Proceedings of the ASME 2011 31st International Conference on Ocean, Offshore and Arctic Engineering
OMAE2012
July 1-6, 2012, Rio de Janeiro, Brazil

OMAE2012-83329

Evacuation from Petroleum Facilities Operating in the Barents Sea

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ABSTRACT

The purpose of this paper is to examine conditions relevant to evacuation and rescue of personnel from facilities operating in the Barents Sea. The paper considers the area from the Norwegian coast to Bjørnøya (Bear Island) in the north and the new border with Russia in the east. This corresponds roughly to the area that is open for exploration and exploitation of petroleum resources in the Norwegian sector of the Barents Sea.

Pertinent meteorological observation data is collected from the Norwegian Meteorological Institute. The data is used to evaluate evacuation and rescue under the observed conditions. The probability and effect of ice accretion on vessels, in particular lifeboats, is considered. Ice accretion on lifeboats is possible and could threaten stability if the lifeboat has to ride off a storm while waiting for a weather window that allows rescue of the passengers.

Meteorological conditions in the Barents Sea are such that existing equipment like life rafts, escape chutes, davit launch lifeboats and 1st and 2nd generation standby vessels may not be appropriate for the prevailing conditions during winter. Access to reliable weather forecasts is paramount for operating in the Barents Sea. Responsible personnel onboard facilities operating in the Barents Sea should be competent in the interpretation and understanding of weather forecasts and the implications the conditions may have in an evacuation and rescue situation.

CONCLUSIONS AND RECOMMENDATIONS

The analysis of the meteorological data for stations around the Barents Sea coincide with what can be expected from literature and norms for the area. The meteorological data and the stability calculations indicate that stability of lifeboats could be impaired due to ice accretion. This is an issue that the designers and producers of lifeboats are aware of, but it has not been investigated in detail. The effect of ice accretion should be investigated for each lifeboat model that may be used on facilities operating in the Barents Sea.

Access to reliable weather forecasts is paramount for operating in the Barents Sea. Responsible personnel onboard facilities operating in the Barents Sea should be competent in the interpretation and understanding of weather forecasts and the implications the conditions may have in an evacuation and rescue situation.

Equipment available for evacuation can encounter conditions that render them inappropriate. The limitations of existing evacuation and rescue systems are generally understood.

Third generation rapid response rescue vessels are recommended as standby vessels in the Barents Sea. Their rescue capacity and ability is by far the best that is currently available.

Norwegian regulations are functional and risk based. They are considered sufficient to regulate safe evacuation and rescue in the Barents Sea. The guidelines to the regulations should be complemented with references to standards like ISO-19906.

All year operation in the Norwegian sector of the Barents Sea is thus considered possible when appropriate risk analysis and risk reduction measures are put in place.

INTRODUCTION

The paper considers the area from the Norwegian coast to Bjørnøya in the north and the new border with Russia in the east, Figure 1 below. Background information on the climate conditions in the Norwegian sector of the Barents Sea is covered. Special features of the area are also presented. Meteorological observations for 2008 and 2009 are used as a basis to discuss the suitability of evacuation and rescue systems that are common in the petroleum industry. Information on the most commonly available evacuation and rescue systems is discussed briefly. A simplified model is used to evaluate the effect of ice accretion on the stability of lifeboats.

The combined probability of an evacuation and rescue being necessary at the same time as challenging weather at the facility is not treated in this report. This is deemed allowable because actual weather conditions are used.

Figure 1 Map of the Barents Sea (Source: npd.no)

METHODOLOGY

Pertinent meteorological data has been collected for 4 stations around the Barents Sea, three on the coast of northern Norway and one at Bjørnøya, Figure 1. The data is gathered from the Norwegian Meteorological Institute and eKlima /15/.

Based on the interpretation of the regulatory requirement, actual weather conditions that have been observed are evaluated for the prospect of a successful evacuation under observed conditions. The data is used in a deterministic evaluation of conditions on given days in 2008 and 2009. These years have been chosen in order to avoid a discussion regarding the relevance of this work regarding issues related to climate change or global warming.

The result of the analysis of the meteorological data is used to consider what effect these may have on an evacuation under the given conditions. The main focus is on lifeboat evacuation and the effect of icing. Some considerations are also given to how long the lifeboat may be exposed to these conditions due to difficulty in retrieving either the persons onboard or the whole lifeboat onto another vessel. Retrieval may be difficult due to wind and sea conditions.

A simplified model of a lifeboat is used to calculate static stability conditions with regard to metacentric height and the roll period.

METEOROLOGY – BARENTS SEA CLIMATE

Air temperature

The maximum average air temperature is +4,4 °C with the annual range between +2,0 to +7,0. The maximum air temperature that can be expected in the southwest, near Goliat and Snøhvit, is in the range of 20°C to 25°C. Towards the north and east, the maximum temperature decreases to the range of 15°C to 20°C.

