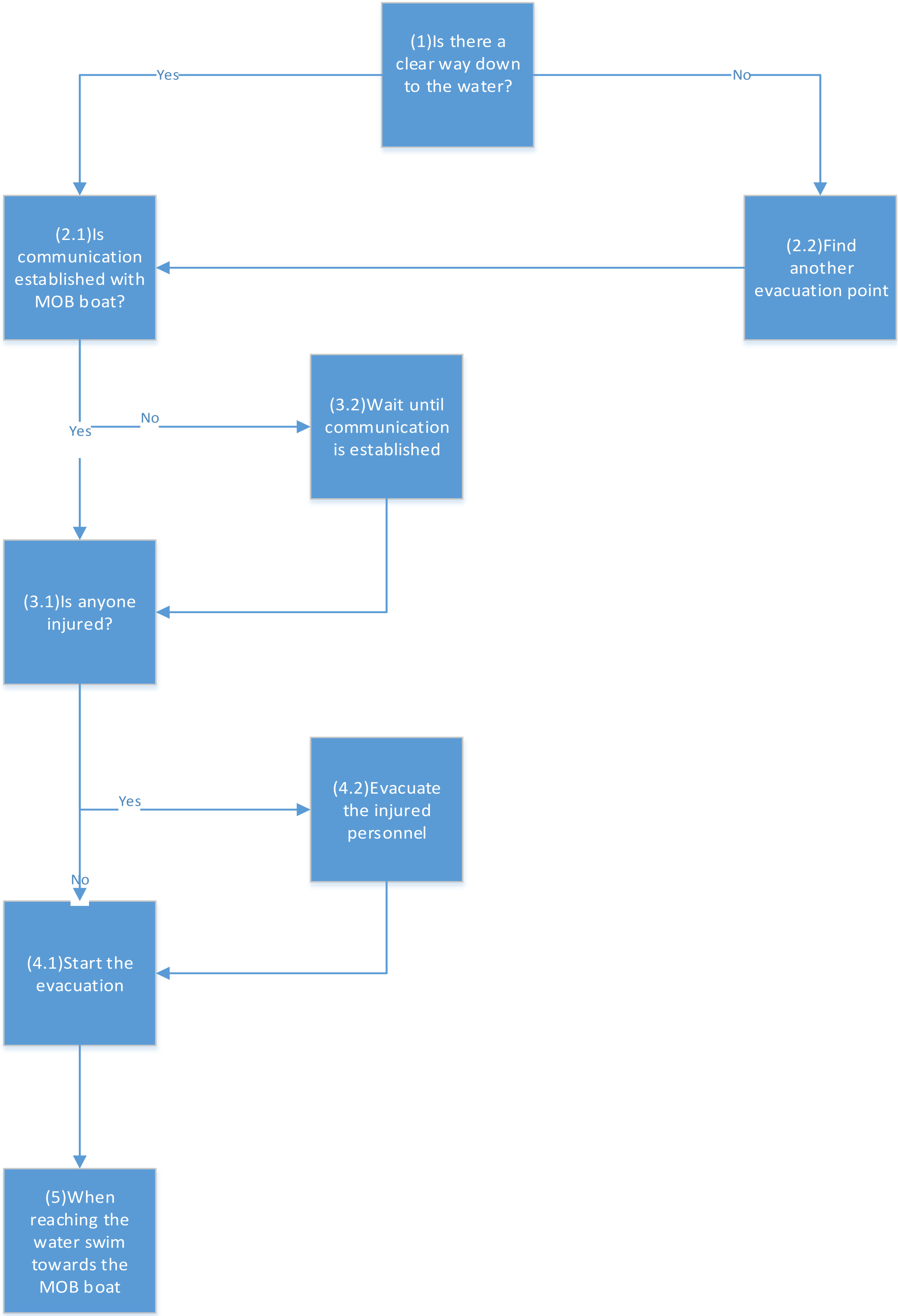
In a two men rappelling system the rope is fixed on the descendants harness, it then goes up to the anchor point and down to the second person who controls the brake. To imagine this system you can think about a water well where you have the bucket on a rope and you are standing above controlling the leaver.

