University of Stavanger

SARex Spitzbergen

April 2016

SEARCH AND RESCUE EXERCISE CONDUCTED OFF NORTH SPITZBERGEN

EXERCISE REPORT

Editors: Knut Espen Solberg, Ove Tobias Gudmestad and Bjarte Odin Kvamme

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Foreword

The Norwegian Coast Guard performs several duties on behalf of Norwegian Society. One important duty is to contribute to search and rescue operations offshore and in particular in Arctic areas.

A very successful rescue operation was carried out by the Coast Guard vessel *KV Senja* on 20 June 1989 when the cruise liner *Maxim Gorkiy* collided with an ice floe on its way from Iceland to Magdalenafjorden, Svalbard, and was close to sinking. Many of the 995 passengers and the ship's crew left the ship in lifeboats, while some were standing on ice floes when *KV Senja* arrived on the scene only three hours after the incident. *KV Senja*, which was assisted by three Sea King helicopters, rescued everyone; however, it was only by chance that the Coast Guard vessel was in the area.

Recently (November 2015), the cruise liner *Le Boréal* suffered a fire in its engine room, when near the Falkland Islands; all 347 passengers and the crew were evacuated into rafts and lifeboats. The emergency evacuation was characterized as "an extremely complex and hazardous rescue operation in difficult conditions". Recent incidents involving rescue operations in Arctic waters also include the rescue of 30 crew members from the Canadian fishing vessel *FV Saputi* in the Davis Strait (February 2016), where the Danish Coast Guard came to assist.

Since the rescue of passengers from *Maxim Gorkiy*, the sinking of a cruise liner has been considered the ultimate challenge for the rescue capability in the Arctic area. While AECO – the Association of Arctic Expedition Cruise Operators – is constantly working to improve safety for cruise vessels and passengers, the official search and rescue capability must be prepared to handle incidents with cruise liners needing support, and there is a need for training in such incidents.

One reason for a renewed interest in Arctic search and rescue is that the new International Maritime Organization (IMO) based regulation, the International Code for Ships Operating in Polar Waters, also known as the Polar Code, will be implemented in January 2017. The Polar Code is a functional risk based code that applies to all vessels covered by the IMO that operate in Arctic/Antarctic waters. The code enforces additional requirements in respect of search and rescue equipment: Those evacuating from a vessel in distress in polar waters should be able to survive a minimum of five days in the rescue equipment, be it in a lifeboat, a life raft or in equipment arranged on the ice. The length of the stay imposes strict requirements on clothing, food supply and equipment. There are currently no guidelines indicating prescriptive measures for how to obtain compliance with the functional requirements.

Concerns related to how the Polar Code requirements can be met and the preparedness of the SAR capabilities to meet the requirements, including the Coast Guard's preparedness to meet the challenges, were discussed in meetings held in relation to safe operations in Arctic regions. The idea of a joint exercise between official government institutions, companies manufacturing safety and rescue equipment, medical expertise and academic institutions arose during discussions with Knut-Espen Solberg of GMC Maritime AS / University of Stavanger and was later applauded by a large number of relevant organizations.

The initiative by the University of Stavanger, in cooperation with other institutions, to put the exercise in place jointly with the crew on board *KV Svalbard*, is much appreciated, and everyone benefitted from a very educational exercise during the period from 22 to 28 April 2016. All activities were conducted in Woodfjorden, north on Svalbard, and it was very encouraging to see how the crew on *KV Svalbard* worked well with the project participants to ensure realism and the collection of scientific data from the exercise. The learnings were much appreciated by my crew and myself. It is to be hoped that the results of the exercise can give input to realistic guidelines for the implementation of the Polar Code.

KV Svalbard, 30 May 2016

Endre Barane, Commanding Officer

Scope of the exercise

The objective of the SARex exercise, conducted north of Spitzbergen in ice-infested water in late April 2016, was to identify and explore the gaps between the functionality provided by the existing SOLAS (International Convention for Safety of Life at Sea) approved safety equipment and the functionality required by the Polar Code. The exercise was a joint collaboration between the Norwegian Coast Guard (using the Coast Guard vessel *KV Svalbard* as the exercise platform), experts from industry, governmental organizations and academia. The exercise scenario was to be along the lines of a "*Maxim Gorkiy* scenario", where an expedition cruise ship sinks in the marginal ice zone north of the coast of Svalbard.

The detailed objectives of the exercise and the associated research program were to:

- Assess the adequacy of the lifesaving appliances as required by the IMO Polar Code.
- Identify the gaps between SOLAS approved rescue craft (lifeboats and life rafts) and the requirements defined in the IMO Polar Code.
- Identify the gap between SOLAS approved personal protective equipment (PPE) and the requirements defined in the IMO Polar Code.
- Assess the personal/group survival kits as defined by the IMO Polar Code.
- Train Norwegian Coast Guard personnel in emergency procedures in ice-infested waters, with particular reference to evacuation and rescue from cruise ships.

The Coast Guard conducted the exercise, together with the scientific team on board the vessel *KV Svalbard*, during the last week of April 2016. The Coast Guard staff on board the vessel were coordinated by the Captain of *KV Svalbard.* The team of academics (with specializations related to Search and Rescue (SAR), cold climate engineering, emergency medicine and winterization of equipment) included members from the following institutions:

- University of Stavanger
- UiT – The Arctic University of Norway
- Norwegian University of Science and Technology (NTNU), Trondheim
- Nord University, Bodø
- St. Olav Hospital, Emergency Center, Trondheim
- The Norwegian Armed Forces' Emergency Surgery Team
- Memorial University of Newfoundland, St. Johns, Canada

Also present during the exercise were the following participants:

- A team of medical doctors with specializations in hypothermia, evacuation and triage
- Equipment manufacturers providing lifeboat, life raft and survival suits/thermal protection aids
- Regulators representing maritime and petroleum regulations, including classification societies
- End users from the oil and gas industry and a winterization contractor
- Students from the University of Stavanger and UiT – The Arctic University of Norway preparing their master theses
- Media coordinator

The exercise was conducted as part of the cooperation between institutions in the Roald Amundsen network, involving the University of Stavanger and UiT – The Arctic University of Norway. Other partners in this network are IRIS, Stavanger, and research institutions in Northern Norway (Norut and Aquaplan-niva). Persons affiliated with the government funded SARiNOR Project, organized by Maritimt Forum Nord, were also invited to participate, and SARiNOR WP7 at Nord University for providing additional financial support to the project.

Summary

The main objective of the SARex full-scale exercise (April 2016) was to identify and explore the gaps between the functionality provided by existing SOLAS approved safety equipment and the functionality required by the Polar Code.

The aim of the exercise was to simulate, in as realistic a manner as possible, the rescue of persons from a sunken mid-size cruise ship in cold climate conditions in the area where the Polar Code is applicable.

The Polar Code is a functional set of requirements. Such requirements specify what to be achieved rather which solutions to choose. Risk and vulnerability analyses become powerful tools in the development of ship design, voyages and safety measures. The Polar Code does specify, however, a minimum of five days' survival time prior to abandoning ship. Achieving this goal puts additional strain on the chain of lifesaving appliances/survival equipment, in addition to the training/knowledge of the crew.

Prior to the exercise, a cross-disciplinary team, comprised of doctors, suppliers, regulators and users, assessed the Polar Code. There was a special focus on the interpretation of Chapter 8: Lifesaving Appliances and Arrangements. The following definition was established as the overarching goal of the chapter:

> *The equipment required by the Polar Code is to provide functionality that enables the casualty to* ***safeguard individual safety****, which means to maintain* ***cognitive abilities, body control*** *and* ***fine motor skills*** *for the maximum expected time of rescue.*

The weather during the exercise was ideal for performing the exercise, with an ambient air temperature of about -9 °C, a water temperature of about -1 °C and little wind. These are considered representative weather conditions for the cruise ship season in Svalbard. Due to the favorable weather conditions, seasickness was not an issue for any of the participants.

The Norwegian Coast Guard vessel *KV Svalbard* was used as the mother ship for the exercise, and the main topics addressed during the exercise can be assessed as follows:

Functionality of life raft/lifeboat under cold climate conditions

The evacuation from the Coast Guard vessel was performed with the help of the vessel's man overboard boats (MOB) and does not represent a valid exercise topic. The transfer of the survivors from the lifeboat and life raft to the vessel was also carried out by MOB boats. It should be noted that all those participating in the exercise were taken back to *KV Svalbard* as soon as one or more of a predefined abortion criteria was met. The majority of the candidates said that they would have been able to extend their stay for a longer time without any major health issues.

In the lifeboat, air quality and low oxygen levels were identified as issues, as the ventilation system required the engine to be operating. The personnel experienced extensive heat loss from the structure (floor, seat and backrest) of the lifeboat. Improvements should be considered with respect to insulation of the lifeboat structure in combination with the insulating capabilities of the personal protective equipment in order to obtain a survivability rate in accordance with the minimum five-day requirement set by the Polar Code.

The personnel in the life raft experienced major heat loss through the bottom of the life raft. This became especially evident when sitting or lying down, regardless of the type of personal protective equipment. The life raft canopy was kept closed to retain heat. The lack of ventilation caused the air to be moist, and extensive condensation developed. Due to the combination of condensation and sweat, survivors suffered from wet insulation layers in their personal protective equipment, followed by loss of insulation

and freezing. Low oxygen levels were also an issue, and the raft had to be vented frequently, losing a significant amount of heat in the process. Furthermore, the congestion inside the raft was a problem, causing reduced ability to move, triggering reduced blood circulation in the body's extremities, resulting in freezing hands and feet.

It is unlikely that the majority of the people evacuated to a life raft and lifeboat (engine shut off) would survive for a minimum of five days according to the Polar Code criteria.

The presence of a well-trained lifeboat/life raft captain proved very important for maintaining both the safety and the morale of the personnel on board. This is especially important when the duration of the stay is long (a minimum of five days, along the lines defined in the Polar Code).

It should be noted that most of the people involved in the evacuation exercise were either young and fit persons or mature persons with good physical health. The lack of elderly or disabled persons involved in the exercise renders the results on the positive side, as the participants were fitter and in better physical and physiological shape than the average seafarer/passenger. Seasickness was not an issue in this exercise, as the waters were calm, and all participants were given seasickness pills to prevent any occurrence.

Functionality of personal lifesaving aids (e.g. thermal protection/survival suits)

The personal protective equipment helped the participants to maintain an adequate body core temperature. The buildup of moisture in the insulating layers inside the survival suits caused a considerable loss of insulating capabilities.

The available standard life jacket with thermal protection (neoprene arms) most commonly utilized on cruise/passenger vessels did not provide the adequate thermal protection required to maintain satisfactory core body temperatures on either the lifeboat or the life raft.

Some of the participants wearing survival suits were submerged in seawater for a short period. As long as there were no leaks and the interior insulating layer remained dry, the submersion proved to have little effect on the equipment's insulating capabilities.

When utilizing personal protective equipment for a prolonged period, the functionality of the hands (fine motor skills) is of key importance. To conduct tasks requiring fine motor skills when wearing neoprene gloves proved difficult.

The exercise also proved the importance of the participants/passengers becoming familiar with the personal protective equipment prior to a potential abandon-ship situation in order to ensure correct sizes and functionality.

Handling of mass evacuations in polar regions

One element of the exercise required the Coast Guard staff to conduct a mass evacuation from the rescue craft onto the Coast Guard vessel. A large number of the evacuated personnel simulated a hypothermic state. Establishing, implementing and conducting regular training on the procedures for handling disabled, wounded and immobile passengers when evacuating a large group of people is of great importance for ensuring an efficient evacuation. Evacuating a large number of immobile casualties takes an excessive amount of time and puts a great strain on the staff on board the Coast Guard vessel. The medical state of the casualties is of key importance in determining the time required to evacuate personnel from a lifeboat/life raft on to a rescue vessel

The potential of involving those casualties who are in good condition in monitoring/aiding the caretaking process of the patients should be emphasized.

Heavily injured persons require considerable resources from the ship's crew. As there are limited resources available on a vessel like *KV Svalbard*, strict principles of triage must be exercised.

Conducting an efficient triage requires clear procedures and puts great mental pressure on the individuals involved in the task.

It is important to distinguish between the number of casualties a rescue vessel is able to carry and the number of heavily injured/hypothermic casualties for whom the rescue vessel can provide medical treatment. It is of great significance to recognize the limited onboard capacity available for the medical treatment of heavily injured/hypothermic patients when determining the SAR capacities in a large accident.

Survivability on sea ice

In addition to evacuation on to the ice, personal and group survival kits were evaluated. The survival kits were heavy and voluminous. The capacity of both the lifeboat and the life raft would be exceeded if the prescribed number of persons were to be carried in addition to the personal and group survival kits.

Utilizing the survival kits also required full functionality of the fingers/hands. This proved difficult as most personal protection equipment is only equipped with thick neoprene gloves. As a result, all activities had to be carried out using bare fingers, which resulted in frostbite.

Many of the activities related to the survival equipment, e.g. pitching a tent and utilizing a stove, require training and familiarity with the equipment.

The life raft proved easy to pull onto the ice with the assistance of only a few persons. On the ice, the life raft served as a tent in a much more comfortable way than a special tent provided for the purpose.

Acknowledgements

The SARex exercise conducted north of Spitzbergen in April 2016 was made possible through the cooperation between the Norwegian Coast Guard and Norwegian official and academic institutions as well as industrial companies.

We appreciate in particular the positive response of the Norwegian Coast Guard to participating in the exercise, and we admire the attitude and interest of all the personnel on board the Coast Guard vessel *KV Svalbard* during the planning and execution of the exercise.

The involvement of the 23 scientists, professionals and students on board, representing the scientific institutions and industrial companies, furthermore, made the exercise a success by meeting all its planned objectives.

All participating companies and all parties bore their own costs of participation. Without the genuine interest and support from all parties, the exercise would not have been possible. Additionally, we thank SARiNOR WP7 at Nord University for providing additional financial support to the project.

We also appreciate the full support of the Faculty of Science and Technology at the University of Stavanger during the planning of the exercise.

University of Stavanger, September 2016

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Ove Tobias Gudmestad Knut Espen Solberg

Exercise leaders

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I. Main Report

The following authors have composed the main report: Knut Espen Solberg[1] (ed.), Ove Tobias Gudmestad[2] (ed.), Bjarte Odin Kvamme[2] (ed.), Tord Nese[3] and Raymond Dalsand[3].

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I.1 Abstract

The International Maritime Organization (IMO) has developed the functionally based Polar Code, which will come into force on 01 January 2017. The code requires marine operators to provide lifesaving equipment that ensures a minimum of five days' survival time. This requirement puts additional strain on the existing lifesaving appliances.

The objective of the SARex Spitzbergen full-scale exercise (April 2016) was to identify and explore the gaps between the functionality provided by existing SOLAS approved safety equipment and the functionality required by the Polar Code. This was performed through an exercise conducted jointly by the Norwegian Coast Guard and leading experts from industry, governmental organizations and academia. The exercise was to be along the lines of a "*Maxim Gorkiy* scenario", where an expedition cruise ship sinks in the marginal ice zone off the coast of Svalbard.

It was planned to simulate relevant polar conditions, incorporating sea ice, sea swell, low air and water temperatures and remoteness. The polar conditions generate additional polar-specific challenges for the exercise's participants and for the lifesaving equipment; these were identified and assessed. The following topics were addressed in the exercise that took place in the marginal ice zone off the coast of Svalbard in late April 2016:

1. Functionality of life raft/lifeboat under polar conditions.
2. Functionality of personal protective equipment (PPE) (e.g. thermal protection/survival suits).
3. Additional training requirements for crew and passengers.
4. Evaluation of Coast Guard's search and rescue procedures, including handling of mass evacuations in polar regions.
5. Evacuation to sea ice.

I.2 Introduction

The Arctic has experienced increased marine traffic in recent years. In 2010 The Arctic Council working group on the *Protection of the Arctic Marine Environment* (*PAME*), during project PAME I (based on automatic tracking system data from the Automatic Identification System (AIS)), identified 954 individual vessels operating in the Arctic. In 2012 PAME II (based on AIS data) identified 1347 unique vessels visiting the same area. Of the vessels identified in 2010, 44 were registered as passenger vessels, while in 2012, 71 individual passenger vessels were identified.

In the document "*Masterplan Svalbard mot 2025*[1]", it is expected that we will see a doubling of tourist activity around the Svalbard archipelago, from today's 60,000 tourist arrivals to 120,000 tourist arrivals towards 2025. This substantial rise in activity level will increase the likelihood of marine accidents occurring and place additional strain on the existing SAR infrastructure.

The increase in likelihood, combined with the high consequence associated with marine accidents in a cold climate environment, has placed the topic of cold climate marine survival on the agenda.

On 1 January 2017, the International Code for Ships Operating in Polar Waters will come into force. The aim of the code is to mitigate the additional risks associated with cold climate marine operation. To enable the successful implementation of the code, it is important to define a baseline with regard to the functionality associated with use of standard SOLAS approved equipment in cold climate conditions.

The majority of testing of current lifesaving appliances has been conducted in a controlled environment. In a real-case scenario, or during full-scale exercises, additional challenges will arise. The aim of the SARex project is to identify these additional challenges and to contribute to the definition of a baseline for standard SOLAS approved lifesaving appliances, as this is essential both for designing lifesaving appliances that are fit for purpose and for proving compliance with the functionally based International Code for Ships Operating in Polar Waters.

[1] http://www.sysselmannen.no/Documents/Svalbard_Miljovernfond_dok/Prosjekter/Rapporter/2015/14-%2020%20Masterplan%20Svalbard%20mot%202025.pdf

I.2.1 Regulatory rationale

The International Code for Ships Operating in Polar Waters is referred to by many as the *Polar Code.*

The code is a supplement to existing IMO instruments, and the intention is to mitigate the additional risks present for people and environment when operating in polar waters.

Contrary to most of the existing IMO instruments, the International Code for Ships Operating in Polar Waters is based on a risk-based approach, only stating functional requirements. This implies that the marine operators are to identify risks and mitigate them through a holistic approach. What is included in a holistic approach needs a proper interpretation based on the systems and activities involved.

Identification of risks is dependent on mariner knowledge and experience. This requires in-depth knowledge in relevant fields, e.g. area of operation, vessel capabilities, crew competence and type of operation. The risk-based approach is already familiar to the industry in the ISM (International Safety Management) code. The Polar Code is, however, more specific, specifying sources of hazards. Nevertheless, the code indicates only to a slight degree the risk acceptance criteria and does not specify adequate mitigation measures. A goal/objective based regulatory regime has very positive experiences in the Norwegian offshore oil and gas industry; this might be explained by stable relationships between the major actors; operators, employees and authorities.

As of today, there is no common industry understanding/interpretation of the code. There is also marginal ongoing official work harmonizing the interpretation of the code between different flag states or class societies. As a result, a degree of discrepancy in the interpretation should be expected in the coming years.

For vessel owners/operators, this lack of consistency, transparency and predictability represents a major challenge. The challenge is cross-disciplinary and affects issues from availability to adequately trained crew to safety equipment. The economic impact associated with the implementation of the Polar Code does not only lie in the purchase, storage and maintenance of new equipment; there are huge economic implications in the risk of having to reduce the passenger capacity of cruise vessels.

A reduction in the number of passengers could emerge as a result of the additional equipment the Polar Code requires to be carried on board the rescue craft, e.g. personal survival kits, group survival kits and food and water for a minimum of five days. All rescue craft have limitations with regard to both available space and weight-carrying capacity. Most vessels have already stretched these capacities. Adding the additional equipment required by the Polar Code will mean that the number of persons per rescue craft will have to be reduced. Decreasing the number of passengers on board a cruise vessel will have a huge economic impact on the cruise operator, as it will affect their income.

Probability of survival

The aim of the functional requirements stated in the Polar Code is to mitigate the additional risks present in the Arctic/Antarctic environment. From a lifesaving perspective, there are two dominant factors influencing the probability of survival in the areas applicable to the Polar Code:

Vulnerability to the environment

Exposure to low air and water temperatures represents a major challenge for the human body. The risk represented by low temperatures can be divided into two:

- Hypothermia – reduction in body core temperature (below 35C), inducing shivering, loss of cognitive abilities and ultimately death.
- Freezing of body extremities – during extreme low temperatures, freezing of body extremities can be induced after only minutes of exposure. This will result in loss of functionality in the affected limb, which again reduces the probability of survival.

Exposure of the body to sub-zero temperatures will reduce the survival time substantially compared to survival in more temperate zones.

In addition to the low temperatures, several distinct features of the Arctic/Antarctic environment represent additional challenges for persons who experience an abandon-ship situation. These challenges are typically the risk induced by sea ice/icebergs to the rescue craft, hostile wildlife and unpleasant sea state and weather conditions.

Time to rescue

Due to a low concentration of infrastructure in most of the areas where the Polar Code is applicable, the rescue time is long. Currently, many of the search and rescue suppliers base their approach on helicopter evacuation. This has limitations, not only with regard to weather but also, more importantly, with regard to both range and capacity to carry survivors. As a result, much of the area where the Polar Code is applicable is outside helicopter range. Within the areas where there are helicopters available, the capacity to carry survivors is limited typically to a maximum of 10 to 20 persons.

For marine accidents with a substantial number of casualties, access to the site of the accident by other vessels is essential. Due to large distances and relatively low vessel concentrations for a larger part of the year/areas, the time to rescue can be relatively long.

The combination of a high vulnerability to the environment and a long time to rescue represents the major challenges with regard to survival in those areas where the Polar Code is applicable. It is clear, however, that the largest discrepancy from an "average" accident occurring in more temperate parts of the world is the vulnerability to the environment, causing a large expected reduction in survival time.

The only way to combat the vulnerability to the environment is through vessels being self-sufficient, carrying lifesaving appliances that are fit for purpose, providing adequate protection. This applies to the rescue craft as well as to the group and personal protective equipment. Furthermore, a cruise ship operator needs to develop survival strategies for the crew and passengers also in the evacuation phases.

Chapter 8 of the Polar Code states that a vessel is to provide equipment that enables the passengers to survive a minimum of five days or the anticipated time of rescue. As the requirements are functional, a holistic approach is required. The holistic safety management approach implies that the vessel owner consider all relevant conditions, factors and parameters. As many of the conditions, factors and parameters are interrelated and dynamic, the task must be carried out with margins of allowance for the

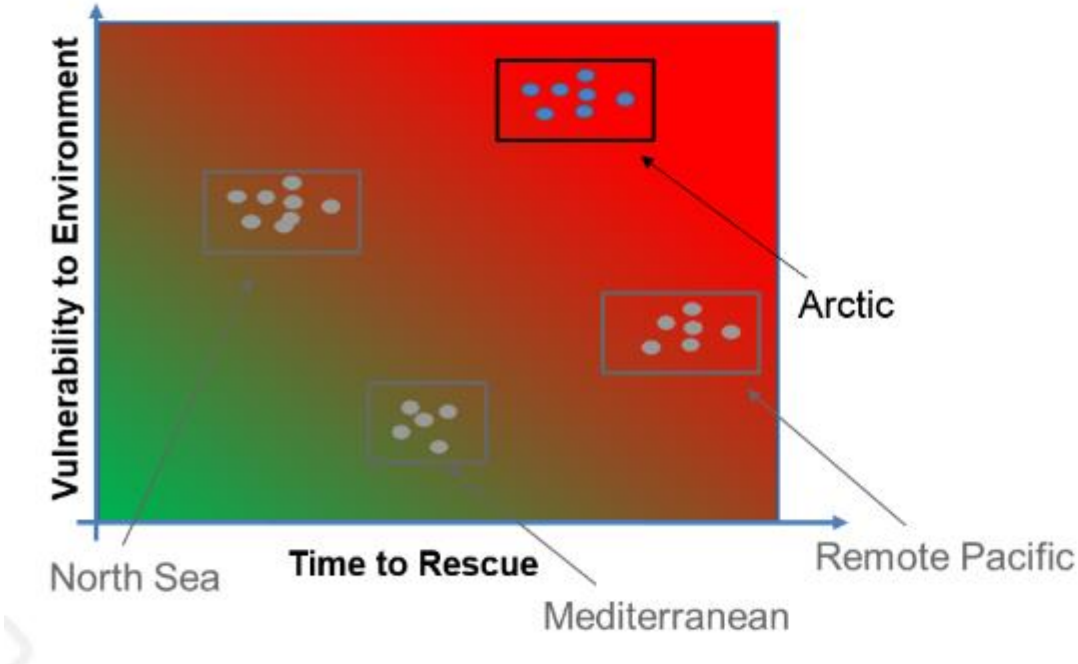

Fig. I–1: Time to rescue as a function of vulnerability to the environment

uncertainty associated with the quantities. The following list of conditions, factors and parameters are to be considered when assessing the probability of survival:

- Governing metocean conditions for the area of operation
- Remoteness
- Available SAR infrastructure
- Performance of SAR operators
- Energy required to maintain the core temperature of the persons
- Water/food required to maintain an adequate metabolism
- Insulating properties of the rescue craft
- Insulating properties of the PPE
- Number of passengers
- Physical condition of the passengers
- Cumulative weight of group and personal survival equipment
- Carrying capacity of survival craft
- Abandon ship activities
- Survival strategies onboard the evacuation vessel
- Survival craft management

Our interpretation of Polar Code – functionality parameters

The IMO Polar Code 8.2.3.3 states:

> *Taking into account the presence of any hazards, as identified in the assessment in chapter 1, resources shall be provided to support survival following abandoning ship, whether to the water, to ice or to land, for the maximum expected time of rescue.*

This sums up much of the rationale behind Chapter 8: Lifesaving Appliances and Arrangements.

The term "survival" is frequently used in the code but not defined. Based on discussions with project partners, including medical personnel, it has become clear that survival is only possible if the casualty is able to maintain adequate functionality to safeguard individual safety when exposed to the environment for a prolonged period. The project chose to define the following as the overarching goal for Chapter 8:

> *Resources provided are to ensure that the personnel are to maintain* ***adequate functionality to safeguard individual safety*** *for a minimum of five days or expected time to rescue.*

A survival period of five days will require the body to maintain "normal" bodily functions for a majority of the time. The body can maintain and survive a hypothermic state with shivering and loss of cognitive abilities for a period but not for five days continuously. Based on discussions with doctors and physiologists, a hypothermic state will in most cases represent the *start of the end* in a cold climate survival scenario with a duration of a minimum of five days. It is of great importance that the survivors never reach a hypothermic state, as recovery will be difficult.

There are variations within a population concerning ability to handle cold, physical abilities in relation to body core temperature and metabolism. When interpreting the Polar Code, it is beneficial to avoid criteria based on body temperature readings (due to large individual variations). Body functionality is the preferred parameter that defines the potential survivability of the personnel.

Survival is dependent on carrying out the right actions at the right time (safeguarding individual safety). Typical actions are rationing/consuming of food/water, bailing, drying insulating layer, communicating with S&R facilities and keeping lookout.

The following functionality parameters have been identified as critical for carrying out the activities essential for survival (ability to safeguard individual safety):

Cognitive abilities

All actions essential for survival are initiated through cognitive processes. Being able to comprehend the situation and carry out relevant actions requires cognitive abilities. Staying mentally fit is also important for the ability to generate the motivation for survival.

There is a strong relationship between loss of cognitive abilities and reduction of body core temperature.

Body control

When the body core temperatures fall below about 35.5C, the large muscle groups start a process of rapid contraction, resulting in shivering. Through the muscle contractions, the body produces heat, trying to increase the body's core temperature. These contractions are not controllable, and the person is unable to attend to his/her own needs or carry out the actions required to ensure survival.

Seen from a five-day perspective, the contractions can only endure for so long before the muscles are exhausted. The duration is dependent on individual health, age and fitness. If the person is not brought into a warm space, a further decrease in body core temperature is experienced when the shivering stops.

Fine motor skills – extremities

Survival is dependent on carrying out actions (see above). Many of these actions require fine motor skills and are carried out by the use of hands, i.e. pushing the PTT (Push-To-Talk) button on a VHF radio, opening water rations and opening/closing zippers for venting.

The Polar Code requires equipment to provide functionality that enables the casualty to **safeguard individual safety**, which means to maintain **cognitive abilities, body control** and **fine motor skills** for the maximum expected time of rescue.

I.2.2 Scenario

Many of the Arctic/Antarctic cruise industry vessels venture into remote areas during the summer season. Most of this activity takes place in open water around the marginal ice zone. Very few vessels have the capacity to venture deep into the polar pack ice.

Operating in the marginal ice zone represents a hazard with regard to collisions with growlers and ice floes. This was the case in both the *Maxim Gorkiy* (Svalbard 1989) accident and the *Explorer* accident (Antarctica, 2007).

The scenario created in the exercise was to be representative of the conditions experienced during the cruise season in Svalbard. This included the following components:

- Relatively high ambient air temperatures, from -10 °C to 0 °C
- Low water temperatures, about -2 °C
- Sea ice present in the area
- Hazards related to wildlife
- Relatively high number of passengers
- Varying insulating capabilities in the personal protective equipment
- Evacuation to life raft, lifeboat and on to ice floes

I.2.3 Exercise goal

Not all aspects of abandoning ship and rescue were highlighted in the exercise. The focus was on the additional challenges present during an abandoning-ship and rescue operation in a cold climate. The exercise contained the following main goals:

- Assessment of the effect of different types of personal protection equipment (PPE) (e.g. thermal protection aids, insulated/non-insulated survival suits)
- Assessment of lifeboat vs. life raft
- Assessment of personal/group survival kits
- Assessment of evacuation on to ice
- Triage
- Assessment of resources required to handle large evacuations in a cold climate

I.2.4 Structure of the exercise

The exercise was divided into different phases, and designated personnel were responsible for documenting each phase. The exercise had the following structure:

1. **Participant preparations** – workshops taking place on board *KV Svalbard* during the transit to the ice edge. The workshops to focus on the measures participants can take during the evacuation and the stay in the survival craft to increase survival time.
2. **Safety workshop** – all participants and crew on board *KV Svalbard* to participate in a HAZID workshop, identifying and mitigating all real hazards present during the exercise.
3. **Evacuation** – disembarkation from *KV Svalbard* to the survival craft. Documentation of hazards/risks.
4. **Stay in life raft/lifeboat** – measurements of body temperatures, assessment of survival strategies. Documentation of survival strategies.
5. **Evacuation on to ice** – the personnel to evacuate from life raft on to an ice floe and utilize group survival kits for survival.
6. **Rescue** – documentation of mass evacuation methods from survival craft to rescue vessel. Assessment of rescue time/challenges for different methods of evacuation.
7. **Post rescue treatment** – documentation of strategies for handling large numbers of patients with varied needs on board *KV Svalbard*. Availability of telemedicine contact.
8. **Technical evaluation of equipment** – information to be obtained regarding winterization of all equipment being used: lifeboat/raft, winterization equipment, effectiveness of clothing, etc.
9. **Exercise evaluation** – evaluation workshop taking place on board *KV Svalbard* during the transit to Longyearbyen. The different phases to be assessed with input from participants, medical personnel and crew of *KV Svalbard*.

I.2.5 Phases

The exercise was divided into three phases. Each phase was to highlight special challenges related to a cold climate accident scenario. Due to technical and safety reasons, there was a pause between the different phases. During the pause, the scientists documented the experience of the participants, in addition to gathering and structuring the measured data.

Phase 1 – Survival

The aim of this phase was to identify the functionality gaps between standard SOLAS approved lifesaving appliances and the requirements imposed by the Polar Code. The focus was on rescue craft (life raft and lifeboat) and personal protection aids.

Phase 2 – Rescue

Conducting large-scale mass evacuations in a cold environment puts additional strain on the rescue operation, as it is of great importance to minimize both time in and exposure to the low air temperatures. In this type of scenario, the personnel to be rescued are expected to have varying degrees of hypothermia that must be taken into account. The aim of this phase was to identify the challenges associated with large-scale mass evacuation in a cold climate.

Phase 3 – Evacuation on to ice

The Polar Code requires group survival equipment to be carried on board a vessel if there is the possibility of evacuating onto the ice or onto land. The code makes recommendations with regard to the equipment that is to be carried. The aim of this phase was to evaluate the functionality of the personal/group survival kits when utilized in combination with personal protective equipment and rescue craft.

I.2.6 Exercise safety

Conducting a full-scale abandon-ship exercise in the sea ice north of Svalbard involves a potential very high risk. Typical risk includes polar bears, unpredictable weather, sea ice crushing rescue craft and long response time. To ensure an adequate risk level during the exercise, the element of risk was introduced to the project in the early planning phases.

The project team had extensive cold climate experience. This included elements like marine operations, scientific fieldwork, expeditions and military operations. This accumulated knowledge was utilized in both the planning and execution phases of the project. This helped to define the time of year to conduct the exercise, exercise area, safety personnel, required marine infrastructure and safety equipment.

Prior to the exercise, a safety workshop was conducted with everyone involved in the exercise to effectively assess and communicate all the risks involved in the planned activities.

During the exercise, extensive precautionary measures were taken to ensure adequate safety for everyone involved. This included:

- Polar bear guards
- MOB boat always present in the exercise area
- Medical personnel on standby
- Relevant onshore safety resources were informed prior to commencing exercise
- Continuous monitoring of weather/ice conditions

1.3 Exercise timeline

The exercise was carried out according to the following timeline:

Day	**Activity**
22.04	Embarkation *KV Svalbard*/transit to ice edge
23.04	Transit to ice edge/exercise: participant workshop
24.04	Exercise Phase 1, survival
25.04	Exercise Phase 1, survival
26.04	Exercise Phase 2, rescue
27.04	Exercise Phase 3, handling of rescue craft in ice/group survival kits
28.04	Transit to Longyearbyen
29.04	Arrival Longyearbyen, disembarkation

I.4 Phase I – Survival in lifeboat and life raft

The IMO Polar Code has a prescriptive requirement of a minimum of five days' survival time. The aim of Phase I was to investigate whether current SOLAS approved lifesaving equipment fulfills the Polar Code minimum five days' survival time requirement. The issue was investigated through a full-scale test, in which a lifeboat and a life raft were occupied with participants wearing different types of personal protection equipment. This included life jackets, thermal protection vests, non-insulated survival suits and insulated survival suits. During the stay in the rescue craft and at the point in which the participants were forced to abort the exercise, their body temperatures and functionality were assessed.

I.4.1 Abortion criteria

Each participant was to participate in the exercise until a predefined condition was reached. To ensure consistency concerning abortion of the exercise, it was important that a clear set of abortion criteria was followed. Based on our interpretation of the Polar Code and due to safety issues, the participants were to leave the exercise when one of the following conditions appeared:

Pt. 1 – Subjective reduction in cognitive abilities

Pt. 2 - Lack of body control (uncontrolled shivering)

Pt. 3 – Subjective assessment of loss of functionality of extremities (e.g. fingers)

Both Pt. 1 and Pt.2 take place when the body's core temperature approaches 35.5 °C. Based on our interpretation of the Polar Code and the workshops with the medical staff, this was defined as *the start of the end*. In a real scenario, the participants would have survived for a period beyond this point. There are, however, large personal variations in the duration of the further cooling process before a fatal state occurs. The duration depends on a combination of parameters like age, fitness and BMI. It is clear, however, that the body cannot endure a further cooling process that has a duration of several days.

I.4.2 Preparations

The extensive scope of the Phase I test required extensive preparations before the test could be carried out. Much of the preparatory work was done in the weeks leading up to the exercise; some remaining elements required the SARex team and *KV Svalbard* crew to be assembled. Performing the last preparations on board *KV Svalbard* while traveling to the designated exercise location meant that the tests were planned in detail, with all necessary resources available.

To identify possible hazards that could arise during the tests and to raise the test participants' awareness of risk, a risk assessment workshop was carried out. The assessment was based on a Preliminary Hazard Analysis (PHA), where possible problems, causes and consequences were identified and described by the analysis group. The session was performed in two separate groups: one for the lifeboat participants and one for the life raft participants. The results from these assessments are presented in *II.2.2 The SAR exercise HAZID prior to the Phase I exercise*.

Members of the *KV Svalbard* crew arranged a polar bear safety information presentation, which gave all participants a good understanding of the dangers related to human activities in areas frequented by these predators. In addition, a general pre-test information and safety briefing for all participants and other involved personnel was conducted. Here, both the SARex team and the *KV Svalbard* crew contributed with important information to ensure that the activities that were to follow would be carried out within acceptable risk limits.

To be able to assess the health effects of remaining in a survival craft for a longer period, a selected group of participants was chosen as test subjects. The medical team, who performed various baseline tests and fitted them with equipment for measurements and data logging, examined these participants.

An important part of the Phase I test was to obtain an indication of the performance of various items of personal protective equipment when used in a lifeboat and life raft and, more specifically, to observe how long the participants could remain functional, along the lines defined in the abortion criteria. The test participants were assigned different types of PPE. In order to have comparable results, all participants wore approximately the same underclothing.

The medical team wanted to establish the effects that a stay in the life raft would have on physiology and psychology. To do this, ten volunteer soldiers were selected, and the medical team performed baseline tests of oxygen uptake, temperature readings and a Conners test. The Conners test is a standardized neuropsychological test and was chosen to obtain a measure of how the brain was affected by cooling. More information about this is found in *Objective report from Phase II of the exercise by the medical team.*

The lifeboat was launched from the aft deck of *KV Svalbard* using the deck crane, as seen in Fig. I–2. Transportation between *KV Svalbard* and the survival craft was performed using the two MOB boats, and these were also utilized for toilet breaks. In addition, there was at least one MOB boat stationed close to the survival craft during the exercise, for safety reasons.

To prevent participants from getting dangerously cold, a set of criteria for assessing their state of health was determined. The SARex medical team set the criteria, in order to control the safety of the participants. All participants were instructed to look for these signs amongst the other participants, in case someone was unable to understand that his or her condition was eligible for exercise abortion. The decision to leave was made by each participant; however, the leader ofn the rescue vessel had the option to force them back to *KV Svalbard* if deemed necessary.

In addition to being observant of the condition of other participants, everyone was instructed to find a “buddy” in the survival craft once the exercise started. This way, two people could look after each other during the exercise and make sure that the “buddy” did not get into a critical state.

I.4.3 Report from lifeboat

This report presents an objective description of how the participants in the lifeboat experienced the Phase I test, as well as the performance of the equipment that was tested.

Exercise

The test started on Sunday 24 April, at approximately 09:40, when all participants had been transported to the lifeboat by the MOB boats, depicted in Fig. I–3. The first hour or so was eventful, with many things happening. The leadership structure was clarified very soon after the exercise started. The designated leader, along with the second in command, was a participant from *KV Svalbard*. The leader managed the situation by performing some tasks himself and delegating others to participants. A question about the general condition of the passengers was asked, and no one reported having any problems. Shortly after this, a participant was given the task of collecting information from the other participants regarding their knowledge and experience, which could be useful in the survival situation. This was performed quickly but thoroughly, through a brief conversation with each participant. The resulting information was recorded in a small notebook.

Fig. I–2: Lifeboat being lowered into the water with the deck crane. ©Jan Erik Jensen

The lifeboat was searched to get an overview of the available rations and equipment on board. When all of the food and water had been located, the leader proposed a plan for handing out rations based on the total amount available. All the participants agreed upon this plan. The water rations were handed out one pouch at a time, each pouch containing 500 ml of water packed in 50–ml portions. It was announced that one 500 ml pouch was supposed to last eight hours then everyone would receive a new ration. It was strongly suggested that everyone should make an effort to drink all of the water from the first ration within the first eight hours, to avoid getting dehydrated. The first handout of food was planned for the afternoon, at approximately dinnertime. This decision was made because all participants had eaten breakfast shortly prior to the test.

Fig. I–3: MoB boat used during test. ©Trond Spande

Approximately 40 minutes into the test, radio contact with *KV Svalbard* was established, and the information was received that the estimated time of rescue would be approximately 48 hours. With this information in place, the leader proposed a watch arrangement, with two people being on watch for two hours, and then the next duo would take over. The two people on watch would spend one hour in the coxswain chair each, while the other would be responsible for keeping the one in the coxswain chair awake and performing other necessary tasks. A watch list with names and times was prepared in a notebook and announced to everyone in the lifeboat. The leader also announced that there would be hourly radio contact with *KV Svalbard*, reporting the status of the situation. All throughout the first hours of the test, the leaders ensured the spirits of the passengers were kept high.

Almost immediately after the exercise start-up, the windows in the coxswain position started to mist up, a minor problem that continued throughout the test. The first general impression was that habitability inside the lifeboat was decent, except for the benches being quite cold and the need to open hatches often due to poor air quality. The benches along the outer edges of the lifeboat were the coldest, along with some of those closer to the centerline. The centerline benches to the rear of the lifeboat doubled as access hatches for the engine room, so, logically, when the engine was running these were warmer to the touch.

After the first eventful hour and a half, the activity level decreased. Some of the participants utilized this time to sleep, while others occupied themselves with the fishing gear that was included in the lifeboat's survival equipment. Earplugs were distributed to everyone, which was a boon because, when the engine was running, the noise was quite loud and annoying for some. Since some of the participants wished to sleep, while others wanted to be sociable, the lifeboat was divided into two zones. The forward zone was dedicated to those who wanted to sleep, and the aft zone was for those who wished to be awake and sociable. Fig. I–4 shows the inside of the lifeboat.

Fig. I–4: Lifeboat test participants in survival suits. One trying to sleep. ©Trond Spande

Around 13:45, a large walrus started to show interest in the lifeboat and life raft, which was attached to the lifeboat by a rope. It surfaced multiple times, on some occasions within only a couple of meters of the raft. The MOB boat was present throughout this episode and succeeded in chasing the animal away after a few attempts. For the occupants in the lifeboat, this experience was mostly entertaining, but it seemed to be somewhat disturbing for the life raft occupants. They had a very limited view from inside the raft, and only thin sheets of rubber separated them from the nearby walrus. Fig. I–5 shows the walrus between the lifeboat and the life raft.

During the appearance of the walrus, the lifeboat's occupants opened most of the hatches on the lifeboat so that they could see the animal. This reduced the interior temperature considerably, and the hatches were therefore closed to allow the temperature to rise again. A general inquiry revealed that the occupants felt all right concerning their body temperature, a bit colder than perfect, but not bad. It was again noted that the cold benches were the main reason for heat loss. Shortly afterwards, a session of

Fig. I–5: A walrus came close to the lifeboat and life raft during the test. ©Tord Nese collective physical activity was organized, including rounds of walking, walking lunges, squats and push-ups. The activities had an apparent positive effect on both body temperature and spirits.

At approximately 15:00, the lifeboat had drifted close to the nearby sea ice, and *KV Svalbard* radioed instructions for maneuvering some distance away from it. After relocating the lifeboat, the engine was shut down to see how the internal temperature would develop without it running. Because the engine could not be used, the MOB boat had to tow the lifeboat and life raft away from sea ice several times during the evening, night and early morning.

The first meal on board the lifeboat was undertaken at 15:40 in the afternoon, as planned. Each passenger received one paper-wrapped ration, containing two square biscuits. It was suggested that everyone should make sure to drink water along with the biscuits, to make them easier to digest. A new water ration was scheduled for distribution at 19:00, so there was no need to save water for later. Opinion was divided regarding the taste and consistency of the biscuits, but there was no doubt that they would have served their purpose in an actual survival situation.

After spending some time wearing the various items of personal protective equipment, the major complaint concerned the moisture buildup inside the suits and thermal protective aids. Those wearing such equipment described it as uncomfortable and stated that the damp underclothing was chilling. Secondly, participants complained about cold feet.

Late in the afternoon, the first participants aborted the test. Throughout the rest of the test period, people left at more or less regular intervals. The early evening was otherwise not very eventful, with the exception of a delivery from *KV Svalbard* containing a quiz book and a deck of cards. The quiz book was used actively for a period, and many of the remaining participants joined in this activity. Others played card games for several hours, while some slept. There were regular physical activity sessions to stay warm and alternative pastime activities such as rocking the boat.

Around 21:00, a watch list for the night was prepared, with teams of two people on one-hour shifts. Names and times were noted on a piece of paper, which was placed on top of the steering console. The MOB boat crew delivered a pack of cookies, which was shared amongst the participants, giving a small spirit boost. The late evening entertainment consisted of telling jokes and having conversations. It was apparent that the interior temperature declined, especially after several participants aborted around midnight. Because of this, there was more focus on staying warm.

Through the night, many means of staying warm were utilized. The remaining participants huddled together in the aft section of the lifeboat, and in the coxswain chair the searchlight was used to heat fingers and hands. Some even took the covers off a lamp to use the heat from the light bulb to warm their fingers. Having the internal lights and headlamp on used a fair amount of battery power. After a while, the electric lights were turned off to save power for starting the engine.

Around 03:30, those who were awake ate some biscuits from the ration and performed a physical activity session. The general opinion amongst the remaining participants was that sleeping was difficult due to the low temperatures. Most of them had tried to get some sleep by then, and everyone experienced being cold on waking. It was therefore necessary to perform physical activity to regain some body temperature. The entertainment throughout the rest of the night and early morning consisted mostly of conversations. These were periodical; in some periods there was no talking at all.

Around 08:00 in the morning, the lifeboat drifted into a belt of ice as seen in Fig. I–6. By then, the wind had also picked up, and there were more waves than there had been previously. This caused the boat to roll, and the ice hitting and scraping along the hull was clearly audible. As the test was nearing the end, there were discussions among the participants whether it would have been possible to survive for several more days in the lifeboat. It was commonly agreed that it would have been possible to survive for some days but that it would become harder and harder to find the motivation to perform physical activity in order to stay warm. It was also mentioned that, in a real situation, the motivation to stay alive would probably have made a big difference, compared to the motivation during the test.

The test officially ended when the lifeboat was safely attached to *KV Svalbard* with a towing rope. This operation required some lifeboat maneuvering, so the engine was used. Shortly after starting the engine, which had been off for 18 hours, the overheating alarm sounded. Norsafe representatives diagnosed the failure as a problem with the cooling system, which could have been caused by air bubbles in the system. Having no engine power complicated the mooring process to some degree, but the MOB boat crew provided good assistance. When the lifeboat was safely moored, the remaining participants were returned to *KV Svalbard* in a MOB boat.

Fig. I–6: Lifeboat drifted into a belt of ice during the test. Photo ©Trond Spande

After the test

Immediately after returning to *KV Svalbard*, each participant went through a medical check. Since the participants aborted at different times, the ship's doctor was on standby during the entire test period. The following medical parameters were checked on all participants:

- Body temperature
- Pulse
- Blood pressure

In addition, the participants in the selected medical test group were put through the same tests they had performed prior to their stay in the survival craft. The SARex team also conducted interviews with all participants shortly after return to the ship. The interviewers followed an interview guide developed specifically for the purpose of the test, to document the personal experiences of each participant.

To conclude the Phase I exercise, a workshop was held, in which the SARex team and involved *KV Svalbard* crew members participated. The objective of this workshop was to gather and discuss experiences and opinions regarding the survival craft and personal protective equipment. The workshop findings are presented in *Notes from workshop after Phase I*.

I.4.4 Report from life raft

This report will summarize the preparations made prior to the exercise and provide an objective description of the events that took place on board the life raft during the SARex Phase I test. Also included is a brief discussion on the equipment used, as well as comments from the participants.

The participants were wearing different types of survival gear:

- Two people wore neoprene survival suits
- Three people wore insulated survival suits
- Three people wore non-insulated survival suits
- Three people wore thermal protection life vests
- Two people wore NoCG Kampvests
- Three people wore NoCG Kampvests with thermal protection aid
- One person wore a NoCG Nordkapp suit
- Two people wore NoCG 307 survival suits

The exercise was conducted in parallel with the lifeboat test and started on Sunday 24 April, at approximately 09:30. Prior to this, the participants had been shuttled to the life raft using the two MOB boats. Present on the life raft were 19 participants, in addition to Doctor Gunnar Vangberg. Originally, the plan was for Vangberg to visit the life raft occasionally, but he ended up being a permanent member of the participants.

Fig. I–7: Preparing for lifting the life raft from the helicopter deck to the sea ©Trond Spande

After all participants had arrived on the life raft, the lifeboat towed the life raft away from *KV Svalbard* and into open waters, approximately 300 m away from *KV Svalbard*.

The life raft used was designed for 25 people, and with all the different types of survival equipment used, it was very cramped inside the life raft. The survival manual of the life raft recommended that people sat with their backs against the pontoons, with their feet in towards the center. With 20 people sitting in this configuration, there was barely any room to move, and people had to sit still. The water, provisions and equipment that accompanied the life raft were stored at the center of the life raft. The leader of the life raft sat here to get a good overview of the participants and to delegate tasks.

Fig. I–8: One of the volunteers wearing an oxygen measuring mask to measure energy consumption. ©Trond Spande

The leader delegated the responsibility of keeping the headcount to the second in command on board the raft, who performed the initial headcount reported back to *KV Svalbard*. However, the count was wrong, and the leader changed the counting method, giving each person the responsibility for saying one number higher than the person to their right. This system gave a correct count and was used for the remainder of the exercise. After the headcount had been performed, everybody was given the task of watching over their buddy. The buddy was selected to be the person sitting to their right at any given time, and this system worked well.

Fig. I–9: Transportation from KV Svalbard to the life raft. ©Trond Spande

Shortly after everybody had found their position, all participants were told to give a brief history of themselves and explain their background. The participants' backgrounds included craftsmen, navigators, experienced seamen and medics, all of whom would have been very useful in an emergency scenario.