The minimum average air temperature is -7,7 °C with an annual range between -6,0 to -9,0 °C. The minimum air temperatures that can be expected in the southwest are in the range of -15°C to -20°C. Towards the north and east, the temperatures decrease to the range of -20°C to -30°C. /6 & 9/

Sea temperature

The maximum average sea temperature is +7,0 °C with the annual range between +5,0 to +9,0. The maximum sea temperatures that can be expected in the southwest are in the range of 10°C to 12,5°C. Moving towards the north and east, the maximum temperatures decrease to the range of 5°C to 10°C.

The minimum sea temperature that can be expected in the southwest is in the range of +2°C to +4°C. Towards the north and east, temperatures decrease to the range of +2°C to -1,9°C. /6 & 9/

Visibility

Visibility can be impaired both by fog and snowfall. Statistically this can occur for a large number of days during the year. Typically there are 64 days per year with visibility below 2km due to snow and 76 days per year with visibility below 1km due to fog. Measures have been taken to establish internationally agreed fixed shipping lanes lying 30nm off the coast from the Russian border to Røst, thereby reducing the probability of collision with passing ships. Fog and snowfall that impairs visibility will be an operational issue reducing the availability of helicopter transport and potentially disturbing operations of supply vessels in close proximity to the facility. Severe fog conditions can also hinder helicopters performing medical evacuation, precautionary evacuation or rescue operations. /6, 9 & 10/

Darkness
The sun is below the horizon for a given period during the winter. This results in total darkness, called polar night, in the middle of the winter. There are limited periods of twilight during the day until the sun returns. The length of the daylight period decreases rapidly from the autumn equinox until the sun leaves. Similarly the daylight period increases rapidly from the return of the sun until the spring equinox /6, 16 & 17/.

Sea conditions
The significant wave height that can be experienced in the southwest is 15 m decreasing to 14 m toward the north and east. Storms can create violent sea and wave conditions disrupting activities and hinder evacuation or survival on the sea. /9/

Wind
The 10 minutes average maximum wind speed at 10 m above sea level is 26,6 m/s with the annual range of 25 m/s to 28 m/s. The dominant wind direction during the summer is from the west. The dominant wind direction during the winter is from the northeast. Extreme wind speeds can occur during polar low and polar front conditions. /6/

Polar lows
Polar lows are weather phenomena that are well known from the Norwegian and Barents Sea. The storm or polar lows occur in the season from autumn to winter with a frequency of 2 to 4 per month. Polar lows are a potential threat to all activity in the Barents Sea due to their nature and suddenness with which they develop. /5 & 14/

Polar lows develop in a short space of time and have a short lifespan. Typically, polar lows have durations of 6 to 48 hours. They develop swiftly when cold wind blows from the ice covered regions in the north over areas with relatively warm sea. The storm dies or dissipates when it moves over land because the driving force, the warm sea, no longer provides the energy to sustain the wind system. A polar low has a typical diameter of ca. 100 to 500 km making it a relatively small weather system. Typically, a polar low can travel at 15 to 25 knots with the highest observed speed of 52 knots. Winds speeds are typically up to Beaufort force 10 or storm with wind speeds up to 28,4 m/s. Hurricane wind speeds have been observed but are more seldom.

The wind is strongest to the west of the centre. The wind decreases in speed to the east of the centre. It is not uncommon that the polar low is accompanied by heavy snowfall. The strong and variable winds can create chaotic conditions on the sea even though there is normally not sufficient fetch to build up very large waves. The combination of wind, snow and sea spray can increase the danger of icing on vessels and structures.

Polar lows are difficult to forecast due to the fact that there are few meteorological observation stations in the Barents Sea. Satellite surveillance is necessary to provide reliable forecasts. The coverage provided by satellites is currently not on a full 24 hour basis as a polar orbit only brings the satellites over the area for a limited period each day.

Sea ice and icebergs
Normally the seawater in the Barents Sea will freeze when the water temperature is from -1,7°C to -1,9°C dependent on the salinity of the water. Sea ice with a return frequency of 100 years normally only occurs north of 73°N and to the east of 31°E. The return frequency for sea ice increases to ca. 10 years at 74°N and ~33°E. It is interesting to note that the area now acquired for exploration due to resolving the border issue with Russia, has a greater probability for sea ice than the areas that are currently opened for activity /6 & 9/. Several large icebergs have been observed south of 74°N and on the coast of northern Norway during 1881 and 1929 /20, 21 & 22/.

Ice accretion
The climate conditions in the Barents Sea are such that icing on vessels can normally occur from October to May. There are two types of icing that need to be taken into consideration, atmospheric and sea spray icing. Atmospheric icing occurs in conjunction with low air temperature and precipitation. This form of icing normally leads to smaller amounts of ice developing on structures than sea spray ice accretion. Atmospheric ice has normally a higher density than sea spray ice /2/. We will here only discuss the effects of sea spray ice accretion as this is the dominant source of ice on structures and vessels.