The company AAK AS will have four different rappelling zones, one on each side of the DolWin Beta. Because the platform during an accident can lean and list in any direction and choosing the safest rappelling zone will be critically. Groups up to four persons will be lowered together down to sea level. The descent will be controlled by personnel from AAK AS on top of the platform. It will also be possible using this system to transport a person with injuries with a stretcher. When all personnel from the DolWin Beta have been lowered down to sea level the personnel from AAK AS will use a single person system and descend on their own.

When the personnel reach the surface they will unhook from the rope and swim away from the platform to a nearby MOB boat from Tristein according to AAK AS (Interview 5). It is important during this phase to have good communication between the personnel from AAK AS and Tristein AS so that everyone that where lowered is accounted for. How this communication will be established is not yet decided by AAK AS (interview 5). The MOB boat will go back and fourth between the rappelling zone and one of the tug boats.

All the personnel during the evacuation will be protected by a rescue suit. These suites are standard on all larger vessels operation on the North sea and they are fitted with lights, designed to be buoyant as well keeping the person warm and dry (interview 1).

5.6.7 Events presented schematically of evacuation by rappelling



5.6.8 Evacuation method #3: Ladder to the pontoons

Offshore installations often have ladders constructed that go all the way down to sea level (interview1). Ladders that are mounted vertically to the structure so that personnel are able to climb down from the platform and step right into the sea. On the DolWin Beta an existing ladder can take the personnel down to the boat landing platform but not all the way down to sea level. If a ladder would be installed for the remaining descent it would have a safety cage surrounding the person and a vertical lifeline (interview4) which in turn is connected to a rope grab deceleration device which locks in the event of a fall (http://www.fallprotect.com).

5.6.9 Review of evacuation ladder

The ladder evacuation method is very simple in its design and it has been suggested that people would feel comfortable using it (interveiw1). It could be used as a backup (interview1) so if both the first and secondary evacuation method would fail there would be a way to manually descend to the sea level. Interview subjects would rather use this method than rappelling in the event of an evacuation (interview1).