Fig. I–10: Life boat and life raft after being towed into position. ©Trond Spande

After this, the leader counted the provided rations and obtained an overview of the equipment provided with the life raft. This equipment was then divided up amongst the participants, who were told to assemble it (if required) and explain it to the other participants. This was done to give all participants an understanding of what equipment was available and how to use it.

When all of the equipment had been demonstrated, the included radar reflector was assembled and mounted on top of the life raft. It was noted that the survival suits without removable hands made it very difficult to lock the small zip ties that were included. The AIS transmitter was tested and verified as working over the radio with *KV Svalbard*. Some of the participants had never seen the emergency flares, rockets or the colored smoke that is used to alert nearby vessels. This equipment was tested after notifying *KV Svalbard*.

The life raft had an opening in the canvas that was used for observing the surroundings. The leader wrote up a lookout schedule, with every participant being allocated 45 minutes. The lookout was designated to man the opening and also to ensure that everybody was awake at the end of the duty. This was done to simulate a real-life scenario, where a lookout should be present in case a ship, helicopter or a plane is nearby and a beacon should be launched. It is noted that it would have been better to have been able to see through the fabric in the canvas, as the lookout's head frequently got cold.

A gas-measuring meter for O_2, CH_4 and H_2S had been brought along from *KV Svalbard*. The meter served as an indicator of when the levels of oxygen became too low or when the levels of methane and hydrogen sulfide became too high. This device proved to be quite important but also a major annoyance in the exercise. Prior to turning on the meter, several participants were sleepy and silent. The consensus was that people were tired and bored. However, when the meter was turned on, the alarm went off immediately, indicating that the oxygen level inside the raft was below the recommended threshold. After this, the meter was suspended from the ceiling of the life raft; the alarm went off every 30-40 minutes, and both doors were opened to get fresh air. One of the participants commented that CO_2 was heavier than air, and that the sensor should be positioned closer to the bottom where people were sitting. After relocating the sensor closer to the bottom, the raft had to be vented every 15 minutes. After this became a routine, the participants started to become more alert. However, this may also have been caused by their waking up every 15 minutes, due to the high-pitched noise of the alarm and the cold air that was rushing in. Nevertheless, this was a revelation for all of the participants, as none had anticipated that air quality would be such a big problem. Better ventilation should definitely be designed, as venting the raft during high seas could be catastrophic if a wave gushed into the raft or if the raft capsized in high waves.

In addition to oxygen levels, humidity in the air was also becoming a problem, despite the frequent replacement of the air inside the raft. The floor in the life raft started to become wet; this was believed to be caused by some of this humidity condensing and gathering on the floor, and also by condensation due to the temperature difference between the sea (-1.6 °C) and the interior of the life raft (10-19 °C). It is also possible that some water entered when people were embarking and disembarking the life raft and when people spilled water from the water rations.

Fig. I–11: Status in life raft at 10:54. Little room for maneuvering. © Jan Erik Jensen

Prior to the exercise, it was decided that people who needed to use the bathroom could be shuttled back to *KV Svalbard* if desired to avoid socially awkward situations. This was a big relief, especially for the female participants.

Around 12:00, the emergency rations were handed out, together with some of the water. The emergency rations did not taste very good, and it was commented that they tasted like a fatty, sweet biscuit. The primary purpose of the emergency rations is to provide energy for sustenance, and participants agreed that these would do the job very well due to the high calorie count. Several of the participants did note, however, that it would have been nice to have some kind of different flavorings, if only to give some variety. Eating the same tasteless bricks for five days could be very demotivating, and some different flavors would have been appreciated. The provided water bags worked well, and it was good that they were portioned out in small water bags to make it easier to ration the water. However, these bags were very difficult to open for the participants wearing survival suits without removable gloves, and this resulted in a lot of spillage, as they had to open the bags with their teeth.

Time went on and, in the early afternoon, some of the participants wearing life jackets and neoprene survival suits became cold and were evacuated back to *KV Svalbard*. The primary reason appeared to be cold feet and hands, but some of the participants, especially those wearing only a life jacket, were also starting to have a lower body temperature. If the doors on the life raft had been closed the entire time, they would probably have lasted longer on board.

Fig. I–12: Status in life raft at 11:54. People with survival suits are warm, and had to open their suit to avoid sweating. © Jan Erik Jensen

By late afternoon, the number of participants had decreased significantly. The only remaining participants were those who had full body survival suits (not the neoprene suits) and two participants with life vests who also had thermal insulation bags. These bags worked very well, as they helped form an insulating layer of air. Those wearing the neoprene suits and those wearing only the life vests had become very wet because their suit and clothes had soaked up the water in the floor of the life raft. The other survival suits had a watertight outer layer, and the thermal insulation bags were also watertight, preventing the participants from becoming wet. However, all participants noted that they had become

Fig. I–13: The ranks are thinned out, and more space was available for the remaining participants. Picture taken at 17:15. © Jan Erik Jensen moist inside the suit, or inside the thermal isolation bag. The greatest source of heat loss was definitely the bottom of the life raft. The bottom was very thin and provided negligible insulation from the cold seawater. All participants, who noted that the feet and legs were the first body parts to get cold, agreed with this assessment. The author returned to *KV Svalbard* around 17:45, primarily due to cold feet and toes.

Boredom was becoming something of an issue and, to cope with this, the participants started telling stories and jokes and also to ask riddles. This kept the participants awake and entertained for quite some time. As evening fell, some of the participants started to sing, to the great enjoyment/horror of the other participants.

As fewer participants remained and night fell, the temperature inside the life raft decreased. At around 04:00, the last four participants radioed in and were picked up by the MOB boats and transported back to *KV Svalbard*.

I.4.5 Main findings from Phase I

Duration of stay

The participants were constantly monitored and had to leave the exercise when one of the abortion criteria in Chapter I.4.1 was met. Based on the Kaplan-Meier Survival plot in Fig. I–14, it is evident that the cooling process started immediately after the exercise commenced and, after about six hours, the first participants had to abort the exercise from the raft.

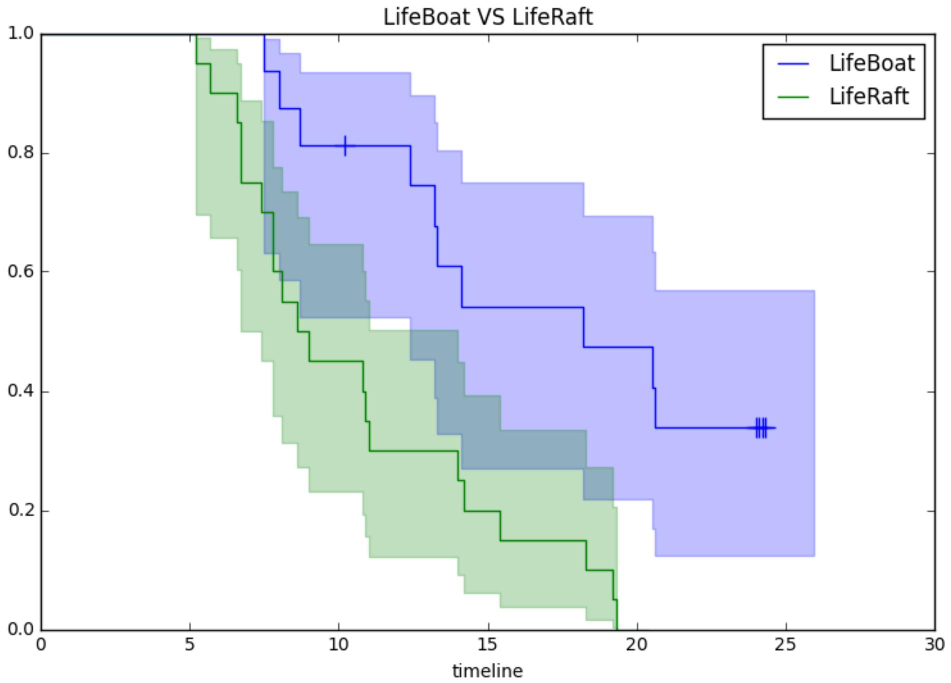

Fig. I–14: Kaplan-Meier plot with 90% confidence interval

Eight hours into the exercise, the engine in the lifeboat was turned off, removing an essential heat source. After this point in time, none of the rescue craft had any heat source except that generated by the participants. It had already become evident that the exposure level is significantly higher in the life raft than in the lifeboat.

In the life raft, the last participants left the raft after 19 hours, while several people still remained in the lifeboat after 24 hours. The participants remaining in the lifeboat at the end of the exercise were regarded as censored in the data analysis.

Hazard curve

Based on the time when the participants left the exercise, a hazard function was generated; see Fig. I–15 for the hazard function for the lifeboat. The curve shows that, for the lifeboat, the highest hazard was experienced after about 15 hours. At around this time, the rate of people leaving the exercise was at its highest. The curve also shows the confidence interval (0.9) increasing as fewer persons remained in the craft.

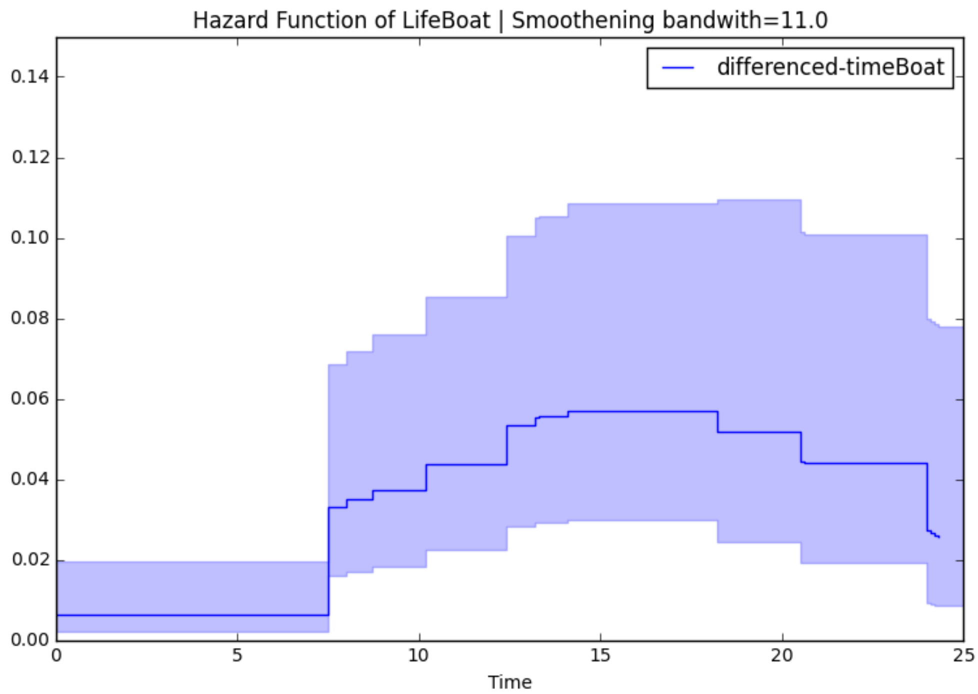

Fig. I–15: Hazard Curve for lifeboat with 90% confidence interval

The hazard curve has distinct features: a period of low hazard, a period of increasing hazard and a period of decreasing hazard. This was very clear on the hazard curve for the lifeboat. For the life raft, the same features could be identified but, by the time the life raft reached the last phase, there were very few participants left.

From Fig. I–16, it is evident that greater hazard levels were present in the life raft than in the lifeboat. This is interpreted as referring to the higher exposure levels present in the life raft. From the graph it is also evident that a relatively large number of participants left the life raft from five to about nine hours into the exercise.

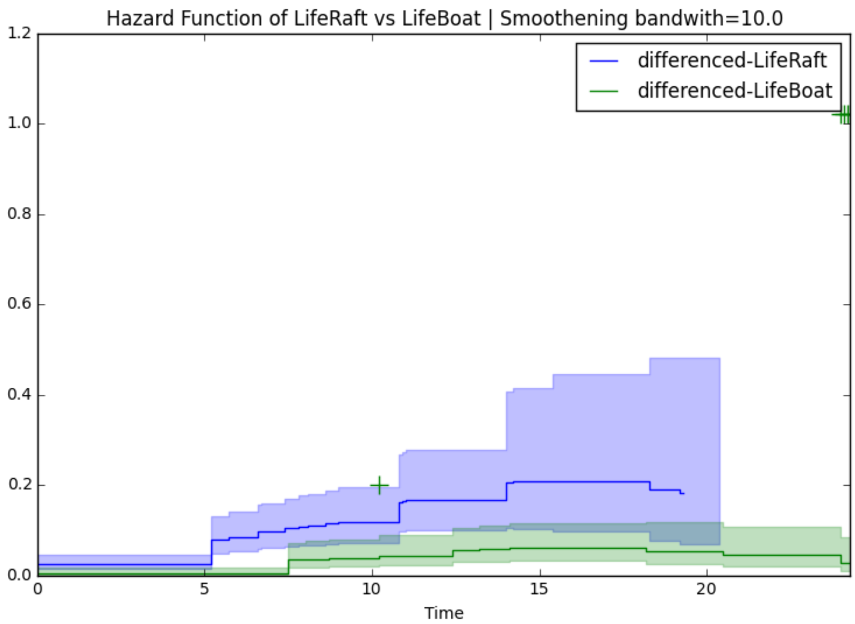

Fig. I–16: Hazard function life raft vs lifeboat with 90% confidence interval

We have chosen to break the analysis into three different stages. See Fig. I–17 for an illustration of the different stages.

Stage 1 - Cooling phase

During the first 7.5 hours, all participants remained in the rescue craft. Everyone was well fed, dry and warm prior to entering the rescue craft. In this phase, the participants became accustomed to their situation. Strategies for staying warm were developed, but very little could be carried out in practice due to space restrictions. During this period, the social structure was established with the lifeboat/life raft captain; a plan on how to distribute resources, e.g. water, was developed; and tasks, e.g. keeping lookout, were distributed.

To increase the internal air temperature, hatches remained closed for the majority of the time. O_2-level meters showed an alarmingly low O_2 concentration, and the air inside the craft had to be replaced about every 15 minutes, depending on the number of people on board. This process contributed to reducing the interior air temperature. For the lifeboat, this also turned into an issue after the engine was turned off.

When the participants entered the rescue craft, anti-seasickness pills were consumed according to normal procedures.

During the first phase, many of the participants spent a considerable time sleeping. It is assumed that this is a result of the combination of the anti-seasickness pills and low O_2 levels.

During this phase, some of the participants were slowly getting colder.

Stage 2 - Stabilization phase

From about 7.5 hours to about 16 hours into the exercise, people were starting to leave; this process increased steadily until it reached its peak at about 16 hours.

Those first to leave were in general people with only life vests/thermal protection aids. Many of them had been unlucky and got wet early in the exercise. The reason for getting wet was typically condensation inside the raft/lifeboat; the moisture caused a reduction in the insulating capabilities of their clothes.

Several also left the exercise early due to freezing of extremities, with the most dominant area of concern being the hands. The cooling of the hands occurred as a result of conducting tasks that required fine motor skills, e.g. opening/closing zippers and opening water bags.

Stage 3 - Survival phase

From 16 hours onwards, the departure rate slowly decreased until the exercise was aborted at 24 hours. As people left the rescue craft, space was freed up, opening up the opportunity for the participants to move and generate heat and increase blood flow to the extremities. The reduction in the number of persons on board also enabled the survivors to have larger food and water rations. The reduced number of persons on board also decreased the need for venting due to low O_2 levels.

This far into the exercise the participants were starting to feel fatigue, which resulted in an urge to lie down and rest. Substantial heat loss was experienced from the body parts that were in contact with the cold surfaces inside the rescue craft. This again resulted in abortion criterion Pt. 2 being met.

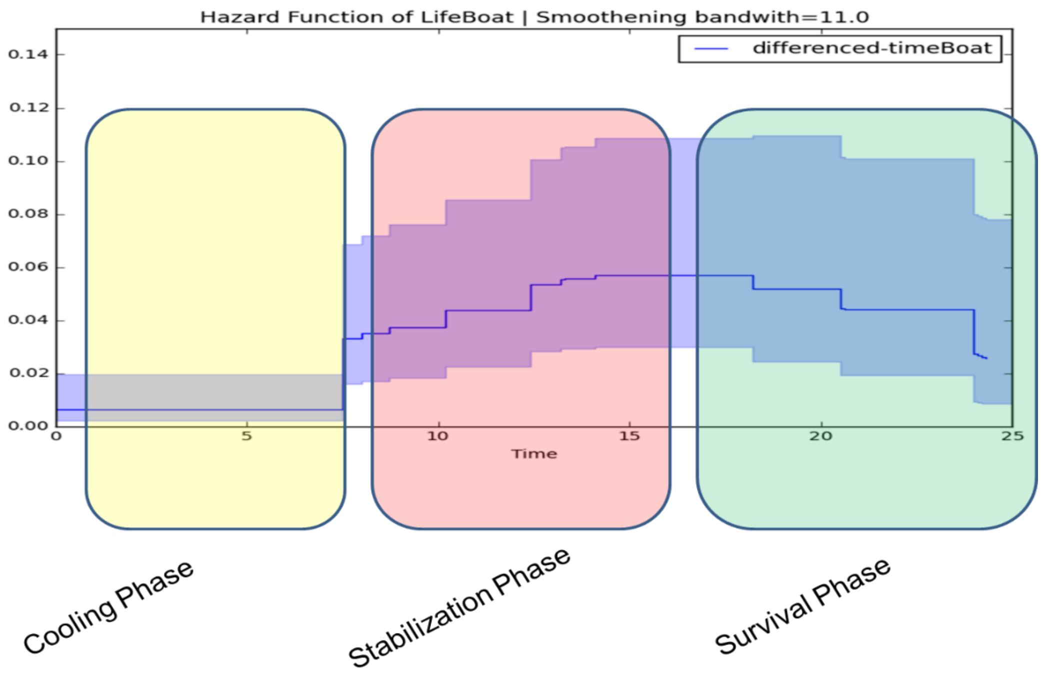

Fig. I–17: Rescue craft phases with 90% confidence interval

Phases' summary

Based on interviews with survivors of real accidents, the theory of the phases experienced during the exercise is valid. It was after the cooling phase and the stabilization phase that the remaining participants had a real chance of surviving the ordeal.

By the time the rescue craft had reached Phase 3, survival phase, several functionalities essential for survival had emerged. The combinations of these make further survival possible. The following functionalities were available when the survival craft reached Phase 3:

- Sufficient space to allow movement
- Increased food and water rations
- Adequate O_2 levels inside rescue craft
- Established rescue craft routines, giving the participants the ability to predict and remain in "control" of the situation.

The combination of the above parameters gave the remaining participants an increased probability of survival.

Very few of the participants on board the life raft reached Phase 3, survival. The few that reached it only remained in this phase for a few hours before they had to abort the exercise. The reasons why only a few of the participants were able to progress to Phase 3 could be psychological, as, to a certain degree, the ability to stay warm will be linked to motivation.

However, none of the participants was able to stay in the raft for the scheduled 24 hours. This proves that the complete rescue system associated with the raft (raft, equipment and personal protective equipment) does not provide adequate protection against the environment from a five-day perspective.

A few of the participants on board the lifeboat were able to remain in the craft for the duration of the exercise. To a large degree, these participants chose to reject the temptation to lie down and rest, due to the heat loss experienced between the body and cold surfaces. This indicates the importance of motivation.

Habitable environment

According to the Polar Code, the rescue craft is to provide a habitable environment. However, the code does not define a habitable environment.

Rescue craft temperature

When a rescue craft is filled to 100% of its capacity, the heat generated by the people on board results in a relatively high air temperature; see Fig. I–18. It is also evident that the heat generated by the engine in a lifeboat contributes a significant amount of heat. In Fig. I–18, this is visible, as the engine is turned off about 500 minutes into the exercise and the interior temperature in the lifeboat starts to drop.

Based on the temperatures logged, it is evident that the interior air temperature does not contribute greatly to heat loss from the participants. During the first half of the exercise, the temperatures were between 5 and 20 °C.

The great dips seen at regular intervals in the curve from the life raft show the occasions when the participants opened the cover for venting.

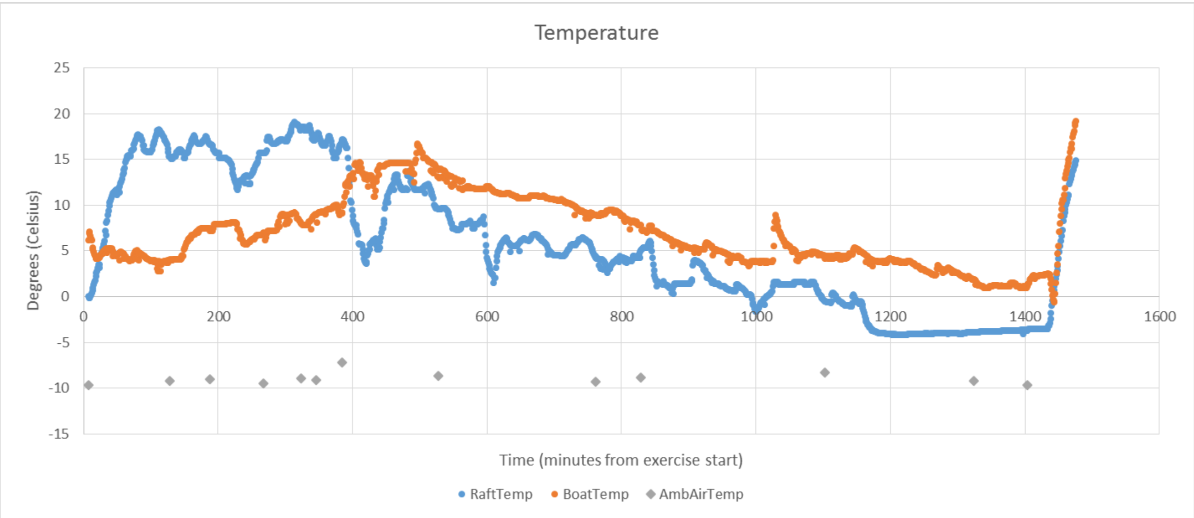

Fig. I–18: Interior air temperature

The ambient air temperature for the duration of the exercise is relatively steady at between -7 and -10 °C. The decrease in the interior temperature is correlated, however, to the number of persons present inside the rescue craft. This relationship is clearly visible in Fig. I–19.

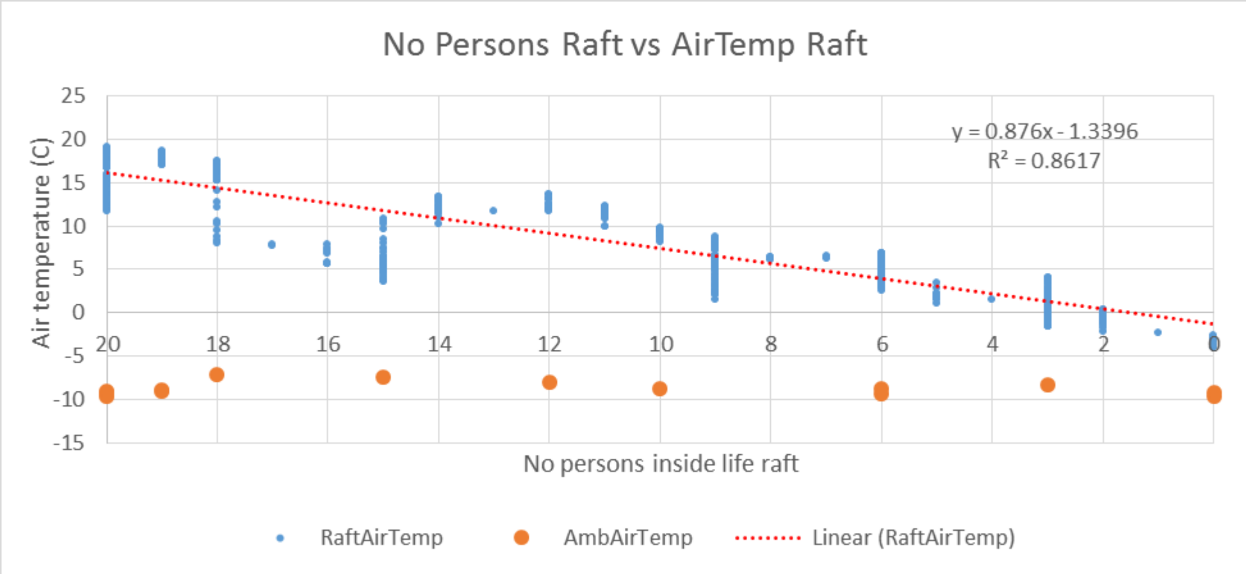

Fig. I–19: Number of persons in life raft vs air temperature

Rescue craft moisture

Moisture in the insulation layer reduces the insulating capabilities. All participants aborting the exercise were wet from moisture. In respect of the participants wearing survival suits, the moisture came from their own bodies. The participants wearing only life jackets or thermal protection aids experienced moisture accumulating in their clothing from the air inside the rescue craft. This moisture inside the life raft caused great concern as it condensed on the inside of the canopy and accumulated on the floor of the raft where people were sitting. From Fig. I–20, it is evident that the humidity experienced in the raft was considerably higher than that experienced in the lifeboat. The figure also shows the need to vent the life raft in the early phases of the exercise (up to about 400 minutes into the exercise) due to the low concentration of O_2 caused by the high number of participants inside the raft.

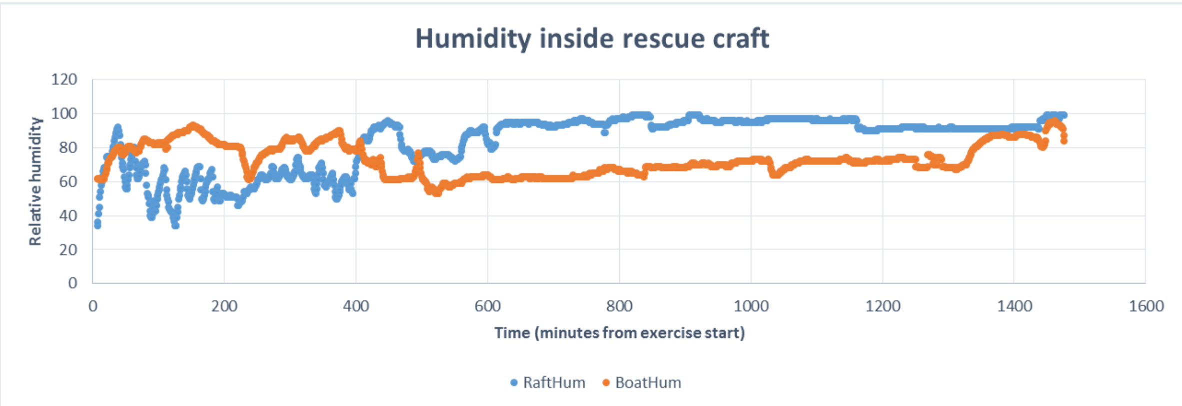

Fig. I–20: Humidity inside rescue craft

Personal protection

All participants were wearing standard long woolen underwear under regular shirt and pants. They were equipped with different types of SOLAS approved personal protective gear. The following gear was utilized:

Neoprene survival suit (PS2004) – Neoprene survival suit with integrated soles, 4 pieces.

PU coated nylon immersion suit, insulated (PS5002) – Immersion suit with an outer shell of PU coated nylon, internal insulating layer and integrated soles, 6 pieces.

PU coated nylon immersion suit, uninsulated (PS5003) – Immersion suit with an outer shell of PU coated nylon and integrated soles, 5 pieces.

Thermal protection vest (PV9720) – Standard SOLAS approved thermal protection vest, 6 pieces.

Kampvest with bag – The standard life jacket utilized by the Norwegian Coast Guard. The participants were wrapped inside a plastic bag during their stay in the rescue craft, 6 pieces.

Kampvest without bag – The standard life jacket utilized by the Norwegian Coast Guard, 4 pieces.

“Nordkapp” suit – The offshore working suit utilized by the Norwegian Coast Guard. The suit had integrated boots with steel toes, and loose neoprene gloves, 2 pieces.

Survival suit 307 – The standard survival suit utilized by the Norwegian Coast Guard. The suit had integrated soles, 2 pieces.

Where applicable, Viking life-saving equipment’s model number is in brackets.

The different types of personal protection offered different advantages/disadvantages. It is clear, however, that the survival suits exhibited a major advantage over the different types of vests. Arranging the different personal protection aids based on time spent in the rescue craft gives an indication of the relative fitness of the equipment (Table I-1).

1. PU coated nylon immersion suit, insulated – 39 hours
2. “Nordkapp” suit – 36 hours
3. PU coated nylon immersion suit, uninsulated – 30 hours
4. Neoprene survival suit – 30 hours
5. Kampvest with bag – 24 hours
6. Thermal protection with vest – 17 hours
7. Kampvest without bag – 15 hours
8. Survival suit 307 – 9 hours

It is important to note that only two persons utilized survival suit 307. The large discrepancy for the neoprene survival suit between the lifeboat and the life raft was due to leaks in the seams. The leaks were not experienced as a problem in the lifeboat, while in the life raft the leaks caused wetness, with a loss of insulating capability in the layers of clothes.

Tab. I-1: Hours stayed onboard as function of protection aid

	Survival suit, neoprene	PU coated nylon immersion suit, insulated	PU coated nylon immersion suit, uninsulated	Thermal protection west	Kampvest with TPA	Kampvest without TPA	“Nordkapp” suit	Survival suit 307
Average lifeboat (hours)	22.3	22.3	16.0	11.0	15.2	10.0	24.3	N/A
Average life raft (hours)	7.6	17.5	14.4	6.4	8.6	6.0	13.2	9.4
Average total	30.0	39.9	30.4	17.4	23.7	15.9	37.5	9.4

It is important to note that when the exercise was concluded, all remaining participants were wearing either the insulated PU coated nylon immersion suit, or the "Nordkapp" suit.

Additional stress factors

Prior to the exercise, all participants were briefed on the risks involved and the safety system in place. During the exercise, all participants felt that their safety was safeguarded properly, and the stress level was low.

When a walrus appeared in the exercise area, the participants in the life raft had to keep a sharp lookout, and the canopy had to remain open for a prolonged period. Routines also had to be abandoned. This diverted participant focus from staying warm and resulted in a few participants having to abort the exercise.

On board the lifeboat, one person had to stay outside for some time to assemble the radar reflector, usually a short and uncomplicated task. Due to the cumbersome survival suit, neoprene gloves, cold metal parts and snow on the deck, this job took longer than usual. The participant also had to remove his gloves to complete the task. This resulted in cooling of the extremities and lack of ability to use the hands. Despite returning to the lifeboat, he did not recover the use of his hands and had to abort the exercise some time later.

The ability to manage additional tasks will in many cases cause additional stress factors. The majority of the participants used most of their mental capacity to focus on staying warm, and the capacity to conduct additional tasks was marginal. In a cold climate survival situation, conducting additional tasks that usually represent no challenge will reduce the probability of survival.

Psychological aspects

All participants were motivated to participate in the exercise. In a real situation, the motivation to survive will of course be stronger, but there will also be additional stress factors for the participants to cope with. All participants expressed the importance of a well-trained lifeboat/life raft captain. This person has a key role in establishing routines and distributing the available resources. The captain of the rescue craft also has an important role in creating routine with regards to the lives on board. In stressful situations in what is, for most people, a new environment, predictability is of key importance for remaining motivated and utilizing the individual resources in a sustainable manner.

Confident leadership will greatly influence the survival rate of those on a rescue craft. The longer the stay in the craft, the more important is the leadership.

Exercise validity

As the exercise was to simulate a cruise ship incident, the conditions were to be representative of the conditions experienced during the cruise ship season in Svalbard. The following boundary conditions were observed:

- Average ambient air temp = - 9 °C
- Average wind speed = 2 m/s
- Water temperature = - 1.2 °C
- Participant health = above average
- Participant insulation layer under the personal protection aids = average
- Additional stress factors = marginal

The metocean conditions were fairly representative of the conditions experienced by the cruise ship industry in Svalbard during the cruise ship season. A higher wind speed would reduce the survival times considerably and the metocean conditions are to be regarded as a "best case".

As the participants were on average not only younger but also fitter than the average cruise ship passenger, they were better able to handle the challenges. An average cruise ship passenger would not be able to handle cold climate conditions as well as the average exercise participant.

There were very few additional stress factors, and all of the participants felt at all times that their safety was safeguarded throughout the exercise, although the presence of the walrus did cause some disturbance to the onboard routines. This event caused some people to abort the exercise due to high exposure levels to the cold environment (based on the defined abortion criteria).

The abortion criteria proved to work quite consistently, and all participants aborted the exercise with a body temperature well within safety limits. See Fig. I–21.

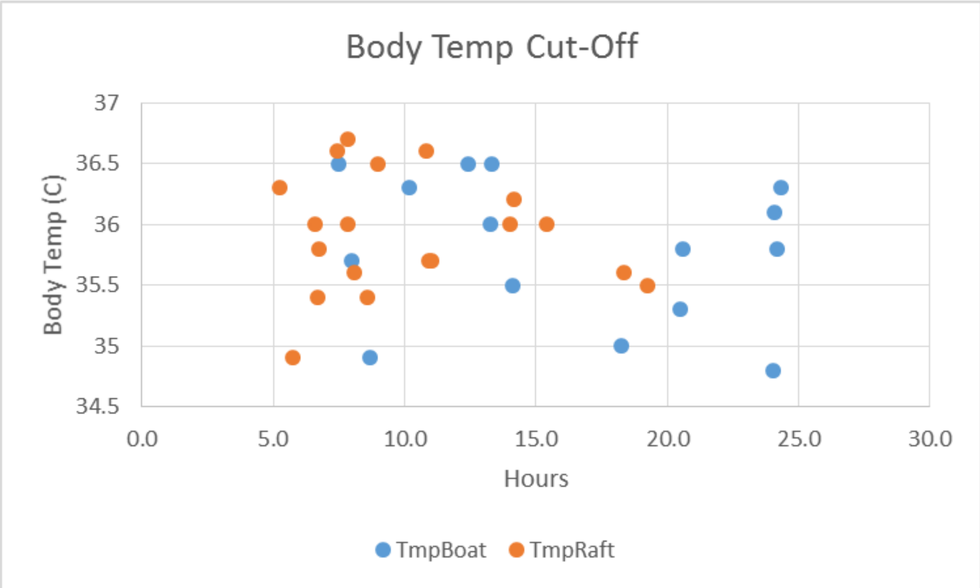

Fig. I–21: Body Temp Cut-Off (not corrected for circadian rhythm)

In a real scenario, most people would be very strongly motivated to stay alive and would survive for an extended period after our abortion criteria were met.

Tab. I-2: Validity

Boundary conditions (average)	Description	Effect on a real scenario (average)
Metocean conditions	Good	Shorter survival time to be expected
Participant health	Above average	Shorter survival time to be expected
Additional stress factors	Few	Shorter survival time to be expected
Motivation to survive	Not as high as in a real incident	Longer survival time to be expected
Abortion criteria	Consistent, but further survival to be expected	Longer survival time to be expected

Based on Tab. I-2, it is evident that some of the boundary conditions were on the conservative side, while others were not. It is clear however, that everyone involved in the exercise would have been able to survive beyond the exercise abortion criteria in a real situation.

Survival in rescue craft - summary

Each of the participants experienced the exercise differently. The reasons for leaving the rescue craft were mainly due to abortion criterion Pt. 2, uncontrolled shivering or Pt. 3, freezing of the extremities. See Fig. I–22, for more information.

It is also clear that individual motivation and knowledge play an important role in a survivability scenario. Conducting simple tasks like unzipping the survival suits at regular intervals for ventilation and drying out the insulating layer can greatly influence the outcome for that individual.

Based on the body temperatures identified at the time of abortion for the individual participants, it is possible to identify the body-temperature development trend for the group in the life raft and the group

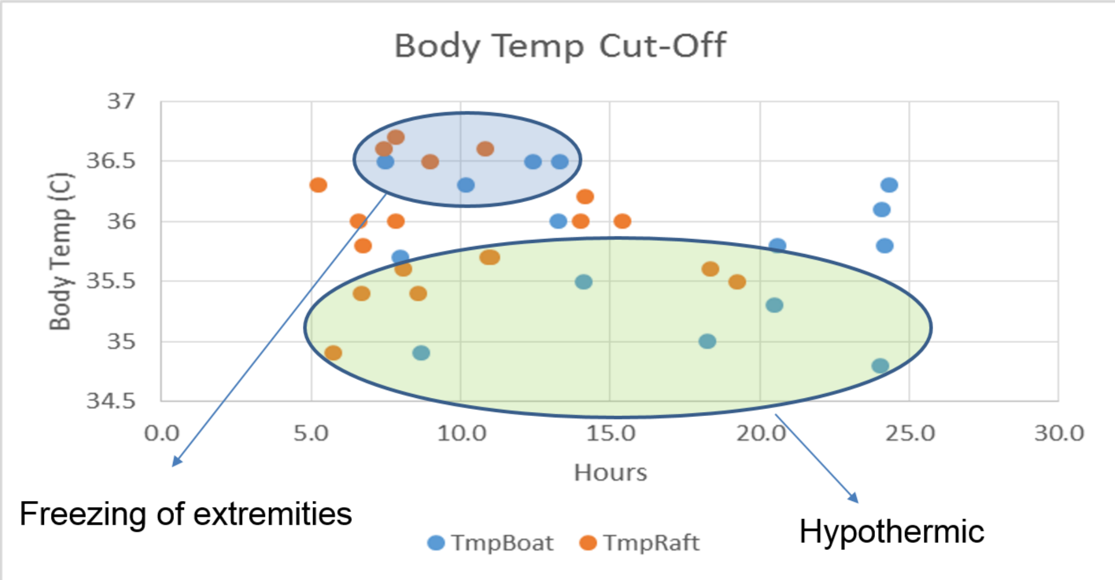

Fig. I–22: Abortion criteria (not corrected for circadian rhythm)

in the lifeboat; see Fig. I–23 below. The trend shows a clear decrease in body temperature as the exercise progresses.

Hypothermia is defined as the body core temperature being below 35 °C. There are, however, large individual variations, and, in many cases, symptoms will be evident before the body core temperature reaches 35 °C.

The Polar Code states that equipment is to protect the passengers/crew from hypothermia. This means that the core body temperatures of participants are not to fall below 35 °C. In the figure below, it is very evident that, at 20 to 24 hours into the exercise, the body temperature approaches 35 °C. When utilizing

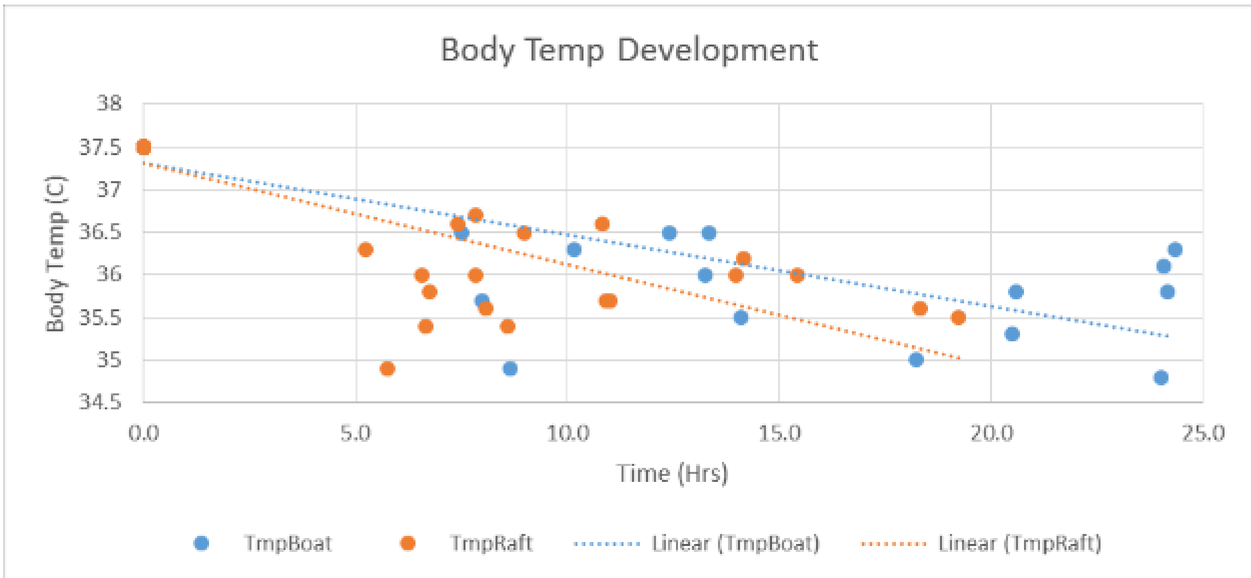

Fig. I–23: Body temperature development (not corrected for circadian rhythm) standard SOLAS approved equipment, compliance with the functional Polar Code requirement of protection from hypothermia (having a body core temperature above 35 °C) cannot be expected after 20-24 hours of exposure.

With few exceptions, all of the participants had reached the abortion criteria well before 24 hours, regardless of the type of survival craft or of personal protection aid. In a real accident scenario, the participants would have survived for an extended period beyond this point. Some might also have regained their heat with the help of others.

It is very unlikely, however, that a majority of the participants would have survived for another four days, due to the physical limitations of their bodies. To increase the survival rate, modifications to the functionality of the equipment would be required. These include:

- Higher degree of insulation in the personal protection aids
- Insulation of the surfaces in the rescue craft
- Increased space per person to enable movement to ensure blood circulation
- O_2 measurement devices/alarms inside the rescue craft
- Larger and extended range of food and water rations
- Training of lifeboat/life raft captains

I.5 Phase II – Search and rescue of stranded persons in lifeboat

Rescuing the personnel from a rescue craft in a cold climate environment involves additional challenges, compared to carrying out the activity in more temperate zones. Exposure of personnel to low air and water temperatures will quickly deteriorate their medical condition. If they are already in a hypothermic state, without adequate personal protection, the transportation from the rescue craft to the safety of the rescue vessel can represent a major challenge.

Handling large groups of people with different degrees of injuries/hypothermia also represents a major challenge for the reception facilities on board the rescue vessel. Conducting an efficient triage combined with an efficient organization of on board medical resources is essential.

About 40 persons were on board the lifeboat, which was located a few hundred meters from the main vessel, and the exercise took place under near perfect conditions with little wind and few waves. The participants wore a variety of items of personal protective equipment.

I.5.1 Preparations

Prior to the exercise, the different individuals were instructed on what injuries/state of hypothermia they were to simulate including symptoms. Five patients were assumed to be hypothermic and deeply comatose, 15 patients had a mix of non-lethal injuries, and 20 participants were assumed non-injured but all more or less mildly hypothermic. The aim was to generate a picture of what could be expected to occur after a prolonged stay in a lifeboat in cold climate conditions.

The crew on board *KV Svalbard* was not informed of the exercise details (with a few exceptions). This purpose of this was to generate as realistic as possible a scenario and to incorporate additional challenges such as identifying the vessel’s procedures and preparing the vessel for the reception of a large number of casualties within a short time span.

I.5.2 Report from practical evacuation exercise

This section is based on *Objective report from Phase II of the exercise by the medical team*, by E. Skogvoll and G. Vangberg.

As *KV Svalbard* entered the vicinity of the lifeboat, an evacuation of personnel from the lifeboat to the vessel was initiated on board *KV Svalbard*. The MOB boats were manned, the medical personnel prepared the hospital and medical facilities, and an emergency coordination group staffed the operational room on the bridge.

All simulated casualties in the lifeboat were transferred to the main vessel by MOB boats capable of carrying six or seven passengers. A senior naval officer led the evacuation onto *KV Svalbard*, accompanied by a medic capable of administering e.g. analgesics, as necessary, prior to the evacuation of victims in severe pain.

The MOB boats shuttled the casualties from the lifeboat to *KV Svalbard*. As soon as the MOB boats reached the cradle, a reception team helped the casualties from the MOB boat on board *KV Svalbard*. The MOB boat was immediately lowered into to the water to return to the lifeboat.

When on board the *KV Svalbard*, the casualties were funneled through a process of triage, dividing the people into three groups:

- Group 1 – no medical attention needed
- Group 2 – slight injuries/relatively mild state of hypothermia
- Group 3 – life threatening injuries/hypothermia, extensive medical attention needed.

Group 1 was accommodated in the officers’ mess, while provision was made for Group 2 in the hangar, under the constant supervision of medical personnel. The hangar was equipped with blankets, enabling the casualties to lie down. Group 3 was taken to the hospital for treatment by medical staff.

Each casualty was given a card, identifying the appropriate group.

As the casualties improved/deteriorated in their medical condition, they were transferred to the appropriate group. Towards the end of the exercise, most of the casualties were moved to Group 1, as their condition had improved.

Towards the end of the exercise, the simulation took place of a helicopter’s arrival from Longyearbyen, providing further medical personnel.

I.5.3 Main findings from Phase II

During the exercise, medical personnel from the project team functioned as observers. The following points were noted:

- Due to very little space in a filled rescue craft, entry of the rescue craft by the *KV Svalbard* crew is difficult. As a result, obtaining a situation overview, identifying the number of persons and different types of casualties is difficult.
- Upon arrival at the lifeboat, it is important that the crew on board the MOB boat maintains strong leadership, reducing the risk of panic or unfavorable behavior among the passengers to be rescued.
- Rapid triage upon arrival in *KV Svalbard* is essential – there is no time for interviewing/ interacting with every individual victim.
- It may be useful to have medical personnel from the main vessel on board the MOB boat to provide analgesia and other treatment allowing for the smooth transfer of the injured.
- It is difficult to treat injured persons in a lifeboat full of people. Swift evacuation of the non-injured allows for proper treatment and handling of the injured.
- It is difficult to move non-ambulatory persons between vessels. During the exercise, all persons (injured or not) moved themselves between the lifeboat and the MOB boat; it was found too risky to actually carry them for exercise purposes.

Regarding the triage and immediate treatment phase on board *KV Svalbard*, patients were triaged immediately on arrival, close to the intake area. Thus, one could quickly identify those who needed more close observation and/or treatment; those patients were taken into neighboring rooms. There was an emphasis on the medics' ability to carry out simple examination and lifesaving measures, while the ship's doctor was available for consultation as needed. The following points were noted:

- Good procedures on board the Coast Guard vessel made for a well-prepared reception of the evacuees.
- Conducting an efficient triage requires clear procedures and puts considerable mental pressure on the individuals involved in the task.
- The vessel's hospital was not actively in use as it was too remote.
- Premade plans were activated, and large areas on board the ship were available for triage and treatment. Thus, quite large groups of (non-injured) people could be handled on board with little preparation.
- Heavily injured/hypothermic casualties placed a great strain on the medical personnel on board *KV Svalbard*. With limited medical resources, with regard to both personnel and infrastructure, it is to be recognized that only a limited number of heavily injured/hypothermic casualties can be saved without outside assistance.

The final phase consisted of simulated communication with the presumed helicopter assistance arriving from Longyearbyen 1 hour 10 minutes after the initial alert. It was noted that further transfer of unconscious patients towards the helicopter deck proved difficult. Uninjured participants noted a lack of information, in particular regarding their spouses and relatives, who might be among the injured.

Conducting mass evacuations requires a large number of staff, e.g. to operate MOB boats, onboard reception facilities, the control room, etc. More staff on board the Coast Guard vessel could have been beneficial in reducing the strain on the individual crew and onboard infrastructure, e.g. cooking facilities. This is especially relevant if an evacuation was to be followed by a prolonged period, during which a large number of casualties remained on board.

The safety of *KV Svalbard* personnel was also questioned. With a large number of unknown people on board, perhaps outnumbering the crew, it is important to remain alert and to have procedures for maintaining control over the situation, e.g. locking off essential parts of the vessel.

The Polar Code states that people should be able to survive for up to five days in a raft or a lifeboat, but it does not define the condition in which they should find themselves at the end of this period. If just a small degree of hypothermia is allowed to develop, one can expect great challenges when attempting to transfer the victims between vessels. Dexterity, arm/leg coordination and cognitive function rapidly deteriorate, even in mild hypothermia. There were no good alternatives for transferring the large number of immobile passengers present.

I.6 Phase III – Equipment testing

I.6.1 Report from exercise

Background

Paragraph 8.2.3.3 in the Polar Code states that the following resources shall be provided to support survival following abandoning ship:

1. A habitable environment;
2. Protection of persons from the effects of cold, wind and sun;
3. Space to accommodate persons equipped with thermal protection adequate for the environment;
4. Means to provide sustenance;
5. Safe access and exit points; and
6. Means to communicate with rescue assets.

In Chapter 8.3.3 of the Polar Code, it states that appropriate survival resources, which address both individual and shared needs, shall be provided. For all scenarios, the following is required:

1. Lifesaving appliances and group survival equipment that provide effective protection against direct wind chill for all persons on board;
2. Personal survival equipment in combination with lifesaving appliances or group survival equipment that provide sufficient thermal insulation to maintain the core temperature of persons; and
3. Personal survival equipment that provides sufficient protection to prevent frostbite of all extremities.