Sea spray icing is dependent mainly on the following parameters /12 & 13/:
- Air temperature: as the air temperature decreases below the freezing point of the seawater, ice will be deposited if sea spray occurs.
- Wind speed: increasing wind speed leads to more sea spray and more water in the air to freeze onto the vessel. Beaufort force 6 equivalent to 10,8 m/s is normally considered as the minimum wind speed for ice accretion to occur.
- Sea surface temperature: when the sea surface temperature decreases towards the freezing point, icing can increase dramatically as there is less energy that needs to be removed from the sea spray. The freezing point for seawater in the

Barents Sea is normally -1,9°C. The freezing point is governed by the salinity of the water and less salt in the water leads to a higher freezing point.

- Sea state: as the sea state gets more severe and wind increases and drives waves, sea spray is blown into the air either when waves break or as a vessel sails into the waves. Beaufort force 6 corresponds to waves of Hs=~3m with maximum waves of ~4m.
- Size and type of structure or vessel: ice accretion due to sea spray does not normally occur over 25m above sea level. Sea spray is generally not carried higher than 25m. It is not uncommon for small fishing vessels to experience icing. These fishing vessels are comparable in size to lifeboats. It is therefore considered relevant to look into the issue of icing on lifeboats.
- Vessel course and speed relative to waves: the amount of sea spray developed is a direct result of the speed of the vessel and the angle that the vessels heads into the waves.

A formula has been developed to predict the rate of ice accretion due to sea spray /2/. The formula takes into account wind speed (Ua), freezing point of seawater (Tf), sea surface temperature (Tw) and air temperature (Ta). The National Oceanic and Atmospheric Administration (NOAA) have developed an ice accretion predictor (PR). The relationship between the predictor and the ice accretion rate is illustrated in the Figure 2 below.

$$PR = Ua(Tf-Ta)/(1+0,4(Tw-Tf))$$

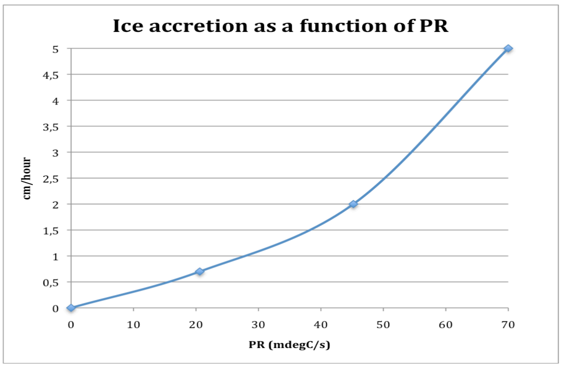

Figure 2 Ice accretion rate as function of ice accretion predictor, PR

Weather forecasting

Reliable weather forecasting is paramount for safe operation and activity at sea. Due to the low number of fixed observation stations in and around the Barents Sea, reliable weather forecasts are challenging, especially with regard to forecasting polar lows. As petroleum resources are developed in this area, valuable information will be gained through new fixed observation stations on the facilities.

EVACUATION AND RESCUE

In 1998 the Norwegian Petroleum Directorate (NPD) engaged Det Norske Veritas (DNV) to prepare a technical report on evacuation and rescue means. The report is titled Evacuation and Rescue Means, Strength Weaknesses and Operational Constraints, YA-795, Norwegian Petroleum Directorate 1998 December /3/. The following information on weather limitations for different means of evacuation are taken from the report and used in this report.

	Documented	Uncertain
Life rafts	6	8
Escape chutes	6	8
Davit LB	7	10
Free Fall LB	12	12

Table 1, Performance of evacuation means defined by Beaufort force /3/

Helicopter evacuation

Helicopter evacuation is considered the preferred method of dry evacuation from a facility. The performance or availability of helicopters is governed mainly by visibility. Under normal operations, a minimum cloud base of 200 to 300 meters is necessary and a horizontal visibility of 0,5 nautical mile. Helicopters do not normally operate on a helicopter deck in winds over 55 to 60 knots, Beaufort 10. Flying to installations may be performed at wind speeds with gusts up to 60 knots. /7 & 8/

Lifeboat evacuation

Lifeboat evacuation by freefall lifeboat is considered the most reliable. The NPD/DNV report /3/ was made prior to the discovery of weaknesses related to free fall lifeboats in 2005 and subsequent years. The Norwegian Oil Industry Association (OLF) has performed extensive work related to issues with freefall lifeboats. OLF work has resulted in many improvements and the new standard for freefall lifeboats, DNV-OS-E406. The Norwegian Shipowners' Association (NR) has performed studies of the issues related to davit launch lifeboats.

Escape chutes and life rafts

Escape chutes and life rafts have a limited operational window /3/. They generally should not be used in conditions over Beaufort 8. The prevailing conditions in the winter and a polar low would probably disqualify the use of escape chutes and life rafts in the Barents Sea for considerable periods of the year. The issue of protection of personnel from the cold will need to be looked into specifically.