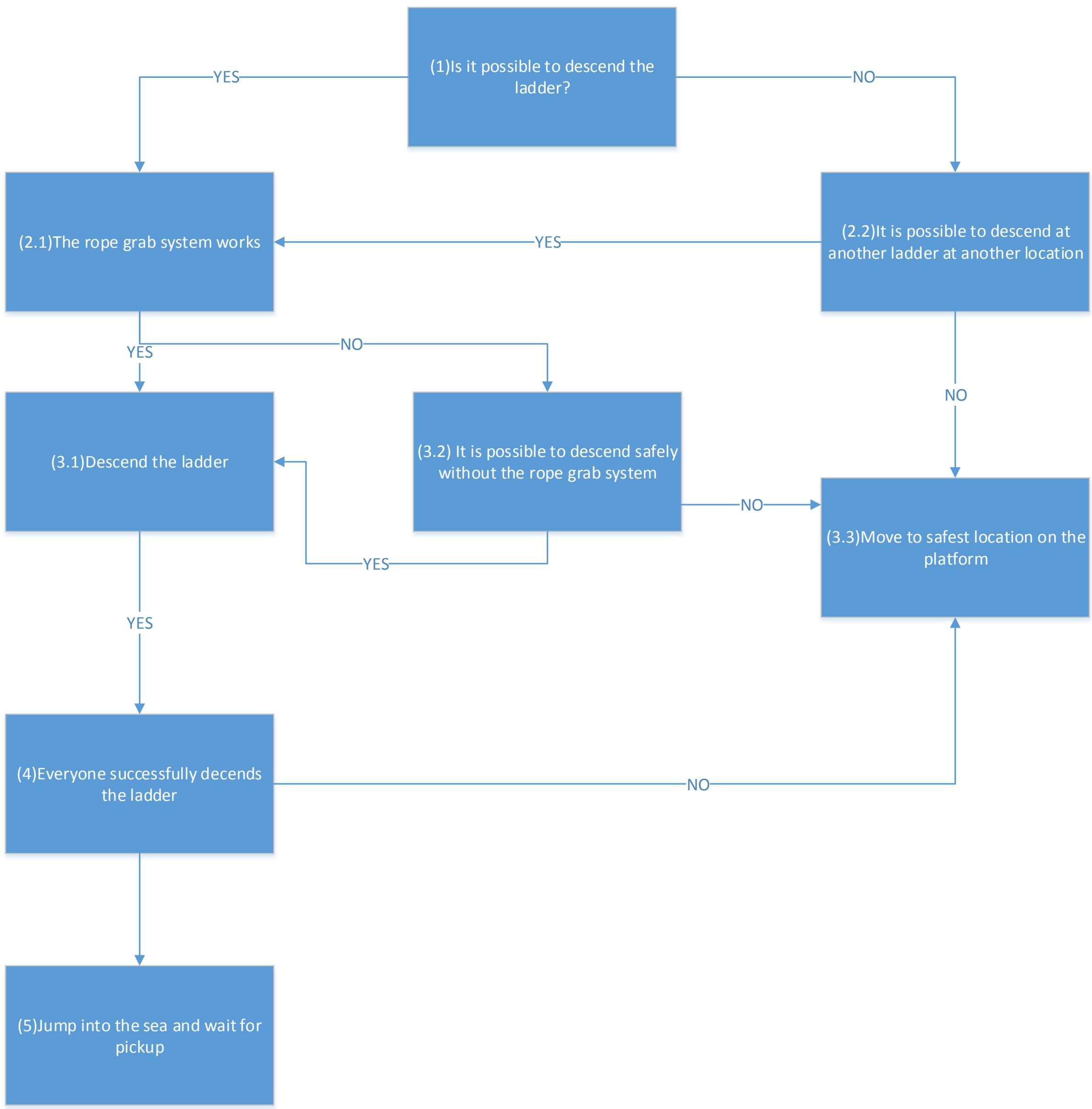
The surrounding cage and the rope grab system can protect a person who would fall. There are different types and patents of rope grabs (http://www.fallprotectionpros.com). A rope grab system is designed so that it is possible for a person to move up and down vertically along a lifeline and in the event of a fall the rope grab will tighten around the lifeline and decelerate and stop the fall (www.fallprotectionpros.com) (www.fallprotect.com).

It is not certain where one would have to exit the ladder to get into the water in the event of an evacuation because the platform could be sinking, thus making the water line relatively higher to the platform. As a cage will be surrounding the ladder a solution of how to get exit points would have to be worked out so that the personnel descending the ladder won’t be trapped inside it (interview4).

A ladder from main deck down to the boat landing platform already exist on the DolWin Beta so all that is needed in order to have a ladder to the sea is an extension of the existing ladder the last 28. It would also be possible to install additional ladders at different locations on the platform (interview4).

It could however prove to be a difficult task to remove the ladder once the platform is seated on the sea bed. The ladder would at that point be under water (interview4).

5.6.10 Events presented schematically of evacuation by ladder



6 Discussion

Advantages and disadvantages of using the chute, rappelling and the ladder as the temporary second line evacuation method on the DolWin Beta are presented in the discussion. The methods have then been compared to each other. The Swiss Cheese model (Reason 1997), the barrier categorization by Hollnagel (2004) and the “Event Tree” (Clemens 1990) has been used as a help to identify weaknesses and strengths of the evacuation methods.