In addition, if the risk assessment identifies evacuation onto land or ice as a possibility, the following applies:

1. Group survival equipment shall be carried, unless an equivalent level of functionality for survival is provided by the ship's normal lifesaving appliances;
2. When required, personal and group survival equipment sufficient for 110% of the persons on board shall be stowed in easily accessible locations, as close as practical to the muster or embarkation stations;
3. Containers for group survival equipment shall be designed to be easily movable over the ice and be floatable;
4. Whenever the assessment identifies the need to carry personal and group survival equipment, means shall be identified of ensuring that this equipment is accessible following abandonment;
5. If carried in addition to persons, in the survival craft, the survival craft and launching appliances shall have sufficient capacity to accommodate the additional equipment;
6. Passengers shall be instructed in the use of the personal survival equipment and the action to take in an emergency; and
7. The crew shall be trained in the use of the personal survival equipment and group survival equipment.

In Part I-B, Chapter 9 of the Polar Code, the following equipment is suggested for the personal survival kit (PSK):

- Protective clothing (hat, gloves, socks, face and neck protection, etc.)
- Skin protection cream
- Thermal protective aids
- Sunglasses

- Whistle
- Drinking mug
- Penknife
- Polar survival guidance
- Emergency food
- Carrying bag

For the group survival kit (GSK), the following equipment is suggested:

- Shelter – tents or storm shelters or equivalent – sufficient for maximum number
- of persons
- Thermal protective aids or similar – sufficient for maximum number of persons
- Sleeping bags – sufficient for at least one between two persons
- Foam sleeping mats – sufficient for at least one between two persons
- Shovels – at least two
- Sanitation (e.g. toilet paper)
- Stove and fuel – sufficient for maximum number of persons ashore and
- maximum anticipated time until rescue
- Emergency food – sufficient for maximum number of persons ashore and
- maximum anticipated time until rescue
- Flashlights – one per shelter
- Waterproof and windproof matches – two boxes per shelter
- Whistle
- Signal mirror
- Water containers and water purification tablets
- Spare set of personal survival equipment
- Group survival equipment container (waterproof and floatable)

It is important to note that this is a list of the suggested equipment, not the required. The requirements are listed in Chapter 8.3.3 of the Polar Code.

Preparations

Prior to the test, the following objectives were defined:

- Test maneuverability of life raft when in ice-infested waters
- Test feasibility of evacuating from life raft to an ice floe
- Test feasibility of pulling the life raft onto an ice floe and moving it on the ice
- Test feasibility of erecting the tents (supplied in group survival kits) in polar conditions
- Validate the usage scenarios of the included equipment
- Test capacity limitations in the life raft when wearing survival gear and having the required survival kits

Before the testing commenced, at 14:30 on 26 April, representatives from Viking lifesaving equipment presented the contents in their personal and group survival kits, and the participants obtained a good overview and idea of all the different equipment in the kits. Four different kits were provided by Viking. Both the personal and group survival kits were provided in a *Standard* and a *Superior* version. The contents in the *Superior* version were typically of better quality and included more equipment than in the *Standard* package. The *Standard* version of the kits covered the suggested equipment in the Polar Code, while the *Superior* version included some additional *nice-to-have* equipment. The contents in the kits are presented in Tab. I-3 to Tab. I-6.

Tab. I-3: Contents of the standard personal survival kits provided for the exercise by Viking life-saving equipment

VIKING PERSONAL SURVIVAL KIT
STANDARD KIT (MEETS STANDARD IMO)

ITEM	IMO Requirement		PRODUCT TYPE	PRODUCT DESCRIPTION	QTY
1	**Protective Clothing**	*	Undergarment	THERMAL LONG JOHNS	1
2		*		THERMAL LONG VEST	1
3		*	TOP	INSULATING JACKET	1
		*	BOTTOM	INSULATING JACKET	1
4			Socks	THERMAL SOCKS	1
5		*	Headprotection	THERMAL HAT	1
6		*	Thermal Head/face Protection	THERMAL HEAD AND NECK PROTECTION	1
7			Hands	THERMAL GLOVES	1
8		*	Shoes	TUNDRA	1
9	**Skin protection**		Cream	VASELINE	1
10	Immersion suit	*	Immersionsuit	**PS5002**	
11			Strobe light	ACR FIREFLY PRO LED STROBE LIGHT (SOLAS)	1
12	**Thermal aid**		Hand warmers	HANDWARMERS	35
12a			Thermal Protective Aid	THERMAL PROTECTIVE AID	1
13	**Miscellaneous**		Sunglasses	CONDOUR SUNGLASSES	1
14	**Whistle**		Whistle	WHISTLE	1
15	**Drinking mug**		Drinking cup	0.4Ltr STAINLESS STEEL THERMAL MUG	1
16	**Penknife**		Knife	FLOATING KNIFE	1
17	**Polar survival Guidance**		Handbook	MOD ARCTIC BOOK	1
18	**Emergency food**			SEVEN OCEANS EMERGENCY FOOD	1
19	**Survival Candle**			EXOTAC CANDLE TIN HOT BURN SMALL	1
20	**Matches**		Windproof Matches	SURVIVAL MATCHES	2
21	**Carrying bag**			90L DRYBAG WITH STRAPS AND WINDOW	1
				Spare equipment not required by IMO	
22	**Safety**		Ice spikes	SHOE ICE SPIKES	1
25			Survival Kit	ULTIMATE SURVIVAL KIT	1
26			First Aid Kit	LIFESAVER 2 FIRST AID KIT (INTERMEDIATE)	1

While most of the equipment would have been very useful, some was deemed unnecessary for an emergency situation (e.g. snowshoes) and could have been omitted for the sake of saving space and weight. Some of the equipment (especially in the *Standard* version) was also deemed inadequate (polyester undergarments, aluminum foil sleeping mat, etc.) and might prove to be a false security.

The PSK and GSK were bulky and would have taken up a significant amount of space, especially on board passenger vessels where individual PSKs would have to be provided for all passengers, in addition to GSKs as required. A lot of space could have been saved if the packaging had been removed before the equipment was packed into the bags. The PSKs were packed in 90L dry bags, while the GSKs were packet in 75L dry bags. The tents were packaged separately. As a result, there were many pieces of relatively heavy gear to be carried and cared for in an emergency situation.

Tab. I-4: Contents of the superior personal survival kits provided for the exercise by Viking life-saving equipment

VIKING PERSONAL SURVIVAL KIT
SUPERIOR KIT (EXCEEDS STANDARD IMO)

ITEM	IMO Requirement			PRODUCT DESCRIPTION	QTY
1	**Protective Clothing**	Undergarment	•	THERMAL LONG JOHNS	1
2			•	THERMAL LONG VEST	1
3		TOP	•	INSULATING JACKET	1
		BOTTOM	•	INSULATING TROUSERS	1
4		Socks		OUTTER SOCKS	1
				LINER SOCKS	1
5		Headprotection	•	WATERPROOF BEEINIE	1
6		Thermal Head/face Protection	•	GURU FACE MASK	1
7		Hands		EXTREME COLD WEATHER GLOVES	1
				LINER GLOVES	1
8		Shoes	•	IMPACT	1
9	**Skin protection**	Cream		CARMEX LIP BALM	1
10	**Immersion suit**	Immersionsuit	•	PS5002	1
11		Strobe light		ACR FIREFLY PRO LED STROBE LIGHT (SOLAS)	1
12	**Thermal aid**	Hand warmers		HANDWARMERS	35
12a		Thermal Protective Aid		THERMAL PROTECTIVE AID	1
13	**Miscellaneous**	Sunglasses		CONDOUR SUNGLASSES	1
14	**Whistle**	Whistle		SOLAS WHISTLE	1
15	**Drinking mug**	Drinking cup		0.4Ltr STAINLESS STEEL THERMAL MUG	1
16	**Penknife**	Knife		COMPACT FIXED BLADE	1
17	**Polar survival Guidance**	Handbook		MOD ARCTIC BOOK	1
18	**Emergency food**			SEVEN OCEANS EMERGENCY FOOD	1
19	**Survival Candle**			EXOTAC CANDLE TIN HOT BURN SMALL	1
20	**Matches**	Windproof Matches		SURVIVAL MATCHES	2
21	**Carrying bag**			90L DRYBAG WITH STRAPS AND WINDOW	1
				Spare equipment not required by IMO	
22	**Safety**			SHOE ICE SPIKES	1
23	**Water Proofs**	Jacket		CASCADA WATERPROOF JACKET	1
24		Trouser		CASCADA WATERPROOF TROUSERS	1
25	**Safety**			ULTIMATE SURVIVAL KIT	1
26				LIFESAVER 2 FIRST AID KIT (INTERMEDIATE)	1

Based on the configuration provided by Viking life-saving equipment, you would require one PSK for every person, in addition to three GSKs to meet the requirements in the Polar Code. Fitting all of this equipment and people in a 25-person life raft/lifeboat would be extremely challenging. There is definitely a disparity between the suggested equipment in the Polar Code and what it will be practical to accommodate based on standard life raft/lifeboat capacity calculations.

Discussion

After the equipment had been presented and the participants had become familiarized with it, 25 participants dressed in survival suits and prepared to embark onto the life raft. See Fig. I–24 for a picture of the participants. The life raft used was classified for 25 persons as per SOLAS requirements. The life raft was lowered to open water and held in place at the edge of the ice floe. Space quickly became a problem as more participants entered the life raft, and people were lying on top of each other, restricting movement.

The two paddles, supplied as standard, were used to relocate the life raft. This turned out to be a very time- and energy-demanding exercise. Due to the short paddles, the paddlers had to stretch out and lean over the pontoons in order to reach the water, as shown in Fig. I–25. In bad weather conditions, this would represent a serious risk.

Tab. I-5: Contents of the standard group survival kit provided for the exercise by Viking life-saving equipment

VIKING GROUP SURVIVAL KIT
STANDARD KIT (MEETS STANDARD IMO)

ITEM	IMO Requirement	PRODUCT TYPE	PRODUCT DESCRIPTION	QTY
1	Shelter	Tent	6 MAN TENT - INFERIOR	1
2	Thermal Protective Aid	TPA	THERMAL PROTECTIVE AID - SHIPSWHEEL APPROVED	6
3	Sleeping bag	Sleeping bag	SLEEPING BAG, SOFTIE 9 FOR -10 DEGREE C, BLACK	3
4	Sleeping mat	Insulation mat	ALUMINIUM FOIL SLEEPING MAT	3
5	Shovel	Shovel	SNOW SHOVEL WITH DETACHABLE HANDLE	2
6		Snow saw	SNOW SAW	2
7	Sanitation	Toilet Paper	SINGLE ROLL OF TOILET PAPER	6
8		Disinfection gel	50ML HAND SANITIZER	3
9		Sanitary napkins	MAXI PADS PK 10 NIGHT	3
10	Stove and Fuel	Stove/Pots	THE CRUSADER COOKING SYSTEM	3
11		Cutlery	KFS SET WITH CAN OPENER	6
12		Fuel	6 BLOCKS FIRDRAGON FUEL	14
13		Matches	SURVIVAL MATCHES	2
14	Food and Water	Desilinator	WATER PURIFYING TABS 2 x 50 IN POLYBAG	6
15		Food	SEVEN OCEANS 12 x 500 GRAM BISCUIT RATION	1
16	Flashlights	Light	ISON COMBAT ZOOM FLASHLIGHT	1
17	Whistle	Whistle	DISTRESS WHISTLE	1
18	Signal Mirror	Signalling	4" STAINLESS HELIOGRAPH	1
19	Packaging	Container	HEAVY DUTY DRYBAG - YELLOW 75L	2
20	Tarpaulin	Tarpaulin	TARPAULIN 180cm x 240cm BLUE	1
21	Candle	Survival Candle	EXOTAC CANDLE TIN HOT BURN SMALL	5
22	Spare Foot protection	Booties	TUNDRA BOOTIES - 40 (as per PSK)	1
23	Drink	Flavoured Drink	FLAVOURED POWDER DRINK 3YR SHELF LIFE	30
	SPARE PSK	SPARE PSK	SAME AS THE SPARE STANDARD PSK	1

			Spare equipment not required by IMO	
24	Life saving appliances	Throwing Line	15M THROW LINE	2
25	Life saving appliances	Dye	SEA/SNOW MARKER DYE	1
26	First Aid Kit	First Aid Kit	SOLAS FAK	1
27	Location	Compass	COMPASS 4B MILITAIRE NATO	1

The raft was moved to a field of rubble ice. Rubble fields are likely to be present in the marginal ice zone. Paddling the life raft in ice rubble proved impossible, and no distance was covered in these conditions.

Evacuating from the life raft to the fast ice proved to represent no additional challenge. One passenger went onto the ice and held the life raft in place as the other passengers evacuated. As more people gathered on the ice, the ice floe started sinking, and the evacuated passengers had to move further onto the ice to avoid breaking the ice edge. After all but four passengers had been evacuated, the life raft was pulled onto the ice. Despite there being four people in the life raft, this went surprisingly well. The life raft was then pulled with ease along the snow-covered ice surface by the participants. The cylinder with the compressed gas had been removed prior to the exercise, which definitely made pulling the life raft easier.

Three people with survival suits went into the water to test the heat loss and whether being submerged in the water for a short time would have a noticeable impact. The neoprene gloves that were strapped to the survival suit worked well. They were cold initially but, after a short while, they became

Tab. I-6: Contents of the superior group survival kit provided for the exercise by Viking life-saving equipment

VIKING GROUP SURVIVAL KIT
SUPERIOR KIT (EXCEEDS STANDARD IMO)

ITEM	IMO Requirement	PRODUCT TYPE	PRODUCT DESCRIPTION	QTY
1	Shelter	Tent with anchors	6 MAN POLAR TENT*	1
2	Thermal Protective Aid	TPA	THERMAL PROTECTIVE AID - SHIPSWHEEL APPROVED	6
3	Sleeping bag	Sleeping bag	ANTARTIC -50C	3
4	Sleeping mat	Insulation mat	ALUMINIUM FOIL SLEEPING MAT	3
5	Shovel	Shovel	SNOW SHOVEL WITH DETACHABLE HANDLE	2
6		Snow saw	SNOW SAW	2
7	Sanitation	Toilet Paper	SINGLE ROLL OF TOILET PAPER	6
8		Disinfection gel	50ML HAND SANITIZER	3
9		Sanitary napkins	MAXI PADS PK 10 NIGHT	3
10	Stove and Fuel	Stove/Pots	THE CRUSADER COOKING SYSTEM	3
12		Fuel	3 L + 500 ML	1
13		Matches	SURVIVAL MATCHES	2
14	Food and Water	Desilinator	WATER PURIFYING TABS 2 x 50 IN POLYBAG	6
15		Food	SEVEN OCEANS 24 x 500 GRAM BISCUIT RATION	1
16	Flashlights	Light	ISON COMBAT ZOOM FLASHLIGHT	1
17	Whistle	Whistle	DISTRESS WHISTLE	1
18	Signal Mirror		4" STAINLESS HELIOGRAPH	1
19	Packaging	Container	HEAVY DUTY DRYBAG - YELLOW 75L	2
20	Tarpaulin	Tarpaulin	TARPAULIN 180cm x 240cm BLUE	1
21	Candle	Survival Candle	EXOTAC CANDLE TIN HOT BURN SMALL	5
22	Spare Foot protection	Booties	TUNDRA BOOTIES - 40	1
23	Drink	Flavoured Drink	FLAVOURED POWDER DRINK 3YR SHELF LIFE	30
	SPARE PSK	SPARE PSK	SAME AS THE SPARE SUPERIOR PSK	1
			Spare equipment not required by IMO	
24		Throwing Line	15M THROW LINE	2
25		Dye	SEA/SNOW MARKER DYE	1
26	First Aid Kit	First Aid Kit	SOLAS FAK	1
27	Location	Compass	COMPASS 4B MILITAIRE NATO	1

comfortable to wear. Conversations afterwards revealed that none of the participants who went into the water noticed any effects as long as they remained dry inside the suit. They were able to participate in activities shortly after crawling up onto the ice. All had a safety line attached but managed to swim back to the ice edge and crawl up onto the ice without assistance. Fig. I–26 shows one of the participants crawling back onto the ice floe.

Erecting the tent, while wearing survival suits and neoprene gloves, proved to be a bigger challenge than anticipated, and only the tent included in the *Superior* version of the GSK was tested. The tent was not designed for use in polar conditions, and assembly was found to be complex. The instruction booklet was not very intuitive. The tent also utilized many small plastic hooks that required fine motor skills, exposing the fingers to the cold environment. As a result, the hands of the participants became very cold. The group had to alternate the task of hooking the canvas to the supporting rods of the tent. The design of the tent also required threading the supporting rods through hoops in the tent canvas. This task proved difficult, even in calm weather, and would have been exceedingly difficult in strong winds. Two different types of spikes were provided with the tent, neither of which appeared to be designed especially for use on snow and ice. The widest spikes could have worked if the tent was erected on snow but, on the sea ice, neither type of spikes worked well. Ice screws could have been provided if the shelter was to be utilized on the sea ice.

As the life raft was easy to transport and drag onto the ice, several of the participants voiced that utilizing the life raft as a shelter would have been the preferred option. The canvas of the life raft was double layered, giving it good thermal insulation properties, similar to those of the tent. The pontoons and bottom would also act as a thermal insulator compared with a tent.

The included sleeping bags were also tested and found to work very well. It is worth noting, however, that the sleeping bags included in the *Superior* version of the GSK were rated for -50°C, while those included in the *Standard* version were only rated for -10°C.

Fig. I–24: Group picture of participants for Equipment Testing ©Trond Spande

Fig. I–25: Relocating the raft with oars to the packed sea ice ©Lars Gunnar Dahle

Fig. I–26: Captain Barane crawling back onto the ice after swimming in the survival suite ©Trond Spande

I.6.2 Main findings from Phase III

The use of group survival equipment is aimed at evacuation onto the ice or onto the shore. In most cases, conducting these types of evacuations will require the mobility of the rescue craft, e.g. to find an appropriate ice floe or a beach suitable for landing. Paddling the raft in rubble fields proved impossible. Utilizing a lifeboat to tow the raft is a possibility; however, it is not an ideal solution, as excessive forces will be exerted on the towing bridle, including the raft attachment points and raft water ballast tanks.

Operating a standard SOLAS approved lifeboat in ice-covered waters is not ideal, as it has limited propulsion power for penetrating fields of rubble ice, and the propulsion train is not dimensioned for the forces generated by ice excitations.

The life raft proved to be a surprisingly good option for providing shelter on ice as it did not involve a large number of tasks requiring fine motor skills, and inflation of a raft requires less skill, training and time compared to the erection of a tent. The raft is also designed with an increased level of insulation, in the bottom, sides and in the canopy, compared to a tent. The standard SOLAS approved life raft does not, however, have any designated attachment points for guy lines, which would be required for utilization as an onshore/on-ice shelter.

Another major advantage of utilizing the raft for shelter when evacuating onto the ice is the raft's ability to provide protection in the case of fracturing of the ice floe.

When designing a group survival equipment package, it is important to consider the fact that the personnel that are to utilize the equipment are wearing personal protective equipment, e.g. limiting movement, thick neoprene gloves restricting the fine motor skills, non-breathing material causing accumulating sweat and moisture.

Both the weight and the volume of the group survival equipment are important parameters with regard to both transportation and storage of the equipment. The total number of individual components is also of importance because the correct utilization of each component requires knowledge and training. Basing the group survival equipment on standard safety equipment standards, striving to implement components of multipurpose use, will reduce the number of individual parts and minimize the need for additional training of the crew.

Based on the findings from this exercise, there is a discrepancy between the equipment suggested in the Polar Code and that, which can realistically be included when abandoning the vessel. Some of the included equipment was unsuitable for use when wearing personal survival equipment. The need for experienced people to assemble these kits was also evident. In addition, it is important to consider a holistic approach when designing GSKs/PSKs, considering all aspects of the survival chain due to the inter-dependencies between the different components; e.g., if only thick neoprene gloves are supplied, no components should require fine motor skills.

The Polar Code, being a functional set of rules, is open to definition for both the group and personal survival equipment, through a risk assessment carried out by the vessel operator. This could result in deviations across the industry in terms of what equipment is deemed suitable and in compliance with the Polar Code requirements, as there are currently no guidelines or accepted industry practices available.

1.7 Further work

There is currently no recognized interpretation of Polar Code requirements. Only SOLAS has prescriptive requirements concerning lifesaving appliances, and it gives no indications of functionality or survival time. Further work will be required to assess and to close the gap between regular SOLAS approved life-saving equipment & appliances and the functional requirements defined in the Polar Code. This work incorporates the following topics:

1. Identifying key parameters critical for human survival
2. Developing methodology for assessment of the safety chain through a holistic approach, identifying:
    a. Heat balances
    b. Water/energy required for personnel to maintain body temperature
    c. Insulating abilities required by PPE
    d. Insulating abilities required by rescue craft
    e. Air quality (temperature, humidity and O_2 level)
    f. Required/ideal amount of equipment in PSK/GSK
3. Identification of psychological aspects of long stays in rescue craft
4. Case study – design of lifeboat in compliance with Polar Code requirements
    a. CFD analysis of heat loss occurring from the lifeboat
5. Case study – design of life raft in compliance with Polar Code requirements
    a. CFD analysis of heat loss occurring from the life raft

1.8 List of participants

Name	Organization
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Ole Hansen	ENI Norge AS
Katie Aylward	American Bureau of Shipping (ABS)
Svein Erik Gaustad	Norwegian University of Science and Technology (NTNU),
Eirik Skogvoll	Norwegian University of Science and Technology (NTNU)
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Johannes Schmied	Nord University in Bodø
Erik Johan Landa	Norwegian Maritime Authority (NMA)
Jan Erik Jensen	Petroleum Safety Authority Norway (PSA)
Jette Næss Schmidt	Viking life-saving equipment
Terje Olsen	Viking life-saving equipment
Erik Mostert	Norsafe AS
Ronald Schartner	Norsafe AS
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II. Appendix: Individual contributions from participants

II.1 SAR Operations and the Polar Code

II.1.1 On the value of SAR exercises in the civil society

By Gunnar Vangberg, St. Olav’s Hospital in Trondheim / Norwegian Armed Forces

Managing disasters is a challenging task for even the most developed societies. Handling multiple casualties where the needs far outreach demand call for robust systems and skilled leadership. Still it is not uncommon that more victims suffer and die than necessary due to suboptimal handling of the event.

Even when a disaster occurs within the borders of one state, history shows that making different national organization cooperate efficiently is hard without previous training and mutual understanding of each other’s capacities, capabilities, and systems. Also the sheer number of victims may overwhelm a nation`s capacity regarding transport, treatment and logistics.

When disasters occur at sea, several additional challenges are added, especially in the arctic.

Ships and oil installations can be hundreds of kilometers from shore. At the same time few or no vessels may be close enough to respond within hours or days. These ships and installations may carry hundreds or thousands of people, numbers making an evacuation extremely demanding. Due to distance and numbers, helicopters may not be able to fly there, or at best evacuate victims at a painstakingly low rate.

Add to that, the harsh climate with often freezing temperatures, survival outside a warmed vessel will be very limited. An evacuation to life rafts or life boats which in temperate climate would be straight forward can in these conditions cause severe mortality and morbidity, further adding to the task of rescue.

The incident may also occur in international waters, where no single nation has an overarching mandate. A combination of SAR units and military ships of different nationalities may be employed as well as civilian vessels happening to be in the area. Take in to account that these units may have different command and control systems, dissimilar communication systems and procedures, language challenges and different cultural understanding of leadership.

In sum, we have a complex mix of challenges, ranging from mere logistical issues to issues of governance, international relations, and common coordination platforms.

If these units are to have a common situational understanding and goal, pre disaster training and cooperation is paramount. In our part of the arctic SAR-exercises are being performed on annual or bi-annual occurrence. One of the major gains of this is networking. Through planning and executing exercises, individuals and organizations meet each other and get to know each other`s modum operandi, resources, strengths and weaknesses. This again makes it possible to create realistic plans regarding who to alert, where to turn for resources and forms the foundations of bilateral agreements between nations as to who will be in lead of specific incidents.

An example of this is the bilateral agreement between Norway and Russia where Norway normally will be in the lead of SAR-operations in the area between the two countries. The rationale being that the

Norwegian Joint Rescue Central for the Northern areas is highly respected for its competency and has ample resources to take on such a complex coordination exercise. This is regularly exercised.

Another spin off is that exercises may create a higher awareness regarding possible scenarios. This may again lead to contingency planning, development of best practices, and thus, further reduction of risks. By including maritime and oil industry in planning and execution of such exercises, we think that there is created an increased awareness of possible risk factor previously not reflected upon.

These risk factors can then be mitigated, prevented and/or prepared for. The same can be said of the civilian healthcare system. In the day to day "production" in hospitals disaster preparedness is often regarded irrelevant. Through participation in such exercises the system and its individual staff and decision makers are forced to relate to possible scenarios and reflect on its systems' own shortcomings. This again will probably force changes towards a higher preparedness and situational awareness which would not otherwise have occurred. It is easier to argue for improvement when shortcomings have been unveiled.

As said many times before: "an ounce of prevention is worth more than a pound of cure".

SAR-exercises are already being conducted in the civilian society. For the relative small investments these exercises cost, great damage reductions can be expected in real life situations. Investments in "peace time" give great dividend in "time of war". Still, it is in the human nature to hope for the best and not necessarily prepare for the worst.

I will end with a saying from the airline industry: "If you think safety is expensive – try an accident!"

II.1.2 The Polar Code and SAR requirements

By Knut Espen Solberg, University of Stavanger / GMC Maritime AS

The International Code for Ships Operating in Polar Waters is by many referred to as the *Polar Code.*

The code is a supplement to the existing IMO instruments and the intention is to mitigate the additional risks present for people and environment when operating in Polar waters.

In contrary to most of the existing IMO instruments, the The International Code for Ships Operating in Polar Waters is based on a risk-based approach, only stating functional requirements. This implies that the marine operators are to identify risks and mitigate them through a holistic approach.

Identification of risks is dependent on mariner knowledge and experience. This requires in depth knowledge in relevant fields, e.g. area of operation, vessel capabilities, crew competence and type of operation. The risk-based approach is already to the industry in the ISM code. The Polar Code is however more specific, specifying sources of hazards. The code does however only to a slight degree indicate the risk acceptance criteria and does not specify adequate mitigation measures.

As of today there are no common industry understanding/interpretation of the code. There is also little or no ongoing work carried out trying to harmonize the code interpretation between different flag states or class societies. As a result, a large degree of discrepancy in the interpretation is to be expected in the coming years.

For vessel owners/operators this lack of consistency, transparency and predictability represents a major challenge. The challenge is cross disciplinary and affects issues from availability to adequately trained crew to safety equipment. The economic impact associated with the implementation of the Polar Code lies not only in the purchase, storage and maintenance of new equipment, but the huge economic implications lies in the risk of having to reduce the passenger capacity.

A reduction in the number passenger can emerge as a result of the additional equipment the Polar Code requires to be carried onboard the rescue crafts, e.g. personal survival kits, group survival kits and food and water for a minimum of 5 days. All rescue crafts have limitations with regards to both available space and carrying weight capacity. Most vessels have already stretched these capacities. Adding the additional equipment required by the Polar Code will mean that the number of persons pr rescue craft will have to be reduced. Reducing the number of passengers onboard a cruise vessel will have huge economic impacts on the cruise operator as it will affect their income.

Polar Code Requirements: Chapter 8 – Life-saving appliances and arrangements

The code states the following:

8.2.3.3 Taking into account the presence of any hazards, as identified in the assessment in chapter 1, resources shall be provided to support survival following abandoning ship, whether to the water, to ice or to land, for the maximum expected time of rescue. These resources shall provide:

.1 a habitable environment;

.2 protection of persons from the effects of cold, wind and sun;

.3 space to accommodate persons equipped with thermal protection adequate for the environment;

.4 means to provide sustenance;

.5 safe access and exit points; and

.6 means to communicate with rescue assets.

Where the following is defined:

1.2.4 Habitable environment means a ventilated environment that will protect against hypothermia.

1.2.7 Maximum expected time of rescue means the time adopted for the design of equipment and system that provide survival support. It shall never be less than five days.

In chapter 8.3, the following is defined:

8.3.3.1 In order to comply with the functional requirement of paragraph 8.2.3.1 above, the following apply:

.1 for passenger ships, a proper sized immersion suit or a thermal protective aid shall be provided for each person on board; and

.2 where immersion suits are required, they shall be of the insulated type.

8.3.3.2 In addition, for ships intended to operate in extended periods of darkness, in order to comply with the functional requirements of paragraph 8.2.3.2 above, searchlights suitable for continuous use to facilitate identification of ice shall be provided for each lifeboat.

8.3.3.3 In order to comply with the functional requirement of paragraph 8.2.3.3 above, the following apply:

.1 no lifeboat shall be of any type other than partially or totally enclosed type;

.2 taking into account the assessment referred to in chapter 1, appropriate survival resources, which address both individual (personal survival equipment) and shared (group survival equipment) needs, shall be provided, as follows:

.1 life-saving appliances and group survival equipment that provide effective protection against direct wind chill for all persons on board;

.2 personal survival equipment in combination with life-saving appliances or group survival equipment that provide sufficient thermal insulation to maintain the core temperature of persons; and

.3 personal survival equipment that provide sufficient protection to prevent frostbite of all extremities; and

.3 In addition, whenever the assessment required under paragraph 1.5 identifies a potential of abandonment onto ice or land, the following apply:

.1 group survival equipment shall be carried, unless an equivalent level of functionality for survival is provided by the ship's normal life-saving appliances;

.2 when required, personal and group survival equipment sufficient for 110% of the persons on board shall be stowed in easily accessible locations, as close as practical to the muster or embarkation stations;

.3 containers for group survival equipment shall be designed to be easily movable over the ice and be floatable;

.4 whenever the assessment identifies the need to carry personal and group survival equipment, means shall be identified of ensuring that this equipment is accessible following abandonment;

.5 if carried in addition to persons, in the survival craft, the survival craft and launching appliances shall have sufficient capacity to accommodate the additional equipment;

.6 passengers shall be instructed in the use of the personal survival equipment and the action to take in an emergency; and

.7 the crew shall be trained in the use of the personal survival equipment and group survival equipment.

8.3.3.4 In order to comply with the functional requirement of paragraph 8.2.3.3.4 above, adequate emergency rations shall be provided, for the maximum expected time of rescue.

Interpretation of Chapter 8 - Life-saving appliances and arrangements

Chapter 8 states that a vessel is to provide equipment that enables the passengers to survive a minimum of 5 days or the anticipated time of rescue. As the requirements are functional and a holistic approach is required. The holistic approach implies considering all relevant parameters. As many of the parameters are interrelated and dynamic, the task has to be carried out with margins taking allowance for the uncertainty related to the different parameters. The following parameters are to be considered:

- Governing metocean conditions for the area of operation
- Remoteness
- Available SAR infrastructure
- Energy required to maintain the core temperature of the persons
- Water required to maintain an adequate metabolism
- Insulating properties of the rescue craft
- Insulating properties of the PPE
- Physical condition of the passengers
- Cumulative weight of group and personal survival equipment
- Carrying capacity of survival craft
- Number of passengers

The aim of the functional requirements stated in the Polar Code is to mitigate the additional risks present in the Arctic/Antarctic environment. From a life saving perspective there are two dominant factors influencing the probability for survival in the areas applicable to the Polar Code :

Vulnerability to the environment – exposure to low air and water temperatures represent a major challenge for the human body. The risk represented by low temperatures can be divided into two:

- Hypothermia – reduction in body core temperature, inducting shivering, loss of cognitive abilities and ultimately death.
- Freezing of body extremities – during extreme low temperatures freezing of body extremities can be induced after only minutes of exposure. This will result in loss of functionality in the affected limb, which again reduces the probability of survival.

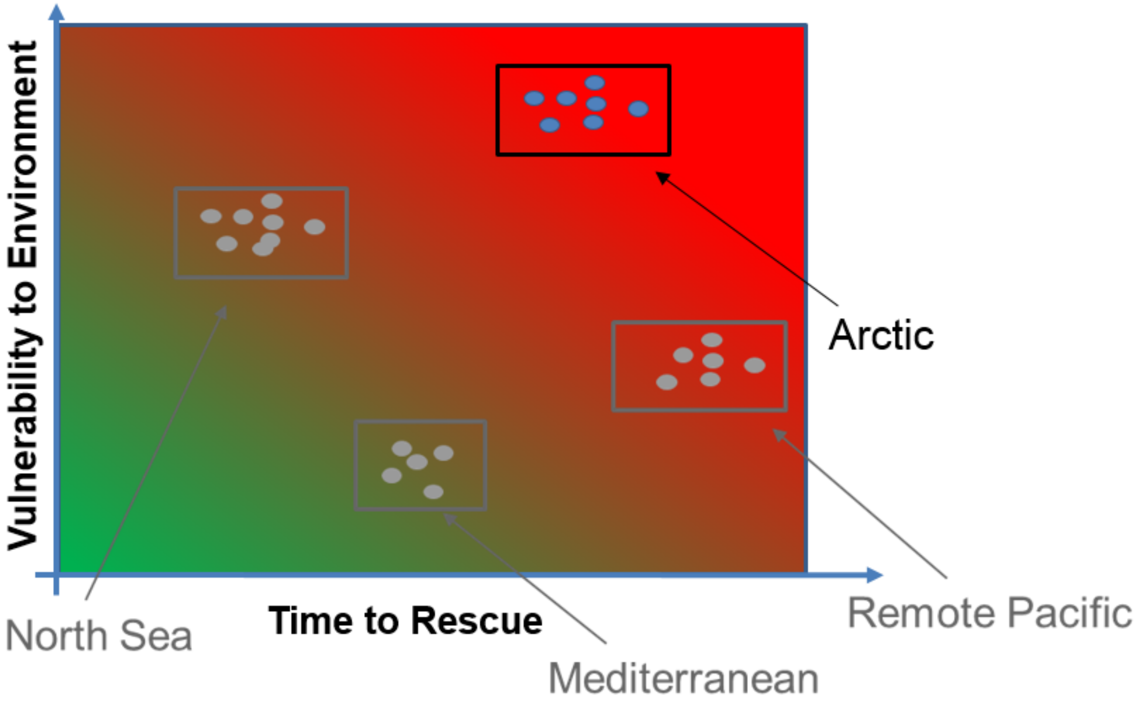
Exposure of the body to sub-zero temperatures will reduce the survival time substantially compared to survival in more temperate zones.

In addition to the low temperatures there are several distinct features present in the Arctic/Antarctic environment that represent additional challenges for persons that are to experience an abandon ship situation. These challenges are typically the risk induced by sea ice/ice bergs to the rescue craft and hostile wildlife.

Time to Rescue – Due to a low concentration of infrastructure in most of the areas where the Polar Code is applicable, the rescue time is long. Currently much of the S&R suppliers base their approach on helicopter evacuation. This has limitations not only with regards to weather, but more importantly with regards to both range and capacity to carry survivors. As a result much of the area where the Polar Code is applicable is outside helicopter range. Within the areas where there are helicopters available, the capacity to carry survivors is limited to typically maximum 10 to 20 persons.

For marine accidents with a substantial number of casualties, access to the site of the accident by other vessels is essential. Due to large distances and a relatively low vessel concentrations for a larger part of the year/areas the Time to Rescue can be relatively long.

Fig. II–1: Time to rescue as a function of vulnerability to the environment



The combination of a high Vulnerability to the Environment and a long Time to Rescue do represent the major challenges with regards to survival in the areas where the Polar Code is applicable. It is however clear that the largest discrepancy from an "average" accident taking place in more temperate parts of the world is the Vulnerability to the Environment, causing a large expected reduction in survival time.

The only way to combat the Vulnerability to the Environment is through vessels being self-sufficient, carrying lifesaving appliances that are fit for purpose, providing adequate protection. This implies to the rescue craft as well as to the group and personal protective equipment.

Identified uncertainties

The overarching goal of Polar Code, chapter 8.2.3 is defined in 8.2.3.3:

> *Taking into account the presence of any hazards, as identified in the assessment in chapter 1, resources shall be provided to support survival following abandoning ship, whether to the water, to ice or to land, for the maximum expected time of rescue.*

Where

> *1.2.7 Maximum expected time of rescue means the time adopted for the design of equipment and system that provide survival support. It shall never be less than five days.*

This is interpreted as the goal of all survival equipment is to provide survival of the passengers and crew for a minimum of 5 days in the area of operation. One of the key-words in this paragraph is *survival*. There is not identified any common, accepted definition of survival. Further down in the code there are however some clues that will give us an indication of IMO expectations.

The Chapter 8.3.3.1.2 states that passenger ships either can provide proper sized immersion suits or a thermal protective aid for each person on board. According to paragraph 8.3.3.3.2.2 the survival equipment is to provide sufficient thermal insulation to maintain the core temperature of the persons and paragraph 8.3.3.3.2.3 states that the personal survival equipment is to provide sufficient protection to prevent frostbite of all extremities.

This means that the personal protective equipment is to provide insulation that ensures an adequate maintenance of the body core temperature, in addition to insulated shoes, gloves and hoods, protecting body extremities.

The Polar Code does not state the exposure levels that are to be utilized in this analysis, and it is to be expected that personal protection has to be seen in relation to the rescue craft where the personnel is to spend their time.

According to paragraph 8.2.3.3, the rescue crafts are to have the following capabilities:

> *.1 a habitable environment;*
>
> *.2 protection of persons from the effects of cold, wind and sun;*
>
> *.3 space to accommodate persons equipped with thermal protection adequate for the environment;*
>
> *.4 means to provide sustenance;*
>
> *.5 safe access and exit points; and*
>
> *.6 means to communicate with rescue assets.*

Where:

1.2.4 Habitable environment means a ventilated environment that will protect against hypothermia.

1.2.4. States that the rescue craft shall provide an environment that will protect against hypothermia. I does not state to what degree it is to protect against hypothermia, or if the need for protection can be seen in relation to the personal survival equipment carried by the survivors.

Maximum expected time of rescue

According to the Polar Code the maximum expected time of rescue is defined as:

Maximum expected time of rescue means the time adopted for the design of equipment and system that provide survival support. It shall never be less than five days.

As SAR providers will not give any guaranty with regards to their expected time of rescue, it is expected that the industry will relate to the requirements of minimum 5 days.

To survive for 5 days in a rescue craft in cold climate will from a medical perspective put additional requirements on the rescue craft. Key areas for survival are:

> **Movement of limbs** – the survivors will have to move their limbs to maintain blood circulation. This is essential for maintaining blood flow to the extremities (to prevent local freezing of extremities). When the survivors are to be rescued out of the rescue craft, ability to move/maintain control over body limbs is also essential for a successful evacuation.

Toilet facilities/hygiene - the ability to maintain a minimum of hygiene is essential for preventing diarrhea. Cases with diarrhea will lose a significant amount of liquid, which in most cases will not be replaced due to strict water rationing. Dehydration will result in a loss of circulation, causing freezing of extremities.

Food/water - The body's ability to produce energy and maintain a normal core temperature is greatly affected by energy and water intake. The energy required produced by the body is greatly affected by the exposure level, which again is affected by the personal thermal protection and rescue craft.

The topics above are briefly touched upon in the Polar Code. 8.2.3.3.*3* states "*space to accommodate persons equipped with thermal protection adequate for the environment"*; and 8.2.3.3.*4 "means to provide sustenance"*. As the code is functional, it does not state space required for movement of libs, toilet facilities or food/water required to maintain a steady core temperature. For the designers of the equipment and the end users this represents a challenge because there is currently no common understanding of the requirements associated with a 5 days survival time in cold climate.

Our interpretation – functionality parameters

A survival time of 5 days will require the body to maintain “normal” body functions for a majority of the period. The body can maintain and survive a hypothermic state with shivering and loss of cognitive abilities for a period, but not for 5 days continuously. Based on discussions with doctors and physiologists, a hypothermic state will in most cases represent the *start of the end* in a cold climate survival scenario with a duration of minimum 5 days. It is of great importance for the survivors to never get into an hypothermic state as recovery will be difficult.

There are variations with in a population concerning ability to handle cold, physical abilities in relationship to body core temperature and metabolism. When interpreting the Polar Code it is beneficial to avoid criteria’s based on body temperature readings (due to large individual variations). Body functionality are the preferred parameters that defines the potential survivability of the personnel.

Survival is depends on carrying out the right actions at the right time. Typical actions are rationing/consuming of food/water, bailing, drying insulating layer, communicating with S&R facilities and keeping lookout.

The following functionality parameters have been identified as critical for carrying out activities essential for survival:

Cognitive abilities

All actions essential for survival are initiated through cognitive processes. Being able to comprehend the situation, and carry out relevant actions requires cognitive abilities. Staying mentally fit is also important for the ability to generate a motivation for survival.

There is a strong relationship between loss of cognitive abilities and reduction of body core temperature.

Body control

When the body core temperatures falls below about 35.5C the large muscle groups start a process of rapid contraction, resulting in shivering. Through the muscle contractions, the body is producing heat, trying to increase the body core temperature. These contractions are not controllable and the person is not able to attend its own needs or carry out the actions required to ensure survival.

Seen in a 5 day perspective, the duration contractions is limited before the muscles are exhausted. The duration is dependent on individual health, age and fitness. If the person is not brought into a warm space, a further decrease in body core temperature is to be experienced when the shivering stops.

Fine motor skills - extremities

Survival is dependent on carrying out actions (se above). Many of these actions require fine motoric skill that are to be carried out by the use of hands, i.e. push the PTT talk button on a VHF radio, open water rations and open/closing zippers for venting.

As survival depends on the above mentioned functionality parameters, the survival equipment required by the Polar Code is to provide properties that enables the personnel to maintain these parameters for the required minimum 5 days.

II.1.3 Polar code - additional SAR competence needs and extra course modules

Key notes from SARex exercise on board *KV Svalbard*, North-West Spitsbergen April 2016.

By Odd Jarl Borch, Nord University

CENTRAL ISSUES RELATED TO THE EVALUATION OF EVACUATION, SURVIVAL AND RESCUE PROCESS ON SAR MANAGEMENT – KEY PERSONNEL AND TASKS

1. Roles and responsibilities
    - Different phases
        - pre-evacuation
        - survival at sea
        - search
        - rescue
        - treatment
        - outbound transport
    - Category of management:
        - On-scene coordination (Master/XO)
        - Duty officer on bridge - navigator
        - Polar bear guard watch
        - Leader on deck (bosun)
        - Medical personnel
        - MOB boat drivers
        - Raft duty officers
        - Life boat duty officers
2. Challenges of coordination and control
    - units involved
    - vulnerable and unpredictable clientele
3. Extra challenges due to cold climate crew
    - Frost wounds
    - Time on duty
    - Fatigue
4. Extra challenges due to ice
    - Navigating
    - Maneuvering
5. Extra challenges life boat/raft duty officer
6. Competence needs for each category
    - Need for external courses
    - Need for external training

- Need for on-the-job training

7. What is your opinion about the exercise?
   a. Planning part
      i. Information exercise contents and timeline
      ii. How to behave
      iii. Risk assessment and mitigation
      iv. Demonstration of equipment

Exercise improvements:

   b. Pre-evacuation part
      i. Information
      ii. Secure area

Exercise improvements:

   c. Evacuation part
      i. Information
      ii. Leadership
      iii. Transfer vessel

Exercise improvements:

   d. Surviving at sea part
      i. Test issues
      ii. Safety
   e. Rescuing part

B. COMPETENCE NEEDS

SAR CONTINGENCY PLANNING

- Polar operational plan contents
- Polar context description (ice maps, weather data)
- Rescue equipment (personal, life rafts/boats)
- Evacuation planning
- Training and exercises
- SAR contingency plan with procedures

EVACUATION FROM DISTRESS VESSELS

- Evacuation plan adjustments and implementation
- Choose life rafts/life boats to use
- Equip them with necessary tools for survival
- Alarming and checking out living quarters/cabins
- Manage the passengers/crew lines at the mustering stations

SURVIVAL AT SEA

- Leadership roles on board
- Checking health status and taking care of each evacuee
- Activate people
- Distributing water and food

- Communication with other life boats/rafts
- Communication with rescue units

RESCUE PHASE

- Rescue plan and check list
- On-scene coordination of rescue units
- Search for survivals
- Communication with life boats/rafts – information on evacuated persons
- Life boat/raft triage (priority)
- Bringing rescued persons from raft/life boat on board rescue vessel
- Receiving rescued persons from helicopter
- Rescued persons' health triage
- Treatment of wounded persons
- Outbound logistics to mainland hospital

C. COURSE PLANS – ADDITONAL MODULES

ALL SAFETY CREW ON BOARD DISTRESS VESSELS

- IMO Safety course at operational level –additional module
    - Polar code operational level safety course module on evacuation, lifeboat/raft management in icy waters
    - Crowd and crisis additional module on survival in icy waters

OFFICERS ON BOARD DISTRESS VESSELS

- IMO Safety courses at management level
- IMO Polar code navigator course
- IMO Polar code master course
- Additional module Polar code:
- IMO Mass rescue operation safety course
- Polar code additional module on evacuation, survival at sea and rescue operations in polar waters
- Polar region contingency plans

MASTERS AND NAVIGATORS ON RESCUE VESSELS

- IAMSAR GMDSS course
    - Polar Code additional module on OSC (On scene coordinator)/ACO-air coordinator roles
- IMO Polar Code additional medical course – frost wounds, hypothermia, triage and emergency logistics

II.1.4 SARINOR project's focus on SAR management during a SAR operation

By Johannes Schmied[1], Odd Jarl Borch[1]

[1] Nord University

The Sarinor project is a Norwegian R&D project emphasizing the gaps in the search and rescue capacities and competences in the Norwegian Arctic region.

Sarinor work-package 7 (Sarinor WP7) focuses on "TRAINING, STUDIES & COMPETENCE DEVELOPMENT FOR SAR-OPERATIONS IN THE HIGH NORTH". Within this work package, we involve researchers from Canada and Russia to emphasize the importance for international cooperation. The work package provides a detailed analysis defining competence gaps and recommending actions for training, studies- and competence development for key personnel involved in SAR-Operations in different phases of a SAR operation.

Several arenas of competence building are to be considered.

As a result, the preparation for the case of emergency depending on the responsibility and task can include one or several of the bellow locations for competence development:

- Educational institutions at different levels
- Training institutes
- SAR institutions with own training facilities
- Competence building by private companies or industries
- Simulator centers

The whole search and rescue chain may include key personnel from different levels as well as different institutions. Different levels are also included in the Norwegian Command System. In large scale emergencies a strategic body may also be included to execute the strategic coordination. As a result, when thinking about the whole SAR-chain, Sarinor WP7 focuses on a broad set of actors including:

1. Distress vessel (captain, chief officer, chief engineer, bridge team members)
2. Distress vessel owner (managing director, preparedness contingency team)
3. On scene coordination
    - On-scene coordinator (OSC)
    - Air coordinator (ACO)
    - Rescue personnel of/connected to vessels
    - Rescue personnel of/connected to helicopters
4. Shore coordination
    - Rescue coordinator RCC
    - Local rescue coordination team
    - Operational and tactical level management of SAR-institutions
    - Strategic level SAR institutions, ministry and directorate

International and national standards create a platform for SAR-related competence building, especially in education for vessel crew and officers. In an Arctic SAR-perspective particularly the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW) plays an important role. The International Code for Ships Operating in Polar Waters (Polar Code) is currently adding new standards for icy waters.

Considering all the above, the contribution of Sarinor WP7 to exercise SARex is therefore of great relevance considering the main goals of SARex. These goals include to:

- *"investigate the adequacy of the rescue program required by the IMO Polar Code, the INTERNATIONAL CODE FOR SHIPS OPERATING IN POLAR WATERS (POLAR CODE)*
- *study winterization means to improve the suitability of equipment to be used for rescue operations in cold regions and ice infested waters*
- *train Norwegian Coast Guard personnel on emergency procedures in ice infested waters with particular reference to evacuation and rescue from cruise ships"*

Sarinor WP 7 therefore not only financially contributes by funding a share of the exercise. Contribution is also done by actively participating as well as observing the whole exercise concept in all three phases of SARex. Special focus is given to the observation of the on-scene coordination team (OSC) of the coast guard vessel *KV Svalbard*.

Relevant findings from SARex, including key findings from the observation of the exercise, are used to create recommendations and guidelines. These focus on the development of efficient knowledge sharing, training and study programs for ship owners, vessel personnel and SAR organizations in the High North. Furthermore, we give recommendations on new procedures for planning, execution and follow-up on SAR-Operation. Recommendations are:

- The planning phase of a training and exercise program
- How to identify best-practices for situational awareness of an operation, to be used for collaboration and execution support during an operation
- Managerial roles related to training and exercise programs
- Identify good procedures for de-briefing and evaluation of training and exercise programs

II.1.5 Navigation and search effectiveness during a SAR operation

By Bjørn M. Batalden, UiT, The Arctic University of Norway

Passage planning for voyages in polar waters should follow similar principles to that of other waters and include appraisal, planning, execution and monitoring (House 2010, Canada. Coast 2012). Still special attention should be directed towards weather routing and maintaining communication (House 2010).