Survival suits (immersion)
Personal survival suits are used during helicopter transport and evacuation of installations. In the Barents Sea high priority should be given to dry evacuation /1 & 5/. The main goal of a survival suit should be to keep a person warm and dry. Entry into the water during winter should be avoided as far as possible especially in temperature conditions where the air temperature is below 0°C and the sea temperature is low. Currently available survival suits need to be proven adequate for the winter conditions in the Barents Sea or replaced by more suitable models.

Rescue
Once lifeboats or life rafts have been launched and come clear of the facility, the issue of rescuing survivors is paramount. If a helicopter or rescue vessel is unable to operate under the prevailing conditions, the survivors will have to ride out the weather and wait for an operational window that allows rescue. The time required to ride out a particular condition will depend on how severe the weather is and how long it is since it started. The discussion in chapters below illustrate that there is a potential to have to stay onboard a lifeboat for a considerable length of time. It is therefore relevant to study the effects of icing on a lifeboat during this time span.

Helicopter rescue
In an emergency situation the operational limits can be exceeded at the discretion of the pilot /8/. The success of an operation in adverse weather conditions will be dependent on wind speed, visibility, fog or snow and the pilot's ability to operate under the prevailing conditions. The transport helicopters are the main resource for evacuating people in an emergency situation. The Norwegian rescue service, 330 squadron, has an excellent record in rescue operations under adverse conditions. The capacity of the rescue service is limited relative to the large number of people who can be onboard a facility operating in the Barents Sea.

Emergency Response Vessels
Custom designed third generation rapid response rescue vessels are now available /18/. They are specially designed to launch and recover a fast rescue craft or daughter craft from a slipway in the stern. The slipway can also be used to recover a lifeboat from the sea. The sea trials of these vessels are promising and it is generally considered possible to operate in sea conditions up to Hs=< 9m /18/, corresponding to Beaufort 10 if the wind has had a short duration. If the wind has had a long duration and the sea has had time to build up, Hs=< 9m is reached already at Beaufort 9. Rescue to conventional standby vessels require the use of lifting equipment or the transfer of personnel from the lifeboat to the standby vessel by MOB boat, limited to Beaufort 6, or Fast Rescue Craft limited to operate up to Beaufort 8. There is therefore good reason to consider the possibility that survivors in the lifeboats may have to ride off the weather conditions for a considerable time.

ANALYSIS AND DISCUSSION

We have chosen to discuss the weather conditions observed during the first 7 days of January in 2009. These conditions are representative for the weather in the Barents Sea during the winter months of 2008 and 2009. An evaluation of the conditions is discussed for each observation station on the following pages. A number of documents are use when evaluating the consequences of the conditions with regard to escape, evacuation and rescue. The main documents are listed in the reference section as /1, 3, 4, 5, 10 & 11/. Similar conditions can be found on numerous occasions during these two years.

Observation data used in the report
Meteorological measurements are limited in the Norwegian sector of the Barents Sea. We have chosen to use information readily available from the Norwegian Meteorological Institute in eKlima /15/. We have selected the four stations shown in Figure 1 on page 2. The stations all lie on the outer edge of the geographical area covered in this report.

The following observations have been used:
TA: Air temperature, °C
TW: Sea temperature, °C
FF: Wind speed at 10 meter, m/s
FG_1: Maximum gust during last hour
FG: Maximum gust
TW is only measured at Bjørnøya and we have used an estimate of 5°C for the other locations. Ice accretion predictor (PR) and wind chill (Wchill) are calculated values. Wind chill is calculated according to the formula in ISO 15743 /19/.

The observation data has been loaded into an Excel spreadsheet. A value for the icing index, PR has been calculated /2/. The difference between the air temperature and the dew point has been calculated as an indication of the likelihood of fog developing /10/. Conditional formatting of the spreadsheet has been used to highlight the analysis of the observation data. The following limits have been used in the spreadsheet. (See also Tables 2 and 3)

TA, air temperature below -10 °C, yellow
TA, air temperature below -15 °C, orange
TA, air temperature below -20 °C, red
FF, FG, FG_1, wind speed >= 24,5 m/s, red, corresponding to Beaufort 10, storm

FF, FG, FG_1, wind >= 17,2 m/s, orange, corresponding to Beaufort 8, gale
FF, FG, FG_1, wind speed >= 10,8 m/s, yellow, Beaufort 6, corresponding to strong breeze
PR, icing index, >= 45,2, red, ice accretion over 2 cm/h
PR, icing index, >= 20,6, orange, ice accretion between 0,7 and 2 cm/h
PR, icing index, > 0, yellow, ice accretion may begin
Wchill below -25°C, red

BJØRNØYA

Bjørnøya – meteorological conditions (Table 2)

Air temperature: The average air temperature during the period is -12.6°C. The air temperature is ca. -10°C for the first five days and drops to ca. -18°C for the last two days. The cold air temperature combined with the wind would represent a considerable wind chill and provide the right temperature conditions for considerable icing.

Sea temperature: The sea temperature is stable at -1,3°C providing "ideal" conditions for the growth of ice.