6.1 Advantages of the chute

The chute is a well known evacuation method and that is in itself a huge strength. If people are familiar with an evacuation method they feel safer using it. People tend to do what they have been drilled to do when an evacuation is about to take place and therefore one can expect a controlled evacuation if the chute were to be used. The chute may also give a sense of security as it envelopes the person and offers a clear route down to the sea level. When using the chute all personnel will stick together and there is never a situation where someone is on their own. Communication between the crew will therefore be a relatively easy task. The fact that it is a well know systems that people are familiar to use makes a strong incorporeal barrier according to Hollnagel (2004) against active failures and would probably have a positive effect when it comes to how willing people would be to descend the chute (see phase4 in the event tree). The communication aspect makes active failures according to the Swiss Cheese model less likely to occur.

Because the chute is a well know evacuation method which is included in basic offshore training there would be no need for the crew to undergo extensive preparations or training in how to operate it. The system is very easy to use; releasing a break and waiting for the chute to reach sea level. If this is done successfully and two people manages to descend the chute and inflate the life rafts it will only take minutes for the rest of the personnel to descend it. The descent in itself is an easy task to perform for anyone who is not injured. These are physical as well as incorporeal barriers according to Hollnagel (2004) as it concerns the technical design of the evacuation method as well as it require organisational training of the personnel. These barriers positively affect the outcome of phase 1, 2.1, 3, 4 and 5 of the ET and makes active failures less likely to occur according to the Swiss Cheese model.

Another advantage to the chute method of evacuation is that life rafts are connected to it at sea level. As soon as a person has descended the chute he or she can immediately transfer to a life raft and therefore never has to enter the water. This is likely to give a sense of security to the personnel onboard, as they will not have to enter the water. This makes a strong physical barrier according to Hollnagel (2004) as it is a technical solution created in order to increase the safety of the personnel. This affects phase 4 and 6 of the ET.

6.2 Disadvantages of the chute

If any personnel would be injured with a broken bone or if anyone would be unconscious it could prove to be very hard to get that person down the chute. According to the Swiss Cheese Model this is a latent condition. It effects phase 4 of the ET and as seen in the ET there is no way to get an injured person down to sea level by using the chute if it were to happen.

An active failure that could penetrate any defense of an evacuation by chute has its cause in the height of the platform. If any personnel would become afraid of the height, it could prove difficult to make this person perform the descent through the chute, regardless of his physical condition.

The chute can only be used if the platform is standing more or less still in the water because otherwise the chute would drag in the water making it impossible to use. This also means that heavy currents or waves could become a problem. This is a significant problem as the weather in a situation where an evacuation is needed is likely to be bad. Also, if the platform would be subjected to heavy list or lean it would not be possible to use the chute. This too is a latent condition according to the Swiss Cheese model and there is lacking a physical and/or incorporeal barrier (Hollnagel, 2004). It affects phase 1 of the ET, which is the most critical phase because if this phase fails there is no way for the personnel to get down to sea level.

Using a chute as the temporary second line evacuation of the DolWin Beta is troublesome because there are few suitable locations to place the chute. The best location would be in the middle of the aft because the life rafts would have the best chance of drifting away from the platform once released from the chute’s platform. This is however not possible due to the design of the DolWin Beta. The second best solution is to have two of them, one on each side of the platform.

6.3 Advantages of rappelling

Personnel dedicated to be in charge of a potential temporary second line evacuation by rappelling will be present during the tow. This makes active failures less likely to occur and one can assume that it will have a calming effect of the rest of the personnel.

The personnel in charge will serve as physical-, functional-, symbolic- and incorporeal barriers (Hollnagel, 2004), at the same time and it affects every phase of the evacuation as seen in the ET. They are an incorporeal barrier (Hollnagel, 2004), in the sense that the rules of action in the event of an evacuation will be very clear. They are physical barrier (Hollnagel, 2004) as they will work to physically prevent unwanted actions to be carried out or events to happen. They also serve as functional barriers; an example being that they will prevent a person to begin descending the rope before that person is properly connected. They serve as symbolic barriers (Hollnagel, 2004) as they will carry out orders and share information with the rest of the personnel and in the end the outcome of the evacuation is highly dependent on that everyone abides these instructions. This shows that barriers (Hollnagel, 2004) can be combined in order to create a safe as possible environment.