Navigating in high latitudes do introduce challenges with respect to charts and navigation instruments. It may also increase the workload on the crew if operating in ice-covered waters with need for more look-outs and navigators (Batalden 2012, Canada. Coast 2012). The Arctic being a demanding area to operate, the quality of navigation charts may also be limited depending on the date of survey and the technology used when conducting the survey (ABS 2016). Many navigation charts may have areas that are inadequately surveyed or make use of old surveys often having limited soundings (Canada. Coast 2012). Even when using new navigation charts, navigators should check the projections and date of survey. As always when navigating, it is good practice to make use of the echo sounder to assess the accuracy of the chart. Navigation charts based on old surveys may also contain errors in measurements of land contours.

Today most navigation at sea make use of Electronic Chart Display and Information Systems (ECDIS). These systems have a limited number of projections available (Skopeliti and Tsoulos 2013). As meridians converge when closing in on the poles, the scale of the parallels is distorted and (ABS 2016). The most used projection in maritime navigation, Mercator projection, is not suitable at high latitudes. It is suggested that the arctic area should be divided into Arctic and sub-Arctic regions when selecting an appropriate projection (Skopeliti and Tsoulos 2013). For sub-Arctic areas, the Lambert Conformal Conic projection and Conic Equidistant projection are most suitable while Azimuthal Polar Equidistant projection and the Azimuthal Polar Stereographic projection are suitable for the Arctic region (Skopeliti and Tsoulos 2013). Today most ECDIS does not include these projections and it is recommended that navigators compare positions plotted in ECDIS with large-scale paper charts (ABS 2016).

Both the magnetic compass and the gyrocompass used in navigation has limitations when operating at high latitudes, more so for the magnetic compass. When operating north of 70 degrees, the magnetic compass require longer periods on a stable course to settle as it depends on the directive force upon the horizontal component of the magnetic field of the earth (Canada. Coast 2012). North of 85 degrees, the gyrocompass is not usable. North of 70 degrees, the gyrocompass needs latitude correction to provide sufficient accuracy. It is therefore important to assess the gyro error frequently when operating north of 70 degrees. Satellite compasses are an additional resource that will give accurate heading information at high latitudes. These compasses make use the phase difference between three or four GPS antennas with known distance between them. This equipment was tested onboard the icebreaker Oden during the north pole mission in 1991 and is superior to the gyrocompass when operating at high latitudes (Kjerstad 2007).

When fixing a position in Arctic waters, it is should be taken into consideration that some navigation charts are developed based on old and inaccurate surveys. Further, ice piled up on shore or along the coastline may give inaccurate measures when applying radar ranges and bearings. The same apply for visual bearings. When fixing a position, it is recommended to make use of three radar ranges, preferably in combination with visual bearings.

Search and rescue operations in polar waters will be similar to operations in other waters. There are, however, some additional issues to be addressed with respect to both navigation and search effectiveness. The prime concern is to know the location of the object in distress and the status of the object. Important indications of location and status are intentions, last known position, hazards, conditions and capabilities, crew behavior, on-scene environmental conditions, and results of previous searches (IMO 2008). By using the last known position, it is possible to estimate the extreme limits of possible location based on assessing the maximum distance the survivors could have travelled. Depending on available resources, it is often necessary to establish a narrower search area based on one or more scenarios. These scenarios need to be established using available facts. Two forces need to be taken into account, leeway as a function of the wind and total water current. With limited information about these forces, the estimated position of the object in distress will be more uncertain.

Two primary factors influence the search conditions. (1) The sweep width depends on the object in distress, the sensors available and the environmental conditions. (2) The ability for the search craft to navigate accurately according to its search pattern (IMO 2008). Sweep width can be determined for different objects in distress using formulas and tables available in International Aeronautical and Maritime Search and Rescue Manual (IAMSAR) volume III (IMO 2008). In search and rescue, it is of paramount importance to minimize the time to estimated rescue position. There is a need for accurate information on meteorological and oceanographic conditions, up-to-date ice charts, ice drift and wind. When operating in ice-covered waters it is important to remember that the shortest time between two positions are not necessarily the same as the shortest route measured in distance. With accurate and up-to-date ice charts, it is possible to assess the shortest route measured in time, which may be different from a direct line.

Positioning and maneuvering own vessel also need to take into consideration the ice drift. When closing in on persons in distress, careful maneuvering should be applied if lifeboats of rafts are on or in contact with ice as changes in ice-pressure might create dangerous situations as the ice may break up or induce high pressure on the rescue crafts.

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II.1.6 Human and organizational concerns during search and rescue operations in the Arctic

By Katie Aylward, American Bureau of Shipping (ABS), Houston

Preface

This research project was organized by the University of Stavanger, Company GMC, and the Norwegian Coast Guard and involved joint efforts from Norwegian academic institutions, Norwegian Industry, Norwegian Government institutions, ABS Houston and Memorial University St. Johns. The research took place in April 2016 on the K V Svalbard, a Norwegian Coast Guard vessel in the northern waters of Svalbard. This report will discuss the human and organizational concerns during Search and Rescue Operations in the Arctic based on findings from this research project.

Introduction

The inherent risks during marine and offshore operations and the continuous increase in vessels operating in Arctic and Antarctic waters are the driving factors behind the International Maritime Organization ("IMO")'s *International Code for Ships Operating in Polar Waters* ("IMO Polar Code"). The IMO formally adopted the Polar Code safety provisions on 21 November 2014 at the Maritime Safety Committee ("MSC") meeting and adopted the environmental provisions on 15 May 2015 at the Marine Environmental Protection Committee ("MEPC") meeting. The IMO Polar Code is a result of over 20 years of effort led by the IMO and will enter into force on 01 January 2017.

The IMO Polar Code introduces a "broad spectrum of new binding regulations covering elements of ship design, construction, onboard equipment and machinery, operational procedures, training standards, and pollution prevention" (ABS IMO Polar Code Advisory).[2] Chapter 8 of the Polar Code provides regulations for lifesaving appliances and arrangements which aim to provide for safe escape, evacuation, and survival.[3]

Industry has raised questions surrounding correct interpretations and application of these requirements. For example, one of the requirements indicates that passengers and crew shall be equipped to enable survival for a minimum of five days in the regions defined by the Polar Code as Arctic or Antarctic while waiting for rescue. Another requirement indicates that "adequate" thermal protection shall be provided for all persons on board. This paper serves to study and interpret the practicality of the IMO Polar Code requirements, given currently available safety and survival systems and equipment.

Risks associated with Arctic Operations

While search and Rescue ("SAR") operations are risky and challenging no matter where they occur geographically, SAR operations in the Arctic present unique hazards. Human survival in below freezing temperatures for any amount of time without proper shelter, food, clothing, and other necessary resources is very difficult. Additional human and organizational related concerns faced by vessels operating in polar waters include, but are not limited to:

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[2] American Bureau of Shipping. *IMO Polar Code Advisory*. Houston, TX (Jan. 2016), available at http://ww2.eagle.org/content/dam/eagle/publications/2016/PolarCodeAdvisory_15239.pdf

[3] IMO. International Code for Ships Operating in Polar Waters. MSC. 385(94), available at http://www.imo.org/en/mediacentre/hottopics/polar/pages/default.aspx

- Low temperatures which affect human performance, equipment efficiency, survival time, and performance of safety systems
- Prolonged darkness or daylight which physiologically and psychologically affect human behavior, health, and wellness
- Remoteness of Arctic work environments may limit the availability of deployable SAR resources that could delay the response time in an emergency
- Lack of crew experience operating in ice infested waters may increase the potential for human error
- The safety and survival equipment may not be appropriate for use in Arctic environments and may not be as effective as it would be in non-polar waters
- Dangers from Arctic wildlife to personnel and equipment, including polar bears and walrus
- Potential for incidents to escalate quickly based on rapidly changing and severe weather conditions.

The safe abandonment of a vessel to survival craft (lifeboat or life raft) has been the prior focus of SAR activities, vessel training programs, and safety research. However, there is a gap in understanding of the requirements of survival after getting into the survival craft. The goal of this project was to study the SAR process from beginning to end in polar waters from the perspective of the human waiting for rescue and the Norwegian Coast Guard as the rescuing body in the form of a full scale training exercise.

Breakdown of Research

Key concerns were addressed though three phases of research examining all aspects of SAR operations in the Arctic:

- Phase one evaluated if people could survive in a lifeboat and life raft in polar waters for up to 24 hours while wearing different levels of thermal protection
- Phase two evaluated Norwegian Coast Guard rescue operations from a lifeboat to simulate a mass casualty situation
- Phase three evaluated the capabilities and limitations of lifesaving appliances (life raft, personal and group survival kits) and their adequacy in polar waters.

Weather conditions were nearly perfect during the test, with sunny skies, virtually no wind or waves, and an average air temperature of -13ºC/ 8.6 ºF and water temperature of -1ºC/30.2 ºF. The participants were research team members and Norwegian Coast Guard personnel which represented an overall healthy and fit study population. Some of the significant human element related risk findings of this study are identified in this report.

Phase One Objectives and Findings

Phase I looked at the survivability of people in a lifeboat and life raft in polar waters for up to 24 hours. The group of 22 participants in a 55-person lifeboat and 20 participants in a 25-person life raft were randomly assigned to wear different levels of thermal protection, including insulated and uninsulated immersion suits, neoprene immersion suits and thermal life jackets. The goal was to determine how long the protective equipment was effective, with a level of ineffectiveness reached when:

- Hands and feet were numb, or the participant experienced the onset of shivering
- The participant was unable to complete a simple physical test (unscrewing a bolt)
- A participant thought another participant looked physically unwell

When any of these criteria were met, the ship's doctor completed wellness checks as each participant left the survival craft.

Thermal Protection

The type of thermal protection significantly impacted the length of time participants were able to remain in the survival craft. Research has shown that in addition to the type of thermal protection, whether or not a person stays dry, will impact survival time (Hayes, 1987).[4] The IMO Polar Code requirement states that "adequate thermal protection shall be provided for all persons on board..." [2] which is vague, and leaves much room for interpretation. This requirement implies that a cruise ship can either supply insulated immersion suits or thermal life jackets to passengers for thermal protection. In a cruise ship emergency situation the passengers could be wearing a variety of clothing combinations (e.g. formal dinner attire), and may not have time to change into appropriate layers of warm clothing. Thus, we pose the question, can people survive at least five days in the Arctic wearing only a thermal life jacket, with no thermal protection on their arms or legs?

In this study, different types of thermal protection were tested, including insulated and non-insulated immersion suits, neoprene immersion suits and insulated life jackets. As expected, the different types of thermal protection had an impact on how long the participants were able to last within each survival craft. Participants wearing thermal life jackets were generally the first to leave the study, followed by neoprene immersion suits, non-insulated immersion suits and finally insulated immersion suits. One of the concerns with thermal life jackets is that they only provide thermal protection to the core and upper body, offering no protection to the feet, legs, or hands. While, the neoprene immersion suit appeared to function well in the lifeboat; however, in met with less success in the life raft, where some participants were damp from opening the entranceways. Participants wearing the insulated immersion suits lasted the longest time, but only three were able to complete 24 hours in the lifeboat. Two of the participants wearing insulated immersion suits remained in the life raft for approximately 18 hours. Not surprisingly, insulated immersion suits provided whole-body thermal protection for the longest amount of time during this study. Preliminary conclusions suggest that insulated immersion suits should be a requirement for vessels operating in Arctic environments because the life jackets tested in this study did not provide enough thermal protection for this type of environment.

Air Quality

The air quality in both the life raft and lifeboat was another important factor identified in this study. Although air quality within life rafts has not been well researched, carbon dioxide (CO_2) accumulation within lifeboats has been cited by Aylward[5], and Baker[6] as a major concern if fresh air is not regularly circulated. In both of these studies, international and national exposure limits were reached within 15-20 minutes. This means that within the first hour after entering a survival craft, people could start to experience some of the initial symptoms of CO_2 exposure: increased respiration, headaches, sweating, increased heart rate and blood pressure, and hyperventilation.[7]

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[4] Hayes, P A et al. (1987). Further Development of Mathematical Model for the Specification of Immersion Clothing Insulation. RAFI IAM Report No R653.

[5]Aylward, K.. The Effects of Simulated Lifeboat Motions on Carbon Dioxide Production. (Master Thesis 2015). Memorial University of Newfoundland, available at http://research.library.mun.ca/11642/

[6] Baker, A. et al.,. Carbon Dioxide Accumulation within a Totally Enclosed Motor Propelled Survival Craft, Chalmers Conferences, Ergoship (2011), available here (click).

[7] National Institute for Occupational Safety and Health. Carbon Dioxide. NIOSH Pocket Guide to Chemical Hazards (2010), available at http://www.cdc.gov/niosh/npg/npgd0103.html (last visited June 2016)

For safety reasons, portable oxygen (O_2) meters were used in each craft. During this study, every 20 – 30 minutes the O_2 meter alarm sounded in both crafts, indicating required ventilation which took the form of opening the entranceways or hatches. Each time venting was required, there was a noticeable temperature drop within the survival craft. Currently, it is not a requirement for survival craft to have an alarm for O_2 or carbon dioxide (CO_2). This is a major concern because during a SAR operation, the occupants may not be aware that fresh air should be periodically re-circulated throughout the survival craft. Many of the initial symptoms of over exposure to CO_2 are difficult to decipher from symptoms of shock and stress which could lead to a potentially deadly situation in a relatively short time span. Existing research and conclusions from this study indicate that all survival craft should be equipped with a means to measure air quality, or alternatively that ventilation options should be explored.

Anthropometrics

Another finding from this study which could significantly impact human survival and SAR operations is the posted persons on board (POB) capacity in survival craft. Lifeboat capacity has been studied in both the Gulf of Mexico and in Atlantic Canada. Findings show that the posted survival crafts' capacity of maximum POB could be an over-estimation. Kozey, et *al.* studied the anthropometric (study of human body measurements) differences of people wearing Arctic PPE compared to normal clothing and how that impacts capacity requirements for lifeboats (2009).[8] The average person with the requisite Arctic PPE (i.e. immersion suits, life jacket, boots, gloves, etc.) occupies more space than the average person without Arctic PPE and as a result, less people are able to fit into the survival craft.

In the present study, lifeboat seating capacity was not an issue because a 55 person lifeboat was used and never filled to capacity. However, life raft capacity is notably an issue; 20 people could barely fit in the 25 person life raft. Even with an overall fit group of participants, the space was insufficient demonstrating a major concern if people had to spend any prolonged amount of time waiting for rescue. Although it was physically possible to fit into the raft, there was no room to move and each time someone needed to adjust their position, it affected the entire group of people. Furthermore, the life raft is equipped with a large bag of survival supplies (food, water, flares, etc.) which encompassed the entire center. This bag occupied so much space that one participant was forced to sit on top of the supplies. In an actual SAR operation, there may be additional safety equipment in the life raft including personal and group survival kits (tents, warm clothes, flashlights, cooking equipment, etc.) which would require additional space. Based on existing research and the present study, the POB capacity for survival craft, including lifeboats and life rafts should be re-evaluated to account for Arctic survival supplies and human anthropometrics wearing appropriate thermal protection.

Phase Two Objectives and Findings

Phase two of this research was primarily a training exercise for Coast Guard personnel and will not be discussed in detail in this report. Overall conclusions are presented below.

Phase two simulated an Arctic cruise ship rescue situation with a mass number of casualties. Approximately 40 participants were loaded into a 55 person lifeboat and each participant was given an illness/injury (hypothermia, broken leg, head injury, etc.) before the start of the exercise to inform the Coast Guard when they arrived for rescue. The Coast Guard team had to figure out how to prioritize the casualties (urgent vs. non-urgent injuries), and plan and allocate resources to get the entire group back to the vessel as quickly and safely as possible.

From the perspective of a "rescued" person by the Coast Guard team, they did an excellent job from an organizational and safety standpoint. During an otherwise stressful situation, the Coast Guard team

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[8] Kozey, J, *et al*. (2009). "Effects of Human Anthropometry and Personal Protective Equipment on Space Requirements. *"Journal of Occupational Ergonomics*, 8(2-3), 67- 79

worked hard to ensure the participants felt safe and comfortable. The Coast Guard rescue team, the medic team, and additional personnel demonstrated good communication and organization throughout the entire exercise. Organizing a mass number of people in an emergency situation requires rigorous communication and team work and the Coast Guard crew proved that even with limited resources on their vessel, they were prepared to deal with this type of situation. This comprehensive training exercise will benefit the crew in future emergency situations.

Phase Three Objectives and Findings

The purpose of phase three was to test the adequacy of the life raft in ice, and study the contents of group and personal survival kits provided by the equipment manufacturers. The first part of phase three involved filling the life raft to capacity (25 people) and using the paddles to row to the ice edge from the open water. The second part of phase three involved evaluating the adequacy of the equipment within the survival kits for use in Arctic environments. The results from phase three will be fully explained in Section I.6.1 of this report. A summary of the findings are provided below.

As identified in phase one, POB capacity was an issue. In this case, five people were laying on top of one another in the middle of the raft with no space to sit. This was an unsafe, risky environment for a short duration (20-30 minutes) and demonstrated a major concern if people had to spend any prolonged amount of time in this cramped space while waiting for rescue. Another risk factor identified was the length of the paddles for the life raft which barely touched the water. In order to gain enough force to paddle, the two participants in charge of rowing the raft had to lean the majority of their body out of the entranceway to reach the water. This is a concern that could be solved with adjustable or retractable paddles that would not require additional space in the raft. Based on existing research and the present study, the persons on board (POB) capacity for survival craft, including both lifeboats and life rafts, should be re-evaluated to account for human anthropometrics and the additional space required for safety equipment.

The group and personal survival kits had many practical items for use in an Arctic environment. A detailed breakdown and evaluation of this equipment will be provided in Section I.6.1. However, one of the items that raised concerns was the tent provided in the group survival kit. The tent was extremely difficult to pitch and required a lot of people working together to successfully set it up. In this type of climate, it is important that the shelter provided has the following characteristics:

- Clear instructions
- Easy assembly
- Requires very few people to assemble
- Lightweight
- Tested in harsh environments

Another interesting finding from this study was that if necessary, the life raft could function as a form of shelter instead of a tent. Some of the benefits of the life raft as a shelter include the following:

- Easy to inflate (if not already inflated)
- Relatively easy to pull up onto the ice (if already inflated)
- Easy to move back into water if there was a danger on the ice (polar bear)
- Double insulated bottom
- Functions as an air mattress because of double layered bottom

Conclusions and Recommendations

Operations in the Arctic involve risks, some of which have been identified in this report. It is presently impossible to determine exactly how long someone could survive while waiting for rescue in polar waters, or the necessary thermal protection needed for survival in this environment. However, the results indicate that even with a healthy group of participants and excellent weather conditions, the risks during SAR operations are very serious. If conditions had been more severe, the results could have been considerably different, particularly for the life raft due to the possibility of seasickness, water entering the life raft, and colder temperatures.

Primary findings suggest that industry may find it difficult to meet Polar Code requirements for surviving for at least five days in polar waters. Additionally, the type of thermal protection provided may have an impact on survival time. The thermal life jackets tested in this study may not be adequate for use in polar waters as suggested by the minimum requirements of the IMO Polar Code. Finally, in a mass casualty situation, due to the risks identified in this article and many others, significant challenges could arise during SAR operations.

The results from this study indicate further research is needed in the following areas:

1. Lifeboat and life raft performance in harsher weather conditions for longer periods of time
2. Thermal protection adequacy after exposure to water
3. Testing of other life-saving equipment in ice and polar waters
4. Air quality and ventilation of lifeboats and life rafts
5. POB capacity for lifeboats and life rafts
6. Similar study in controlled conditions (lab setting)

The results from this research will help industry meet Polar Code requirements for escape, evacuation and survival. ABS is thankful to the University of Stavanger, Company GMC, and the Norwegian Coast Guard for the opportunity to participate and contribute to this world class Arctic research project.

Disclaimer: This report was prepared by Katie Aylward in her personal capacity. The opinions expressed in this article are the author's own and do not reflect the view of American Bureau of Shipping.

II.1.7 Canadian Perspective on Passenger Ship Evacuation in Arctic Waters

By Robert Brown, Memorial University of Newfoundland, St John's

Overview

Maritime emergency response ideally requires individuals to move sequentially through the steps of assembling on board, preparing for abandonment, boarding life-saving appliances (LSAs), abandoning the vessel and surviving in the environment until they can be rescued. It is generally accepted that individuals involved in a ship evacuation in the Canadian Arctic may, because of the vast distances and remoteness, be required to survive a period of five or more days before rescue can take place. Much research carried-out in Canada has focussed on this expectation of the extended survival phase and has attempted to provide an improved understanding of the thermal protection requirements for personal protective equipment (PPE) and life-saving appliances (LSAs) (i.e. life rafts and lifeboats).

Personal Protective Equipment (PPE)

In Canada, the work of Tikuisis, Ducharme, Giesbrect, Xu, Power, Brookes and Potter (see references section) has involved thermal performance testing of immersion suits with both human participants as well as thermal mannequins. Their research provides a better understanding of the insulation requirements for individuals wearing PPE when immersed in cold water for relatively short term exposures. However, it is challenging to perform long-term exposure testing with humans (for safety and ethics reasons) and thus, a direct comparison between human and mannequin thermal performance for long duration exposures is still needed. The Cold Exposure Survival Model (CESM) (Tikuisis et al., 2005 and Xu et al., 2005) is capable of predicting the thermal performance of humans in cold environments, however, CESM is not considered reliable for making accurate predictions beyond much more than 36h exposures.

Aspects of PPE use that must be considered in Arctic abandonment scenarios include the time and space requirements for donning on board the ship and the impact of inexperienced passengers or the infirm, non-ambulatory or elderly in donning PPE. The impact of PPE on walking speeds and mobility needs to be examined. This research has not been carried out but is being planned by a Canadian/Norwegian/UK consortium, with the aim to incorporate findings into evacuation simulation software and, ultimately, the regulatory framework at the IMO. The reduction of available space inside lifeboats as a result of bulky PPE has been measured for offshore populations (Kozey et al., 2009) but should also be measured for Arctic passenger vessel applications.

Liferafts and Thermal Protection

The work of Mak, Evely and Ducharme (see references section) has led to a significant improvement in our understanding of how much thermal protection is provided by inflatable life rafts in cold environments and has built on the research carried-out in Canada by Melville Shipping 1988-1993 (see references section). Mak, Evely, Ducharme et al. (2007-2011) measured and modelled the heat loss from humans in life rafts for a range of temperatures, clothing ensembles and life raft floor insulation materials for wet and dry cases (Fig. II–2). Subsequent modelling of the heat loss process produced the data shown in Fig. II–3, which suggests the requirements for *dependent* survival (i.e. survivor requires assistance) and *functional* survival (i.e. survivor is capable of helping himself/herself) inside a life raft

Fig. II–2: Liferaft thermal performance testing with mannequin (left) and human participant (right).

for a 36h exposure for the different conditions of wet/dry and clothing/PPE used. The horizontal lines show the minimum insulation requirements for four different environment temperatures: +20°C, 10°C, 0°C and -10°C (showing, as expected, that the system thermal insulation requirement for functional and dependent survival over 36h rises as the temperature decreases). For the approximate temperature experienced during the Svalbard SARex (-15°C), the predictions by Mak et al. suggest a 36h survival time is likely to be accomplished only if the life raft has a double layer floor that is inflated to provide insulation from convective heat loss to the ocean and if the occupants are dry and wearing a thermal protective aid.

Further research by Mak et al. discusses microclimate issues in the life raft and balancing ventilation needs (i.e. CO_2 that accumulates as occupants exhale inside) with the need to retain heat (accumulated heat escapes as the life raft canopy is opened). Inadequate ventilation will result in high concentrations of carbon dioxide, causing headaches, dizziness, restlessness, breathing difficulty, sweating, as well as increased heart rate, cardiac output and blood pressure. All of these may adversely affect occupants in performing survival tasks. This research has shown that CO_2 accumulation can reach dangerous levels in relatively short periods of time and that ventilation will be required from time to time but should be kept to a minimum in order to reduce the effects of losing accumulated heat inside.

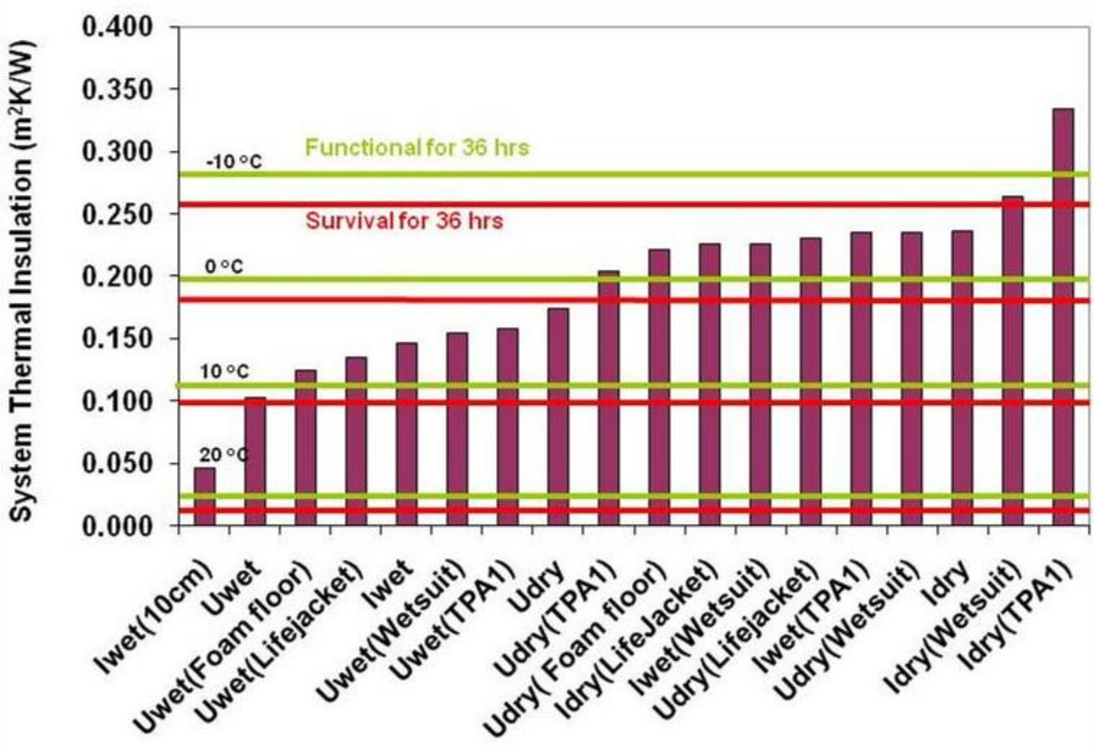


Fig. II–3: System insulation values for different clothing/PPE ensembles and required insulation for 36h dependent and functional survival time at +20°C, +10°C, 0°C and -10°C.

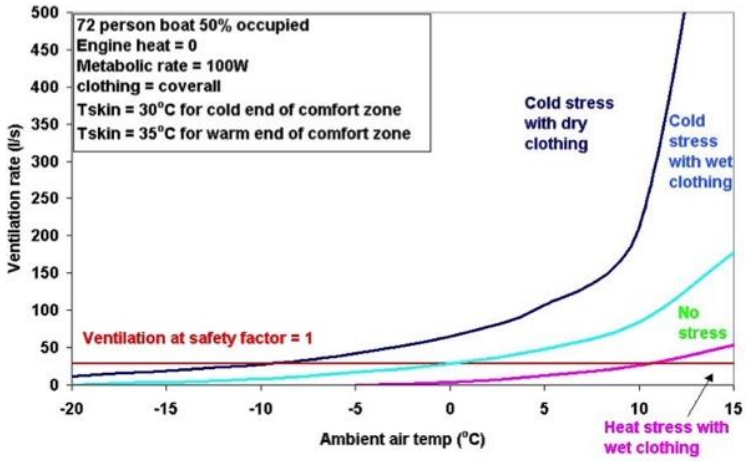
Tab. II-1: Key to the x-axis labels for Fig. II–3

Iwet (10 cm)	Inflated floor; 10 cm high water on the raft floor
Uwet	Uninflated floor; wet clothing
Uwet (Foam floor)	Closed cell foam floor placed on uninflated floor; wet clothing
Uwet (Lifejacket)	Uninflated floor; wet clothing; sitting on own lifejacket
Iwet	Inflated floor; wet clothing
Uwet (Wetsuit)	Uninflated floor; wet clothing and 3mm neoprene wetsuit
Uwet (TPA1)	Uninflated floor; wet clothing and TPA
Udry	Uninflated floor; dry clothing
Udry (TPA1)	Uninflated floor; dry clothing and TPA
Udry (Foam floor)	Closed cell foam floor placed on uninflated floor; dry clothing
Idry (Lifejacket)	Inflated floor; dry clothing; sitting on own lifejacket
Iwet (Wetsuit)	Inflated floor; wet clothing and wetsuit (3mm neoprene)
Udry (Lifejacket)	Uninflated floor; dry clothing; sitting on 2nd lifejacket
Iwet (TPA1)	Inflated floor; wet clothing and TPA
Udry (Wetsuit)	Uninflated floor; dry clothing and wetsuit (3mm neoprene)
Idry	Inflated floor, dry clothing
Idry (Wetsuit)	Inflated floor, dry clothing and wetsuit (3mm neoprene)
Idry (TPA1)	Inflated floor, dry clothing and TPA

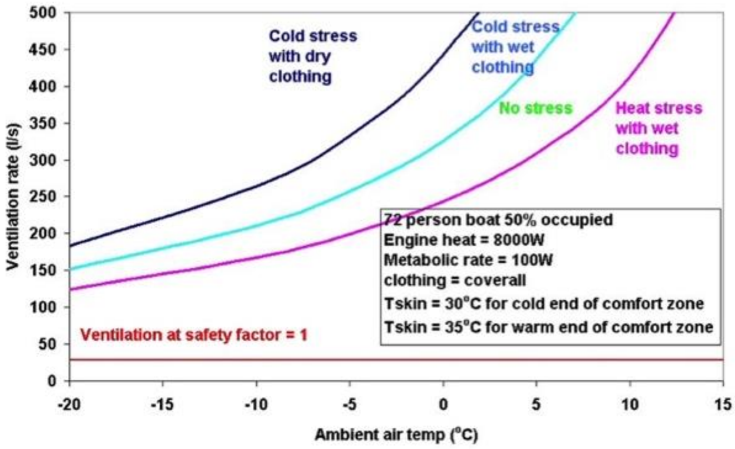
Lifeboats and Thermal Protection

Following their studies with life raft thermal performance, Mak et al. (2010) executed a test program to assess the thermal protection and microclimate of a 72 person SOLAS lifeboat for Arctic conditions. The study found that, similar to life rafts, the lifeboat had a ventilation rate that may not be adequate. Using a thermal manikin, only a slight decrease in thermal resistance (less than 10%) was observed in many test cases, when active ventilation was implemented (ventilation rate of 31 and 42 liters/s) and when the larger side hatches were opened (ventilation rate of 95 liters/s). This suggests that ventilation rates can be increased to required levels without trading off much in thermal protection losses. However, a more noticeable decreases in thermal resistance (15% to over 30%) were observed when clothing was wet, suggesting it is critical to stay dry.

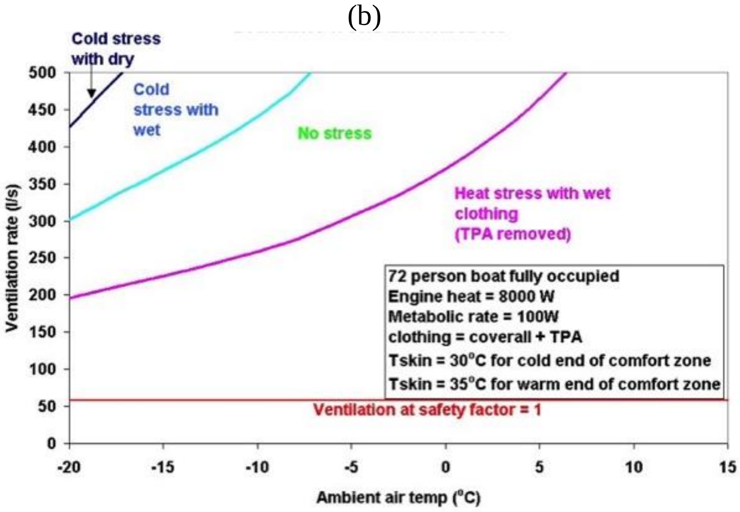
A mathematical model was also developed to assess heat and cold stress of lifeboat occupants under different environment, lifeboat, occupant and ventilation conditions, as depicted in Fig. II–4. The figure shows, for different ventilation rates, environment temperatures and clothing conditions, the boundaries between different thermal comfort zones for the three conditions – no engine heat and occupants wearing standard clothing (Fig. II–4a), with engine heat and occupants wearing standard clothing (Fig. II–4b) and with engine heat and occupants wearing standard clothing with a thermal protective aid (Fig. II–4c). The figure also shows the ventilation rate that will provide a safe level of air quality inside.



(a)



(b)



(c)

Fig. II–4: Balancing lifeboat ventilation needs with thermal needs for (a) basic street clothes, no engine heat; (b) basic street clothes, with engine heat; (c) basic street clothes + TPA, with engine heat.

Survival Strategies and Training

Using these findings, we can recommend strategies for extended survival in LSAs, from the point of view of thermal protection by:

- reviewing training standards related to LSA use in cold environments,
- analyzing training needs to determine how occupant actions can improve survival in cold environments, and
- identifying the training needs required to provide essential knowledge and build critical skills relating to the performance issues examined.

The following international and Canadian standards were reviewed:

- Standards of Training, Certification and Watchkeeping, 1995 (STCW '95)
- Transport Canada Marine Emergency Duties Training Standards (MED)
- Canadian Association of Petroleum Producers Training and Qualifications Guidelines (CAPP-T&Q)
- Safety of Life at Sea (SOLAS)
- Offshore Petroleum Industry Training Organization (OPITO)

Substantial training competencies exist in the regulations for general survival, including in LSAs. However, little or no guidance is provided on training competencies for survival in LSAs in *cold* environments, except as outlined in the sections presented in Tab. II-2.

Tab. II-2: Training standard guidance for LSA use in cold environments.

Transport Canada MED Training Programme – TP4957E(1998)		
Course	**Syllabus Section**	**Instruction & Competency Requirements**
MED-A1 Basic Safety Course (Section 5)	Section 6: Survival	- 3 hours instruction to cover aspects of survival ranging from immersion in water to abandonment in lifeboats (open and closed) and life rafts - Only specific reference to thermal considerations is to discuss "Medical aspects of survival including thermal balance, water balance and energy balance" - Competency assessed in writing, orally and by practical demonstration
MED-A2 Small Passenger-Carrying Vessel Safety Course (Section 6)	Section 6: Survival	
STCW Basic Safety Course (Section 10)	Section 9: Survival	
Proficiency in Survival Craft and Rescue Boats other than Fast Rescue Boats Course (Section 11)	Section 3: Principles of Survival	- 0.75 hours instruction to cover principles of survival ranging from the need for regular onboard drills to abandonment and survival - Only specific reference to thermal considerations is to note that an "immersion suit or thermal protective aid must be worn if required"
	Section 4: Use of Personal	- 3 hours of practical instruction including: - "unpack and don a thermal protective aid in a life raft/lifeboat"

	Survival Equipment	- "put a thermal protective aid on a person simulating unconsciousness in a life raft/lifeboat"

Two main types of gaps exist in the regulations:

1) Performance gap – exists in the engineering domain and refers to the lack of knowledge of how the life raft will perform thermally in a given set of environmental conditions.

2) Knowledge/skills gap – exists in the training domain and refers to the lack of useful characterization of the magnitude of risk to life safety from a thermal standpoint.

While SOLAS regulations indicate that life rafts must have an insulated floor, the amount of insulation required to adequately protect occupants is not specified. One possible improvement could be to provide training for occupants and operators in order to overcome life raft thermal performance design issues. It is safe to assume that even without a basic understanding of the mechanisms of heat loss in life rafts, users will try to achieve thermal comfort in order to survive. However, with an understanding of the relative importance of the different heat loss mechanisms and what can be done on an individual level, chances of survival would certainly be improved.

Using the research findings of Mak et al. (2008, 2010, 2011), the strategy provided below in Fig. II–5 is suggested for use by trainers to ensure the best chance of survival for LSA occupants in cold conditions. While Fig. II–5 presents little new information for those with a basic understanding of survival in cold environments, those with little experience in cold conditions (as may be the case for passengers on cruise ships in Arctic regions) would benefit from this information as it provides an overall strategy for extended Arctic survival.

From this work, it is clear that being dry inside an LSA is of the utmost importance to ensure survival for long exposures in temperatures below freezing. In such conditions, 80% of the cases for which the model predicts functional survival require the strategy to include being dry. The other main strategies that contribute significantly to ensuring functional survival in such conditions are: adding an insulating barrier between the occupant and the liferaft floor, which is in direct contact with the ocean (80% of strategies include insulation of some type), and wearing some sort of thermal protective aid (60% of strategies include some type of TPA).

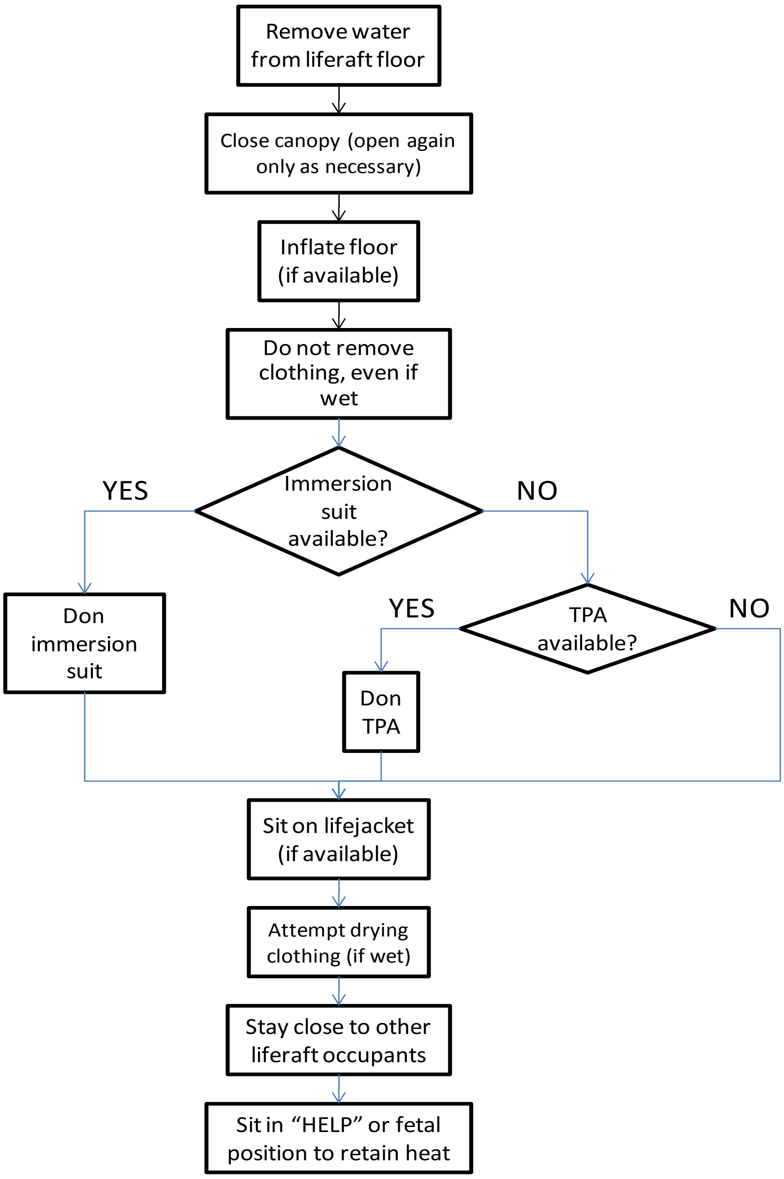


Fig. II–5: Recommended strategies for training guidance on survival in life rafts in cold environments

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II.1.8 The relevance of the exercise task; a cruise ship being abandoned near the ice edge

Assessment of the impact upon functional requirements in the Polar Code

By Ove Njå, University of Stavanger

Polar Code requirements and philosophies

The Polar Code (IMO, 2016) is based on self-regulation principles and is thus risk based directing functional requirements. The case studied in this study is abandonment of a cruise ship in polar waters. In this case the Polar Code's major task is to ensure knowledge based cruise ship designs and operations in accordance with hazard sources pertaining to the geographical locations and seasons and type of marine operations under consideration. This puts many demands upon the ship-owner, but at the same time the maritime safety authorities involved and the representatives for the employees must be fully aware of the systems performances in case of emergencies. Passengers' preparations for emergency and evacuation behaviour are an important issue in the safety management based on the Polar Code. For the exercises covered by SARex the Polar Code's chapters (IMO, 2016); General; Polar water operational manual (PWOM); and Life-saving appliances and arrangement, are given the major attention. The definition in clause 1.2.7 related to *maximum expected time of rescue* says: "Maximum expected time of rescue means the time adopted for the design of equipment and system that provide survival support. It shall never be less than five days". For the exercise, we specifically address the life-saving appliances, which shall provide for safe escape, evacuation and survival in the polar conditions deemed as design scenarios.

How can the technology adopted for the escape, evacuation, and survival provide positive influences in the most critical phases of an emerging crisis in Polar waters? How can technology within complex emergency response systems enhance performance in situations, for example when the crisis is in its early stage, the consequences may be unclear, different authorities may be involved, many actors on-board and in surrounding areas may be involved in the on-scene crisis combating and the media may be paying particular attention? Incident commanders and rescue services in any country have not substantial experience from large/major incidents, thus novelty is an important feature (Rake, 2008). The questions are numerous and uncertainties large if we are to assume large-scale crises in Polar waters.

In order to conceive an understanding of the performance of the safety appliances, we need an overall conception of the emergency response system within certain frames. Ship-owners, maritime authorities and technological scientists must discuss and agree upon a description of the escape, evacuation and survival systems as they are generally understood. Such a mode must include specific characteristics, for example decision making, uncertainties, collaborative efforts, response phases, time frames, local conditions etc. This leads us to the major issue of this note: *What is the relevance of the cruise ship abandonment exercise close to the ice edge, in order to reveal the appropriateness of the evacuation and survival systems?* The evacuation and survival systems consisted of a conventional lifeboat, a conventional life raft and various personal safety equipment/survival suits that are all relevant for current cruise vessels operating in Polar waters, cf. the Main Report.

Relevance of the exercise

From the Online Etymology Dictionary “relevant” as from Middle French *relevant* is presented as "depending upon," originally "helpful". Our stance in this project rest on Popper’s criticism of induction concerning the extent to which it is possible to draw general conclusions regarding the “validity” of a theory from a single observation or a few only. We apply the concept of falsification, assuming that a theory can never be confirmed to be true but is only falsifiable. This is compatible with the complex world on crisis response; there is no truth about future successes of safety appliances, only situation-based positive and/or negative experiences in the response operations. Thus, ***we do not falsify as such but raise objections about the excellence of the system under scrutiny***. This point is an important assumption of our safety appliances and the assessor must carefully consider and adopt this issue. Neither performances of the life boat, life raft or personal safety equipment can be 100% validated (Babuska & Oden, 2004). *“A validated model is therefore one where tests have been performed which could have shown it to be invalid, but which failed to do so”* (Ivings, 2007, p. p. 10).

The most important perspective in an evaluation process is the performance criteria set to conclude on the safety appliances’ usefulness. These must address our *expectations*, *assumptions*, *uncertainties* and *observations*. The purpose with this note is to provoke issues and conditions that might influence the involved actors’ tolerances for adopting conventional safety appliances tested by the SARex exercise.

Fig. II–6 depicts our model of validation from a passenger perspective protected by the Polar Code functional requirements. The validation process is separated in two processes.

The starting point for the validation process is the experiments established through the exercise. The functional requirements, the experimental set-ups and the procedures for the technical validation outlined in the exercise base the preparations for the end-user validation described as Validation – 1. The validation assessor prepare for the validation by carrying out a *close reading*, which “is the kind of reading in which the reader, as a matter of habit, pays attention not only to the words and the plot but to all aspects of the literary apparatus of a text”. This means that the validation assessor have obtained a clear understanding of the safety appliances, the context of the experiments at sea and what functions and performances to be expected by the personal equipment worn during the time in the raft or lifeboat. During this process the validation assessor from the end user group (passenger stance) is supposed to clarify important issues connecting his or her understanding of the crisis contents and the relevant validation experiments. The crisis situation in this respect consisted of cold water (appr. -1 ºC), ambient average air temperature -9 ºC, blue sky and no wind. The experiment was kept under surveillance by two MOB boats, *KV Svalbard* close by and the test persons were told to quit when they felt uncomfortably cold, cf. the abortion criteria presented in the Main Report. The assessment process would then consist of how the experiments fit with standardized procedures, typical organisations, tasks and efforts, which could be directly associated with the experiments itself, which is the core of validation – 1 (see Fig. II–6).

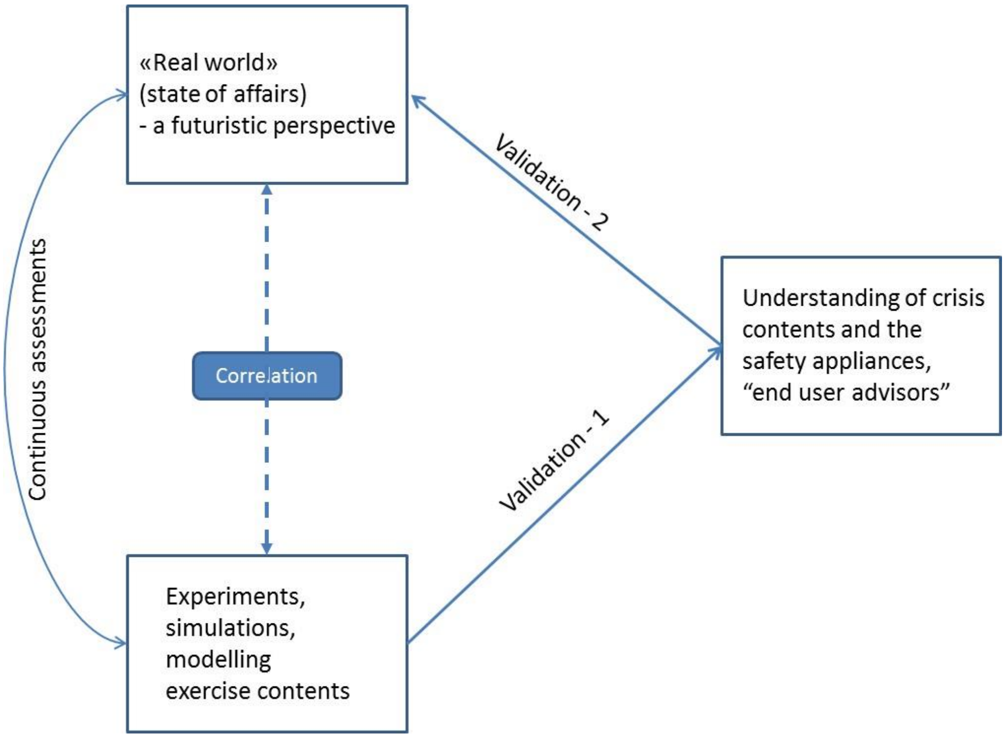

Fig. II–6: Validation model from a passenger perspective, based on Borg & Njå (2013)

Validation – 2 is even more difficult than validation – 1 and require high level expertise on Polar waters activities, the emergency response systems and an ability to abstract plausible worst case scenarios. Using Dreyfus & Dreyfus' (1986) scheme for characterising personnel knowledge from novice to expert, we can say that validation – 1 require a proficient performer, while validation – 2 require the experts. An expert generally knows what needs to be done based on mature and practised understanding. Dreyfus & Dreyfus (1986) describe their skill acquisition model as follows:

> "The moral of the five-stage model is: there is more to intelligence than calculative rationality. Although irrational behaviour - that is, behaviour contrary to logic or reason - should generally be avoided, it does not follow that behaving rationally should be regarded as the ultimate goal. A vast area exists between irrational and rational that might be called arational. The word rational, deriving from the Latin word ratio, meaning to reckon or calculate, has come to be equivalent to calculative thought and so carries with it the connotation of "combining component parts to obtain a whole"; arational behaviour, then, refers to action without conscious analytic decomposition and recombination. Component performance is rational; proficiency is transitional; experts act arationally."

With such characterisation of the expert end-users the validation – 2 process will contain a screening of future demanding events relevant for the safety appliances in Polar waters, various factors influencing the flexibility of the response system, how complexity in the situations would be resolved and how collaborations and coordination activities could or could not succeed. A major task for the expert is to make his/her assumptions and assessments explicit.

The validation of the exercise

The principle of the validation is a checklist of issues found relevant for the functional requirements in the Polar Code. The check list is not presented in this note, and we have only summarized important results below. The validation issues are formed as statements, which you can agree to, you can raise major uncertainties or you reject it. These categories are as follows:

Agree. I agree the safety appliances have this weakness and more work should be done to overcome this weakness.

Major uncertainties. I cannot see that the statement is covered by the experiments or the experiments raise major uncertainties regarding whether the statement will occur or not. This is an issue for further exploration of the safety appliances considered for Polar waters.

Reject. I reject this statement and I am convinced that the safety appliances will improve the specific crisis response performance and even have a positive impact on the overall crisis response system, in line with the functional requirements of the Polar Code.