Visibility and darkness: The visibility in the whole period can be considered mostly as very good. However, January is dark and no daylight should be taken into account as far north as Bjørnøya.

Wind: The average wind speed in the period is 8,95 m/s i.e. mainly below strong breeze, 10.2 m/s, Beaufort force 6 which is considered minimum for icing to start. There are short periods gusting to gale force winds and only 2 observations of gusts up to storm. Icing should be expected in these periods due to the cold air.

Cloud base: The cloud base is low but would not hinder the use of helicopters in the case of an evacuation or rescue operation.

Sea conditions: Based on the wind speed and gust observations for the first period, one could expect waves with an Hs=~3m with maximum waves of ~4m. On the 5th of January higher wave conditions could be expected. Almost certainly in excess of Hs=4 to 5m and maximum waves possibly developing to 10m for shorter periods.

Icing factor, ice growth rate: The average icing index for the period is 70,2 with ca 60 for the first 4 days and increasing to over 70 for the last 3 days. This gives a theoretical ice growth of 3 to 4 cm per hour in the beginning and over 5 cm per hour for the end of the period. If the lifeboats have to stay in the sea with the passengers onboard for many hours, considerable ice growth can be experienced and the issues illustrated in the stability calculations (see later chapter) could occur. At the same time, any vessel involved in a rescue operation would also suffer from the same icing conditions. A rescue operation under the conditions observed during the 5th to 7th of January could prove to be very difficult.

Date	Time	TA	TW	FF	FG	PR	Wchill
1	1	-10,3	-1,3	9,8	17,5	66,4	-20,5
1	7	-10	-1,3	10,3	16,5	67,3	-20,4
1	13	-9,4	-1,3	7,7	14,4	46,6	-18,3
1	19	-10,1	-1,3	8,7	15,4	57,5	-19,8
2	1	-10,8	-1,3	10,3	14,4	73,9	-21,4
2	7	-8,9	-1,3	10,8	15,4	61,0	-19,1
2	13	-8,9	-1,3	11,8	17,5	66,6	-19,5
2	19	-10,5	-1,3	12,9	17,5	89,5	-22,0
3	1	-10,2	-1,3	11,8	17,0	79,0	-21,2
3	7	-11,1	-1,3	5,1	13,9	37,8	-18,8
3	13	-10	-1,3	9,8	16,0	64,0	-20,1
3	19	-11	-1,3	7,7	13,4	56,5	-20,4
4	1	-12,5	-1,3	7,2	9,8	61,5	-22,1
4	7	-12,4	-1,3	2,1	9,3	17,8	-17,0
4	13	-10,5	-1,5	6,2	7,7	46,0	-18,9
4	19	-2,6	-1,3	12,9	17,5	7,3	-11,3
5	1	-16,4	-1,3	6,2	27,3	72,5	-26,4
5	7	-9,1	-1,3	17	29,8	98,7	-21,4
5	13	-10,9	-1,3	15,4	24,2	111,8	-23,4
5	19	-13,2	-1,3	7,7	20,6	70,2	-23,3
6	1	-16,4	-1,3	6,2	11,3	72,5	-26,4
6	7	-18,1	-1,3	5,1	9,3	66,6	-27,6
6	13	-18,4	-1,3	7,2	10,8	95,8	-29,7
6	19	-18,9	-1,3	10,3	14,4	141,2	-32,2
7	1	-17,5	-1,3	9,3	12,9	117,0	-29,8
7	7	-18,8	-1,3	9,3	13,4	126,8	-31,5
7	13	-18,1	-1,3	6,2	12,9	81,0	-28,5
7	19	-18,2	-1,3	5,7	9,3	74,9	-28,3

Table 2, Weather data for Bjørnøya 1.-7. Jan. 2009

Discussion

Helicopter evacuation is possible under these conditions. The use of lifeboats would be the second preference. If necessary, escape chutes and life rafts would probably lead to successful evacuation under these conditions, however, the low temperature would be of concern. The main challenge to evacuation by lifeboat in this period is that the icing factor indicates the possibility for severe icing with icing rate starting at 3 to 4 cm/hr and increasing to over 5 cm/hr. If the lifeboats were not recovered from the sea within 4 to 5 hours, the effects of icing, especially towards the end of the period with air temperatures in the region of -18°C, would become noticeable by increased roll period. The sea conditions for most of the period should allow rescue of the passengers and lifeboats due to a low significant wave height of 3 to 4m. It must also be taken into account that any other vessels involved in the rescue operation would also run the risk of ice accretion on the superstructure. Awareness of the issue would be of the utmost importance and manoeuvring of all vessels should be done at low speed to limit bow waves and sea spray. Rescue by helicopter or rapid response rescue vessels would be possible under these conditions. Conventional standby vessels with appropriate support equipment should be able to perform a rescue under these conditions.

Conclusion for an evacuation in this period

Evacuation and rescue would be possible. The main challenges would be the low temperature, lack of daylight and the possibility for icing. All possible precautions should be taken to avoid an evacuation in these conditions.