Technically the system doesn't contain any difficult parts and very little can malfunction according to AAK AS (interview 5); it's basically a rope, a harness and a brake.

When adapting the system to the DolWin Beta you easily see the flexibility of the system. There are different evacuation points that don't take up a lot of space and it is easy to switch from one evacuation point to another (see phase 1 and 2.2 in ET). You can set up the system on the side of the platform that has the lowest height over the water in case of list and/or lean. The evacuation points will be prepared a head of time on the different sides so no equipment has to be moved (interview 5). Since the rules of action will be very clear in any platform condition it serves as an incorporeal barrier.

Another advantage is that is the only system that can handle a person with injuries. It is possible to lower a stretcher with one person and have another person attached on the side.

6.4 Disadvantages of rappelling

An active failure that could penetrate any defense of an evacuation by rappelling has its cause in the height of the platform. If any personnel would become afraid of the height, it could prove difficult to make this person perform the descent; although the fact that there are experienced personnel present who is in charge is a barrier which hopefully counters this.

Having satisfying communication between the people that are being lowered and the personnel from AAK AS and between the MOB boat and AAK AS is an important aspect of the evacuation (interview 5). If this is not worked out it would be a latent condition that could jeopardise the safety of the personnel onboard the DolWin Beta.

It is planned to rappel the personnel into the sea in groups between 2-4 people. When reaching the surface of the sea the personnel will then unhook themselves from the vertical life line and be picked up by a MOB boat from Tristein AS (interview 5). This could be dangerous because of potential platform movement and possible wind and wave factors. According to AAK AS this is the most critical point of the evacuation and it's not decided exactly how it will be solved.

If there are strong winds and the ocean is carrying heavy waves there is a possibility that it would not be possible to launch a MOB boat from the tugboats. There is no weather limit for launching the boats but it is up to the captain on each vessel to decide if the launch can be done in a safe way (interview 3). If the MOB boats can't be mobilized and launched due to the weather there will be no way of transporting the personnel of the DolWin Beta from the water to safety.

Also the fact that the personnel on the DolWin Beta would have to descend into the sea rather than into a life raft is a disadvantage with using rappelling as an evacuation method. This adds a new danger in the middle of the evacuation which is not the purpose. Water presents a new danger to the situation as the person still need to be picked up by a MOB boat in order to reach safety and this can not be controlled by AAK AS. An evacuation is designed to start at a potentially dangerous situation and gradually take the personnel to a safer environment.

Although there seem to be little risk of active failures when using rappelling as an evacuation according to the Swiss Cheese model, there are obviously few barriers against unwanted events to happen in the last phase of the evacuation (see phase 5 of the ET).

6.5 Advantages of the evacuation ladder

The ladder evacuation method is very simple in its design and people would likely feel at ease using it as a method of evacuation. The cage surrounding the ladder as well as having a rope grabbing system connected to a vertical life line makes the system safe when descending as there is little risk of falling. The cage is a physical barrier (Hollnagel, 2004), and the rope grabbing system is a functional barrier (Hollnagel, 2004), as it intervenes when a certain pre-condition is met, i.e. when a person is falling.

Because of the simplicity of the ladder method there is little that could fail technically and an evacuation is executed in a few steps (see ET). If ladders were to be mounted on several locations of the platform it would enable descent in most platform conditions in regard to list and lean.

There is little risk of active failures when using this method of evacuation.

6.6 Disadvantages of the evacuation ladder

The descent from main deck to the sea could be physically challenging for the personnel, especially when wearing a life suit. If the platform were to lean to any side it could be hard to make the descent regardless if there were ladders mounted in different locations on the platform. It could also prove to be very hard to evacuate an injured person by using a ladder. If no solution is prepared for this it is a latent condition according to the Swiss Cheese model.