In order to carry out the assessment there is a need for specific performance measures that can aid the validation assessor. We recommend the following performance measures:

Reliability/availability is a measure describing to what degree the safety appliances will be there and carry out its task in an expected manner. The reliability and availability of the life boat would be a measure of the life boat being in operation when needed (real event) and serving its purpose in case of a crisis. A quantitative measure here could be in case of rather similar contexts as the exercise; down-time, probability of functioning, ability to enter and launch, etc.

Capacity. The System's capacity is a measure of the intended functionality considered, for example the number of persons to be gathered in the life raft. The requirement from the Polar Code is a "habitable environment", which is closely related to passengers' survivability criteria, cf the Main Report. The capacity values are observable, but uncertain quantities. Capacity could be expressed by strength, number, pressure, flow rate, area coverage etc. Uncertainty should be included to express the validation assessor's degree of belief regarding the capacity quantities. An alternative could also be more coarse assessments.

Execution time represents the time needed for specific crisis operations. Usually it is the time from the situation has occurred to the operation or function is successfully carried out, but limiting the tasks and operations might be necessary. For an evacuation scenario in Polar waters the interesting time aspect is the duration from the entering of the life raft to the body temperature is below tenable limits.

Survivability/vulnerability relates to the safety appliance's ability to withstand the loads and conditions in the crisis, for example the metocean conditions. The life raft's ability to withstand wind and ice floes is an example of survivability. Qualitative descriptions are often applied as measures on survivability.

VALIDATION – 1

General issues

The condition of the passengers and the population from which the test personnel was selected were neither not representative for typical cruise passengers in polar waters. This is a study, which should be carried out in the future.

Lifeboat

The interesting issues was not entering and launching of the life boat, but the long term temperature exposure when being on board.

With this assumption, the number of passengers being part of the experiment was quite low.

The operation of the life boat was neither not an issue, besides the organizational hierarchy a commander and a second in command. It could be questioned whether this strict command and control system would be in place, it is not an issue in the Polar Code.

The various personal survival suits and other equipment made a good opportunity to carry out coarse comparative assessments. These assessments are coarse due to the test persons' variability to withstand freezing and the subjective abort criteria.

The test persons seemed not to be from a typical cruise ship passenger population.

The arrangements for do one's duty were organized for convenience, and would be different in a real situation.

Risk perception, mental and emotional exposure were low.

Insulated survival suits functioned very well and no conclusion could be made whether it could last for five days. The experiment was aborted after 24 hours.

Life raft

Much of the same considerations for the life boat are also relevant for the life raft.

However, the life raft is more vulnerable to sea states and thus the influence from waves and environmental forces was not experienced.

There was no activity onboard the life raft to reduce the exposure from the cold floor.

Air quality made it necessary to open hatches, which lowered the temperature inside the raft.

Insulated survival suits functioned very well and no clear conclusion could be made whether it could last for five days. The experiment was aborted after 18.5 hours.

VALIDATION – 2

This process is necessary to fully relate the functional requirements from the Polar code to the exercise experiments. As such, neither of the safety appliances were tested against design scenarios and there are no ideas of safety margins besides the fact that the personal safety equipment/survival suits in general did not meet the criteria. Thus, as a general observation the exercise in calm and controlled situations showed the need for careful considerations when the Polar code shall be enforced. In order to clarify this level of relevance further studies are needed, both of the data material collected in SARex, but also combined with other available literature and knowledge.

Preliminary conclusions

There is no doubt that the SARex exercise and the experiments provided useful insights into the complexity and uncertainties of the Polar Code. The data gathered are thus important to fully analyze and interpret in terms of addressing considerations to be emphasized when designing the safety management systems in accordance with the Polar Code.

What is included in a holistic approach to safety management is not clear, and a traditional risk based approach should be reconsidered in order to adopt more multidisciplinary system theoretical approaches, in which resilience, constraints, emergent properties, hierarchical safety control structures (see for example Leveson, 2011).

The major contribution from the SARex is the questions raised regarding the conventional and recognized life-saving equipment whether it fulfills its purposes. The responsible parties (authorities and ship-owners) should clarify how habitable environment and survivability can be achieved in a period of five days, based on a design evacuation scenario in polar waters. Most of the equipment tested in SARex needs improvement, and this is before even thinking about the holistic approach. There are a lot of uncertainties that still needs to be addressed and included in the guidelines of the Polar Code. Some examples are as follows:

- *Hypothermia and cold conditions exposure to evacuees*. Maxim Gorkiy, LeBoreal and Saputi are all events, in which people did not suffer cold and wet conditions. The Norwegian accident *MS Sleipner* (NoU, 2000) was a completely different story, which gave hypothermal sufferings decisive for the outcome.
- *Organisational factors and abilities in crisis situations*. Incident reporting from Maxim Gorkiy and LeBoreal provide a reception history of successful operations. However, organizational abilities are matters of major concerns and uncertainties associated with contextual environmental conditions (personal communication with rescuers involved in the Saputi-case). The *MS Sleipner* investigation revealed lack of competence and irrational behavior amongst the crew.
- *SAR performance in real situations*. Even though resources might have been available, communication between rescue resources is a huge challenge in providing necessary equipment and aid in due time. Doing research in emergency response systems, it is a common finding that rescuers possess stories of less optimal responses with often descriptions of fatal outcomes (Rake & Njå, 2009). From the *MS Sleipner* loss it is known that one passenger died from hypothermia, which could have been avoided if the communication and rescue operations had been carried out slightly different (cf. personal communication with the medical incident commander at the scene).

SARex has shown to be relevant as an initial discussion of important parts of the Polar Code, especially Chapter 1 and 8. The data material provided needs to be further analyzed. It is no doubt that conventional life-saving equipment is not fit for purpose, and there is a strong need to provide guidelines that ensure consistent adoption of the Polar Code.

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II.2 SARex Exercise 23 – 27 April 2016

II.2.1 The planning of SARex, the Svalbard North SAR exercise

By Knut Espen Solberg[1] and Ove Tobias Gudmestad[2]

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1.1 Search and Rescue in the Polar Region

Search and Rescue operations in the High Nord is a prioritized activity by the Maritime Forum in Norway. During autumn 2012, Maritimt Forum Nord and Maritim21 launched a pilot project SARiNOR, concerning search and rescue in the Arctic. The concern was the increased shipping and offshore activities in this region, which will require safe solutions to keep the safety at an acceptable level for the society, (SARiNOR, 2016). Funds were made available by the Norwegian Government (Foreign Ministry) to prepare documentation on relevant SAR aspects.

The SARiNOR project involves authorities like regulators and SAR providers, Coast Guard, shipping and oil companies as well as consulting companies and academic institutions. The SARex exercise being planned by the Norwegian Coast Guard in cooperation with GMC Maritime AS and University of Stavanger will be part of the ongoing SAR activities and SARiNoR is invited to participate.

1.2 Incidents in the cruise liner industry

It may be extremely difficult to rescue everyone from a large cruise vessel in case of an accident in polar waters, far from available emergency infrastructure. A cruise vessel in polar areas might represent the ultimate evacuation and rescue challenge and may represent the highest risk in terms of personnel loss. In recent times, there has, however not been any great disasters with the loss of great numbers of lives in cold climate regions. In most cases, this has been a result of extreme fortune with regards to low response time from nearby vessels and relatively mild metocean conditions – neither high winds or extreme low temperatures have been present at the time of the accidents. Despite the fortune present during the recent evacuations/rescues taking place in cold climate there has been several lessons identified based on these accidents.

Unfortunately, the maritime regulatory regimes often can be regarded as reactive. This means that regulatory adaptions/changes usually are initiated/fueled by accidents, e.g. the Titanic accident initiated the development of the SOLAS convention. The Polar Code is, however initiated, developed, ratified and implemented prior to any large-scale accident. The Polar Code is also function based, opening up for interpretation. Currently there is no common understanding among neither users nor regulators on interpretation of some of the Polar Code elements. For the Polar Code to reach its full potential with regards to increasing safety it is therefore important to keep in mind the recent accidents throughout interpretation of the code.

1.2.1 The "*Maksim Gorkiy*" rescue situation, 1989

On 16 September 1989 at 23:05, the cruise vessel *Maksim Gorkiy* ran into an ice floe with full speed 60 nm West of Isfjorden, Svalbard. There were 953 persons onboard, of these 575 passengers; many of these were elders with reduced mobility. The Norwegian Coast Guard vessel *KV Senja* was called at 00:40. The vessel arrived at 4:00 after having travelled with a speed of 22 knots. The passengers went into lifeboats at 01:30. Then the ship started to take in water and was listing (Kvamstad, Fjørtoft, Bekkadal, Marchenko, & Ervik, 2009). Eventually all were rescued due to the lucky situation that the

Coast Guard vessel was that close and the rescue was carried out in a professional manner (Hovden, 2012). The potential for loss of many lives was eminent.

1.2.2 The "Explorer" rescue situation, 2007

In November 2007 the *M/V Nord Norge* was involved in the salvage of the crew and passengers of the *M/V Explorer* in the Antarctic. The *Explorer* was flooded due to a hole on the starboard side and listed to starboard. The position of the *Explorer* was 62 degrees 22.7 minutes South and 057 degree 20.4 minutes West in Bransfield Street. The ship was drifting due to wind and weather. *Nord Norge* received "Mayday" at 3:00 am and the ship was alongside *Explorer* at 06:35 in the morning. Eventually, all 154 people onboard *Explorer* was rescued as *M/V Nord Norge* came so quickly to the location. It should be noted that the close proximity of the "buddy vessel Nord Norge saved many lives. The *Explorer* had only open lifeboats and rafts, which would have been unsuitable for long time survival in the cold, (Hansen, 2008).

1.2.3 M.V. William Carson, 1977

The ferry/ passenger vessel *H.V. William Carson* was since 1976 operating along the coast of Labrador. On 2 June 1977, she collided with a small iceberg and sunk in 150 m of water depth 12 nautical miles off Battle Harbor. All 129 passengers and 29 crew aboard survived after having evacuated into lifeboats. The evacuation was carried out efficiently. Canadian Coast Guard icebreakers and helicopters rescued all passengers and crew, (Noel, 1977, Kennedy, 2010).

1.3 The oil and gas industry

For the oil and gas industry operating in the far distances in the Barents Sea, the distances to hubs make it difficult to reach targets within reasonable times and the weather conditions are on many days very problematic. During the wintertime, darkness makes SAR activities even more difficult. Discussions about evacuation and rescue in the Barents Sea in Norwegian waters is prepared by Jacobsen (2012). The discussion covers the area south of the Bear Island at 74.5° N and east to 19° E toward the border with Russia. This is the area where Norwegian authorities recently have issued licenses to the oil and gas industry. Preliminary results were presented by Jacobsen and Gudmestad (2012). Of particular concern is the need to station Search and Rescue helicopters at coastal locations where offshore facilities can be reached and at the offshore facilities. This might also involve stationing of vessels half way between land base and offshore facilities so fuel can be ensured for the flight to the facilities and the return flight to base.

1.4 The Polar Code

The goal setting and functional based Polar Code (IMO, 2015) will enter into force 01.01.2017. The code's Chapter 8 requires marine operators to provide lifesaving equipment (see Appendix to this paper) that ensures a minimum of 5 days survival time. This requirement puts heavy strain on existing life-saving appliances. An interpretation of the Polar Code has been published by ABS (2016).

2. Details of the exercise

2.1 Structure

The research program has the following structure (Fig. II–7):

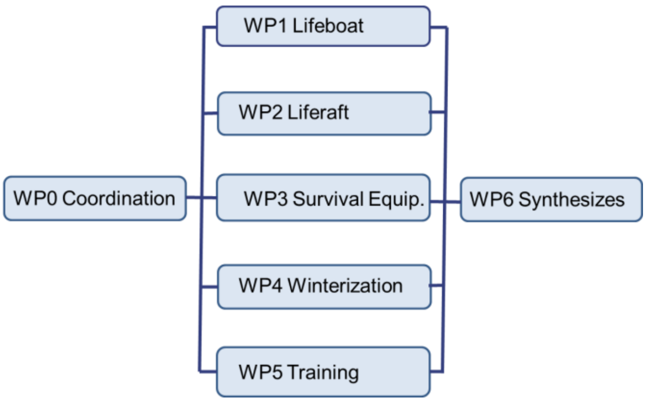

Fig. II–7: Project structure

Each work package has a separate delivery to WP6 - Synthesizes. WP6 will gather all findings and produce a data report containing all gathered data and a summary report summing up the findings. Of particular interests are WP1, WP3 and WP4. Note that WP2 will be similar to WP1, however WP" will deal with the life raft rather than with the lifeboat.

2.2 Issues of special interest

The project aims to identify the gaps between the existing requirements for vessels operating in cold climate and the requirements enforced by the new IMO Polar Code. The following areas are of special interest as the represent new challenges to the end users, equipment manufacturers and regulators:

2.2.1 Survivability – Polar Code minimum 5 days survivability requirement

The polar code requirement defines a survival time of minimum 5 days. This puts new and additional strain on equipment (including ergonomics, Pertie et al., 2012 and Tabera et al., 2009) and personnel compared with past regulatory requirements.

The participants' survivability is closely linked to the participants' functionality and body temperature. A survival time of 5 days will require the participants to maintain a high level of functionality throughout the survival period. (Kennedy et al., 2013). A reduction in a participant's functionality will in many cases be closely connected with hypothermia. (Eidstuen, 2015).

During the exercise, key parameters describing survivability will be logged. This includes core body temperature, extremity body temperature, heart rate, cognitive abilities and metabolism. In the exercise evaluation phase, key items affecting survivability will be identified. This includes technical functionality of survival craft and personal survival equipment, procedures/leadership, participant activity level and participant food intake. (Aylward, 2015).

Both lifeboat and life raft will be utilized simultaneously. The participants will also be wearing a variety of personal life saving appliances. This includes the most common personal survival aids, including SOLAS approved light thermal protection aids to thermal protected survival suits. As the assessment is taking place simultaneously, encountering the exact same conditions, benchmarking of the survivability will be possible.

2.2.2 Evacuation from survival craft on to rescue vessel

With a large number of personnel to be evacuated from the survival craft on to the rescue vessel the time utilized for each individual is critical, both with regards to the survivors' physical condition and even with regards to the 5 days survival time. Traditionally large baskets have been utilized for these kind of operations. In ice-covered waters, this represents a challenge, as the baskets cannot be lowered into the sea, risking filling the basket with sea ice. The project will assess and quantify alternative means of evacuation of large numbers of personnel. The issue of keeping the survivors horizontal (essential when evacuating hypothermic personnel) will be addressed.

2.2.3 Handling of survival crafts

The polar code includes a requirement for group survival kits. These kits are to be utilized on shore or on solid sea ice. To reach a suitable area where these kits can be utilized will require transit of the survival crafts, possibly in ice covered waters. Utilization of the kits also require evacuation from survival craft onto either land or solid ice. The following is to be evaluated:

- Identification of suitable ice flow from a position close to the sea surface (life boat/life raft)
- Transit/operation of lifeboat in ice covered water, including fuel consumption
- Transit of lifeboat towing life raft in ice covered water
- Time required/risk associated with evacuation from survival craft on to ice flow
- Turning of life raft in ice covered waters

2.2.4 Triage – handling large amounts of hypothermic survivors onboard a normal rescue vessel.

Handling of a large number of hypothermic survivors represents a challenge for the rescue vessel. A large increase in the number of persons onboard the vessel will put additional strain on the vessel infrastructure, e.g. the medical facilities, accommodation, food and sanitary conditions. Due to the remoteness present in the Arctic/ Antarctica, this condition can have to be sustained for a prolonged period. The exercise will assess the following items:

- Triage – conduct a controlled triage, including registering of survivors
- Triage follow up - implement a system where each survivor is monitored individually and obtaining the treatment required
- Ensuring sustainable accommodation, food and sanitary conditions for the survivors.

3. Risk associated with the planned exercise

Conducting a full scale exercise, involving about 100 persons, one vessel, two man overboard boats in addition to one lifeboat and one life raft in the sea ice North of 80 degrees North involves handling a large varieties of uncertainties/risks.

The risks can mainly be divided into two risk dimensions; risks related to safety of participants and risks related to degradation/quality of the scientific results. Prior to the exercise, thorough risk assessments has been carried out. The main aim of the assessments have been to identify key uncertainties and develop risk mitigation measures. There is no compromise with regards to the safety of the participants, and the risk mitigation measures will ensure a sustainable risk level associated with the dimension covering safety.

Mitigation measures related to the dimension covering the quality of scientific results have also been developed. Despite the implemented mitigation measures, the quality of the scientific results cannot be guaranteed. This is mainly due to parameters outside project control. The following key uncertainties have been identified relevant for the dimension “quality scientific results”:

- Unpredictable weather causing unfavourable test conditions causing:
    - Lack of reliable/regular data recordings
    - Exercise cancelation due to extreme conditions

    - Exercise cancelation due to too mild (not representative) conditions
    - Exercise abortion due to rapid changing weather conditions
- Rapid changing ice conditions requiring abortion of exercise
- Test equipment malfunction due to human error or production faults
- Logistic/safety infrastructure (including *KV Svalbard*) malfunction causing abortion/cancellation of exercise
- Injuries/sickness causing *KV Svalbard* need to return to port
- "No play" search and rescue operation requiring participation of *KV Svalbard*

4. Summary regarding the planned exercise

The needs for intensifying search and rescue planning in the Polar Regions have been identified by IMO issuing the Polar Code for ships operating in Polar Waters. Norwegian maritime industry and Norwegian authorities have also identified the needs. Several near accidents have contributed to the general acceptance of spending funds to increase safety of shipping in the Polar Regions.

We are planning an exercise in coordination with Norwegian Coast Guard, authorities and industry partners and present in this paper the background for the exercise and the preparations. The actual results from the exercise will be presented orally at the IAHR Symposium on Ice in May of 2016.

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II.2.2 The SAR exercise HAZID prior to the Phase I exercise

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SARex Phase 1 Risk assessment – Lifeboat

ID	Problem	Cause	Consequence	Risk-reducing measures	Comments
1	Maneuvering difficulties	Heavy sea, sea ice, wind	Little or no control of lifeboat position/heading Lifeboat cannot be positioned correctly in the waves, heavy lifeboat motion (uncomfortable for passengers)	-Lifeboat pilot training/experience	
2	Maneuvering of lifeboat not possible	Damage to steering system/ rudder/steering nozzle	Lifeboat unable to maneuver away from ship; -possible collision with ship -lifeboat drifting helplessly, affected by waves and wind -lifeboat stuck in sea ice		
3	Lifeboat integrity compromised	-Collision with ship during/after launch -Collision ice floes	Water intrusion, exercise stopped.		
4	Rescuing passengers from sea to lifeboat	Insufficient arrangements on lifeboat for extraction of people. Mob boat far away.	Difficult/impossible to rescue survivors from sea	Mob boat nearby.	
5	Transfer of persons from lifeboat to rescue vessel	-Insufficient/no arrangements for moving passengers from one craft to another -Passengers have physical problems after long time in lifeboat -Heavy seas/strong winds	Complicated rescue process, potential injuries/fatalities Time consuming 30 minutes?	Helmet Evenly distribute the weight in the mob boat Hold onto the rail in the boat	Mob boat is used primarily in all instances by *KV Svalbard*.
6	Danger getting down to lifeboat	Hoisted down in mob boat	Falling into sea/injury	Helmets, life-vest or survival suit, instructions on holding on while lowering.	

7	Falling into sea	Transfer of persons between lifeboat and mob boat. Trying to urinate from either lifeboat or mob boat.	Becoming soaking wet and very cold. Exercise over for that person.	Assistance from mob boat crew. Mob boat always nearby, *KV Svalbard* also nearby.	
8	Tripping and falling	-Passengers not used to heavy suits/equipment -Slippery surfaces	-Fall damage (injuries, broken bones) -Ending up in the water	-Be cautious -Follow instructions -Detailed safety information and procedures from *KV Svalbard* crew	
9	MOB boat lifting hook swinging after release	-Hook operator error -Rough seas	-Hook arrangement hits passengers in MOB boat, leading to injuries.	-Follow instructions -Detailed safety information and procedures from *KV Svalbard* crew	
10	Exercise participant becomes ill/injured needs immediate assistance	Decease, accident, medical issues.	They are in need of medical assistance.	Mob boat nearby, *KV Svalbard* nearby. Helicopter from Longyearbyen next option.	
11	MOB boat occupied when an accident occurs	-MOB boat have many tasks	-Long time to rescue -People getting seriously chilled	-Use both MOB-boats for redundancy	
12	Passengers not noticing getting severely cold (core and extremities)	-Individual differences -Little or no experience with being cold -Sleeping	-Risk of injuries/fatalities	-Have buddies near you which can check on you -Leader onboard raft should keep overview.	Reception routines for chilled people? Check on safety briefing
13	Freezing body extremities	-Getting wet -Little clothing	-Frost bite leading to injuries	-Bring hats, gloves, etc. for backup in case. -Low threshold for returning people to *KV Svalbard* -Additional immersion suits in lifeboat for emergencies (for those not wearing suits during tests)	Reception routines for chilled people? Check on safety briefing
14	Personal protective equipment not functioning	Damaged, production error, not maintained correctly.	PPE does not work as intended.	Maintenance and functionality check before use.	
15	Pilot is incapable of leading	Injury, death, pilot has to abort exercise and return to ship.	Anarchy? Without leadership people might not survive as long.	Find a new leader/next in command	
16	Immersion suit integrity compromised	-Improper entering of suit --Openings not properly closed (zippers), etc	-Exposure to cold water with potential injuries/chilling of body	-Buddy check on suit after putting it on, prior to test	
17	Lack of sleep	Uncomfortable seating, stressful situation (physical and psychological)	Sleep deprivation		Due to short duration of

					exercise, not expected to be a problem.
18	CO and CO2 build-up inside lifeboat	Insufficient ventilation, many people breathing. Leak from exhaust system	Headaches, sleepiness, poor concentration, loss of attention, increased heart rate, slight nausea, oxygen deprivation.	-Detectors will measure CO and CO2 build-up and give alarms. -Opening hatches	
19	High temperature inside lifeboat	Insufficient ventilation, many people generating heat	Dehydration caused by perspiration. Nausea which can lead to vomiting, causing further dehydration.	-Opening hatches	
20	Low temperature in lifeboat	Outside temperature.	Core body temperature of passengers dangerously low (hypothermia)	-Passengers wearing warm (waterproof) clothing	
21	Hygiene	No toilet available	Insanitary conditions	Bucket or other solutions? -Bottles used in hospitals/small aircraft?	
22	Clogging/blocking of ventilation	Warm and moist air from inside the lifeboat condensates and freezes around the ventilation outlet	Reduced ventilation, rapid deterioration of air quality	Opening hatches	
23	Not enough food	Lifeboat not stocked	Hunger	-Ensure lifeboat carries enough food for exercise duration	
24	Not enough water	Lifeboat not stocked	Thirst	-Ensure lifeboat carries enough water for exercise duration	
25	Seasickness	Lifeboat movements	Vomiting, inducing dehydration and starvation.	-Anti-seasickness medicine How to handle this if exercise participants starts vomiting?	
26	Sea spray into lifeboat	The lifeboat hatches are open (ventilation, extracting persons from sea, etc.)	People get wet and cold. Water inside the lifeboat.	-Close hatches	
27	Poor sight	Fog, snow squalls. Icing (sea spray) on windows	Navigation difficulties Possible collision	-Lifeboat pilot training	
28	Sea spray icing on lifeboat	Sea spray combined with low temperatures	Skew loads, hinges and locks on hatches stuck, ventilation compromised.		
29	Rapid weather changes	-Weather in this region can change in minutes	-Exercise gets much more difficult -Stopping the might be necessary	-Check weather report prior to/during test	

				-Procedure for rapid evacuation of all participants -Ensure that MOB boat is close to lifeboat during test, for emergency preparedness	
30	Communication difficulties	-Wind noise -Many people talking at the same time -Routines for how to communicate -Radio equipment failure	-Important messages cannot be communicated via radio	-Backup radio equipment/battery -Clarify communication routines prior to test	
31	Disturbance from other vessels in area, not part of exercise	-Nearby vessels not informed of test	-Interruption of test -Possible collisions and hazard for participants	-Notify any nearby vessels of the test -Establish safety zone around test area	
32	Polar bear attack (from underwater…?)	-Animal curiosity/hunger/threatened	-Injuries/fatalities	-Polar bear guard (*KV Svalbard*) -Armed personnel onboard MOB-boat -Flares/signal rockets -Situation awareness -Sonar…?	Could be dangerous if lifeboat drifts into ice floes.

SARex Phase 1 Risk assessment – Life raft

ID	Problem	Cause	Consequence	Risk-reducing measures	Comments
1	Life raft damaged	-Production error	-Equipment unusable	-Check prior to launch (Viking)	
2	Life raft integrity compromised	-Collision with ship during/after launch -Collision ice floes	-Water intrusion, exercise stopped	-Abortion if the ice conditions gets too severe -Procedures for rapid evacuation of all participants	
3	Transfer of persons from life raft to rescue vessel	-Insufficient/no arrangements for moving passengers from one craft to another -Passengers have physical problems after long time in life raft -Heavy seas/strong winds	-Complicated rescue process -Potential injuries/fatalities -Time consuming	-MOB boats will be used for transfer of passengers from life raft to *KV Svalbard*, piloted by experienced crew.	
4	Disturbance from other vessels in area, not part of exercise	-Nearby vessels not informed of test	-Interruption of test -Possible collisions and hazard for participants	-Notify any nearby vessels of the test -Establish safety zone around test area	
5	Tripping and falling	-Passengers not used to heavy suits/equipment -Slippery surfaces	-Fall damage (injuries, broken bones) -Ending up in the water	-Be cautious -Follow instructions -Detailed safety information and procedures from *KV Svalbard* crew	
6	MOB boat lifting hook swinging after release	-Hook operator error -Rough seas	-Hook arrangement hits passengers in MOB boat, leading to injuries.	-Follow instructions -Detailed safety information and procedures from *KV Svalbard* crew	
7	Falling into water during transfer between MOB boat and life raft	-Slippery surfaces -Distance between raft and MOB boat (e.g. due to poor mooring) -Rough seas	-Rapid cooling of persons in the sea	-*KV Svalbard* personnel entering life raft first, to assist with keeping the life raft and MOB boat close, and to help passengers from one vessel to the other	Will passengers be wearing immersion suits during transport to raft? Yes, some sort of suit shall be used during transit.
8	Many people ending up in the water at the same time	-Life raft integrity compromised -Capsizing -Etc.	-Mass injuries/hypothermia -Possible fatalities	-Establish procedures for rapid evacuation of all participants if necessary	
9	MOB boat occupied when an accident occurs	-MOB boat have many tasks	-Long time to rescue -People getting seriously chilled	-Use both MOB-boats for redundancy	

10	Long distance from MOB boat to life raft during test	-MOB-boat have many tasks -MOB-boat not on the water during test	-Long time to rescue -People getting seriously chilled -Long rescue time if people fall into the sea	-Ensure that MOB boat is close to raft during test for emergency preparedness -Use both MOB-boats for redundancy	
11	Rescuing passengers from sea to life raft	-Insufficient arrangements on life raft for extraction of people	-Difficult/impossible to rescue survivors from sea	-Ensure that MOB boat is close to raft during test for emergency preparedness	Most relevant for phase 3, REMEMBER
12	Communication difficulties	-Wind noise -Many people talking at the same time -Routines for how to communicate -Radio equipment failure	-Important messages cannot be communicated via radio	-Backup radio equipment/battery -Clarify communication routines prior to test	
13	Insufficient observation during test (of the entire area)	-Poor overview	-People fall into water without someone noticing	-Crew onboard *KV Svalbard* and MOB boats ensures lookout	
14	Immersion suit integrity compromised	-Improper entering of suit --Openings not properly closed (zippers), etc	-Exposure to cold water with potential injuries/chilling of body	-Buddy check on suit after putting it on, prior to test	
15	Poor sight	-Fog -Snow squalls -Sea spray	-Impact with drift ice -Difficulties with keeping an overview (polar bear lookouts, spot/locating participants falling into sea, etc.)	-Abort test if weather conditions gets too severe -Ensure that MOB boat is close to raft during test for emergency preparedness	
16	Sea spray into life raft	-The life raft canopy are open (ventilation, toilet breaks, extracting persons from sea, etc.)	-People get wet and cold -Water enters the life raft.	-Keep canopy closed whenever possible	
17	Sea spray icing on life raft	-Sea spray combined with low temperatures	-Change in life raft buoyancy qualities -Zippers and other small details frozen stuck	-Shaking canopy from the inside to loosen any ice	Unlikely
18	Clogging/blocking of ventilation	-Warm and moist air from inside the life raft condensates and freezes around/in the ventilation outlet	-Reduced ventilation -Deterioration of air quality	-Opening canopy for ventilation	Unlikely
19	CO2 build-up inside life raft	-Insufficient ventilation, combined with many people breathing.	-Headaches, sleepiness, poor concentration, loss of attention,	-Opening the canopy -Air quality measurement instruments onboard life raft	

			increased heart rate, slight nausea, oxygen deprivation.	-Ensure control of air vents.	
20	High temperature inside life raft	-Insufficient ventilation, combined with many people generating heat	-Heat stress: Dehydration caused by perspiration. Nausea, which can lead to vomiting, causing further dehydration.	-Opening canopy when necessary	
21	Low temperature in life raft	-Outside temperature.	-Core body temperature of passengers drops dangerously low (hypothermia)	-Bring hats, gloves, etc. for backup in case. -Low threshold for returning people to *KV Svalbard* -Ensure that MOB boat is close to raft during test for emergency preparedness	
22	Rapid weather changes	-Weather in this region can change in minutes	-Exercise gets much more difficult -Stopping the might be necessary	-Check weather report prior to/during test -Procedure for rapid evacuation of all participants -Ensure that MOB boat is close to raft during test, for emergency preparedness	
23	Passengers not noticing getting severely cold (core and extremities)	-Individual differences -Little or no experience with being cold -Sleeping	-Risk of injuries/fatalities	-Have buddies near you which can check on you -Leader onboard raft should keep overview.	Reception routines for chilled people? Check on safety briefing
24	Freezing body extremities	-Getting wet -Little clothing	-Frost bite leading to injuries	-Bring hats, gloves, etc. for backup in case. -Low threshold for returning people to *KV Svalbard* -Additional immersion suits in life raft for emergencies (for those not wearing suits during tests)	Reception routines for chilled people? Check on safety briefing
25	Medical problems of passengers	-Latent health issues -Other medical condition factors	-Possible medical emergencies for participants	-Low threshold for returning people to *KV Svalbard*	
26	Seasickness	-Lifeboat movements -Seasickness medicine not effective immediately	Vomiting, inducing dehydration and starvation.	-Anti-seasickness medicine -Take medicine prior to test	

				-Check with KV personnel on advice	
27	Not enough food	-Lifeboat not stocked	-Hunger -Exercise must be stopped	-Ensure lifeboat carries enough food for exercise duration	Raft stocked with enough for 24 h
28	Not enough water	-Lifeboat not stocked	-Thirst -Exercise must be stopped	-Ensure lifeboat carries enough water for exercise duration	Raft stocked with enough for 24 h
29	Hygiene	-No toilet available	-Insanitary conditions	-Bucket or other solutions? -Transport people with MOB boat to *KV Svalbard* for toilet visits	
30	Lack of sleep	Uncomfortable seating, stressful situation (physical and psychological)	-Sleep deprivation: Reduced cognitive abilities Ability to take care of yourself reduced, etc.	-Try to sleep when possible	Unlikely, due to short duration of exercise. Not expected to be a problem.
31	Polar bear attack (from underwater…?)	-Animal curiosity/hunger/threatened	-Raft puncture -Injuries/fatalities	-Polar bear guard (*KV Svalbard*) -Armed personnel onboard MOB-boat -Flares/signal rockets -Situation awareness -Sonar…?	Sonar suggested, as the sounds it emits (possibly) can scare polar bears in the water. NOTE to HAZID: Evaluate having bear spray in life rafts/boats for arctic use?
32	Walrus/orca attack	-Animal curiosity/hunger/threatened	-Raft puncture -Injuries/fatalities	-Armed personnel onboard MOB-boat -Flares/signal rockets -Situation awareness	

II.2.3 Notes from workshop after Phase I

By Raymond Dalsand[1] and Tord Nese[1]

[1] UiT – The Arctic University of Norway

Walkthrough no-play planning

- People says they felt safe in the life raft, with mob boat close and ready
- In a real life scenario, there should be some sort of security measure when transferring between lifeboat/life raft and MOB
- Interviews revealed that some people would have liked to receive more information prior to test
- Perhaps there should have been clear notifications on how to behave during the tests, e.g. can you use any means in the raft/boat? Clap your hands, move around etc.? Could participants use survival strategy?
- SARex participants was very pleased with risk analysis/session prior to test, but we could have included *KV Svalbard* personnel in addition to SARex participants.
- General: everyone felt safe and secure during the test

MetOcean – Was it representative?

- We were lucky with the conditions, they could have been worse.
  - Wind could have been a lot worse, experienced some effect during towing of raft
  - We had the best possible conditions
  - Calm waters, no significant waves
  - -1 degree water temperature
  - -9 degrees air temperature

Data presentation

- Medical
  - Medics felt comfortable regarding the criteria for stopping the exercise for each participant, buddy system worked
  - One of three test subjects (people rigged with core-temperature measurement equipment) had a rapid decline in body temperature (it is mentioned by NTNU medic that this is a misreading…? This is discussed, but no specific conclusion), the two others show a slower decline
  - Large discrepancies between cont. monitoring and ear measurements
    - Can be caused by various unknown reasons
  - Other test solution (for bigger budgets, maybe?) might be measurements using pills that are wireless and can be swallowed.
  - Discussions around peaks in body temperature measurements, no conclusion on why. Toilet break is suggested as a possible reason, as core temperature can go up during urination, caused by higher blood flow during urination (medic's opinion).
  - No change in reaction time tests (10 *KV Svalbard* crewmembers) before and after exercise exposure.
    Uncertainties regarding whether this reaction time method (designed for ADHD purposes) is suitable for this test, needs some further medical evaluation.
  - The persons with the worst protection used around twice as much energy on staying warm as the ones with the best protection. Needs more calculations that are thorough.
- Temperature measurements
  - Quite constant ambient temperature

    - More "even" temperature graph for lifeboat than raft
    - Raft temperature fluctuates more than boat temperature
    - The correlation between the sun and heat generation of people versus temperature is unknown, when the sun was disappearing there was also people stopping the exercise
    - Temperature dropped 3-4 degrees from when there was 2 people in the raft to when there were no people left
        - Number of people matters for temperature inside raft especially
- Humidity measurements
    - People in raft complained more about condensation than the people in the lifeboat
- People leaving crafts
    - Reasonably gradually
    - Is it possible to estimate after about 15 hours, whether it is possible to stay for 5 days…?
        - Medics comments that the build-up of moisture has a long-term effect on this matter, so this may not be reasonable to estimate
        - Moisture gradually builds up and you will have less insulation. An assumption was that the first 24 hours would not be identical to the next 24 hours due to build-up of moisture. Being wet in the raft would be a big problem in the long run.
        - Humidity very relevant in raft, again mentioned. Raft crew says that the moisture turned into water which collected around the heaviest people. Moisture in raft was reduced when people kept their suits closed.
- PPE
    - Interesting distributions, no specific comments

Definition of survival

- A lot of people was able to take care of themselves, but they were not far away from being unable to do this; comments from participants:
    - Some people from the raft were borderline to not be able to take care of themselves
    - Body temperature is very individual; it is more about whether you are able to take care of yourself.
    - Exposure to cold surroundings during MOB transit from crafts to *KV Svalbard* might affect the results, hard to be exposed to harsher conditions during "rescue", this uses the last bit of energy for the participants.
    - Noted that there was a significant difference between the conditions of the participants when they were leaving the raft/boat and when they arrived at *KV Svalbard*
    - Participants comment that the MOB transit was harsh
- Some of the persons getting off were actually really cold, but many said that they could have lasted longer. Impression from interviews, there was a motivational factor as well as a physical.
- Taking into consideration the condition of the participants when arriving at *KV Svalbard*, how much further could they have lasted in the crafts (question for medical people)?
    - Several could have lasted for at least 12 more hours
        - Nobody shivered seriously, which would have been a critical point
        - Everyone were able to be reasonable and take proper care of themselves.

        - They were far from the point where they would be the subject of external forces and unable to resist.
        - Most people from the boat were in good physical condition.
    - Not possible to say exactly how long (Ship's doctor)
    - Shivering phase can last for long time, as long as the body has enough energy reserves and does not get hypothermic
    - If this was a real 5-day survival situation, would there be any casualties?
        - Most experiment participants (not necessarily SARex) are healthy individuals
    - Leadership very good onboard raft and boat; in a real incident, it is thought that the leaders would have included measures to avoid fatalities.
        - Shared PPEs, warmed each other, etc.
    - Exhaustion will make you lay down on raft floor for sleep (-1degree), and this will severely affect survival time and chances.
    - Most people thought that the test participants were lasting longer than expected, especially the ones wearing only lifejackets.
    - Ove Tobias mentions that his survival was ok; he had much clothing on though. Also mentions that he does not think he would survive as long in the raft as in the boat.
    - In the raft people were cold on their feet, could not really test that with the pre-defined exclusion tests.

Leadership

- Fantastic social arrangements in the rafts got everyone engaged.
    - Language barrier can be present in a real scenario
- Limited how long a leader can perform his role perfectly
    - Would the leaders have credibility in a cruise situation? Are people tolerant and will they listen to the leader in such a situation?
    - "Guests are like fish, they become rotten in 3 days". One would need more time to figure out how people would react and behave in a real survival situation.
- Leadership in lifeboat; a bit hard to communicate at times, due to engine noise. It is commented that the leaders and participants onboard the lifeboat "had more up their sleeves" in terms of socialization. However, the social activities were rationed out over the course of the stay.
- Life raft leader mentions that this test was somewhat similar to e.g. tent exercises from military, etc.
- They were trying to get everyone involved, and focus on something else than the situation, during hand out of rations and water, and instructions on how to use.
- Difficult to determine whether people was actually cold and should leave, or whether they could have stayed longer (comment from participants in the life raft). Leader let persons decide themselves, this turned out to be correct, as many was actually cold without him noticing the severity.
- Everyone got food when they were hungry (in the life raft), leader says that in a real scenario, he would have been much more strict about the rations.
- Important to have a deputy, to take care of additional tasks and which can take over if leader needs to sleep.
- Boat: Deputy says that leader managed the situation for most of the time. If leader had to leave, deputy took over.

- Worst part of lifeboat stay was opening hatches for various reasons, which affected temperature. This was commented on by participants wearing less protective suits/lifejackets.
    - Simulated doing toilet breaks in buckets by opening hatches briefly and doing them in the mob boat.

PPE

Noted challenge that life-saving appliances did not fit everyone, the KampVest was too small for one person. Some of the suits were very tight on several participants even though they were within the suits size ranges.

- Survival suits
    - Biggest challenges:
        - Buildup of moisture
        - Leader in the raft with insulation suit: Got very sweaty, had to choose between venting his suit or keeping the warm and sweat inside. Clothing inside suit make a difference? Could the suit have been taken off?
        - Sweat and heat problem during some stages in life raft, maybe we should have taken more notice of the overheating problem. Since some participants did not have insulated suits or even suits at all, the raft had to be kept closed to keep a high enough temperature in the raft. If all participants had a good suit on, the inside temperature of the raft could perhaps have been kept lower (by ventilating the raft) to avoid sweat.
        - Functionality and suggestions for improvement:
            - There should be pockets on the suits, for storing food/water/garbage etc.
            - Hard to eat with the suit gloves, suggested having external gloves or thin gloves/liners underneath
            - Two-way zipper to simplify bathroom visits
            - Valve systems for peeing
            - Ventilation, can this be increased or improved by a solution?
                - Other fabrics available, but these are much more expensive
            - Exercise simulated "dry evacuation", and it might be necessary to have other qualities for suits depending on whether the evacuation is dry or wet. However, the life raft becomes wet, especially the floor.
            - No vapor barrier on the inside of insulation/liner in suits, so the material absorbs the moisture/sweat and "fills up". This can be solved using other materials, but again these are expensive.
            - Highest heat loss in life raft from the feet and lower body due to cold floor.
                - In the life raft, one would need insulation of the lower body and it would have to be waterproof.
            - Viking suit with/without liner; size adjustment solution worked very well, and the Velcro ankle straps worked. How the suit fits the person is very important, and the solution of this suit worked well. Inside sole should have more friction

and insulation, to avoid the foot from slipping inside the "boot".
  - 307 suit had very thin insulation underneath the sole

- Vests
  - Not big performance difference between the insulated vest and the Kamp vest
  - Neoprene vest was very uncomfortable in the raft
  - Life jackets with thermal protection was not very usable for the arctic conditions:
    - The lower part of body is not covered by the vest, so in the raft the available neoprene did not cover the most important body parts
    - Uncomfortable hoods

- TPA (bags)
  - Made a huge difference for the ones in the raft, especially to not get wet. It was a waterproof layer.
  - More criticism from lifeboat, much humidity inside, and difficult to move around in the boat.
  - Overall, the TPA had an effect.

- PPE: What is necessary?
  - Whole-body covering suit (watertight) to stay dry
  - Insulation wanted

- Lifeboat
  - Suggestions:
    - Something to sit on, because the seats (benches) were cold.
    - Air vent system to avoid CO_2 build-up and drop in O_2
    - Heating: Diesel heater (separate from engine). This sort of solution will only need to be type approved to be used for this purpose in a lifeboat, according to Sjøfartsdirektoratet. No issues related to implementation, so this should be investigated. No Norsafe representatives present during this discussion.
    - Canopy/tarp included in lifeboat, to close off a small area in lifeboat if there are few passengers compared to total capacity. This would increase the heat within the closed off area.
    - Insulation in benches
    - Food with different flavors/colors etc.

- Life raft
  - Positives:
    - More stable than expected
      - Five people stood in one opening in the raft to watch the walrus, not a lot of movement.

        - Insulation (canopy)
        - Good performance compared to the simple design (basically a tent)
        - Good temperature in the “tent” itself, the only large problem was the floor insulation (or lack of)
    - Negatives:
        - Air quality a problem. During exercise, the weather was good. If a lot of waves, rain, wind, etc. It could be a big problem.
        - In harsh weather, the raft will take in water if not completely sealed.
        - A lot of movement in rough seas.
    - Suggestions:
        - Bottom insulation (e.g. double bottom): to provide extra distance from the sea water underneath, and reflect heat on the surface inside
        - Cushion so people do not have to sit on the floor where there might be water.
        - Storage pockets/bags to sort and store equipment
        - Food with different flavors/colors etc.
        - Drainage channel of some sort, to collect water flowing in the raft, and to facilitate easy pumping
        - Drainage pump broke during test; this should be stored in a pocket or some sort of mount to avoid this. Sturdier pump design wanted.
        - Only one lookout position (air vent hole), should have two or more, because one person can only look to one side of the raft (for polar bear watch etc.). This can improve air venting as well.
        - The lookout hole let a lot of cold air in, better solution for closing when not in use is wanted.

Downgrade max carrying capacity of raft (max nr of occupants) to ensure enough space to facilitate polar clothing and immersion suits. This can be done by Sjøfartsdirektoratet

II.2.4 The lifeboat's capabilities and capacity during the Phase I exercise

By Erik Mostert[1] and Ronald Schartner[1]

[1] Norsafe AS

1. BACKGROUND, PURPOSE AND SCOPE

Background:

Norsafe AS, was contacted after the summer of 2015 to participate in realistic full scale evacuation exercises in ice infested waters on the north side of Svalbard in May 2016.

Purpose:

The purpose of Norsafe's participation is to evaluate standard/conventional LSA equipment by looking at the newly introduced IMO POLAR CODE which was introduces as a recent supplement to existing IMO instruments.

From a lifeboat's perspective the following polar code elements are focused upon in this evaluation and report:

8.2.2 – Safe evacuation

8.2.3 – Survival, thermal protection

8.2.3.2 – LSA equipment shall take account of the potential of operation in long periods of darkness.

8.2.3.3 – Survival support following abandoning the ship to either water, ice or land for the maximum expected time of rescue (minimum 5 days). LSA resources shall provide:

- a habitable environment
- Protection from effects of cold, wind and sun.
- Accommodation space for persons incl. thermal equipment.
- Safe access and exit points, incl. means to provide sustenance.
- Communication means.

Scope:

The goal of the Polar Code is to increase the safety of ships' operation by mitigating the impact on the people and environment in these remote and harsh areas. Mitigations for potential risks can only be evaluated by understanding the risks involved in such operations. These tests and exercises are specifically designed and organized to create proper understanding.

As the polar code is a RISK based guideline, a RISK assessment was used as input for the trials and summarized after the exercise as a handbook for future product and evacuation procedure evaluations. This report is a combination of Norsafe's individual findings during the exercise with focus on technical elements in the lifeboat combined with possible solutions to mitigate RISK's that are summarized in the RISK analysis.

2. LIFEBOAT DESCRIPTION

During previous winterization projects Norsafe has gained a strong basis with understanding the implications of using LSA equipment in cold conditions. For this exercise all this knowledge was disregarded. Well knowing that certain systems would fail, it was decided to use a 100% standard conventional (davit launched) lifeboat. This lifeboat type, called Miriam 8,5 is a 8,5 meter 55 persons lifeboat.

This specific lifeboat was available from stock, it is a 2013 model boat, which was originally delivered with serial number 16849. External GA can be seen in Fig. II–8, Internal GA in Fig. II–9.

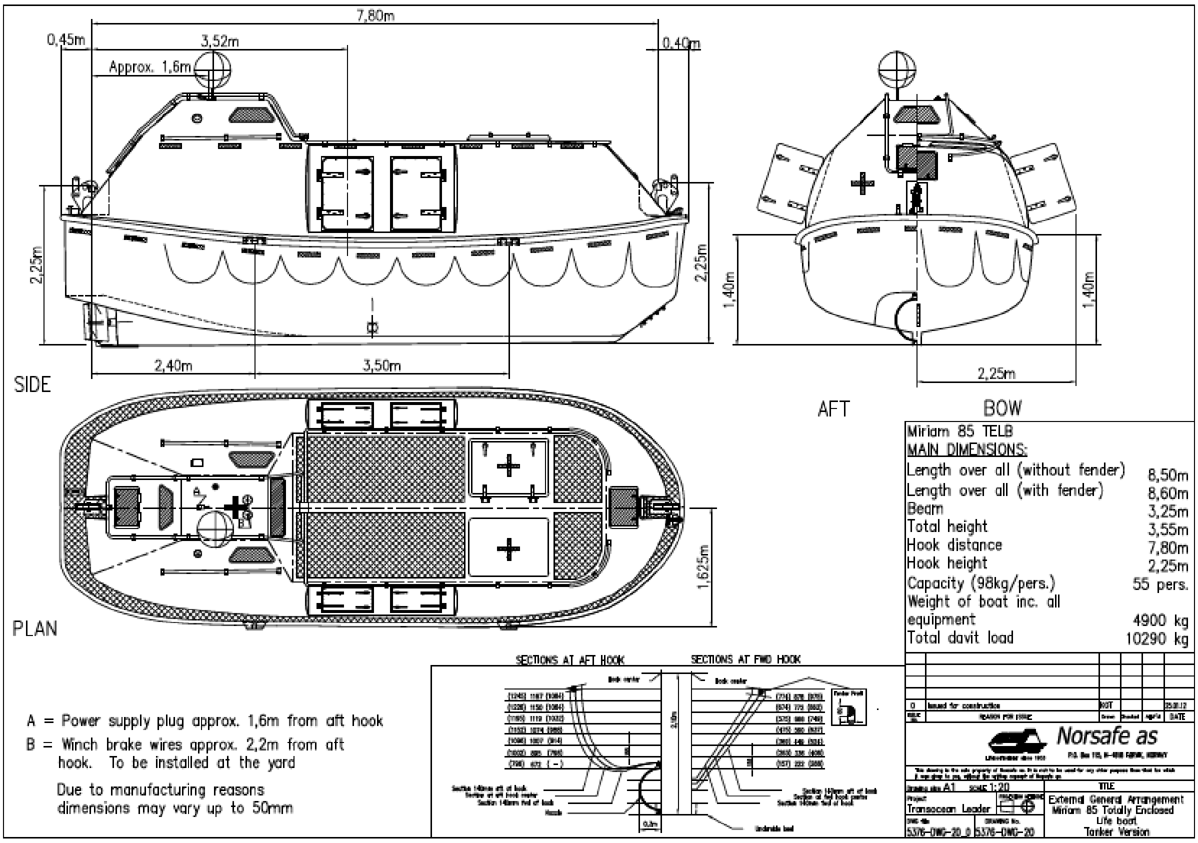


Fig. II–8: External general arrangement of the Miriam 8,5 with serial number 16849.

Standard features and elements that were thought off prior to the decision of using this lifeboat:

- Miriam 8,5 is a type of lifeboat that is likely to be used/be available on those vessels the polar code and this exercise tries to cover.
- 4 large hatches (2 on either side) make for easy access when water borne, as well as safe operations during the exercise.
- Sprinkler system and ability to run the lifeboat as a habitat on internal air make polar code rules possible to implement, but will also challenge the air management.
- The lifeboat has been stored for 2 years in outside storage locations onshore. Maintenance was performed prior to the trials: MAN-0182.