FRUHOLMEN

Fruholmen – meteorological conditions (Table 3)

Air temperature: The average air temperature during the period is -4,7°C. The air temperature is below the period average at the beginning and the end of the examined period.

Sea temperature: The sea temperature is not recorded for Fruholmen. A typical value of 5°C for the area is used in the calculation of the icing predictor.

Cloud base: The cloud base is not recorded for Fruholmen

Visibility and darkness: Visibility is not recorded for Fruholmen. Taking the difference between the air temperature and the dew point for this period, it is unlikely that visibility would be impaired by fog. The visibility in the whole period should be considered mostly as good. January is dark but short periods of twilight can be expected during the middle of the day as Fruholmen is further to the south than Bjørnøya.

Wind: The average wind speed in the period is 15,6 m/s i.e. mainly in the band of near gale or Beaufort force 7 and is above minimum for icing to start. There are short periods of winds speeds in the band of severe gale or Beaufort force 8. There are periods of wind gusts up to violent storm, Beaufort force 11. Combined with the relatively cold air, the wind chill could be considerable.

Sea conditions: Based on the wind speed and gust observations, one could expect waves with an Hs=~4m with maximum waves of ~5,5m. On the 5th and 7th of January higher wave conditions could be expected. Almost certainly in excess of Hs=7m and maximum waves may develop to 10m for shorter periods.

Icing factor, ice growth rate: The average icing index for the period is 11,0 during the period. Icing during this period is almost negligible. In the period of the 5th to the 7th of January the combination of high wind speeds, potentially rough sea conditions with spray developing, some icing could be expected but probably not more than 0,5cm/hour. This would not threaten the stability of the lifeboat or any vessel involved in a rescue operation.

Date	Time	TA	TW	FF	FG_1	PR	Wchill
1	1	-6,3	5	18	23,1	21,06	-17,7
1	7	-6,1	5	15	21,5	16,76	-16,7
1	13	-4,8	5	12,8	18,4	9,872	-14,3
1	19	-5,4	5	11,9	19,6	11,08	-14,8
2	1	-5	5	14,1	20,1	11,63	-14,9
2	7	-4,9	5	13,4	17,6	10,69	-14,6
2	13	-3,5	5	17,6	23,5	7,489	-13,8
2	19	-1,8	5	15,6	20,3	-0,41	-10,9
3	1	-3	5	12,7	20,3	3,715	-11,8
3	7	-2,5	5	13,7	21	2,186	-11,4
3	13	-5,3	5	15,2	20,7	13,74	-15,7
3	19	-4,5	5	15,6	19,7	10,79	-14,7
4	1	-5,8	5	13,4	17,1	13,9	-15,8
4	7	-5,1	5	12,8	17,6	10,89	-14,7
4	13	-5	5	6,6	14,8	5,441	-12,1
4	19	-3	5	10,4	14,9	3,043	-11,1
5	1	1	5	22	30,3	-17	-8,3
5	7	-1,5	5	22,8	28,4	-2,43	-12,0
5	13	-3,4	5	24	30,6	9,574	-14,9
5	19	-4,1	5	20,3	25,9	11,88	-15,2
6	1	-6,2	5	16,9	21	19,33	-17,3
6	7	-7,3	5	15,1	21,6	21,69	-18,4
6	13	-7,7	5	14,2	19,9	21,9	-18,7
6	19	-7,6	5	11,8	17,1	17,89	-17,7
7	1	-7,6	5	12,1	17,3	18,34	-17,8
7	7	-7	5	18,9	23,7	25,64	-18,9
7	13	-4,7	5	22,5	28,1	16,76	-16,5
7	19	-4,4	5	17,2	21,6	11,44	-14,9

Table 3, Weather data for Fruholmen 1.-7. Jan.2009

Discussion

The main challenges for an evacuation in this period would almost definitely be the wind and sea conditions. Helicopter evacuation is possible under these conditions. The use of freefall lifeboats would be the second preference. Davit launch lifeboats, escape chutes and life rafts could potentially be inappropriate for these conditions. With current technology it could be difficult to retrieve the lifeboat from the sea onto a rescue vessel. A rapid response rescue vessel would be recommended in these conditions. An evacuation on the 5th or 7th of January would probably lead to the lifeboat having to ride off the weather and wait until the sea conditions improved before transfer either of the entire lifeboat or the passengers to a rescue vessel. Under these conditions, it would be possible although difficult at times, to perform a helicopter lift of the passengers from the lifeboat. The potential icing conditions would not threaten the stability of the lifeboat or rescue vessel but would make conditions on top of the lifeboat dangerous if the passengers are required to position themselves there for hoisting to a helicopter.

Conclusion for an evacuation in this period

Evacuation and rescue would be possible. The main challenge would be sea conditions and the passengers may have to remain in the lifeboat for some time before being rescued.