A potentially dangerous situation that could occur is if the ladder would have a safety cage surrounding it is that a person might not be able to exit if the platform were to sink and the water level got above where the cage's bottom exit is. This could be seen as a latent condition according to the Swiss Cheese model. The cage is initially a physical barrier with the purpose of hindering a person to fall of the ladder but in certain conditions, as the one described above, it could become a death trap.

6.7 Comparison of the evacuation methods

Following is a comparison between the temporary second line evacuation methods where the most important factors for a successful and safe evacuation will be discussed.

6.7.1 Which method makes people feel the safest?

If an evacuation was to take place it is of great importance that the people on the platform would feel safe using it. If the platform would have no or little list or lean a stairway down to sea level would probably be the best method of evacuation in this aspect. At the same time a chute would be to prefer over rappelling due to the recognition that the chute has in the offshore environment compared to rappelling. The chute also gives a person a sense of safety because of its design where one is descending in a firm structure. It is likely that rappelling would be frightening to some but on the other hand it has an advantage over both the ladder and the chute because if it were to be used, people dedicated to lead the evacuation would have to be present on the platform. Having personnel onboard whose only task is to execute and lead an evacuation would likely have a positive impact on how safe people would feel if an evacuation was to take place.

6.7.2 Simplicity and safety

Technically, a stairway down to the water level is by far the easiest system to use of the three. Stairways would be mounted to the platform and little preparation would be needed before personnel could start to descend one of them. There is not much that could malfunction with a stairway. A chute is easy to launch as it is only a break that needs to be lifted. Going down a chute is an easy task. However, if anything would malfunction on the chute and it would fail to launch properly there is very little personnel onboard could do to fix the problem. Under normal circumstances it is unlikely that the chute would fail to deploy but weather or platform conditions like list or lean or velocity could make it not work. Rappelling is a more versatile evacuation method then the chute because it can be used regardless of list or lean and because there are more possible sites from where it could be launched. Since dedicated personnel will be in charge of lowering all people to the sea level the method is to be considered technically simple to use. The personnel hired to be in charge of the evacuation also serves as barriers against technical problems with the rappelling method.

The chute has an advantage over both the rappelling- and ladder method when it come to the part of the evacuation where the people on board have managed to descend the platform and reach sea level. The chute has life rafts connected to the landing platform at sea level so there is no need to ever go directly into the water. It is not certain that this would be the case if using either the rappelling method or the stairway method and the personnel might have to go into the sea. However if it would be arranged so that the personnel could either rappel straight into life rafts or step into life rafts when using evacuation ladders the three methods would have to be considered equally good in this aspect.

6.7.3 Handling injured people

If any personnel would be injured it would be very hard to get them down to the sea level by a stairway or chute. In this aspect rappelling come out on top as it is possible to rappel a person on a stretcher or to rappel a person with a fractured limb.

6.7.4 Physical layout of the DolWin Beta

When it comes to installing the evacuation methods on the platform both ladders and rappelling has an advantage over the chute as the placement of the chutes are restricted to the starboard and port side of the platform. Also the chute requires a more extensive construction to be built before it could be installed than the other two methods.

7 Conclusion

The three evacuation methods, chute, rappelling and ladder, all have strong sides. When compared against each other it is clear that the chute is the most recognizable system, rappelling is the only system that can handle injured and the ladder would be the easiest to use. So based on the strong sides all of them could be used as a secondary evacuation method for the DolWin Beta but every solution comes with its own disadvantages and it is the system with the least disadvantages that will be the most suitable.

Based on the discussion and the available data we conclude that the best evacuation method for the DolWin Beta would be rappelling due to the fact that it is the only system that can handle injured, it is flexible and not easily affected for list/lean and AAK AS will provide with personnel that will be responsible for the evacuation.

The problem remains to how the personnel that has reached the water will be brought to safety; this is the most critical point in the evacuation. A solution has to be found before the tow of the DolWin Beta begins.

The ladder and the chute are both good systems and could be recommended systems for other projects but for the DolWin Beta they are not optimal.

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