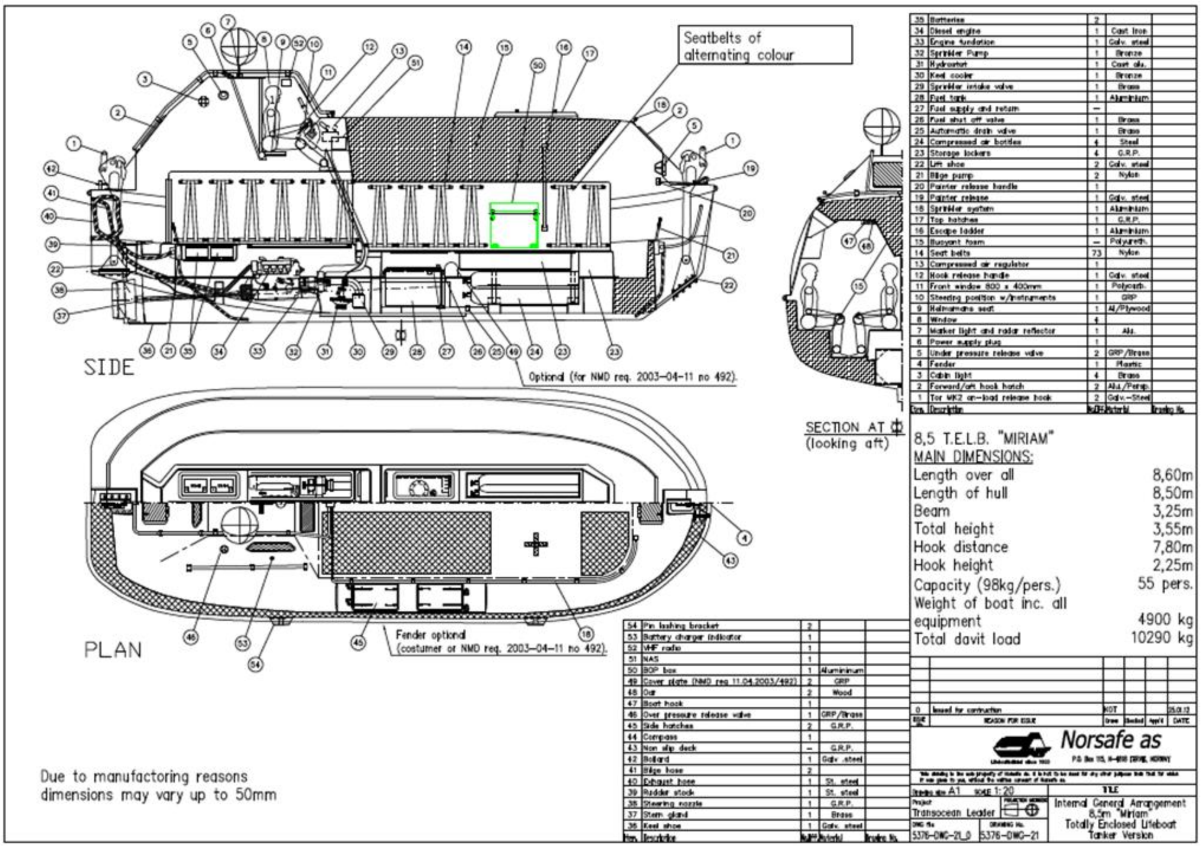


Fig. II–9: Internal general arrangement of the Miriam 8,5 with serial number 16849.

Total boat weight incl. standard SOLAS equipment and fuel = 4900 Kg

Adding 55 x 98 kg personnel makes the total weight = 10290 Kg

3. REFERENCES

- IMO Solas LSA-code MSC.48(66) and MSC.81(70)
- Polar code (MEPC 68/21/Add.1)
- Icing on lifeboats at sea – Stability & Sprinkler de-icing tests (Norsafe doc nr.: REP-0700)
- Conventional lifeboat winterization principles (Norsafe doc nr. : REP-0736)
- Conventional lifeboat and rescue boat DAVIT winterization principles (Norsafe doc nr.: REP-0753)
- Air quality in conventional lifeboats (Norsafe doc nr.: REP-0786)
- Norwegian working environment regulation (FOR-2011-12-06-1358)
- Polar evacuation RISK assessment – Appendix A.

4. EXERCISE/TEST EXECUTION SUMMARY

The polar code related exercise was conducted during the first day of testing.

1. Host ship (KV Svalbard) was positioned close by in the southern section of Woodfjorden. Lifeboat was cold stored before the operation was started. Only supported by battery charger (ship's power supply).

2. Lifeboat hoisted to sea by means of KV Svalbard deck crane.

3. Lifeboat captain and second in command boarded the lifeboat: 09.00.

4. Lifeboat was started and driven away from host.

5. 16 additional crew members were taken on board by means of MOB boat shuttle.

6. 10.00 trial execution started.

7. Temperature and air quality measurements in place.

8. 15.00 Engine was shut down to “simulate” running out of fuel.

9. Gradually temperature downturn dropping to minus 2 early in the morning causing a number of persons to leave the lifeboat.

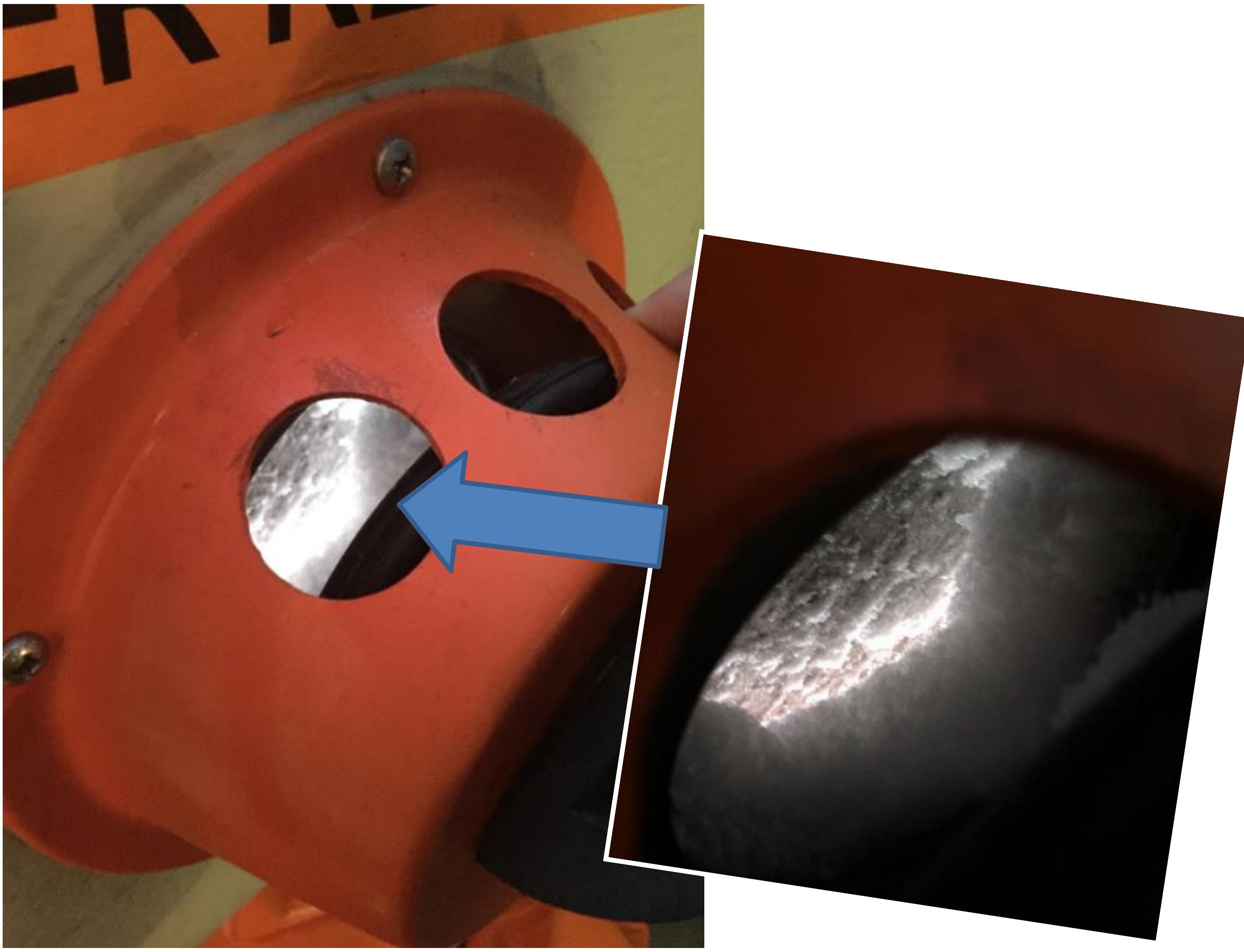
10. After 24 hours, the test was aborted, this lifeboat still held 6 persons at this stage:

5. NORSAFE FINDINGS

5.1 PHASE 1: ENGINE RUNNING

With outside temperatures of -10 to -15 during the test, including moderate winds at the end of the exercise. None of the subjective findings were of any surprise:

While the engine is running and with approximately 18 persons on board the temperature gradually climbed to 17 degrees. Some of the test crew left the lifeboat for toilet visits or other reasons. With the engine running, and the opening of the hatches for different reasons, the air quality in the lifeboat stays acceptable. The cold air flow through the under pressure valve into the lifeboat to the engine is however uncomfortable (as expected) resulting in the accumulation of cold air at the bottom (feet height) of the passenger area. If this part of the exercise would have been extended, including more moisture wind, waves and sea spray we know from experience that the under pressure valve would ice up completely. This would have caused vacuum/under pressure in the cabin, resulting in engine stop and demanding procedures to open the hatches. This is a technical issue that needs to be mitigated with a fixed procedure on how to handle after the sprinkler phase of an evacuation has passed.



Apart from this there are a number of challenges in this phase:

- Comfort: Issues regarding space, seat comfort, noise, moisture. However, all these items are better (apart from noise) compared to a situation where one loses the effect of the engine.

- The generated heat of an idling engine raises the probability of survival and preparedness of personnel. However, it is an ineffective way to generate heat. Alternatives could be proposed (webasto type heaters) to generate this more effective and comfortable.

- Moisture is an issue especially after the engine and air flow was cut off.

- Boredom is an underestimated issue. As long as there is nothing to do but wait, without purpose it is much more common to focus on "how cold one is feeling". Doing is forgetting. Simple activity equipment like a deck of cards could help keep mental health.

- Lifeboat stability can be compromised, different deicing and/or ice buildup prevention should be evaluated e.g. Nano polish or sprinkler system steam de-icing.

- Lifeboat capacity is a difficult issue. Especially when survival / habitat issues are to be included. With 55 persons over time it would have been extremely difficult to feel any form of comfort. Balancing number of persons for each journey with deviating possible survival length and dimensioning survival kits and resources will become a major issue for regulatory bodies.

- Cockpit windows need special attention for deicing or extra heating to prevent ice buildup. In all standards this is a main issue. Being able to see directly after launch. This was not an option with the standard lifeboat. The captain had to climb out and use an LSA Axe to remove the ice.

- Simple measures like neoprene foam on the seats and other hard and cold object should be standard in any polar code pending lifeboat.
- Sanitary solutions including some sort of privacy important. Any “outside the boat” operation for sanitary reason will add to huge risk for that person.
- As long as there is heat generating devices in place in the lifeboat, there is moisture removal measures installed, the need for thermal protection is NOT present. In fact, during the trials, the worn protection inside the lifeboat added to internal sweat that later generated discomfort and problems with moving around. Normal clothes and jackets appeared to function best (while inside the lifeboat).

- With the above list it is obvious that one needs to be able to rely on the correct functioning of the engine and its equipment. This requires very tight and stringent maintenance follow up and systems. This was clearly shown during the test, when the engine stalled due to air in the cooling system that caused freezing of the cooling line and high temperature when the engine was run at high speed.

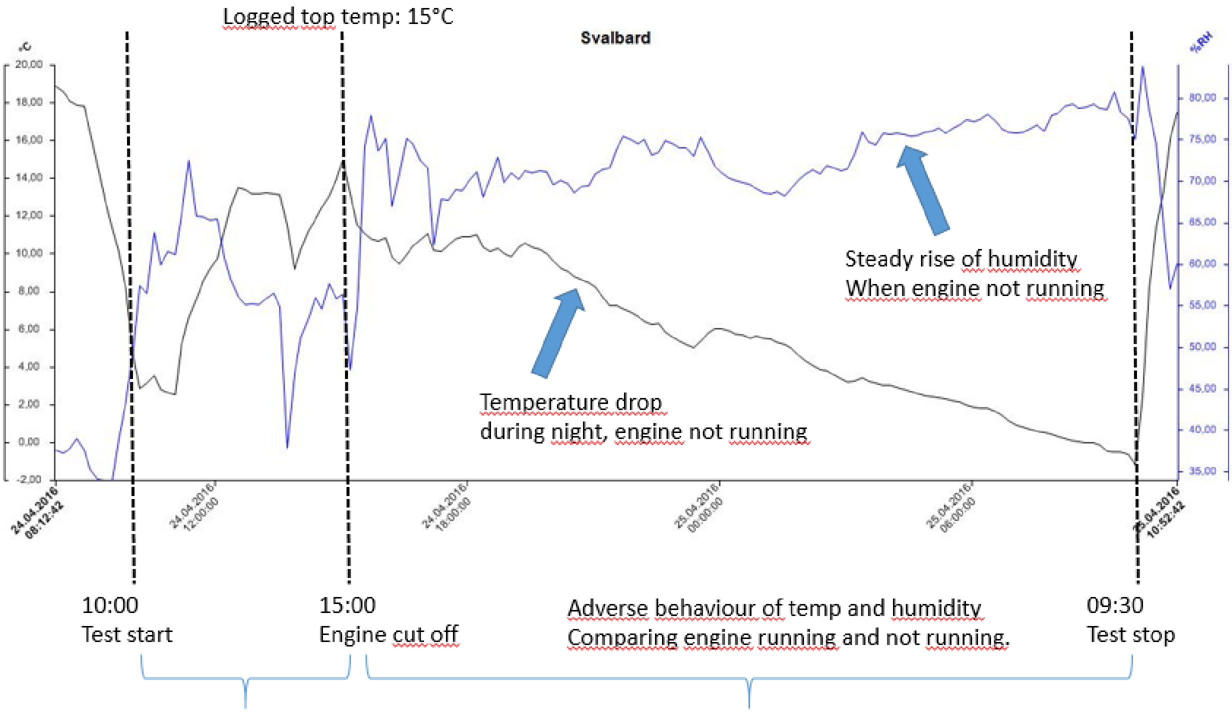
- Standard conventional lifeboats do not have sufficient lighting. Modern LED alternatives can be used to create enough light to safely use the lifeboat as a habitat for longer periods.

- The survival food and water is sufficient and functional. However, it is found that this also generates huge amounts of garbage especially plastics when unpacked. As there is no place to abandon waste this becomes an irritation and unpractical issue. Can be easily mitigated.

5.2 PHASE 2: SURVIVAL IN LIFEBOAT WITHOUT MEANS OF PROPULSION/HEAT.

Five hours into the exercise it was decided by the test management to cut the engine. This was to simulate the effect of running out of diesel and/or engine failure for whatever reason.

This was around 15:00 hours. Until then it had been reasonably fine to be inside the lifeboat. Due to the steady flow of fresh air into engine bay through the cabin, a good balance between humidity, temperature and CO/CO2/NOx/O2 levels was obtained.



The above presented graph shows clearly how drastically this effect was altered once the engine was cut off. Air quality sensors in the lifeboat gave a constant reminder that CO2 levels were unacceptable, even with only 16 persons onboard.

As the effect of CO2, gives a comfortable effect and makes people want to sleep, it was annoying to have this reminder and in addition the need to shift the air out by opening hatches, also caused for rapid drop in temperatures and cold moist feeling inside the lifeboat.

This gives a number of issues to address in addition to the ones already mentioned.

- It can be discussed if lifeboats that are thought to be a functional habitat should be equipped with standard air quality monitoring equipment.

- Fresh air access that shifts air from the cabin when the engine is not running should be evaluated.

- The rapid increase in air moisture combined with the dropping temperature, caused the moist to collect in the highest area of the lifeboat. Drains should be considered mechanically. In periods the moist was dripping down. Unprotected persons, will get wet, decreasing survivability if the rescue phase is extended.

6. CONCLUSIONS & RECOMMENDATIONS

6.1 SUBJECTIVE FINDINGS: NORSAFE EVALUATION

Above chapter 5 lists the subjective findings Norsafe has made during the participation of the test. The findings vary from practical too serious. Everything can be quite easily mitigated and the reason and purpose used in the marketing activities of such lifeboats.

The cost is not necessarily high which makes execution less problematic.

However, every cost is a cost. The Polar Code requirements are extremely little specific, so-called goal based. This invites for serious suppliers like Norsafe to creative thinking and possible solutions. But for unserious suppliers to do as little as possible, since it is difficult to contradict solutions. The lifeboat would have functioned fine even in the standard configuration without modifications to mitigate anything.

Lack of legislation and specific requirements causes always to end up with minimum solutions, in a competitive world. If this is not addressed, our good intentions, will probably not pay off in actual improvements nor increase in safety. The polar code wording is impossible to proof without risk, and therefore not doing anything with a product impossible to contradict.

As long as rules and regulations are falling behind in specific requirements, Norsafe tries to explain the possibilities and advantages towards the operator (end user responsible). Focusing on the lessons learned lessens the uncertainty, which is the best way forward for both parties.

6.2 OBJECTIVE FINDINGS: STRUCTURED RISK ANALYSIS

Besides subjective observations, a more structured RISK analysis was performed during the cause of the exercise and this project.

Norsafe has been involved in this work to discuss and propose mitigating actions of the potential findings and risks.

Preliminary Hazard Analysis on Page 125, shows this in detail.

6.3 RECOMMENDATION

Norsafe's hope is that in the pending rules and legislation changes, duty holders will put effort in the details of this Risk analysis as well as the subjective observations in reports like this one. Specific product related solutions to mitigate risks should be followed up and be handled similar for all suppliers of LSA equipment.

Especially definitions on PSK (personal survival kit) and GSK (group survival kit). What is the purpose? How can it be stored? How can these kits be tuned to meet each potential cruise/voyage? Bringing such equipment onboard the lifeboat will have significant effect on the capacity of the lifeboat. With capacity being one of the main evaluation criteria, this is currently one of the least flexible items when building new ships.

Surviving in a lifeboat and using it as a habitat is a good solution. However, it is also then necessary to make available for more space inside the lifeboat. Combining both survival kits with the possibility of survival in a habitat (incl. Sleeping, sanitary equipment, extra food, fuel etc.) it would be likely to reduce lifeboat capacity with 25 to 50% depending on the anticipated survival length (minimum 5 days, max ? days).

The above issue is extremely difficult for one stakeholder to conclude on. There are so many different scenarios and possibilities, that certain boundary conditions and demands must be agreed upon. Norsafe recommends to extend this conditions with this focus. We know that everything is possible to solve, but we need to define how to put the solutions into manageable consistent requirements.

II.2.5 Preliminary Hazard Analysis

By Tord Nese[1], Raymond Dalsand[1] and Erik Mostert[2]

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Risk matrix for preliminary hazard analysis

Consequence → **Probability↓**	**A** **Minimal**	**B** **Low**	**C** **Medium**	**D** **High**	**E** **Very high**
5 - Very high					
4 - High					
3 - Medium					
2 - Low					
1 - Minimal					
Consequence categories	No injuries, and/or long-term survival chances not reduced	Minor injuries, and/or long-term survival chances slightly reduced	Major injuries, and/or long-term survival chances reduced	Life-threatening injuries, and/or long-term survival chances severely reduced	Fatalities, and/or long-term survival chances minimal

<table>
<tr><th colspan="8">Stage one: Evacuation to lifeboat</th></tr>
<tr><th></th><th>Hazard number</th><th>Problem</th><th>Cause</th><th>Possible Consequences</th><th>Pre risk-reducing measures risk</th><th>Risk-reducing measures</th><th>Post risk-reducing measures risk</th></tr>
<tr><td></td><td rowspan="3">1.1</td><td>Slippery walkways and surfaces (gunwale, stairs, etc.)</td><td>Icing on surfaces (atmospheric/sea spray)
Wet surfaces (rain/sea spray)</td><td>Injuries from falling.</td><td>Probability: 3
Consequence: C</td><td>-Sheltered walkways
-Heated walkways
-Enclosed/sheltered lifeboats/stations
-Surfaces covered with friction material</td><td>Probability: 1
Consequence: C</td></tr>
<tr><td>Pre RRM comments</td><td colspan="6">Note: This problem does not cover incidents where people stumble, twist their ankles, etc., only falling accidents due to low-friction surfaces. Probability is set to medium (3). On a boat, there are usually slippery surfaces due to wet floors, snow, ice etc. If the lifeboat station is unsheltered, slipping might be a relevant problem for a cruise ship. Consequences are set to medium (C) due to the possibility of relatively serious injuries from falling.</td></tr>
<tr><td>Post RRM comments</td><td colspan="6">If the suggested risk-reducing measures are implemented, the probability is reduced to minimal (1).</td></tr>
<tr><td></td><td rowspan="3">1.2</td><td>Insufficient space in lifeboat</td><td>Polar clothing, PSK and GSK takes extra space</td><td>Passengers cannot evacuate to the lifeboat they are assigned to.
Available lifeboat capacity insufficient.
All passengers are not able to bring along their PSK.</td><td>Probability: 4
Consequence: B</td><td>- Lifeboat passenger capacity with full polar clothing, PSK and GSK to be certified/determined prior to operation</td><td>Probability: 1
Consequence: A</td></tr>
<tr><td>Pre RRM comments</td><td colspan="6">Note: Problem is based on today’s lifeboats and their capacity, with polar clothing and PSK & GSK equipment brought along. Probability is set to high (4). Polar clothing requires some extra space, but not a lot. If a sufficient amount of PSK’s and GSK’s are to be brought along in the lifeboat, these will require some space. This problem depends on whether the total lifeboat passenger capacity is needed in an evacuation. Consequences are set to low (B). If there is insufficient space in the lifeboat for all necessary passengers and the required amount of PSK & GSK, the kits will have to be left behind. Polar Code requires space for passengers with all necessary equipment, if the risk assessment requires this.</td></tr>
<tr><td>Post RRM comments</td><td colspan="6">If the cruise ship has lifeboats with capacity to take all passengers with the necessary equipment (PSK & GSK), this problem is eliminated. Probability reduced to minimum (1), consequence reduced to minimum (A).</td></tr>
</table>

Stage one: Evacuation to lifeboat							
	Hazard number	**Problem**	**Cause**	**Possible Consequences**	**Pre risk-reducing measures risk**	**Risk-reducing measures**	**Post risk-reducing measures risk**
	1.3	Lifeboat not usable	-Fire in area -Lifeboat damaged (due to collision etc)	-Not enough total lifeboat seats remaining to evacuate all passengers -Passengers entering hazardous area	**Probability: 2** **Consequence: C**	-Ensure additional evacuation possibilities -Emergency routines	**Probability: 2** **Consequence: B**
Pre RRM comments	1.3	Probability is set to low (2) because it is not very likely that the ship has list/trim over design limits before the evacuation is finished. Depending on what the emergency is (fire, collision, etc.), one or more lifeboats can be unavailable or too damaged to be used for evacuation, but the probability of this is also low. Consequences are set to medium (C) due to the fact that if a lifeboat is unavailable, there are not enough space in the remaining lifeboats to accommodate the extra passengers. These will therefore have to evacuate by using other means, e.g. life rafts. Having to do this, might require them to remain onboard the ship longer than if their lifeboat was operable.					
Post RRM comments	1.3	By ensuring additional means of evacuation, the consequences of this problem is reduced to low (B).					
	1.4	Clothing not sufficient for evacuation	-Poor information routines onboard -Chaotic evacuation situation (passengers don't remember information)	Reduced chance of prolonged survival	**Probability: 4** **Consequence: D**	-Improve information routines and emergency drills -PSK and GSK easily accessible close to muster station and embarkation. Polar Code requirement.	**Probability: 4** **Consequence: B**
Pre RRM comments	1.4	Probability is set to high (4), because it is likely that people are wearing less than ideal clothes in a chaotic evacuation situation. The consequences are set to high (D), severely reducing the long-term survival chances. Even though the passengers are informed of recommended clothing for evacuation in e.g. a standard pre-journey safety briefing, it is likely to be a problem. PSK and GSK can be vital in such situations, so it is important to bring these along in the evacuation vessel.					
Post RRM comments	1.4	With PSK and GSK available, and brought along in the lifeboat in an evacuation situation, the consequences are reduced to low (B). This is because the PSK and GSK contains spare clothing and equipment that can be put on once in the lifeboat. The Polar Code requires that the PSK & GSK equipment provide sufficient thermal insulation to maintain the core temperature of persons. Despite information routines, the probability is unchanged. This is because in reality, the passengers are indoor, and it cannot be expected that they wear e.g. woolen underclothing at all times. In addition, even though emergency routines might say that passengers are to change to/bring along extra clothing in case of an emergency, this is entirely dependent on each passenger and the nature of the emergency.					

Stage one: Evacuation to lifeboat							
	Hazard number	**Problem**	**Cause**	**Possible Consequences**	**Pre risk-reducing measures risk**	**Risk-reducing measures**	**Post risk-reducing measures risk**
	1.5	PSK and GSK are not available or not brought along in lifeboat	Human/organizational error Polar Code risk assessment did not require PSK/GSK	Reduced chance of prolonged survival	**Probability: 3** **Consequence: C**	-Ensure proper information routines -Crew training -Qualified and experienced personnel handling risk assessment	**Probability: 2** **Consequence: C**
Pre RRM comments		Note: This problem presumes that the Polar Code requirement to PSK & GSK has entered into force. This requirement is based on the Polar Code risk assessment, which are to be performed prior to voyage. Whether PSK and GSK is available onboard the ship is therefore entirely dependent on the conclusions from the risk assessment. Probability is set to medium (3). PSK and GSK are to be stored (easily accessible) close to the muster/embarkation stations, so they will have to be manually moved into the lifeboats pre-launch. It is therefore likely that there are too few PSK & GSK in each lifeboat compared to the number of passengers. Consequences are set to medium (C), at least if the number of PSK & GSK is very low compared to the passenger count.					
Post RRM comments		Assumed that PSK and GSK is available in ideal locations. The probability of this problem can be reduced significantly by ensuring that the risk assessment is performed thoroughly by an experienced analysis group, and by sound emergency procedures and crew training. If this is in place, probability is reduced to low (2). Due to the stressful nature of an evacuation situation, it is difficult to lower the probability further.					
	1.6	Passenger unable to evacuate to lifeboat without assistance	-Health problems/injuries, combined with complicated boarding arrangements	Passenger needs extra assistance when boarding Evacuation process is delayed	**Probability: 5** **Consequence: A**	-Design boarding arrangements for easy access - Information on passenger health problems prior to sailing -Procedures in place for crew to help	**Probability: 4** **Consequence: A**
Pre RRM comments		Probability is set to very high (5). It is very likely that a cruise passenger, of which many are elderly and unfit, will need some sort of assistance when embarking the lifeboats. Consequences are set to minimal (A), but can include negative impacts on the overall evacuation time.					
Post RRM comments		By designing the boarding arrangements to be as easily accessible as possible, excluding ladders or steps, the number of people requiring assistance can be reduced. This will in turn reduce the probability of this entire problem. With such measures in place, the probability is reduced to high (4). These measures will also require less effort from the crew, which then can concentrate on other important tasks.					

<table>
<tr><th colspan="8">Stage one: Evacuation to lifeboat</th></tr>
<tr><th></th><th>Hazard number</th><th>Problem</th><th>Cause</th><th>Possible Consequences</th><th>Pre risk-reducing measures risk</th><th>Risk-reducing measures</th><th>Post risk-reducing measures risk</th></tr>
<tr><td></td><td rowspan="3">1.7</td><td>Passengers go to «wrong» muster station</td><td>-Poor information routines onboard
-Chaotic evacuation situation (don’t remember information)</td><td>Delayed evacuation process</td><td>Probability: 3
Consequence: B</td><td>-Ensure proper information routines
-Crew training</td><td>Probability: 2
Consequence: B</td></tr>
<tr><td>Pre RRM comments</td><td colspan="6">Probability is set to medium (3), because an evacuation situation is likely to be very chaotic. It is probable that some of the passengers will escape to another lifeboat station than they are preassigned to, hence this problem. Consequences are set to low (B), due to possible delays in the overall evacuation process, and because in a worst-case scenario passengers can be left behind in the confusion.</td></tr>
<tr><td>Post RRM comments</td><td colspan="6">To limit this risk, there must be good communication between the lifeboat crews, and sound routines in place. Combined, this lowers the probability to low (2).</td></tr>
<tr><td></td><td rowspan="3">1.8</td><td>Sea ice conditions around ship unsuited for launch of lifeboats</td><td>Dense/thick sea ice</td><td>Lifeboat evacuation not possible</td><td>Probability: N/A
Consequence: N/A</td><td>Avoid using lifeboats for evacuation by:
-Evacuating passengers directly onto ice sheet
-Deploying inflatable life rafts on the ice sheet</td><td>Probability: 1
Consequence: A</td></tr>
<tr><td>Pre RRM comments</td><td colspan="6">This problem was included prior to conversations with a lifeboat manufacturer (Norsafe), but the risk was not estimated due to lack of information.</td></tr>
<tr><td>Post RRM comments</td><td colspan="6">Norsafe revealed that the lifeboats can be lowered onto fast ice without problem, and will due to a shallow keel lay relatively stable on the ice. In addition, cruise ships does not normally venture into areas with fast ice. The probability of this problem is therefore set to be minimal, and the consequences equally low. The problem is not removed from this analysis due to informational value.</td></tr>
</table>

Stage two: Launch of lifeboat							
	Hazard number	**Problem**	**Cause**	**Possible Consequences**	**Pre risk-reducing measures risk**	**Risk-reducing measures**	**Post risk-reducing measures risk**
	2.1	Mechanical failure on launching mechanisms	Icing on parts and components	-Lifeboat launching process cannot be initiated - Lowering obstructed during launching process - Release hooks do not function as intended	**Probability: 3 Consequence: D**	-Sheltered components/mechanisms -Heated components/mechanisms -Release hook redundant override function -Manual inspection -Manual removal of ice	**Probability: 1 Consequence: D**
Pre RRM comments		Probability is set to medium (3). At sea, one are exposed to two types of icing (sea spray and atmospheric). The temperatures in the Arctic, even during the summer months, are often low enough to cause icing. The lifeboats and launching arrangements are likely to be fitted relatively high on a cruise ship, but in harsh weather and with rough seas, the altitude above the sea is still not enough to prevent sea spray icing altogether. The fact that launching arrangements are constructed from steel members, and has small-diameter details such as steel members and wire ropes, facilitates icing. The consequences of this problem is set to high (D). This is because mechanical failure on the launching mechanisms can render a lifeboat unusable, or in worst case, a failure can occur during the lifeboat lowering. There is also a probability that icing can prevent the release hooks from functioning properly, which would render it impossible to get away from the ship.					
Post RRM comments		The suggested risk-reducing measures can effectively prevent the formation of icing, reducing the probability to minimal (1).					
	2.2	Mechanical failure on launching mechanisms	Poor maintenance Corrosion Material fatigue	-Lifeboat launching process cannot be initiated - Lowering obstructed during launching process - Release hooks do not function as intended -Cable breaks	**Probability: 3 Consequence: D**	-Ensure proper maintenance routines	**Probability: 2 Consequence: D**
Pre RRM comments		Probability is set to medium (3). This is mainly due to the operational environment of the launching equipment. Salt water and marine air facilitates corrosion, and low temperatures can cause metal to get brittle. It is therefore very important that inspections and maintenance is performed regularly as per requirements. The consequences of this problem are set to high (D). This is because mechanical failure on the launching mechanisms can render a lifeboat unusable, or in worst case, a failure can occur during the lifeboat lowering. Mechanical problems can also prevent the release hooks from functioning properly, which would render it impossible to get away from the ship.					
Post RRM comments		Following the inspection and maintenance routines can prevent failures from occurring, given that it is performed thoroughly and with quality. Still, there is always a risk of failure in mechanical systems, due to a number of reasons. The probability is therefore reduced to low (2).					

Stage two: Launch of lifeboat							
	Hazard number	**Problem**	**Cause**	**Possible Consequences**	**Pre risk-reducing measures risk**	**Risk-reducing measures**	**Post risk-reducing measures risk**
	2.3	Power (electric/hydraulic) for launching arrangements not available	Ship's main/secondary/emergency power is out	Lifeboat launch not possible	**Probability: 2 Consequence: D**	-Gravity based launching systems (not dependent on power systems) -Redundant systems	**Probability: 1 Consequence: D**
Pre RRM comments		Probability is set to low (2) because if the launching arrangements depend on power, there will almost certainly be redundant back-up systems. Consequences are set to high (D) due to the fact that if multiple lifeboats are unavailable, the evacuation possibilities is reduced to secondary means (e.g. life rafts). This will also complicate the evacuation process a lot.					
Post RRM comments		If all launching systems are gravity based only, there will be no need for any type of power to launch the lifeboats. Hence, the problem is eliminated, and the probability is reduced to minimal (1).					
	2.4	Stress on lifeboat and davit exceeds design limits	Lifeboat launch is initiated when ship has list/trim angle above what the lifeboats and arrangements are designed for	-Injuries/fatalities due to mechanical failure	**Probability: 1 Consequence: D**	-System/procedures to avoid launch when ship has too high list/trim angle	**Probability: 1 Consequence: D**
Pre RRM comments		Minimal probability (1) for this problem to occur, because the arrangements probably have a maximum working load much higher than the safe working load. Consequences are set to high (D) because if the stress on the lifeboat and davit exceeds the design limits, there is a slight chance that a mechanical failure might occur, and in a worst case scenario e.g. the lifting cables can snap and send the lifeboat into a freefall.					
Post RRM comments		Some sort of system or procedures can be implemented to prevent lowering of lifeboats when the list or trim angle is too high. This will have minor impacts on the probability, but there will be no changes in the probability grade since it is already minimal (1).					

<table>
<tr><th colspan="8">Stage two: Launch of lifeboat</th></tr>
<tr><th></th><th>Hazard number</th><th>Problem</th><th>Cause</th><th>Possible Consequences</th><th>Pre risk-reducing measures risk</th><th>Risk-reducing measures</th><th>Post risk-reducing measures risk</th></tr>
<tr><td></td><td rowspan="3">2.5</td><td>Uncontrolled lifeboat movement during lowering</td><td>-Rough sea state
-Strong winds
-Ship rolling</td><td>Lifeboat crashing into the ship side/other lifeboats, subsequent consequences includes passenger injuries</td><td>Probability: 3
Consequence: C</td><td>-Shock-absorbing fenders and skates on lifeboat exterior hull
-Passengers using seatbelts in lifeboat</td><td>Probability: 3
Consequence: B</td></tr>
<tr><td>Pre RRM comments</td><td colspan="6">Probability set to medium (3) because it is quite likely that the sea conditions will cause the ship to move, and controlling the subsequent lifeboat movements during lowering is close to impossible. Strong winds can also be a factor that initiates lifeboat movement. The consequences are set to medium (C) because if the lifeboat moves uncontrollably and crashes into the ship's hull at relatively high speeds, the passengers will be thrown around inside the lifeboat. The lifeboat itself shall be designed to withstand an impact with the ship's hull of at least 3,5 m/s.</td></tr>
<tr><td>Post RRM comments</td><td colspan="6">The risk-reducing measures will reduce the consequences to low (B). Fenders and skates on the lifeboat will to some degree absorb energy from crashes, and seatbelts will ensure that the passengers remain in their seats even when the lifeboat movement is substantial. Minor injuries can still be expected.</td></tr>
</table>

<table>
<tr><th colspan="8">Stage three: Initial operation</th></tr>
<tr><th></th><th>Hazard number</th><th>Problem</th><th>Cause</th><th>Possible Consequences</th><th>Pre risk-reducing measures risk</th><th>Risk-reducing measures</th><th>Post risk-reducing measures risk</th></tr>
<tr><td></td><td rowspan="3">3.1</td><td>Unable to start engine</td><td>Mechanical/electrical failure</td><td>Lifeboat unable to maneuver away from ship;
-possible collision with ship
-lifeboat drifting helplessly, affected by waves and wind
-lifeboat stuck in sea ice</td><td>Probability: 3
Consequence: B</td><td>-Winterization
-Ensure proper maintenance routines</td><td>Probability: 2
Consequence: B</td></tr>
<tr><td>Pre RRM comments</td><td colspan="6">Probability set to medium (3) because there is always a possibility that mechanical or electrical failures occur. This might be due to poor inspections/maintenance, or the harsh conditions (engine fluids freeze). Consequence low (B), because if the engine does not work, the lifeboat is dead in the water. This can lead to collisions in this critical stage, which may in turn cause injuries.</td></tr>
<tr><td>Post RRM comments</td><td colspan="6">Following the inspection and maintenance routines can prevent failures from occurring, given that it is performed thoroughly and with quality. Still, there is always a risk of failure in mechanical systems, due to a number of reasons. Probability reduced to low (2).</td></tr>
<tr><td></td><td rowspan="3">3.2</td><td>Maneuvering difficulties</td><td>Heavy sea, sea ice, wind</td><td>Little or no control of lifeboat position/heading
Lifeboat cannot be positioned correctly in the waves, heavy lifeboat motion (uncomfortable for passengers)</td><td>Probability: 3
Consequence: B</td><td>Lifeboat designed for arctic use, with:
-Sufficient engine power
-Steering (nozzle, rudder, etc) designed for operation in ice
-Hull for operation in ice
-Lifeboat pilot training</td><td>Probability: 2
Consequence: B</td></tr>
<tr><td>Pre RRM comments</td><td colspan="6">Note: Same problem as hazard number 4.4.
Probability set to medium (3) because it is likely that the weather and sea conditions are rough in arctic areas, and because lifeboats usually have a design less than ideal for stable operation in such conditions (shallow keel, hull shape, etc.). It is also likely that there might be some type of sea ice, which complicates maneuvering. Consequences are set to low (B) because even if the maneuvering is difficult, the lifeboat will continue to provide a safe habitat. Smaller consequences such as that the lifeboat cannot be positioned correctly in the waves can cause a lot of lifeboat motion, which in turn is uncomfortable for passengers.</td></tr>
<tr><td>Post RRM comments</td><td colspan="6">If the lifeboat is designed with specific features for arctic operation, and the lifeboat pilot has sufficient training in maneuvering lifeboats in harsh conditions, the probability is reduced to low (2).</td></tr>
</table>

Stage three: Initial operation							
	Hazard number	**Problem**	**Cause**	**Possible Consequences**	**Pre risk-reducing measures risk**	**Risk-reducing measures**	**Post risk-reducing measures risk**
	3.3	Lifeboat integrity compromised	-Collision with ship during/after launch -Collision with ice floes	Flooding of lifeboat	**Probability: 2 Consequence: B**	-Shock-absorbing fenders -Reinforced gunwale -Reinforced hull -Buoyancy capabilities	**Probability: 1 Consequence: B**
Pre RRM comments	3.3	Probability set to low (2) because it is not very likely that a lifeboat crashes into something hard enough to break the hull. There is still a possibility, because the hull of a standard lifeboat is not very thick, and a collision at full speed with solid sea ice can probably do some damage. The same goes for a collision with the ship. Consequences is set to low (B) because the LSA code requires lifeboats to have sufficient buoyancy even if there is a breach in the hull below the waterline.					
Post RRM comments	3.3	Implementing the suggested risk-reducing measures will reduce the probability to minimal (1).					
	3.4	Maneuvering of lifeboat not possible	Damage to steering system/ rudder/steering nozzle due to impacts with ice.	Lifeboat unable to maneuver away from ship; -possible collision with ship -lifeboat drifting helplessly, affected by waves and wind -lifeboat stuck in sea ice	**Probability: 2 Consequence: B**	Lifeboat designed for arctic use, with: -Steering (nozzle, rudder, etc.) designed for operation in ice	**Probability: 1 Consequence: B**
Pre RRM comments	3.4	Probability set to low (2) because it is not likely that a lifeboat's rudder or propeller is damaged by for instance sea ice. Consequences are set to low (B) because even if maneuvering is disabled, the lifeboat will continue to provide a safe habitat. Smaller consequences such as that the lifeboat cannot be positioned correctly in the waves can cause a lot of lifeboat motion, which in turn is uncomfortable for passengers.					
Post RRM comments	3.4	If the lifeboat is designed for arctic use, with steering components that can handle the impact from ice, the probability is reduced to minimal (1).					

<table>
<tr><th colspan="8">Stage three: Initial operation</th></tr>
<tr><th></th><th>Hazard number</th><th>Problem</th><th>Cause</th><th>Possible Consequences</th><th>Pre risk-reducing measures risk</th><th>Risk-reducing measures</th><th>Post risk-reducing measures risk</th></tr>
<tr><td></td><td rowspan="3">3.5</td><td>Difficult rescuing passengers from sea to lifeboat</td><td>Insufficient arrangements on lifeboat for extraction of people from sea.</td><td>Unable to rescue survivors from sea. Will require a lot of manpower.</td><td>Probability: 4 Consequence: D</td><td>-Lifeboat design, e.g. (retractable) ladder or stern is designed for easy rescue
-Life buoy</td><td>Probability: 2 Consequence: D</td></tr>
<tr><td>Pre RRM comments</td><td colspan="6">Probability set to high (4) because it is likely that it will be difficult to rescue someone from the sea into the lifeboat. This is because on a normal SOLAS-approved lifeboat, there are usually not arrangements that makes it possible to get onboard on your own, and the distance from the hatches down to the sea surface means that at least one person inside the lifeboat will have to drag or lift a person from the sea onboard. Consequences are set to high (D), because if someone cannot get out of the water, the survival chances are severely reduced in any circumstances. It is therefore very important to get out of the water as soon as possible, making it critical to be able to get onboard a lifeboat.</td></tr>
<tr><td>Post RRM comments</td><td colspan="6">If the lifeboat has arrangements for extraction of people from the sea (for instance a ladder which one can use to get oneself up, or a platform that facilitates people onboard the lifeboat lifting people onboard from the sea), the probability is reduced to low (2). There will however always be a possibility that persons immersed are too cold to climb onboard a lifeboat on their own.</td></tr>
</table>

Stage four: Operation							
	Hazard number	**Problem**	**Cause**	**Possible Consequences**	**Pre risk-reducing measures risk**	**Risk-reducing measures**	**Post risk-reducing measures risk**
	4.1	Poor sight	Fog, snow squalls, low light (no searchlight/headlights) Icing (sea spray) on windows Icing/moisture on the inside of windows	Navigation difficulties Possible collision	**Probability: 4** **Consequence: B**	-Lifeboat pilot training -Searchlights/headlights -Heating/anti-ice solution on windows -Air vent at the highest point in the lifeboat	**Probability: 3** **Consequence: B**
Pre RRM comments		Probability is set to high (4) because it is likely that one or more of the causes for poor sight will be present at any time when in a lifeboat. Consequences are low (B), because even though navigation is difficult due to poor sight, the lifeboat will continue to provide a safe habitat.					
Post RRM comments		Risk-reducing measures will mitigate some of the causes for poor sight, reducing the probability to medium (3). Other causes, however, such as fog and snow squalls, are impossible to eliminate.					
	4.2	Communication devices not available/working	No power (engine not running), or battery not charged LSA code does not require more than a radar reflector or survival craft radar transponder.	Time to rescue is prolonged Delay/difficulties in rescue operation	**Probability: 4** **Consequence: C**	-Maintenance (battery) -Battery charging possibilities in lifeboat -Polar Code requirements -All devices required by Polar Code could be permanently installed in lifeboat	**Probability: 1** **Consequence: C**
Pre RRM comments		Probability is set to high (4) because currently, there are no requirements to communication devices onboard survival crafts. When the Polar Code enters into force, it is only required that such equipment are brought along in the lifeboat, not permanently fixed. The chances that some crewmember forgets to bring along a radio is still present. If the radio is brought along, it might still be low on battery due to lack of charging prior to evacuation, or due to excessive use post evacuation. Consequences are set to medium (C), because if there are no devices for communication onboard a lifeboat, the only means of keeping in contact with nearby vessels is the signaling mirror. The range of portable radio equipment is not very long, but it might still make a difference when it comes to rescue time.					
Post RRM comments		If all risk-reducing measures are implemented, the probability is reduced to minimal (1). This is because if all communication equipment is permanently fixed in the lifeboat, there is no risk of crewmembers forgetting to bring the equipment with them during evacuation. With either charging possibilities or power directly from the lifeboat's batteries, it is possible to overcome the Polar Code requirement stating that the communication devices shall be operative for the maximum expected time of rescue.					

Stage four: Operation							
	Hazard number	**Problem**	**Cause**	**Possible Consequences**	**Pre risk-reducing measures risk**	**Risk-reducing measures**	**Post risk-reducing measures risk**
	4.3	Lifeboat runs out of fuel	Not enough fuel available for maximum expected time of rescue	-Lifeboat drifting uncontrollably -Loss of battery charging	**Probability: 4 Consequence: B**	-Additional fuel to accommodate Polar code 5-day survival requirement -Oars for rowing -Only use engine at very low speeds (idle) to conserve fuel	**Probability: 2 Consequence: B**
Pre RRM comments		Probability is set to high (4) because the amount of fuel currently required in lifeboats shall only be sufficient to run the boat at 6 knots for 24 hours. When the Polar Code enters into force, the maximum expected time of rescue is no less than 5 days. According to Norsafe, the current amount of fuel is enough to run the lifeboat tested in SARex at idle for 5 days. This means that for 5 days of survival time, it will be possible to run the engine, but not get anywhere without running out of fuel. Consequences are set to low (B), as the lifeboat will continue to provide a safe habitat even though the propulsion possibilities is gone.					
Post RRM comments		It is possible to add bigger fuel tanks capable of carrying more fuel. Supposing that the lifeboat should have enough fuel to run at 6 knots for the maximum expected time of rescue, the amount of necessary fuel is 5 times what is currently required. For the specific Norsafe lifeboat used in SARex, that means carrying 800 liters of fuel instead of 160. A possible solution is to have enough fuel to run at 6 knots for 48 or 72 hours, and in addition instruct the crew to ration the fuel by running the engine at idle when possible. This all comes down to how the Polar Code requirements are interpreted. With double amount of fuel compared to the current requirements, together with fuel rationing, the probability is reduced to low (2).					
	4.4	Maneuvering difficulties	Heavy sea, sea ice, wind	Little or no control of lifeboat position/heading Lifeboat cannot be positioned correctly in the waves, heavy lifeboat motion (uncomfortable for passengers)	**Probability: 3 Consequence: B**	Lifeboat designed for arctic use, with: -Sufficient engine power -Steering (nozzle, rudder, etc.) designed for operation in ice -Hull for operation in ice -Lifeboat pilot training	**Probability: 2 Consequence: B**
Pre RRM comments		Note: Same problem as hazard number 3.2. Probability set to medium (3) because it is likely that the weather and sea conditions are rough in arctic areas, and because lifeboats usually have a design less than ideal for stable operation in such conditions (shallow keel, hull shape, etc.). It is also likely that there might be some type of sea ice, which complicates maneuvering. Consequences are set to low (B) because even if the maneuvering is difficult, the lifeboat will continue to provide a safe habitat. Smaller consequences such as that the lifeboat cannot be positioned correctly in the waves can cause a lot of lifeboat motion, which in turn is uncomfortable for passengers.					
Post RRM comments		If the lifeboat is designed with specific features for arctic operation, and the lifeboat pilot has sufficient training in maneuvering lifeboats in harsh conditions, the probability is reduced to low (2).					

Stage four: Operation							
	Hazard number	**Problem**	**Cause**	**Possible Consequences**	**Pre risk-reducing measures risk**	**Risk-reducing measures**	**Post risk-reducing measures risk**
	4.5	Clogging/blocking of ventilation	Warm and moist air from inside the lifeboat condensates and freezes around the ventilation outlet	Reduced ventilation, rapid deterioration of air quality	**Probability: 2 Consequence: B**	-Ventilation design (winterized)	**Probability: 1 Consequence: B**
Pre RRM comments		Probability set to low (2) because the temperature conditions must be ideal for this to happen, and the ventilation must be designed so that it is vulnerable to this problem. Consequences are set to low (B) because even though the ventilation arrangement is not functional, it is possible to ventilate by opening windows or hatches. The ice blocking the ventilation will probably be possible to remove as well.					
Post RRM comments		By winterizing the ventilation design, the probability of this problem to occur is reduced to minimal (1).					
	4.6	Sea spray into lifeboat	The lifeboat hatches are open (ventilation, extracting persons from sea, etc.)	People get wet and cold. Water inside the lifeboat.	**Probability: 2 Consequence: B**	- Proper ventilation design (adjustable), to avoid having to ventilate using hatches -System/equipment for draining water from lifeboat (Manual bilge pump, bailers)	**Probability: 1 Consequence: B**
Pre RRM comments		Probability set to low (2) because for this to happen, hatches or windows will have to be open. If the weather is bad, the hatches will probably be kept closed as much as possible, with exceptions for ventilation etc. Consequences are set to low (B) because even though a significant amount of water enters the lifeboat, there are bilge pumps to drain the water from the boat. People getting wet is also a consequence, which can have minor effects on the survival situation. If immersion suits or TPA is used, this problem is not so relevant.					
Post RRM comments		With a proper passive ventilation design in place, it will not be necessary to open the windows or hatches often for ventilation purposes. This will in turn prevent sea spray into the lifeboat. With this risk-reducing measure, the probability is reduced to minimal (1).					