Slettnes and Vardø Radio – meteorological conditions

Weather data for Slettnes and Vardø Radio in the period 1st to 7th Jan. 2009 are very similar to the results found for Fruholmen. The findings regarding evacuation do not show a significant difference compared to Fruholmen.

LIFEBOAT STABILITY

A simplified model of a lifeboat has been used to examine the effects of ice accretion on the metacentric height, GM, and roll period, T_{roll}.

Description of the model

The lifeboat cross section is described as a triangle below the waterline and a rectangle above the waterline. The triangle is dimensioned such that the height of the triangle is equal to the draught of the lifeboat when empty. Any additional weight added to the lifeboat, people and ice, will start submerging the rectangle. This cross section is used for the entire length of the lifeboat. This model is chosen to allow simple calculations with the purpose of illustrating the effect of ice on the lifeboat. It is not intended to be an exact model and correct calculation of real stability of any particular make of lifeboat. As the lifeboat model is simplified, the resulting GM and T_{roll} must not be taken literally. The amount of ice that any particular lifeboat can tolerate before losing stability must be investigated for each type and model of lifeboat. These calculations are only intended to illustrate a potential problem.

In the case of a real lifeboat experiencing icing, the ice will spread more evenly and the centre of gravity will probably be lower than used in the spreadsheets. This is due to ice forming on the sides of the lifeboat as well as the top. The lifeboat is a small vessel with limited height and any waves or green sea washing over the lifeboat could melt away ice and reduce the problem. When performing such a rudimentary calculation as is done in this report, it is intended that these calculation shall not be identified with any existing lifeboat on the market. The dimensions of the lifeboat used on the model are selected as an "average" of lifeboats available on the market.

Errors associated with the model

The underwater volume is greater than what is realistic for a lifeboat of the given dimensions. Curvature of the hull towards the bow and stern are not taken into account. This gives a smaller initial draught than is the case in a real lifeboat.

The way the model is used gives the full beam of the lifeboat at the waterline breadth already from the empty boat case. The beam of the lifeboat model does not increase as it is loaded with people or ice. This gives a high initial moment of inertia that remains constant for all subsequent loads on the lifeboat model. The result of this is a higher initial metacentric height than can be expected in a real lifeboat. As a real lifeboat is loaded the beam will increase as the draught increases. This leads to an increase in the moment of inertia resulting in a higher GM than in the model. The model thus predicts quicker degradation of GM than may be observed with a real lifeboat.

The load from ice on the lifeboat is only distributed across a flat surface on the top of the lifeboat. In a real situation ice would form along the sides as well as the top. The total ice load in the model is probably higher than may be observed in a real situation.

In total it is considered acceptable to proceed with the selected model and method of calculation because the results are intended only as an illustration of how the ice will affect the stability of the lifeboat and give an easy method for detecting icing by observing the change in the roll period of the lifeboat.

Stability calculation results

The parameters given in Table 4 have been used in the base case for the stability calculations.

Description	Value
Length of lifeboat	13,6 m
Beam of lifeboat	3,6 m
Height of lifeboat	4 m
CoG empty lifeboat	30% of height
CoG passengers	45% of height
Mass of empty LB	13500 kg
Mass of passenger	100 kg
No. of passengers	65
Density of seawater	1025 kg/m3
Density of ice	650 kg/m3
Type of lifeboat	free fall lifeboat

Table 4, Lifeboat parameters

The diagram illustrates how the beam and centre of gravity of the passengers affect the metacentric height and the roll period. In figure 3 the COG of the passengers is set at 45% of the lifeboat height. The results illustrate how the metacentric height is effected by the combined CoG of the lifeboat, passengers and ice. It is always wise to ensure that the CoG in all cases is as low as possible in order to optimise and improve stability.

The effect of ice accretion is clearly illustrated. As the ice load increases and the metacentric height approaches zero, the roll period increases dramatically. This provides an easy method for the occupants of a lifeboat to detect that the lifeboat is icing over. It is extremely important that the lifeboat crew are aware of the issue of icing and manoeuvre the vessel optimally with regard to minimising icing. If icing becomes serious the lifeboat will roll more slowly from side to side. The ice has low density compared to seawater and will float. The ice density can be expected to be in the range of 500 to 800 kg/m^3 because air will be mixed into the spray before being deposited as ice. The passengers would be strapped in and ensure a righting moment as required by the standards. The situation could become worse if the lifeboat is damaged and there is free water inside. Lifeboats are designed to have sufficient buoyancy and stability in a damaged state with free water inside. They are however not evaluated for the combined effects of icing and free water inside due to damage. A slow roll caused by icing may lead to the lifeboat developing a high angle of heel and lack of response to righting. In this damage condition, it can be expected that people may release their seat belts and further increase problems with stability due to the loss of righting moment.