<table>
<tr><th colspan="8">Stage four: Operation</th></tr>
<tr><th></th><th>Hazard number</th><th>Problem</th><th>Cause</th><th>Possible Consequences</th><th>Pre risk-reducing measures risk</th><th>Risk-reducing measures</th><th>Post risk-reducing measures risk</th></tr>
<tr><td></td><td rowspan="3">4.7</td><td>Sea spray icing on lifeboat</td><td>Sea spray combined with low temperatures</td><td>Skew loads, hinges and locks on hatches stuck, ventilation compromised.</td><td>Probability: 3
Consequence: B</td><td>-Lifeboat design, winterization</td><td>Probability: 2
Consequence: B</td></tr>
<tr><td>Pre RRM comments</td><td colspan="6">Probability set to medium (3) because even though a standard lifeboat has a design that relatively effectively prevents build-up of ice, the conditions in the Arctic are often ideal for icing. A lifeboat also has some small details that are extra vulnerable to icing, such as hinges, handles, locks, etc. Consequences are set to low (B) because a lifeboat has hatches on multiple sides, so that if one is stuck due to icing, another will probably be possible to open.</td></tr>
<tr><td>Post RRM comments</td><td colspan="6">With a proper winterized design, protecting small details from ice build-up, the probability is reduced to low (2).</td></tr>
<tr><td></td><td rowspan="3">4.8</td><td>CO_2 build-up inside lifeboat</td><td>Insufficient ventilation, many people breathing.</td><td>Headaches, sleepiness, poor concentration, loss of attention, increased heart rate, slight nausea, oxygen deprivation.</td><td>Probability: 5
Consequence: B</td><td>-Proper ventilation design (adjustable)
-Opening hatches</td><td>Probability: 3
Consequence: B</td></tr>
<tr><td>Pre RRM comments</td><td colspan="6">Probability is set to very high (5) because several tests reveal that the CO_2 concentration in a lifeboat will increase rapidly when no hatches or windows are open, even with few passengers onboard. Consequences are low (B) because it is highly probable that someone will open the hatches to ventilate long before any serious health effects occurs.</td></tr>
<tr><td>Post RRM comments</td><td colspan="6">If an effective passive ventilation design is in place, it is not necessary to ventilate so often using the hatches. This solution will also improve the general survival situation by providing airflow through the boat, preventing seasickness. Implementing the risk-reducing measures lowers the probability to medium (3).</td></tr>
</table>

Stage four: Operation							
	Hazard number	**Problem**	**Cause**	**Possible Consequences**	**Pre risk-reducing measures risk**	**Risk-reducing measures**	**Post risk-reducing measures risk**
	4.9	CO build-up inside lifeboat	Leak from exhaust system	Headaches, nausea, vomiting, dizziness, fatigue, asphyxiation. Confusion, disorientation, visual disturbance, fainting and seizures.	**Probability: 1 Consequence: D**	-Engine exhaust system designed and tested to be leak proof -Opening hatches	**Probability: 1 Consequence: D**
Pre RRM comments		Probability is set to minimal (1). This is because the only source of CO-gas in a lifeboat is the engine, and if the exhaust system has leaks that causes gases to enter the lifeboat habitat, this is clearly a manufacturer or maintenance error. The consequences are set to high (D) because CO-gas is very dangerous to humans.					
Post RRM comments		The only risk-reducing measures for this problem is that the exhaust system is designed and assembled so that it does not leak. The manufacturer and maintenance crew must ensure this. If the problem actually occur, the only option is to open the hatches. The probability grade is already at the lowest level, and cannot be reduced further.					
	4.10	High temperature inside lifeboat	Insufficient ventilation, many people generating heat	Dehydration caused by perspiration. Nausea which can lead to vomiting, causing further dehydration.	**Probability: 4 Consequence: B**	-Proper ventilation design (adjustable) -Opening hatches	**Probability: 3 Consequence: B**
Pre RRM comments		Probability is set to high (4). The temperature depends on how many passengers there are onboard, compared to the total capacity of the lifeboat. Assuming that the lifeboat is full, the temperature would probably be very high. Consequences are set to low (B), and mainly involves dehydration from perspiration. The consequences are low because opening hatches to ventilate periodically will help lower the temperature.					
Post RRM comments		With a good adjustable passive ventilation design, airflow will help to maintain the right temperatures without having to keep the hatches open, which can be problematic in rough weather. This will reduce the probability to medium (3).					

Stage four: Operation							
	Hazard number	**Problem**	**Cause**	**Possible Consequences**	**Pre risk-reducing measures risk**	**Risk-reducing measures**	**Post risk-reducing measures risk**
	4.11	Low temperature in lifeboat	Outside temperature. Few people in lifeboat generating heat.	Core body temperature of passengers dangerously low (hypothermia) Frozen extremities	**Probability: 3** **Consequence: C**	-Passengers wearing warm (waterproof) clothing -Lifeboat design (hull insulation, efficient adjustable ventilation, etc.) -Polar Code clothing and PPE requirements -Survival strategy -Insulated seats/benches -Diesel heating system -Tarp or canopy to close off an area in the lifeboat to preserve heat if there are few people onboard	**Probability: 3** **Consequence: B**
Pre RRM comments		Probability is set to medium (3). The temperature depends on how many passengers there are onboard, compared to the total capacity of the lifeboat. Assuming that there are few passengers compared to the total capacity, and the weather is cold, there is a probability that the temperature inside the lifeboat will be low. Consequences are set to medium (C), and involves low core body temperatures and freezing extremities.					
Post RRM comments		The equipment in a PSK and GSK required by the Polar Code will provide good means of staying warm in a cold lifeboat. Insulation on the benches is a low-cost measure that will reduce the heat loss significantly. A tarp to close off a section of the lifeboat is also a very low-cost measure that can be helpful if there is few passengers compared to the total capacity. These measures will contribute to lower the consequences to low (B). Adding a diesel warmer is a more extensive measure, but it does not necessarily have to be very costly. Improving the hull insulation can also be effective, but this is a more costly upgrade. These solutions will be probability reducing.					

Stage four: Operation							
	Hazard number	**Problem**	**Cause**	**Possible Consequences**	**Pre risk-reducing measures risk**	**Risk-reducing measures**	**Post risk-reducing measures risk**
	4.12	Seasickness	Lifeboat movements	Vomiting, inducing dehydration and starvation.	**Probability: 4 Consequence: C**	-Anti-seasickness medicine sufficient for all passengers -Maintaining fresh air inside lifeboat	**Probability: 3 Consequence: C**
Pre RRM comments		Probability is set to high (4) because it is likely that passengers in a lifeboat will get seasick. A standard lifeboat construction with shallow keel means that if the sea state is anything else than calm, the lifeboat will have a lot of rocking motion. In addition, the majority of the passengers will have no windows to look out of, which increases the probability of getting seasick. It is also likely that the air quality in a full lifeboat will be poor, which increases the probability. Consequences are set to medium (C), because if a person gets seasick and does not improve, there is a possibility for dehydration. This would not be ideal in an extended survival situation.					
Post RRM comments		Anti-seasickness medicine is a useful risk-reducing measure, but it does not always work well on everyone. Providing airflow through the boat can also prevent seasickness. Having sufficient medicine for the maximum expected time of rescue, along with fresh air inside the lifeboat, lowers the probability to medium (3).					
	4.13	Hygiene	No toilet available	Insanitary conditions	**Probability: 4 Consequence: B**	-Lifeboat design to accommodate disposal of human waste	**Probability: 2 Consequence: B**
Pre RRM comments		Probability is set to high (4) because hygiene is likely to be a problem when passengers in the lifeboat needs a toilet. Currently, standard lifeboat has no toilet facilities, and with a maximum expected time of rescue of 5 days, this will become an issue. A simple solution might be to use buckets, but in a full lifeboat this can still be highly problematic. Consequences are set to low (B) because even though this problem will have major effects on the comfort, it will not affect the survival chances more than slightly.					
Post RRM comments		The Polar Code sets the maximum expected time of rescue to 5 days, meaning that there should be some solution to this hygiene problem. A simple but crude solution is to have a hole in one or more of the benches, with lid on top and a tank below, to function as a toilet. There would be little privacy, but that is not paramount in a survival situation. Adding this feature to the lifeboat will reduce the probability to low (2). A more sophisticated solution is to integrate a small separate toilet room, for example like in an aircraft. This would however require more space, and be more costly.					

Stage four: Operation							
	Hazard number	**Problem**	**Cause**	**Possible Consequences**	**Pre risk-reducing measures risk**	**Risk-reducing measures**	**Post risk-reducing measures risk**
	4.14	Not enough food	LSA demands not sufficient for 5-days survival. Poor execution of rationing the food.	Starvation.	**Probability: 5 Consequence: B**	-Ensure lifeboat carries enough food for maximum passenger capacity (5 days survival) (Polar Code requirement) -Information/guide for rationing of food	**Probability: 1 Consequence: B**
Pre RRM comments		Probability is set to very high (5) because the current requirements (LSA code) is not sufficient for 5 days of survival. Consequences are starvation, set to low (B) because a person can survive for a long time without eating anything.					
Post RRM comments		If the lifeboat carries enough food for each passenger for the maximum expected time of rescue, this problem is eliminated. Information about rationing should be included in the packaging. Probability reduced to minimal (1).					
	4.15	Not enough water	LSA demands not sufficient for 5-days survival. Poor execution of rationing the water. Water might be frozen.	Dehydration.	**Probability: 5 Consequence: D**	-Ensure lifeboat carries enough water for maximum passenger capacity (5 days survival) (Polar Code requirement) -Information/guide for rationing of water -Heating of lifeboat when stored in davit to avoid water rations from freezing	**Probability: 1 Consequence: D**
Pre RRM comments		Probability is set to very high (5) because the current requirements (LSA code) is not sufficient for 5 days of survival. Consequences are set to high (D), because dehydration is a major threat to the human body.					
Post RRM comments		If the lifeboat carries enough water for each passenger for the maximum expected time of rescue, this problem is eliminated. Information about rationing should be included in the packaging. Probability reduced to minimal (1).					

Stage four: Operation							
	Hazard number	**Problem**	**Cause**	**Possible Consequences**	**Pre risk-reducing measures risk**	**Risk-reducing measures**	**Post risk-reducing measures risk**
	4.16	Lack of sleep	Uncomfortable seating, stressful situation (physical and psychological)	Sleep deprivation, fatigue.	**Probability: 4 Consequence: A**	Seat design: -Angled seatbacks -Head rests with side support -Insulated benches	**Probability: 3 Consequence: A**
Pre RRM comments		Probability is set to high (4) because it is likely that one will get less sleep than needed in a survival situation. The consequences are set to minimal (A), because eventually one will fall asleep if the body needs it, especially inside a relatively safe habitat such as a lifeboat. As long as the temperature inside the boat is ok, or the passengers wear proper polar clothing or insulated suits, sleeping will only have positive effects on the survival chances. There will probably always be someone among the passengers that are at least somewhat rested, and can take care of the necessary tasks.					
Post RRM comments		A simple measure that can improve the sleep situation is to have insulated benches, which will provide a more comfortable seating and reduce heat loss. This will reduce the probability to medium (3). More extensive measures, such as angled seatbacks and headrests with side support, would improve the situation further. It is however not realistic that these measures are implemented due to costs and space.					
	4.17	Lack of basic medical equipment (sedatives, defibrillator, common medicines)	Emergency planning/requirements	Deteriorating health/fatalities Unable to treat injuries	**Probability: 4 Consequence: D**	-Supply lifeboat with selected basic medical equipment. Some of this can e.g. be included in GSK brought along in lifeboat. -Passengers dependent on special medicines should be advised to carry these with them at all time	**Probability: 3 Consequence: D**
Pre RRM comments		Probability is set to high (4), because the normal cruise passengers are often elderly and not necessarily healthy. They might therefore need several medications on a daily basis, which is not available in the first-aid equipment onboard a lifeboat. Persons that are severely cold, for example from being immersed, can also experience cardiac arrest. In such cases, a defibrillator would be critically important. Consequences are set to high (D) because any severe illness that are left untreated can be life-threatening.					
Post RRM comments		It is impossible to provide medicines for all types of illnesses that passengers may have. Passengers that are dependent on special medicines should therefore be advised to carry these with them at all time during the cruise, which would be a very good risk-reducing measure. This will bring the probability down to medium (3). It would also be useful to have a defibrillator onboard each lifeboat, but this is costly equipment.					

Stage four: Operation							
	Hazard number	**Problem**	**Cause**	**Possible Consequences**	**Pre risk-reducing measures risk**	**Risk-reducing measures**	**Post risk-reducing measures risk**
	4.18	Polar bear attack	The polar bear can attack humans if it: -is hungry enough -feels threatened -is curious -is injured and desperate	Injury and/or death of people	**Probability: 1 Consequence: A**	-Bear spray -Weapons -Flare guns -Polar bear guards/lookout	**Probability: 1 Consequence: A**
Pre RRM comments		Probability is set to minimal (1). This risk is considering a polar bear attack on a lifeboat with hatches closed. It is regarded as very unlikely that a polar bear can force its way into the lifeboat, and the consequence is minimal (A) because there is no real danger that a polar bear will get into the lifeboat. If the passengers choose to leave the lifeboat and move onto ice instead, the danger is much more real.					
Post RRM comments		Risk-reducing measures will be helpful if the passengers choose to leave the lifeboat. Risk unchanged.					
	4.19	Engine failure	Coolant freezes due to coolant not being suitable for low temperatures.	-Lifeboat drifting helplessly, affected by waves and wind -Lifeboat stuck in sea ice -Lifeboat cannot be positioned correctly in the waves, heavy lifeboat motion (uncomfortable for passengers)	**Probability: 2 Consequence: B**	-Ensure that engine coolant is effective in very low temperatures	**Probability: 1 Consequence: B**
Pre RRM comments		Probability is set to low (2) because the engine coolant should be suited for arctic operation when the lifeboat is delivered from the manufacturer. This must also be ensured if the coolant is changed during maintenance. Any water or air in the cooling system can cause the fluid to freeze. Consequences are set to low (B), as the lifeboat will continue to provide a safe habitat even though the propulsion possibilities is gone.					
Post RRM comments		If the manufacturer ensures that the coolant it designed for operation in cold environments, and this is followed in the maintenance as well, the probability is reduced to minimal (1).					

<table>
<tr><th colspan="8">Stage five: Rescue</th></tr>
<tr><th></th><th>Hazard number</th><th>Problem</th><th>Cause</th><th>Possible Consequences</th><th>Pre risk-reducing measures risk</th><th>Risk-reducing measures</th><th>Post risk-reducing measures risk</th></tr>
<tr><td></td><td rowspan="3">5.1</td><td>Transfer of persons from lifeboat to rescue vessel</td><td>-Insufficient/no arrangements for moving passengers from one craft to another
-Passengers have physical problems after long time in lifeboat
-Heavy seas/strong winds</td><td>Complicated rescue process, potential injuries/fatalities
Time consuming</td><td>Probability: 4
Consequence: C</td><td>-Lifeboat design optimized for easy rescue</td><td>Probability: 3
Consequence: C</td></tr>
<tr><td>Pre RRM comments</td><td colspan="6">This is a split problem. One side of the problem is the design of the lifeboat to accommodate easy rescue, and the other side is the ability of the rescue ship to get the lifeboat passengers onboard. The scope of this analysis is limited to the lifeboat and its arrangements. Probability is set to high (4) because it is likely that there will be difficulties when many people are to be rescued from a lifeboat to a rescue vessel. The passengers are likely to be in poor shape after long time in the lifeboat, and might therefore have reduced physical capabilities. Consequences are set to medium (C) because there is always some danger involved in the process of transfer from one craft to another. In a situation like this, people can end up in the water, or become injured.</td></tr>
<tr><td>Post RRM comments</td><td colspan="6">The lifeboat design can be optimized for easy rescue by implementing some simple features. For instance, an exterior platform on the stern of the lifeboat, with access hatch, can provide an easy pick-up point for MOB boats and other small rescue vessels. It is difficult to estimate the risk-reducing benefits of such measures, and transfer of people will always involve some hazard. Without knowing anything about the capabilities and design of the potential rescue vessel, it is hard to determine what types of design features the lifeboat should have, except facilitating easy disembarkation. If the lifeboat design is optimized for easy rescue, the probability is lowered to medium (3). Further risk reduction is connected to the rescue vessels, and there is too many unknowns involved in this problem to suggest specific measures.</td></tr>
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<tr><th colspan="8">Stage five: Rescue</th></tr>
<tr><th></th><th>Hazard number</th><th>Problem</th><th>Cause</th><th>Possible Consequences</th><th>Pre risk-reducing measures risk</th><th>Risk-reducing measures</th><th>Post risk-reducing measures risk</th></tr>
<tr><td></td><td rowspan="3">5.2</td><td>Transfer of persons from lifeboat to helicopter</td><td>-Insufficient arrangements on lifeboat for helicopter extraction
-Heavy seas/strong winds</td><td>Complicated rescue process, potential injuries/fatalities
Time consuming</td><td>Probability: 3
Consequence: D</td><td>-Lifeboat design to accommodate rescue swimmers being lowered onto/into lifeboat to extract passengers</td><td>Probability: 2
Consequence: D</td></tr>
<tr><td>Pre RRM comments</td><td colspan="6">Probability is set to medium (3), because it is difficult to accommodate for helicopter extraction from lifeboat, and such rescue processes involves many potential hazards. Consequences are set to high (D), because if a helicopter rescue is necessary, it is likely that any vessels are some distance away. This is because a lifeboat-to-vessel rescue is less risky than a lifeboat-to-helicopter rescue. If the process in that case is further complicated by insufficient arrangements on the lifeboat, it can be critical in terms of survivability. It is probable that a rescue helicopter prioritizes to evacuate passengers with critical health problems only, as long as the lifeboat is still habitable and rescue vessels will arrive within a relatively short period.</td></tr>
<tr><td>Post RRM comments</td><td colspan="6">The only thing that can be done to better this problem, is to design the lifeboat with specific features for this rescue method. One must consider the need for using a stretcher for lift of critical patients, and this is considered a problem with a standard lifeboat. Evacuation method is of course up to the helicopter crew to decide. The only risk-reducing measure in terms of the lifeboat is to accommodate for patient extraction. If these measures are in place, the probability is reduced to low (2).</td></tr>
</table>

II.2.6 The life raft's capabilities and capacity during the Phase I exercise

By Terje Olsen[1] and Jette Næss Schmidt[1]

[1] Viking life-saving equipment

Polar Life raft L025D0002

Capability:

Temperatures measured 19ºC at the top of the life raft. Average temperatures during the exercise were 15-16 degrees.

The overall assessment was that the life raft provided very good protection during the exercise.

The challenge is condensation. After some hours the humidity was high and water dripped down from the roof. Therefore, ventilation is important.

The thermal protective layer in the floor works generally well, however it does not cover the entire floor. Where the test persons sat, there was a gap at the edges where cold air could seep in. This can cause the bottom and lower back to get cold. Reducing the gap without a thermal protection layer should be considered to avoid this issue. Adding an inflated bottom for improved insulation was also discussed.

It could be a good idea with one more viewing port with an ability to close it (e.g. a string) as there is a draft from viewing port when open.

A comment from the test persons sitting in the life raft for 24 hours. was that they needed some pockets/organizer for storage of rations and trash. Pockets could be placed on the roof.

The pump broke because someone sat on it. Better quality should be considered.

Paddles are very short and almost impossible to paddle with from the life raft. Longer and sturdier paddles would be a good idea for paddling just a short distance to e.g. an ice float.

Capacity:

A 25 person life raft at capacity would not have enough room to carry Group Survival Kits (GSK x 4 pcs.) and Personal Survival Kits (PSK with 25 pcs). Limiting the capacity to 20 persons for Arctic areas, due to the volume of the GSK + PSK should be considered.

Can this product be recommended for Arctic areas?

Yes. The life raft performed well during the exercise. Collision with an ice float was not an issue and it was possible to drag/pull the life raft up on the ice float.

With a few adjustments the life raft offers very good protection. Capacity should be limited because the GSK + PSK takes a significant amount of space. Better insulation of the life raft floor should be considered.

II.2.7 The capabilities of personal protection equipment during the Phase I exercise

By Terje Olsen[1] and Jette Næss Schmidt[1]

[1] Viking life-saving equipment

General comment

The PPE equipment was only used in dry conditions. This means that all test persons wearing PPE equipment during the exercises were not submerged in water. This was decided by the medical team on board, due to the risk of hypothermia.

PV9720 Thermal lifejacket

Adequacy:

This was not tested, as the test person was not submerged at sea.

Capability:

General impression of the lifejacket was that it was uncomfortable to wear. The construction with a built-in torso suit would make it difficult to sit in a survival craft over a longer period of time while wearing this lifejacket.

Short sleeves and no leg coverage did not seem to be appropriate for arctic waters. The body temperature falls quickly when the extremities get cold, which causes a very high risk of hypothermia.

As there was no hand protection, there would be a significant risk of not being able to board a survival craft. Hands get cold instantly when immersed in the sea at low temperatures.

Test persons wearing lifejackets were the first to get cold on the liferaft and lifeboat, due to lack of protection of the legs and lower arms.

Can this product be recommended for Arctic areas?

This product is not appropriate for the extreme conditions in the Arctic, even though the product is approved according to the LSA code.

PS2004 Neoprene suit

Adequacy:

This was not tested, as the test person was not submerged at sea.

Capability:

It is available in two sizes, however only the universal size was tested. Smaller and taller/larger test persons had difficulties problems wearing this suit, as it was either too big or too small.

It is a disadvantage that a lifejacket is necessary. Even though the suit has quick donning, the lifejacket must be put on afterwards.

Users experienced that they quickly got cold. The 5mm neoprene may not be thick enough for these conditions.

Can this product be recommended for Arctic areas?

Neoprene will provide protection for a certain period, depending on the conditions. For Arctic areas we will recommend a Neoprene heavier than 5mm.

PS5003 non-insulated suit

Adequacy:

This was not tested, as the test person was not submerged at sea.

Capability:

No built-in buoyancy, so a lifejacket is necessary.

Without insulation this is a 1 hour suit. Is it possible to survive for 1 hour in water temperatures of 5ºC? If the wearer has thermal clothing on underneath maybe, however if there are no thermal layers on underneath it is not likely that a person would survive 1 hour in the water.

This suit was tested without lining. Test persons had different layers on underneath, but even with dry shod evacuation to the survival craft none of the test persons lasted longer than 24 hours without a critical temperature drop.

The suit is comfortable to wear.

The semi-integrated neoprene gloves offer good protection.

Fully integrated boots with hook/loop straps for better fit around the foot work well and ensure that the one-size sole fits various sizes of feet.

Can this product be recommended for Arctic areas?

Without insulation the answer is no.

It is possible to buy this suit with a 1 layer lining, which would improve the thermal protection of the suit, but we would recommend the PS5002 with a double layer lining instead.

PS5002 insulated suit

Adequacy:

This was not tested, as the test person was not submerged at sea.

Capability:

It has built-in buoyancy. Better comfort and quick donning as a lifejacket is not necessary.

Insulation is very good. It keeps the wearer warm over a very long period. The insulation is 2 layer 300g/m2 quilted polyester, which is double the requirement of the standard.

The inside straps to adjust body length on suit is valued highly. It provides good comfort, especially for shorter people.

Fully integrated boots with hook/loop straps for better fit around the foot work well and ensure that the one-size sole fits several sizes of feet.

Semi-integrated neoprene gloves offer good protection.

Would Viking recommend this product for Arctic areas?

Yes. In Arctic conditions, insulation will make a huge difference on how long it is possible to survive with an immersion suit. It is important that the entire body is covered with high insulation. Compared to the other PPE equipment tested, the PS5002 insulated immersion suit provided the absolute best protection and is an excellent choice.

II.2.8 Leadership onboard life raft during the Phase I exercise

By: Anders Christensen, Navigator, *KV Svalbard*

Background

In view of my background as a navigator onboard the *KV Svalbard*, I was elected to be in charge of the life raft. In a real-life situation, navigators will be put in charge of evacuation and the stay in a rescue vessel, no matter which vessel they are operating. I am among the youngest and least experienced of the officers aboard *KV Svalbard*, and participating in this exercise would be of great help for my further career as a naval officer.

As an officer, I have experience in leadership from the naval academy, which is unlikely to be the case for navigators on civilian vessels.

Discussion

As the exercise was planned, I had the advantage of knowing the duration, start and end times and goals of the exercise. This allowed me to think about possible scenarios and choose some basic strategies in advance. One of the key aspects was the importance of personnel control in the initial phases of survival, and I designated a person to keep count of the number of people aboard the life raft at any time. The life raft turned out to be more crowded than originally anticipated; counting the number of people was difficult, and miscounts were made, which resulted in an incorrect head count. This was resolved by changing the counting method, making all persons say their number as the tally was taken. This method was used for the remainder of the exercise.

During the first minutes of the exercise, I introduced myself briefly and divided everyone into buddy pairs. Unlike a real-life scenario, all persons were motivated and calm and not affected by shock, grief or other physical or psychological sufferings that would have significantly complicated my job as leader.

Getting an overview of the available tools and aids aboard the life raft was one of my primary objectives. I solved this by handing out the equipment and tasking each person with describing the equipment and its purpose. This method was chosen for the following reasons: I wanted to delegate responsibility and give people simple tasks they could perform in a situation where shock is likely to occur. This would also lighten my responsibility as a leader and secure an even distribution of knowledge and equipment responsibility. It is also easier to remember the different tools from a pedagogical perspective, as you can connect the knowledge to the different people who presented the equipment. The first item of equipment to be deployed was the radar reflector, and the AIS beacon was explained by me and confirmed with *KV Svalbard* to be working.

After establishing a common understanding of the equipment, I wanted to get an overview of the different skills the persons onboard the life raft had. In this manner, it would be possible to identify our strengths as a team. After discussing this, I delegated the responsibility of distributing the seasickness pills to the nurse and waste management to another. Maintaining tidiness was deemed important, to avoid wasting time finding the required equipment when needed.

Early on, we started getting alarms from our gas-monitoring device about a low oxygen level, something that was also noticed by the people onboard. To avoid unnecessarily long cooldowns, we opened both doorways completely for a short period of time. Having the doorways open for longer was rejected, as the people sitting by the doorway would be significantly affected by this.

Humidity was also a problem from early on, and water from snow melting, condensation and survival suits gathered at the lowest point in the raft. Those who were heaviest noticed this the most, as water gathered around them. Sponges were utilized to try to mitigate this, but once you got wet, you did not dry out, due to the high level of air humidity inside the raft.

As the air temperature inside the raft increased, people got more tired. At 15:26, the temperature was recorded to be 18.2 °C. At this point in time I found it sensible for as many people as possible to be sleeping and saving energy for later, when maintaining the core body temperature would require movement. This implies that the sleeping pattern further on would follow the sun, and that one would rest during the day and stay active during the night. Any movement proved difficult, due to the lack of space inside the crowded life raft. The people wearing life vests were experimenting with their sitting position to minimize heat loss from the bottom. Essentially, the area of the vest in contact with the bottom should be as high as possible. This could be done either by lying curled up in a flat position, or by taking off the life vest and sitting on it. The latter must consider the environmental conditions. During this period, I got very warm and encouraged people to open their clothing a bit if they felt the same. Being sweaty can be very uncomfortable and eventually one will become cold.

I assigned lookouts to keep an eye out for ships, airplanes and rescue helicopters. The lookout had the added function of ensuring that, at any given time; one person was awake and could monitor the oxygen levels and listen to the radio for any news or updates. The lookouts rotated every hour to minimize the temperature loss that took place from having their head outside.

According to the survival manual included in the life raft, no food or water shall be consumed during the first 24 hours of survival. This is designed to allow the body to become accustomed to a lower intake of energy and water, but this was not taken into consideration in this exercise. I told the second-in-command to establish a rationing scheme for the following days. It is my belief that the management of food and water is crucial for morale and a feeling of fairness in the life raft. This was discussed with the people onboard the life raft and we concluded that the fairest thing would be to implement even rationing, regardless of sex, age, medical condition, etc. We would rather die with pride than know that we ate at the cost of others. This is of course an idealized version. What would our conclusion be if there were children, elderly people and those from other cultures aboard that do not necessarily share our views on what should be prioritized? Some cultures might be very unfamiliar with cruises and ships and suddenly face the possibility. Our general mindset is that women and children should be prioritized if there is a survival situation. This mindset might not be shared in all cultures and should be considered when an increasing number of people can afford a voyage to the Arctic. So far, these voyages have been most common for the Western, white upper class. Will this hold for the future? We also discussed food distribution in case of sickness, or if somebody is close to dying. This brings up more ethical dilemmas. It is easy to be a guardian of morale when you are warm and know that rescue is possible whenever you want, but when faced with death you risk survivors turning against each other and the leader. I am therefore under the impression that a clear distribution with fixed rules must be implemented as soon as possible to avoid dissatisfaction and the feeling of injustice.

The water inside the life raft in Arctic environments could be frozen when the life raft is deployed. This means that you must use your body temperature to melt the water. Different means of achieving this were discussed in the life raft. Using the ocean as an intermediary would help, as it has a temperature of at least -1.8 °C. However, there is a risk of losing some bags of water to the ocean, and water will also be pulled into the life raft when bringing the bags back in. Another option is to keep your daily ration inside your survival suit, thus warming the water up to liquid. This raised the question of what was ideal in terms of energy consumption: drinking water at a temperature of 1 °C or warming it up with your body before drinking it. After discussing this with the doctor, it was concluded that this would require the same amount of energy, but drinking the cold water would ensure that no energy was wasted. Additionally, having bags of water inside your survival suit could be uncomfortable and would occupy a volume that would otherwise be used for air, which could have a small impact on the insulation abilities of the survival suit: all in all, marginal differences, but good to have had some thoughts on the subject.

With regard to how one should be positioned inside the raft, the survival manual recommended that: each person should sit facing the opposite direction of the person next to him or her. In the raft, we sat with our backs against the inflated pontoons, with our legs towards the center of the life raft. Personally, I sat at the center of the life raft, on top of the equipment. This was comfortable enough but limited my possibility of maintaining line of sight with the people who sat behind me. This was made more difficult due to the restrictions imposed by the survival suit. As soon as there was room, I therefore sat down together with the others. In a survival situation you would use any means possible to insulate the bottom of the life raft. In this exercise, we chose not to do this, as this would be impossible to distribute equally the insulating material across the bottom, and would lead to another source of error for the main goal of this exercise: to test the abilities of the different suits.

Staying in the life raft for an extended period of time will be boring. To increase morale and to focus on other things, we found it sensible to have quizzes, ask riddles and tell the stories of our lives. I made it clear that anyone could contribute to this with other suggestions, which they did! At points, the time passed very quickly. The fact that we knew that this was only an exercise certainly contributed to this.

The continuous follow-up on the people onboard was systemized by checking those who were quiet and/or did not look too comfortable. In addition, before reporting to the bridge at *KV Svalbard*, I made a round, in which I asked everyone how he or she were feeling. I tried to keep the buddy system up to date, by ensuring that people found a new buddy when they moved around inside the raft and when someone returned to *KV Svalbard*. Discovering signs of hypothermia turned out to be difficult, especially in those who were sleeping, and I found it important to keep the conversation going while they were awake.

We also discussed some possible improvements to the design of the life raft. The suggestions were as follows. Double bottom: 90% of the heat loss took place through the bottom. A mesh on the insides of the pontoons would really help in keeping track of the equipment, keeping it safe from damage, and allowing clean and dirty items to be separated. A mesh would also allow food and water to be kept out from the bottom, where it would be subjected to feces/vomit, etc. Another suggestion was pockets in the ceiling for items that might be needed quickly, such as flares and emergency signal rockets. The worst we could image would be to spot an airplane on the horizon and not find the flare or emergency signal rockets in time to alert the airplane. There should also be observation possibilities in both directions of the life raft. Currently, the viewing angles are limited to 180°. There should be an oxygen or CO_2 measuring device, as this turned out to be a potentially large problem. The roof could have transparent sections, such as windows. This would help lighting conditions and morale.

Sources of error: The temperatures declined as fewer people remained onboard. It is therefore likely that those who had the best survival suits could have stayed comfortable a lot longer in a life raft where the number of people was constant.

Conclusion

With regard to my role as leader in an emergency, I had many advantages. I knew about the situation in advance and could prepare myself to some extent. I had a motivated group, who knew that this was an exercise with a time limit and a clear sense of safety, and that they could leave the life raft when things started to become too uncomfortable. Nobody was in shock, felt afraid, in grief or separated from their family and children. This made my role as leader significantly easier than it would have been in a real-life condition. I did not experience anyone questioning my role as leader. In a real-life situation, nobody would keep silent if their life was at stake and the leader made decisions they were not 100%

satisfied with. They would have listened to the person who made the most sense to them at the time. This might very well have been a passenger or a cook from the abandoned ship.

It is also very difficult to say how I would have handled this situation in real life. Maybe I would have been the one who struggled the most? I only needed to be a leader for 20 hours, and I expect that I would have had to dig deep for the remaining four days to be able to remain optimistic and maintain good morale in the life raft. Truth be told, I expect that I would feel lost and without hope. It is also difficult to say how I would handle unrest, arguments, deaths, etc. I still think that by staying calm, being fair and consistent in my decisions, the amount of unrest would be reduced, but people in a survival situation are ticking time bombs, and the range of challenges could be large.

I started the exercise relatively rested and had prior experience from officer training. Everyone in the life raft had the same culture, spoke a common language and was in good health. I knew that the exercise had a time limit, and I could choose not to save energy. I think that, when faced with a survival situation, it is important to vary the leadership style: from the authoritarian in the initial phase to a more inclusive and democratic style when the situation calls for it. Overall, I felt that I had a good overview of everyone onboard, although I might have been more aware of speaking only in English, as one of the people onboard did not speak Norwegian. This was, however, resolved by their buddy translating into English as required.

Surviving for five days might have been possible under optimal conditions, but after 20 hours, we were cold, exhausted and afraid to sleep, as we feared waking up very cold.

All things considered, this was a very educational experience to have!

II.2.9 Leadership onboard life boat during the Phase I exercise

By: Simen Strand, Fishery Inspector, *KV Svalbard*

Background

As a certified navigator, it is likely that I may have to function as the leader of a survival craft at some point in the future. This exercise was therefore an excellent opportunity to experience a situation, which is relevant within my choice of profession and in an area where relatively new challenges related to rescue and survival are relevant.

Air temperature: -10 °C
Water temperature: -1 °C
Persons on board: 16
Lifeboat driver: Simen Øen Strand, Fishery Inspector, *KV Svalbard*

Discussion

Before the exercise

At relatively short notice, I was informed that I would act as the leader in the lifeboat during the exercise. My first thoughts revolved around the following themes:

1. What would we do in the lifeboat over a long period of time?
2. What demands would we face regarding watch rotation and routines in the lifeboat?
3. How should we ration food and water?
4. How cold would it be?

Initially I was under the impression that we should try to follow a normal daily schedule during the exercise, apart from the watch rotation. This impression changed during the exercise.

During the exercise

In the first phase of the exercise after all the passengers had arrived, I implemented measures to obtain an overview of the resources on board in terms of provisions and survival equipment. Simultaneously, I established what I assumed would be a sensible watch rotation. The passengers were divided into pairs and were assigned two-hour watches, one hour of which was designated for lookout duties, and the other for performing necessary routine tasks onboard, ensuring that the lookout was awake and monitoring the passengers onboard. During this phase, I also became aware that I lacked knowledge regarding rationing. What is the minimum amount of water a human needs to survive for five days? What would be the best way to distribute the rations? Would climate and hypothermia affect this rationing? Keeping these thoughts in mind it was suggested at an early stage that melting snow on the engine could be a way to acquire more water onboard. Equipment should therefore be available to enable this to be carried out in an easy manner.

When the watch rotations were established and we had acquired an overview of the resources available onboard, I became aware that this would be a test of our patience rather than a struggle against the cold. Socializing and activating people therefore became one of the first challenges I faced as a leader in the lifeboat. The lifeboat was built in such a way that the starboard and port sides of the vessel were divided, so visual contact with the people on the opposite side was not possible. The passengers were also spread around the lifeboat for a long period, and small groups formed. Communication onboard proved to be a major challenge due to the positioning of the groups, lack of visual contact and noise from the engine, which drowned out the voices onboard. I had to power down the engine to make public announcements and noted that many people were prioritizing rest and sleep during the first hours of the stay in the lifeboat. The atmosphere in the lifeboat at this time allowed people to rest and sleep without risking a faster onset of hypothermia. This also resulted in communication problems, as people were sleeping at different times and did not pick up the announcements that were made. The lifeboat was therefore split into two regions. The bow was designated for people who wanted to sleep, and the aft section was designated for those who wanted to stay awake. As previously mentioned, I was under the impression that it was desirable to maintain a normal circadian rhythm while onboard the lifeboat. It was therefore a dilemma for me as to whether to activate people to follow this pattern or leave each individual to choose whether they wanted to sleep or socialize. The two people who were on watch could cover the duties onboard. After a while, it turned out that sleeping was more difficult later in the day and the night; in fact, it was almost impossible to sleep during the night as you faced the risk of hypothermia unless you kept in constant movement. This was caused primarily by the low temperature in the lifeboat but also by the lack of insulation on the benches and the bulkhead, where ice started to form.

The exercise leader, Knut Espen Solberg, decided that the engine should be turned off to see whether this had any impact on the temperature in the lifeboat. We could not notice any immediate impact, other than the fact that communication onboard became significantly easier, and I noticed that people moved towards the aft section of the lifeboat where more light was present and the temperature was higher than at the front. I decided to sit at the center of the aft section so that I was able to have a visual overview of both the port side and the starboard side of the lifeboat. This contributed to us starting some common activities such as quizzes, jokes and storytelling. I immediately noticed that the mood lightened and everybody became more cheerful. This led to fewer people going to sleep, as they preferred to stay active and socialize.

When the temperature declined as the night settled in, it became clear that it would only be possible to avoid hypothermia if you were wearing an insulated survival suit. After a short while, the people wearing uninsulated survival suits or life jackets were so cold that they were not able to keep warm, despite moving around and keeping active. The people who were getting cold were sent back to *KV Svalbard*. Disregarding the obvious problems related to hypothermia, there were also challenges related to the option of moving around. The people who wore life jackets and a thermal bag had no way of moving around without taking off the bag, losing all the heat stored inside the bag. In the lifeboat, you have to move around to stay warm but also to contribute to the routines and watch duties onboard. The people who were assigned the thermal bags also became some of the first to leave the lifeboat, due to the moisture that gathered inside the thermal bags, leading to their clothes getting wet. It was obvious before the exercise that the equipment complying with the minimum requirements in the Polar Code would not be suitable for five-day survival under the current conditions. Nevertheless, I discovered that the people wearing life jackets and thermal bags lasted a lot longer than I originally anticipated. They were, however, much colder during the entire exercise, but it was evening first approaching and an assessment being made of how the night would turn out that was the deal breaker for those wearing life vests and thermal bags.

Before the exercise commenced, the idea behind the two-hour watch rotation was that it should make it possible for people to get some rest. As the temperature dropped and rest/sleep became a bigger challenge, I noticed that watch duty became more popular. This was a variation from the boredom and cold down in the lifeboat, as you could get into the driver’s position and obtain a view of the outside. This was also the warmest place in the lifeboat, but it could only fit one person at a time. It was therefore decided to increase the rate of rotation to 30 minutes, and I individually decided who had the most need for the lookout position with regard to hypothermia and mood. I found this to be a good solution, in which those with the greatest need got a small break and were even able to regain some heat.

As the leader in the lifeboat, it became my responsibility to judge the condition of every individual onboard and whether they should be sent back to *KV Svalbard*. I was given some guidelines in advance for what to look for based on the degree of hypothermia, but I found this very difficult to assess. The person I thought was the coldest turned out to have a core temperature of 1 °C warmer than the person I thought was warmer.

Conclusion

Before the exercise, I was under the impression that hypothermia would be a challenge at an earlier stage than was experienced, and that the number of people on board would be reduced dramatically during the first hours of the exercise. The thoughts that I focused on in preparation for the exercise primarily revolved around rationing, distribution of tasks and watch rotation. Apart from the most obvious challenge related to hypothermia during the exercise, I also became aware of challenges related to socialization and the importance of including people, maintaining morale, motivation and communication. Although the most basic physiological needs must be covered in order to survive, I feel that these are also important aspects that should be focused on. I also felt that the training I received in leadership in the army was more useful in this situation than the mandatory courses and safety training for seamen that I had obtained through my naval education.

Sleep should be a priority when the temperature levels inside the lifeboat are at their peak. This will help you stay active and in motion during the night when the temperature inside the lifeboat will decline. During the polar night this will not apply, as the temperature will remain more or less the same throughout the day. Simple steps could have made a big difference for the people who stayed onboard the lifeboat. The most obvious is the necessity of insulating all large areas where the body is in contact with the lifeboat. Getting rest turned out to be a considerable challenge, as it was not possible to sit or lie down on the benches without being greatly cooled down by the cold benches; you had to stay upright most of the time. The danger of hypothermia during these conditions is so significant that more measures should be available to prevent this. A lifeboat that is designed to provide a survival environment for five days under Arctic conditions must include blankets, hypothermia bags and all possible means to stay warm.

II.2.10 Report from field testing and observations from KV Svalbard

By Bjarte Odin Kvamme, University of Stavanger

Results from field experiment

As part of my master thesis, I was performing field experiments during the voyage with *KV Svalbard*. Further details about the field and the findings can be found in my thesis (Kvamme, 2016). The purpose of the field experiments was to measure the heat loss that occurs from uninsulated and insulated pipes in real-life conditions. The test was performed using two 50 mm stainless steel pipes, with a 1000 W heating element inside. The heating element was regulated down to approximately 50 W to keep temperatures in a reasonable range. The two pipes were mounted on a testing jig, and which was positioned on the aft deck of *KV Svalbard*. A picture of the assembled testing jig is found in Fig. II–10.

Temperatures, wind speed and humidity was logged for 36 hours. Longer experiments were planned, but had to be skipped due to equipment malfunction in the initial phase of the testing.

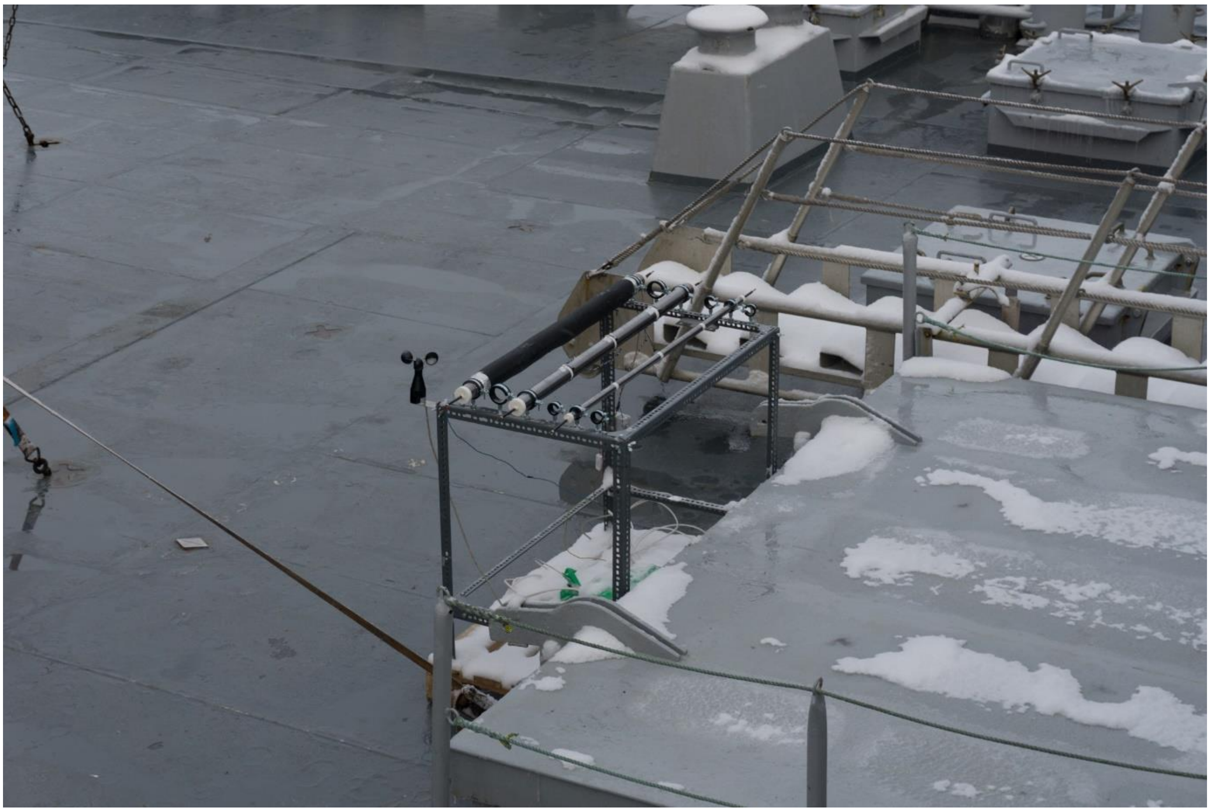

Fig. II–10: Testing rig position on the aft deck of KV Svalbard ©Bjarte Odin Kvamme

Time series plots from the testing is found in Fig. II–11 to Fig. II–14, and statistics from the testing is found in Tab. II-3.

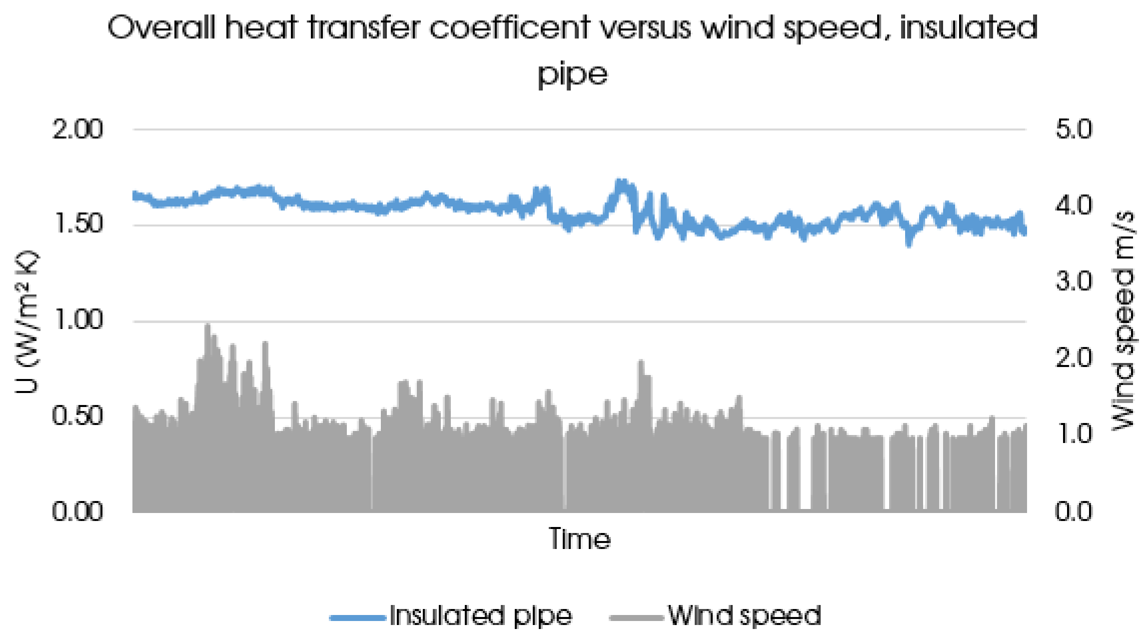

Fig. II–11: Time series plot of overall heat transfer coefficient versus wind speed for the insulated pipe.