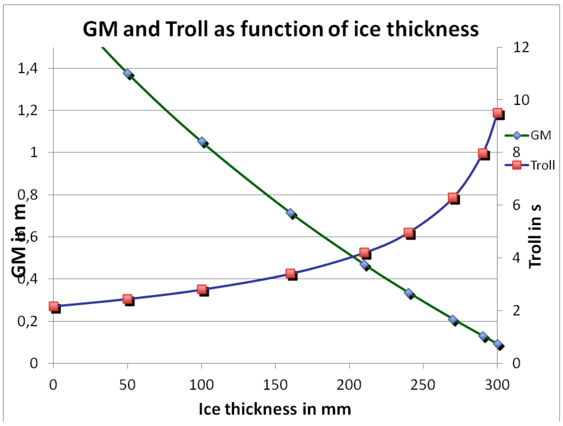

Figure 3, Metacentric height (GM) and roll period (Troll) shown as a function of ice thickness

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Meteorological conditions

The analysis of the meteorological data for 2008 and 2009 for stations around the Barents Sea coincides with what can be expected from ISO-19906 and Norsok N-003. Ice accretion needs to be considered for lifeboats and rescue vessels. Weather conditions can be such that lifeboats and passengers may need to ride off the weather and wait for a better window for rescue. The main weather concerns during the period of October to May when operating in the Barents Sea will be the threat of polar lows, ice accretion and low air temperature. Impaired visibility due to fog can be experienced mainly from May to August but cannot be ignored for the remainder of the year.

Lifeboat stability

The meteorological data and the calculations indicate that the stability of lifeboats could be impaired due to ice accretion. Capasizing is not likely but an unstable situation with the lifeboat potentially lying on its side and rolling slowly can be expected. This type of situation may threaten stability even further if passenger release their seat belts. Ice accretion is an issue that the designers and producers of lifeboats are aware of, but has not been investigated in any detail. Proper consideration of ice accretion and lifeboat stabilty is required.

Evacuation and rescue means

Equipment available for evacuation may encounter conditions that render them inappropriate. The limitations of existing evacuation and rescue systems are generally understood /1, 3 & 6/. Life rafts could prove a poor option for evacuation if they do not have sufficient thermal insulation for cold climate conditions. Poor performance of life rafts in rough sea conditions, especially if evacuation should be required in a polar low, must be considered before choosing them as an option.

It is important that the effects of the cold air on human performance during the winter are examined thoroughly and that current evacuation systems are designed accordingly. Thermal insulation of survival suits, lifeboats and life rafts should be examined specifically before being applied as survival equipment in the Barents Sea.

Fog may represent the main threat to medical evacuation of sick or injured personnel from a facility. This is also the case for other areas than the Barents Sea, however there is generally a greater risk of fog in some areas of the Barents Sea.

Operational considerations

Access to reliable weather forecasts is paramount for operating in the Barents Sea. Responsible personnel onboard facilities operating in the Barents Sea should be competent in the interpretation and understanding of weather forecasts and the implications the conditions may have in an evacuation and rescue situation. Awareness to potential ice conditions is important as activity moves to the north, to or beyond Bjørnøya, and to the east towards the borderline with Russia. All year operations in the Norwegian sector of the Barents Sea is considered possible when appropriate risk analysis and risk reduction measures are put in place.

Recommendations

Third generation rapid response rescue vessels are recommended as standby vessels in the Barents Sea. Response to ice accretion must be investigated for these vessels. Their rescue capacity and ability is by far the best that is currently available. They have a larger operation window for recovering a lifeboat from the sea thereby reducing the exposure of the lifeboat to weather and potential icing situations.

Freefall lifeboats are strongly recommended for the Barents Sea in the areas where sea ice is not expected. This conclusion is drawn based on their superior performance as indicated by NPD report YA-795, /3/, and the improvements that have been made to these lifeboats during recent years.

This report indicates that the effect of ice accretion on lifeboat stability should be of concern and must be investigated for each lifeboat model that is intended to be used on facilities operating in the Barents Sea.

The effect of ice accretion on standby and rescue vessels should also be investigated for each vessel that is intended for operation as a support vessel to any petroleum facility.

The adequacy of thermal insulation should be evaluated for all evacuation, rescue and survival equipment that is intended for use in the Barents Sea.

Regulatory requirements

The currents regulations are functional and risk based. They are considered sufficient to regulate safe evacuation and rescue in the Barents Sea. The guidelines to the regulations should be complemented with references to standards like ISO-19906. Specific requirements for thermal insulation of evacuation, rescue and survival equipment for use in the Barents Sea should be developed and referenced in the regualtions. This is work that will take place in the continuation of the Barents 2020 project. Specific requirements to the use of third generation rapid response rescue vessels should also be considered. It is important to note that the new freefall lifeboat standard, DNV-OS-E406, does not apply for the design of lifeboats on host facilities where sea ice or ice floes can occur. The functional requirements in the regulations regarding evacuation are, however, still applicable for facilities where sea ice can occur although they do not refer to any standard or technical solution.

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Note: /10, 11, 12, 13, & 14/ were presented at a seminar at Petroleumstilsynet, February 2009, Preparations for the development of oil & gas fields in the Barents Sea South.