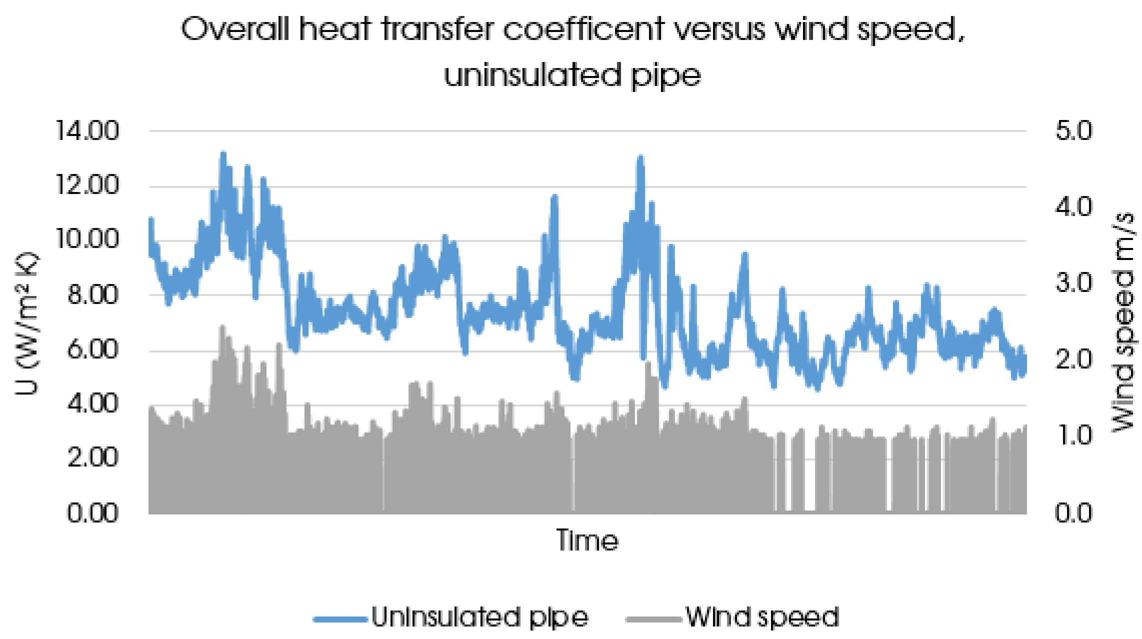

Fig. II–12: Time series plot of overall heat transfer coefficient versus wind speed for the uninsulated pipe.

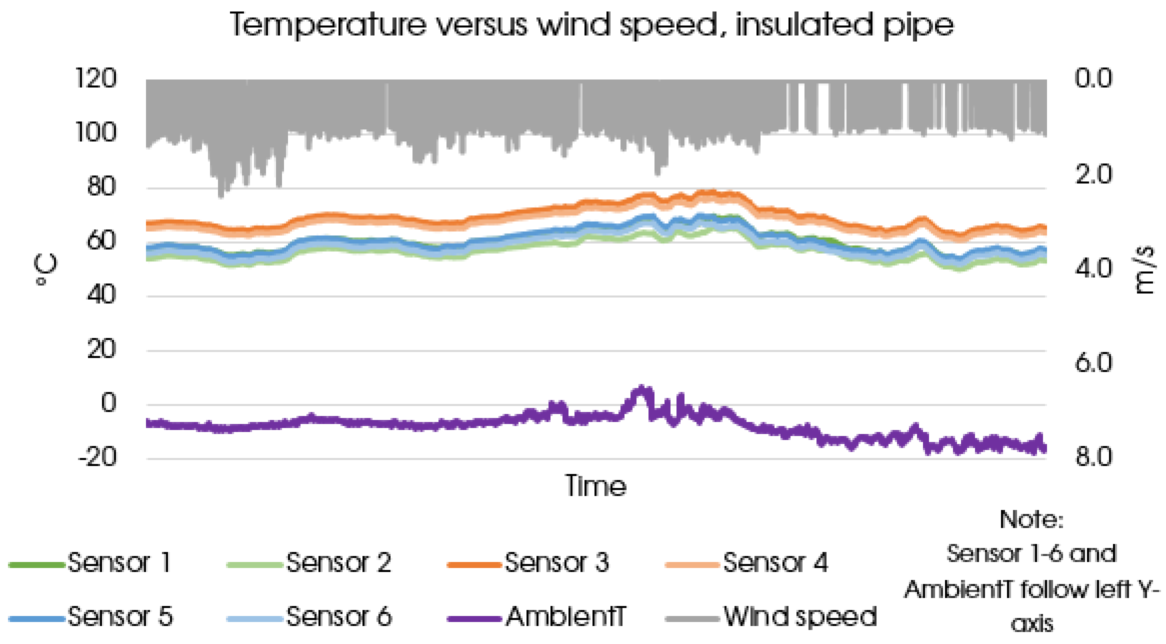

Fig. II–13: Time series plot of temperatures versus wind speed for the for the insulated pipe.

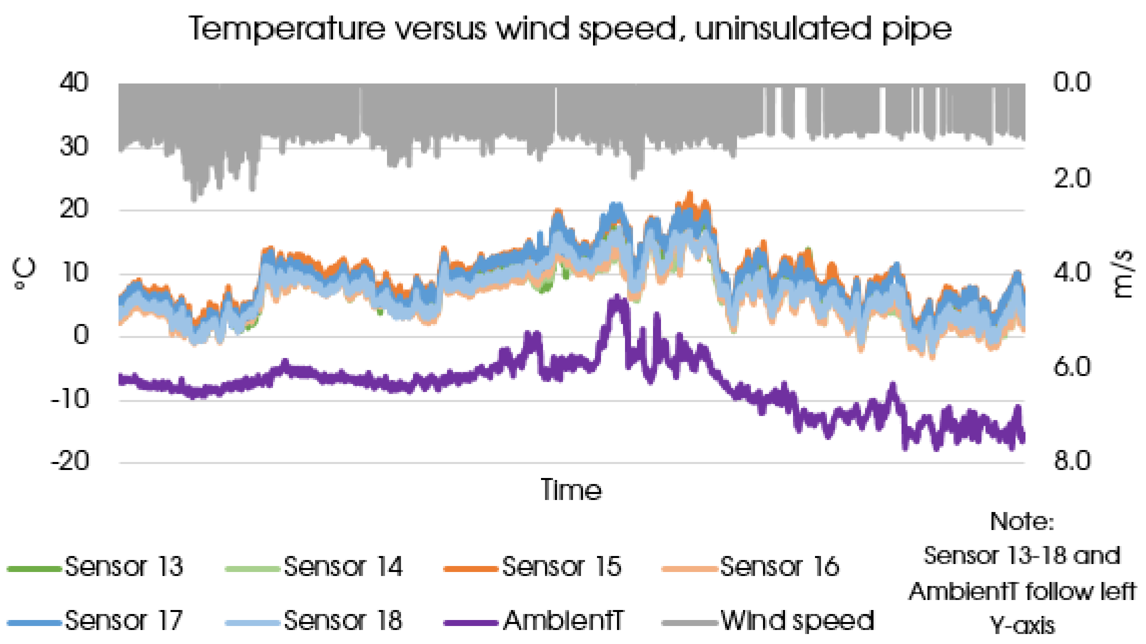

Fig. II–14: Time series plot of temperatures versus wind speed for the uninsulated pipe.

Tab. II-3: Statistics from field testing, overall heat transfer coefficients and temperatures.

		U (W/m² K)				T (°C)			
		Min	Max	Avg	St.Dev	Min	Max	Avg	St.Dev
Uninsulated	Overall	4.57	13.18	7.43	1.59	-3.24	22.81	7.81	4.46
	Top	4.30	13.05	6.93	1.49	-0.89	22.81	8.93	4.55
	Bottom	4.83	20.34	8.04	1.83	-3.24	18.14	6.69	4.08
	Sect. 1	4.33	15.45	7.78	1.72	-2.86	20.74	7.15	4.16
	Sect. 2	4.51	13.10	7.27	1.55	-3.24	22.81	8.14	4.63
	Sect. 3	4.57	13.78	7.28	1.58	-2.22	21.04	8.14	4.52
Insulated	Overall	1.40	1.74	1.58	0.06	50.26	78.93	62.41	6.11
	Top	1.38	1.70	1.55	0.06	52.13	78.93	62.45	5.85
	Bottom	1.42	1.78	1.61	0.07	50.26	76.50	61.12	6.10
	Sect. 1	1.47	1.86	1.66	0.07	50.26	69.96	58.82	4.29
	Sect. 2	1.30	1.58	1.45	0.05	61.00	78.93	68.61	4.16
	Sect. 3	1.45	1.80	1.64	0.07	52.13	70.10	59.78	4.24

Comments

In Fig. II–11 and Fig. II–12 plots of the overall heat transfer coefficient versus the measured wind speed is presented. The wind speed sensor used was not very accurate, and required a minimum of 0.8 m/s wind speed before the output voltage is provided to the data logger. When combined with a sample resolution of 30 seconds, this becomes very evident in Fig. II–11 & Fig. II–12, as the measured wind speed frequently drops to 0 m/s. Comparing the insulated and uninsulated pipe does however reveal a very distinct difference between the two. The overall heat transfer coefficient of the uninsulated pipe range from 4.57 to 13.18 W/m^{2}K, while the insulated pipe range from 1.40 to 1.74 W/m^{2}K. In Fig. II–13 we can see that the insulated pipe is barely affected by the different wind speeds, while the uninsulated pipe shown in Fig. II–14 has very large changes due to wind.

Fig. II–14 also shows that the pipe temperature dropped below 0◦C on several occasions, while the insulated pipe shown in Fig. II–13 never dropped below 50◦C.

Observations from *KV Svalbard*

On board the vessel *KV Svalbard*, examples of underpowered heat tracing was observed. The aft and helicopter deck had heat tracing installed, supposedly rated at 400W/m2. This was the requirement from Det Norske Veritas (now: DNV GL), who classed the vessel at the time of commissioning, 15.12.2001 (NoCGV Svalbard, 2016). The heat tracing was not able to keep the deck surface ice and snow free while the vessel was in transit, or if the vessel was subjected to wind. Fig. II–16 shows snow and ice accumulating on the helicopter deck during the transit to Woodfjorden. Fig. II–17 shows a thermal image of the starboard side of the helicopter deck. The ambient temperature was -12 ◦C, and the vessel was moving at 13 knots. Once we arrived at our destination, the heat tracing was able to de-ice all sections of the deck.

Conversations with officers on board revealed that in rough conditions they have to cover the helicopter deck with tarpaulin to remove the effect of the wind. This was done when they were expecting a helicopter, and would be difficult to achieve in case of an unexpected landing. Further conversations revealed that the power consumption of the heat tracing during bad weather caused the transit speed to be reduced. The heat tracing used a considerable amount of power, which reduced the available power to the azipod propulsion system. The officers noted that this could be mitigated by starting additional diesel engines to drive the generators, but this would again increase fuel consumption. When taking into consideration that the heat tracing was not even able to keep the surfaces ice free, it is evident that this is not an optimal scenario.

Ice was also found to be forming on nozzles used in the vessels fire extinguishing system. The pipes used were insulated, but the diameter of the pipe used and the thickness of the insulation is not known.

Fig. II–15 shows a picture of a nozzle and some piping on the starboard side of *KV Svalbard* during the transit to Woodfjorden. The fire extinguishing system was not tested, but conversion with the chief engineer on board revealed that water was constantly circulated through the pipes to avoid freezing.

Fig. II–15: Ice accumulation on fire extinguishing nozzle on KV Svalbard. Picture taken in April 2016, west of Ny Ålesund. Ambient temperature was -12 ◦C and no wind apart from the air flow caused by the transit at 13 knots. ©Trond Spande.

Fig. II–16: Snow and ice accumulation on the helicopter deck on KV Svalbard. Picture taken in April 2016, west of Ny Ålesund. Ambient temperature was -12 ◦C and no wind apart from the air flow caused by the transit at 13 knots. ©Trond Spande.

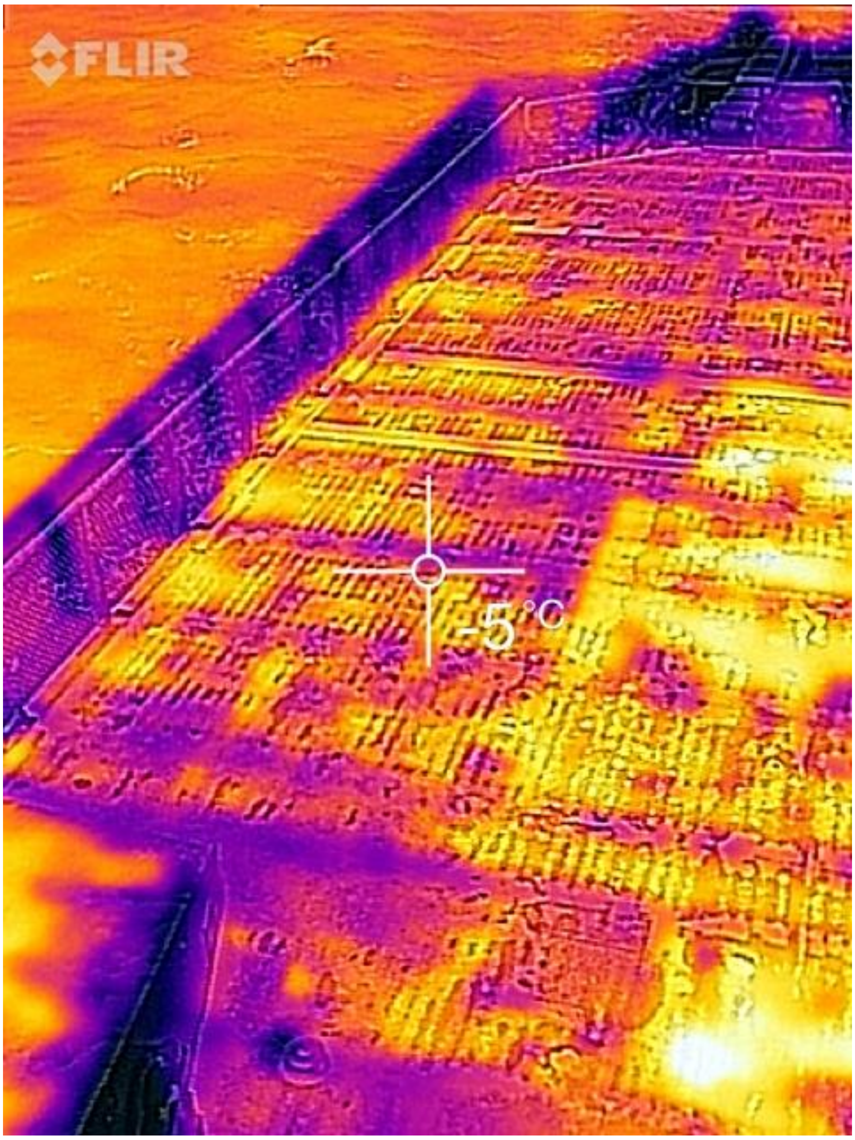

Fig. II–17: Thermal image of the starboard side of the helicopter deck. Heat tracing is visible as the yellow lines in a grid. ©Trond Spande.

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Kvamme, B. O. (2016). *Validation of heat transfer coefficients - Single pipes with different surface treatments and heated deck element* (Master thesis, University of Stavanger).

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II.2.11 Winterization of rescue equipment

By Bjarte Odin Kvamme, University of Stavanger

Abstract

This report will discuss problems related to winterization of rescue equipment, with particular emphasis on the rescue vessels. While the rescue vessels will in general serve its purpose well without any winterization measures, there are numerous challenges that should be resolved in order for the evacuees to have a good chance of survival.

Introduction

In Chapter II.2.5, Nese, Dalsand and Mostert present a very thorough analysis of potential hazards and mitigating measures regarding the use of a life boat in polar waters. The analysis performed in this report will focus mostly on the additional challenges caused by cold climate and the implementation of the Polar Code, challenges faced with a life raft, and suggestions to the PPE.

Discussion

Potential problems, consequences and suggestions to mitigating measures for a life boat, life raft and PPE are presented in Tab. II-4, Tab. II-5 and Tab. II-6 respectively.

Tab. II-4: Problems, consequences and mitigating measures for a life boat in polar waters

ID#	Problem	Consequence(s)	Mitigating measure(s)
1	Icing on the exterior of the lifeboat prior to launch	• Hatches and doors cannot be opened • Slippery surfaces for boarding	• Protect lifeboat using tarpaulin • Use a life boat hangar to protect the life boat from the environment • Install a protective, retractable wall in front of the life boat • Use heat tracing on critical areas, such as hatches and door openings
2	Icing on the lifeboat launcher mechanism	• Life boat cannot be launched immediately • Might require manual deicing • All passengers are not evacuated in time	• Use heat tracing on critical components • Use a life boat hangar to protect the life boat from the environment • Install a protective, retractable wall in front of the life boat • Explosive launch mechanism, not dependent on deicing
3	Lack of space in lifeboat due to added equipment and additional clothing	• Claustrophobia • Difficult to move around inside the life boat • Injuries due to tumbling inside the lifeboat	• Downgrade the capacity of the life boat • More efficient packing of GSK • Preload the life boat with the GSK in special compartments

		• Increased evacuation time • Survival equipment is not included	• Change the "loadout" in the PSK, avoid unnecessary gear and redundant gear
4	High heat loss to surfaces due to uninsulated surfaces	• Loss of body function • Frostbite in extremities • Increased energy consumption due to heat loss	• Insulated padding in seat and backrest • Insulate floor of life boat • Insulate life boat walls and roof • Include blankets in the lifeboat loadout
5	High humidity in lifeboat	• Higher heat loss through the air • Uncomfortable air quality • Loss of heat due to manual venting • Fogging of windows • Sweating • Condensation of water • Slippery surfaces	• Include chemical dehumidifier • Increase ventilation possibilities
6	High temperature in lifeboat	• Sweating / dehydration • Nausea • Loss of excessive amounts of heat due to manual venting	• Increase ventilation possibilities • Install passive ventilation options on various locations on the life boat that can be opened on demand, regardless of weather conditions
7	Poor air quality due to lack of ventilation	• Bad decision making • Lack of attention • Dizziness/sleepiness • Nausea	• Increase ventilation possibilities • Install passive ventilation options on various locations on the life boat that can be opened on demand • Include CO_2 alarm to notify crew of poor air quality
8	Battery time of communication equipment is reduced due to cold surface	• Longer time before rescue • Difficult to communicate with responders	• Store communication equipment on an insulated surface • Keep communication equipment inside clothing
9	Radar reflector is lost to sea	• Difficult for responders to locate life boat • Extended time before rescue	• Include backup radar reflector • Include radar transponder • Install a permanent radar reflector in the construction of the life boat

10	Engine coolant is not designed for cold climate, prone to freezing/change of properties	• Engine failure • Loss of ventilation • Loss of power • Loss of heat source • Loss of navigation	• Ensure that the engine coolant has antifreeze and is designed for cold climate • Include anti-freeze in the lifeboat
11	Low temperatures inside lifeboat	• Hypothermia • Frostbite • Sleepiness • Drinking water freezes	• Include small heat source that can be operated with the engine fuel • Insulate walls, floor and roof of life boat
12	Insufficient fuel in lifeboat	• Not possible to navigate in rough seas • Not possible to escape onto ice if required • Hypothermia • Poor air quality	• Provide sufficient fuel for the estimated time of survival
13	Blocked ventilation channel due to external icing	• Poor air quality • Nausea • Bad decision making • Hypothermia due to manual venting	• Provide deicing capabilities for the venting channels • Design venting channel so that it is possible to manually remove ice from the inside of the life boat
14	Icing on exterior of life boat post-launch	• Decrease in stability • Nausea • Vomiting • Loss of life	• Use hydrophobic or ice phobic paint to prevent the water/ice from forming
15	Included water is frozen	• Dehydration • Extensive heat loss due to reheating of the water	• Install heat tracing around the water compartments that is permanently activate during storage • Available means of thawing the water using the excess engine heat
16	Included diesel fuel is frozen/gelled	• Engine failure • Loss of ventilation • Loss of power • Loss of heat source • Loss of navigation • Damaged fuel filter	• Ensure that the diesel use is designed for use in polar conditions • Provide additive in the life boat that can be added to the life boat • Install electric pre-heater in the fuel tank/line that is active during storage
17	Low temperature due to unused parts of life boat	• Loss of heat	• Include tarpaulin/canapé to close off unused portion of life boat
18	Loss of motivation due to extended time in life raft	• Mutiny • Suicide • Psychological damage	• Include simple means of entertainment • Provide rations with different flavorings to increase variation

Tab. II-5: Problems, consequences and mitigating measures for a life raft in polar waters

ID	Problem	Consequence	Mitigating measure
1	Icing on the life raft container prior to launch	• Life raft will not inflate properly • Life raft is damaged during inflation	• Protect life raft container using tarpaulin • Use a life raft hangar to protect the life raft from the environment • Install a protective, retractable wall/tarpaulin in front of the life raft • Use heat tracing on the seal between the two lids
2	Icing on the life raft launcher mechanism	• Life raft cannot be launched immediately • Might require manual deicing • All passengers are not evacuated in time	• Use heat tracing on critical components • Install a protective, retractable wall in front of the life raft • Explosive launch mechanism, not dependent on deicing
3	Lack of space in life raft due to added equipment and additional clothing	• Claustrophobia • Difficult to move around inside the life raft • Injuries due to tumbling inside the life raft • Increased evacuation time • Survival equipment is not included	• Downgrade the capacity of the life raft • More efficient packing of GSK • Preload the life raft some parts of the GSK in special compartments • Change the “loadout” in the PSK and GSK, avoid unnecessary and redundant gear
4	High heat loss due to bad insulation in flooring	• Loss of body function • Frostbite in extremities • Increased energy consumption due to heat loss	• Double layered flooring in life raft • Include insulated/inflatable sitting pads in the life raft loadout
5	High humidity in life raft	• Higher heat loss through the air • Uncomfortable air quality • Loss of heat due to manual venting • Sweating • Condensation • Wet floor, leads to higher heat loss through the bottom	• Include chemical dehumidifier • Increase ventilation possibilities • Use double layered flooring with drainage channels which can be easily emptied
6	Water accumulation in life raft floor	• Increased heat loss due to loss of insulation	• Use double layered flooring with drainage channels that

			can be emptied using hand pump
7	Hand pump breaks	• Unable to remove large quantities of water from life raft	• Improve hand pump design • Include redundant pumps
8	High temperature in life raft	• Sweating / dehydration • Nausea • Loss of excessive amounts of heat due to manual venting	• Increase ventilation possibilities • Install passive ventilation options on various locations on the life raft that can be opened on demand, regardless of weather conditions
9	Poor air quality due to lack of ventilation	• Bad decision making • Lack of attention • Dizziness/sleepiness • Nausea	• Increase ventilation possibilities • Install passive ventilation options on various locations on the life raft that can be opened on demand • Include CO_2 alarm to notify crew of poor air quality
10	Battery time of communication equipment is reduced/lost due to cold	• Longer time before rescue • Difficult to communicate with responders	• Store communication equipment on an insulated surface • Store communication equipment in a pouch in the pontoons • Keep communication equipment inside clothing
11	Radar reflector is lost to sea or broken	• Difficult for responders to locate life raft	• Include backup radar reflector • Install a permanent radar reflector in the ceiling of the life raft
12	Low temperatures inside life raft	• Hypothermia • Frostbite • Sleepiness • Drinking water freezes	• Insulate walls, floor and roof of life raft
13	Included water is frozen	• Dehydration • Extensive heat loss due to reheating of the water	• Install heat tracing around the water compartments that is permanently activate during storage • Available means of thawing the water using the excess engine heat
14	Water intrusion when venting	• Raft is filled with water • People get wet, hypothermia	• Provide more ventilation options to avoid open doors

15	Water intrusion when observing environment	• Raft is filled with water • People get wet, hypothermia	• Provide plastic windows in the canapé to avoid open doors
16	Navigation difficulties in ice infested waters	• Could get stuck in ice • Polar bear attack • Walrus attack	• Include telescopic oars • Include oar mount in doorways to ease navigation
17	Wild life attack on life raft	• Life raft sinks • Damage to canapé • Hypothermia • Loss of life	• Include equipment to scare away walrus
18	Zippers on doors are damaged	• Not able to close doors • Hypothermia • Loss of life • Instability in harsh seas	• Ensure the use of high quality zippers that are not sewed on, but adhered
19	Loss of motivation due to extended time in life raft	• Mutiny • Suicide • Psychological damage	• Include simple means of entertainment • Provide rations with different flavorings to increase variation

Tab. II-6: Problems, consequences and mitigating measures for PPE

ID	Problem	Consequence(s)	Mitigating measure(s)
1	High levels of humidity inside survival suit	Sweating Wet clothing, loss of insulation	• Include chemical dehumidifiers (ex. Silica gel) inside the survival suit • Use a breathable, watertight fabric • Add zippers for venting without taking off the survival suit
2	Reduced dexterity due to permanent gloves on survival suit	• Increased evacuation time • Loss of heat if taking off survival suit • Not able to notify responders • Loss of drinking water/ration • Not able to operate equipment	• Use removable gloves on survival suit
3	Survival suit is too large	• Loss of dexterity • Tumbling • Hypothermia due to falling in the water • Not properly protected from water intrusion	• Provide different sized survival suits • Provide Velcro straps to improve fit of survival suit
4	Insufficient insulation in survival suit	• Hypothermia	• Include insulation in survival suit • Ensure that passengers are wearing sufficient clothing prior to evacuation
5	Insufficient insulation of extremities in survival suit	• Loss of dexterity • Frostbite	• Add additional insulation around feet and hands
6	Survival suit does not have dual zippers	• Loss of heat when peeing (men) • Loss of mobility	• Include a double zipper on survival suits
7	Lack of storage space on survival suits	• Clutter • Loss of drinking water/rations • Contamination of drinking water/rations	• Include pockets on survival suit for storing drinking water bags and rations
8	Lack of insulation with life jacket	• Hypothermia • Loss of dexterity • Extensive heat loss throughout the body • Loss of life	• Only use full-body PPE (survival suit)

Conclusion

During the various exercises, valuable feedback and experiences was acquired. The majority of the issues are directly related to the additional challenges arising due to the requirement of a five-day survival. With some minor modifications, both of the rescue vessels would provide a suitable habitat. If the lifeboat is well insulated, and a heat source is provided, life jackets could prove suitable. This will however need further testing and verification. If life rafts are used, only full-body protection (survival suits) should be considered, and these should ideally be insulated.

II.2.12 Winterization of rescue vessel launchers

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Introduction

While most cruise vessels operating in the Arctic tend to avoid the seasons with the worst weather, atmospheric icing and marine icing can take place under certain weather conditions.

Atmospheric icing is defined by the International Standards Organization (ISO) and the International Council on Large Electric Systems (CIGRE) as any process of ice or snow accumulation on objects exposed to the atmosphere (Ryerson, 2011). The precipitation and deposition methods of freshwater and the characteristics of deposits can further be used to classify atmospheric icing as glaze, rime ice, snow and hoar frost.

Marine icing is results from the interaction of the waves with the hull of the vessel or other offshore structures in the wave zone. Sea-spray is generated as a result of this interaction, which eventually leads to icing of salt water. Sea-spray can also be caused when water droplets from the wave crests is blown off by the strong wind as explained by Jones and Andreas (2012), which freezes on the deck and is also known as spume. The annual probability of exceedance of the ice actions caused by sea-spray as compared to atmospheric icing from (NORSOK, 2007) indicates that the sea-spray icing is the most critical and major source of icing in terms of its consequences and extent for structures and vessels in the cold-climate conditions.

Winterization can roughly be split up into two main categories. Preventive and mitigating methods. Preventive methods are implemented to prevent issues regarding cold climate, an example being the prevention of ice accretion. A mitigating method is a reactive method, which is used to limit the consequence of the cold climate, alternatively to remove it. An example is deicing chemicals which can be used to remove accreted ice. The following sections will discuss various winterization methods relevant to lifeboats and lifeboat launchers. For more detailed analysis and discussion regarding winterization methods, see Ryerson (2009) and Yang et al. (2013).

Preventive methods

To ensure that the lifeboat/liferaft is able to launch when required, there should be no physical obstructions that may prevent the launch. All the mechanical and release mechanisms also need to remain functional at all times. To ensure the functionality, the following preventive methods can be utilized.

Protection from environment

To protect the launcher from the environment, a structure can be constructed around the lifeboat/liferaft launcher. This will protect the lifeboat/liferaft launcher from atmospheric icing, and more importantly, sea spray icing. The structure should be constructed in such a way that the lifeboat/life raft can be launched without removing the structure or opening doors. This is easier to do for freefall lifeboats and liferafts. Alternatively, a simple frame can be constructed around the lifeboat/liferaft launcher and a protective mesh/tarpaulin can be utilized for a more light weight solution. A common term for this type of super structure is a lifeboat hangar.

Heat tracing

Heat tracing involves some sort of heating of features on the equipment. Areas that might need heat tracing are valves, pipes, door coamings, walkways, stair wells, hand rails and emergency escape routes

(Yang et al., 2013). The two most common types of heat tracing are electric heat tracing and steam heat tracing.

Electric heat tracing

Electrical heat tracing is performed by using a heating element which is positioned in direct contact with the object. The heating elements are typically in the form of cables with varying levels of resistance, which heats up when current is passed through them. This is a very simple and cheap way of heating specific parts which needs to be ice free. As electrical power is required, larger areas could be quite expensive to heat using electrical power, as the generators on the ship might need to be upgraded as well.

Steam heat tracing

Heat tracing using steam requires more extensive modifications and will be significantly more expensive to implement for smaller systems. However, if large areas need to be heated, steam heat tracing can be very attractive. The heat used for generating steam can come from gas turbines or other generators, which would normally be exhausted and lost.

Ice repellent coatings

The usage of ice repellent coatings can reduce the accumulation of ice and snow. These coatings have non-stick properties, which would help reduce ice accretion and also make it easier to remove in case ice forms on the surface. Ice repellent coatings is a low cost method, which should be considered for all external surfaces (Yang et al., 2013).

Mitigating methods

If accretion of ice takes place, it has to be removed. There are various methods of doing this, some of which will be discussed here.

Physical removal

The simplest, and most common way of removing ice is physical force. This is usually done by hitting the ice using rubber/wooden sledgehammers. This can however be dangerous, especially if the ice is at a height. When removed blocks of ice may fall on the surrounding equipment and cause serious damage, both to equipment, and crewmembers nearby.

Other methods

Steam and deicing chemicals can also be used to remove ice, but for lifeboats and liferafts this has a very limited range of use, as the ice removal would need to happen very rapidly when abandoning ship.

Lifeboat/liferaft concepts

There are three primary concepts for lifeboats and liferafts. Modern lifeboats are typically enclosed to protect people from weather conditions, and some have a propulsion system. The self-righting property of lifeboats makes it very stable in comparison to liferafts. Lifeboats can however be very heavy, and require a sturdy launching system which again takes up a fair amount of space. If a ship with lifeboats is listing to one side, this might cause problems evacuating the ship if there are only lifeboats on one side and icing occurs on the same side. Thus, it is recommended to have sufficient lifeboat capacity on both sides of the ship, or have the lifeboat launcher at the stern. One major advantage with lifeboats is that people can board the lifeboat while still on the ship.

Smaller fishing boats typically utilize inflatable liferafts. These liferafts are not self-righting, do not have a propulsion system. In large waves, especially if combined with strong wind, liferafts can easily capsize. Liferafts are typically launched into the water, where they inflate. People then have to jump into the water and get in the liferaft from the water or board the liferaft from the vessel. Advantages of liferafts is that they are light and do not take much space.

Crane launched lifeboats

Crane launched lifeboats have been around for a long time, and are very common on bigger ships, for example cruise liners. An example is shown in **Error! Reference source not found.**. These require cranes/winches to lower the lifeboats into the sea, which can take some time, especially if the ships are very tall.

Fig. II–18: Crane launched lifeboat (Lloyds British Testing, 2015)

Freefall lifeboat

Freefall lifeboats and crane lifted lifeboats are very similar, but freefall lifeboats are sturdier than crane launched lifeboats, as these have to be able to withstand the shock that occurs when the lifeboat hits the water surface. Freefall lifeboats allows for a very rapid evacuation, and are required on bulk carriers that are in danger of sinking too rapidly for conventional, crane launched lifeboats as of 2006 (SOLAS, 2004). Freefall lifeboats are typically installed at the stern of the ship as seen in **Error! Reference source not found.**, but can also be mounted on the sides if the stern is required for other equipment.

Fig. II–19: Freefall lifeboat launcher (SV-Zanshin, 2011)

Inflatable liferaft

Inflatable liferafts are very common on small to medium sized fishing boats, and other types of ships. They take up very little space on the vessel, and can be moved around. They are typically mounted to a tilted rack to allow for quick launch of the liferafts. These rafts are inflatable, and the release mechanism is connected to the rack for them to inflate as soon as they are launched. After the liferafts have been launched, the crew have to board the liferaft, typically by jumping into the water and swimming to the liferaft.

Fig. II–20: Inflatable liferaft launcher (Total Marine Safety, 2014)

Crane launched hovercrafts

A new type of lifeboats are suggested in Mejlaender-Larsen (2014), which are based on hovercraft technology. The lifeboat would have air cushions which makes it possible for the lifeboat to float above the surface of the sea, and more importantly, travel over ice. Traditional lifeboats can only be used in open waters, and will have difficulties navigating in waters containing large concentration of ice. A hovercraft will mitigate many of these issues, but is a very new concept, and to the knowledge of the authors, a hovercraft lifeboat designed for use in the Arctic still has not been produced. Hovercraft lifeboats would need to be launched using a crane, unless they are constructed in such a way that they would be able to withstand the shock when the hovercraft hits the surface of the sea or the ice.

Fig. II–21: Mockup of hovercraft lifeboat (Mejlaender-Larsen, 2014)

Discussion

Considerations in Arctic environments

Richardsen (2014) presents case studies performed by DNV GL which estimates the risk in the Arctic to be significantly higher when compared to other regions. The study concludes that the risk is approximately 30% higher for cruise ships, and 15% higher for bulk carriers. This makes the design considerations for improving safety equipment and mechanisms very important.

Lifeboats used in Arctic regions require a significant amount of modifications and improvements when compared to lifeboats used in other regions. Based on studies performed by DNV GL, Mejlaender-Larsen (2014) presents the following design considerations that must be implemented for improving lifeboat safety to a sufficient level when operating in Arctic regions:

- Enclosed lifeboat hangars provides protection to the lifeboat and lifeboat launchers from marine and atmospheric icing, and makes deployment possible even in harsh conditions.
- Enclosed lifeboats and ice-phobic materials. The enclosed lifeboats provide protection to the crew under extreme environmental conditions, and ice-phobic materials or paint can be used on the superstructure surrounding the lifeboat hanger to lower the rate of ice accretion. Ice-phobic materials or paint should also be used on the passageway to the lifeboat launcher if these are not enclosed.
- Preheating of engines and freeze-proof engine cooling systems are required for lifeboats with propulsion systems
- Special propulsion and steering design
- High thermal insulation
- Survival equipment and emergency communication

Mejlaender-Larsen (2014) also suggest that hovercrafts can be used for lifeboats for vessels operating in areas with heavy ice coverage. A traditional lifeboat is only suitable for use in open waters, while a hovercraft would also be able to operate in heavy ice conditions. Hovercrafts will likely be more expensive than traditional lifeboats, making them uneconomical for use on passenger ships and cruise vessels. For bulk carriers and other commercial ships, the crew size is usually small (around 10 people), making hovercrafts worth considering.

Selection of lifeboat/liferaft concept

The Polar Code only allow the usage of partially or totally enclosed lifeboats when operating in Arctic waters. The use of inflatable liferafts is not recommended, as they lack self-righting behavior, have limited protection from the environment, and requires the crew to launch the lifeboat into the sea, and then board it. This will increase the required time for evacuation, and require the crew to expose themselves to the environment when boarding the liferaft.

Selecting the lifeboat and launching system should be carefully examined based on the expected operating conditions of the vessel. Lifeboats used for freefall launching are enclosed and reinforced to withstand the stresses that take place when the lifeboat slam into the water, and will protect the crew and personnel from the environment. If a hovercraft is chosen, it would need to be lowered into the sea or onto the ice by a crane, as the hovercraft cushions could not withstand a drop onto the ice, and probably not to the sea if the hovercraft is located high on the ship.

The usage of a crane launched lifeboat will increase the time required to abandon the ship, and must be considered when writing up the evacuation procedures.

Protection of lifeboat launcher

The area surrounding the lifeboat/liferaft should be accessible, and not prone to icing. Any latches or hatches should be protected from direct exposure if possible and have heat tracing installed. Electric heat tracing is recommended, as the coamings and hatches represent a very small area.

The lifeboat/liferaft launcher should be placed in such a way that sea spray is not of concern. If possible, the launcher should be positioned at the stern of the ship. This will be the natural position for many bulk carriers, where the bridge and living quarters are located on the stern of the ship. For other ship designs, this might not be possible, as the aft region is often used for storage and equipment. This the case for supply vessels used in the offshore industry, and some naval warfare/coastguard vessels, such as *K/V Svalbard*.

If installation at the stern is not possible, the liferaft launcher should be enclosed in a lifeboat hangar to protect the launcher from atmospheric icing and particularly marine icing. Ice-phobic materials and coatings should be applied on the external surface area to lower the possibility of ice buildup surrounding the hangar. If a lifeboat hangar is used, it should be installed to enable the crew and personnel to board the lifeboat without having to expose themselves to the environment. The walkways leading to the lifeboat should be enclosed if possible. If this is not possible, the walkways should have ice-phobic materials and heat tracing to ensure an ice-free passage to the lifeboats.

Conclusion

The research and arguments presented in this report, establish that marine activity and operations performed in the Arctic region carries significantly higher risk compared to other region. Detailed planning is required before performing any type of activity offshore in Arctic regions. It is also found that the biggest challenge for operations in the Arctic is the harsh environment, as this makes all operations more complicated and hazardous. Cold temperatures, strong wind and ice are all environmental conditions that requires consideration when planning operations and field developments in the Arctic.

Marine and atmospheric icing is a major hazard which relates directly to the environmental conditions, but can be handled with safety focused engineering and management with focus on preventive and mitigating techniques. Big advancements are made in the development of ice-phobic paint and coatings, especially with the advancements made in nanotechnology.

The lifeboats should be installed in lifeboat hangars to provide protection from the environment, and ensure the availability of the lifeboats at all times. The lifeboat hangars should ideally be installed at the stern of the ship, but can also be installed on the port and starboard side if preventive and mitigating measures are taken to protect the opening where the lifeboat will be launched from.

Based on our findings, we recommend freefall lifeboats for vessels operating in open waters, where sea ice is not likely. For waters where sea ice is likely, the hovercraft lifeboat should be further investigated, and the technology for this should be investigated and analyzed. If found suitable, hovercraft lifeboats are recommended for waters where sea ice is likely.

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II.2.13 Objective report from Phase II of the exercise by the medical team

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Practical evacuation exercise

As part of SAREX, an exercise was arranged in which about 40 injured and non-injured persons were evacuated from the lifeboat onto the main ship KV Svalbard. The lifeboat was located a few hundred meters away from the main vessel, and the exercise took place under near perfect conditions with little wind and waves. The participants wore various protective clothing as well as floating equipment. Five patients were assumed to be hypothermic and deeply comatose, 15 patients had a mix of non-lethal injuries, and 20 participants were assumed non- injured.

All persons were *transferred to the main vessel* with MOB-boats capable of carrying six or seven passengers. A senior naval officer led the evacuation on to KV Svalbard accompanied by a medic capable of administering i.v. analgesics, as necessary, prior to evacuation of victims in severe pain.

The following points were noted from this phase:

- Rapid triage is essential – there is no time for interviewing/ interacting with every victim.
- It may be useful to have medical personnel from the main vessel on board the life-boat to provide analgesia and other treatment allowing for smooth transfer of the injured.
- It is difficult to treat injured persons in a life-boat full of people. Swift evacuation of the non-injured allowed for proper treatment and handling of the injured.
- It is difficult to move non-ambulatory persons between vessels. During the exercise, all persons (injured or not) moved themselves between the lifeboat and the MOB-boat; it was found too risky to actually carry them for exercise purposes.

The Polar code states that people should be able to survive for up to 5 days in a raft or a lifeboat, but not in which condition they should be at the end of this time period. If just a small degree of hypothermia is allowed to develop, one can expect great challenges when attempting to transfer the victims between vessels. Dexterity, arm/leg coordination and cognitive function rapidly deteriorates even in mild hypothermia. There were no good alternatives for transferring large amounts of immobile passengers present.

Regarding the *triage and immediate treatment phase* on boards KV Svalbard, patients were triaged immediately on arrival, close to the intake area. Thus, one could quickly identify those who needed more close observation and/or treatment, those were brought in neighboring rooms. Emphasis was put on to the medics' ability to carry out simple examination and life-saving measures while the ship doctor was available for consultation as needed. The following points were noted:

- Good procedures on board the Coast Guard vessel made for a well prepared reception of the evacuees.
- The vessel's hospital was not actively in use as it was too remote.
- Premade plans were activated, and large areas onboard the ship were available for triage and treatment. Thus, quite large groups of (non-injured) people may be handled on board these vessels with little preparations.

The final phase consisted of simulated communication with the *presumed helicopter assistance* arriving from Longyearbyen 1 hour 10 minutes after the initial alert. It was noted that further transfer of unconscious patients towards helicopter deck proved difficult. Uninjured participants noted a lack of information, in particular regarding their spouses and relatives who might be among the injured.

Fig. II–22: Injured person handled by medical staff

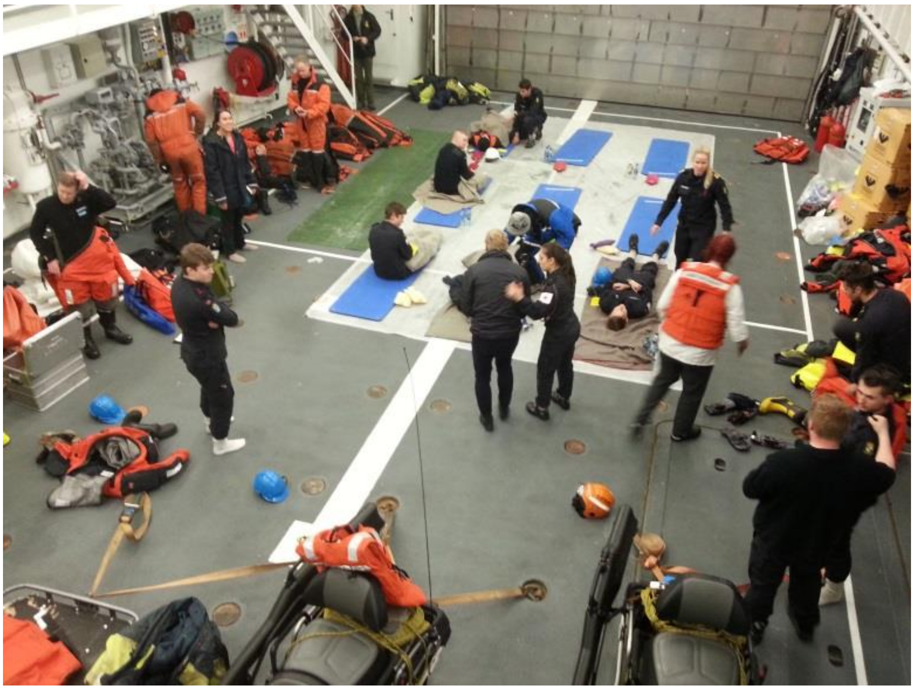

Fig. II–23: Receiving grounds in helicopter hangar.

II.2.14 Findings of the medical team from the SAR exercise

By Svein Erik Gaustad[1], Ulrik Wisløff[1] and Eirik Skogvoll[1]

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Ten healthy soldiers (8 male, 2 female, yrs. 19-31) of *KV Svalbard* who had read and signed the informed consent were to spend up to 24 hours in a life-raft on open sea with a sea temperature of -1.5°C and ambient temperature of -10°C. They were dressed in survival equipment with various degree of thermal protection and were told to abandon the life-raft when feeling uncomfortable (either due to becoming cold or from any other reason). In addition, there was an officer in charge in the life-raft, objectively assessing the subjects' response to cold with the authority to make subjects abandon the life-raft when showing signs of hypothermia.

To examine how the subjects with various degree of thermal protections were affected by the stay in the life-raft we decided to perform the following measurements:

1) On all subjects, core-temperature was measured (ear measurement) before and after life-raft exposure
2) On two male subjects (one with minimal thermal protection (Kampvest) and one with the best available thermal protection at SARex (SSliner)), core rectal temperature was continuously registered
3) On all subjects, cognitive function was assessed before and after life-raft exposure, in terms of a standardized neuropsychological ("Conners") test.

Results

Ear core temperature

The cut-off value for core temperature in this study was 35 °C and none of the subjects were significantly colder than 35 °C. The average ear core temperature was 35.9 ± 0.5 °C and the lowest recorded ear-temperature was 34.9 °C. For further parameters of medical examination, see point 19.

Continuous rectal core temperature

The subject dressed in minimal thermal protection (Kampvest) was able to stay in the life-raft for a significantly shorter time than the subject dressed in the best available thermal protection (SSliner). Dressed in Kampvest, the subject stayed in the life-raft for 6.5 hours with a rectal and ear core temperature at 35.9°C and 36.3°C, respectively. Dressed in SSliner, the subject stayed in the life-raft for 14 hours with a rectal and ear core temperature at 36.2°C and 36.0°C, respectively.

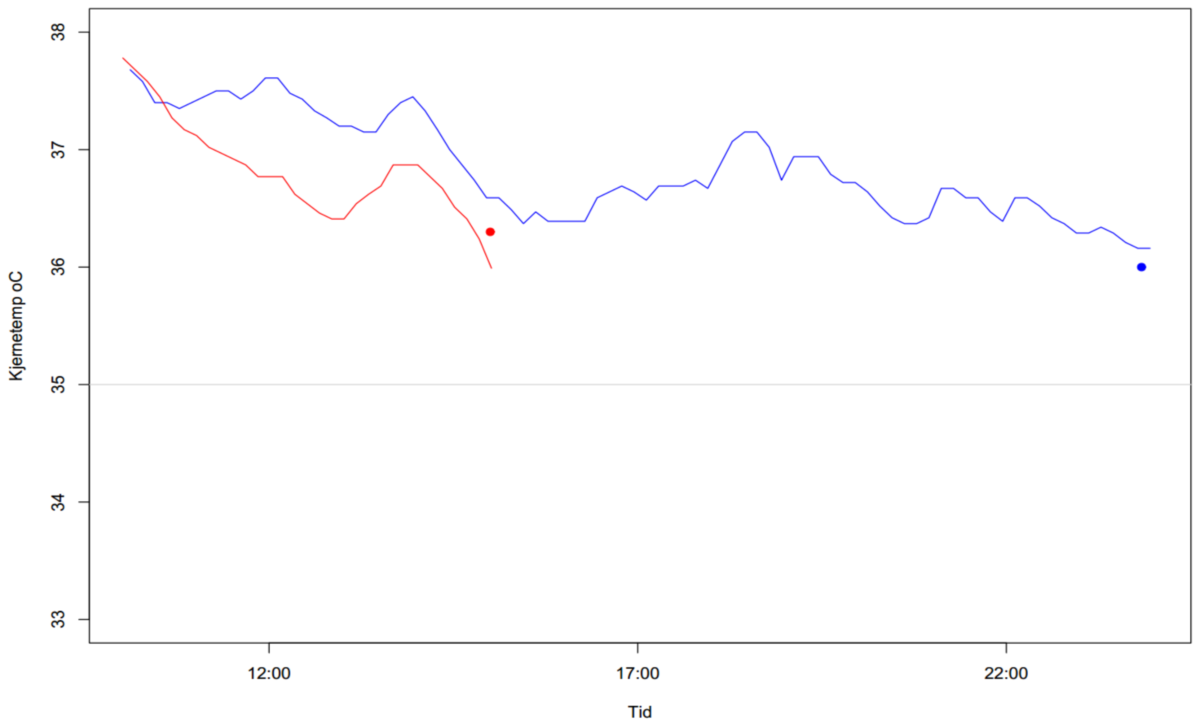

Fig. II–24: Illustration of continuous rectal core temperature recordings in 2 subjects in life-raft. Red curve illustrates subject dressed in minimal thermal protection (Kampvest). Blue curve illustrates subject dressed in best available thermal protection at SARex (SSliner). Red & blue dots represent ear core temperature recorded after termination of life-raft exposure.

Cognitive function

To asses if a reduction in core temperature in young healthy subjects could affect cognitive function, the subjects performed the Conners Consecutive Performance TEST (Conners CPT3) before and after the life-raft exercise. In short, the Conners CPT3 test is a 14-minute scientific test to assess attention-related problems where test subjects are required to respond when any letter appears on a computer screen, except the non-target letter "X". By indexing the subject's performance in areas of inattentiveness, impulsivity, sustained attention and vigilance, the Conners CPT3 can be a useful tool to evaluate psychological and neurological conditions related to attention.

The results from the Conners CPT3 test showed no consistent differences in cognitive function before and after the life-raft expose. In orders words, a lowered core temperature did not have a negative effect on cognitive function in young healthy soldiers.

II.2.15 On the fitness of the rescued passengers

By Ulrik Wisløff, Norwegian University of Science and Technology (NTNU)

The male and female subjects had an average maximal oxygen uptake of 57 ml/kg/min (range 52-68) and 46 ml/kg/min (range 43-49), respectively. The average maximal oxygen uptake of this age group in Norway is about 55 and 45 ml/kg/min, for males and females, respectively. Thus the participants must be regarded as somewhat fitter than the average cruise boat passenger.

II.2.16 On the general health condition of the rescued passengers

By Eirik Skogvoll, Norwegian University of Science and Technology (NTNU)

Upon evacuation from the life-raft and lifeboat, all of the 34 participants were brought directly to the Hospital of *KV Svalbard* and subjected to a brief medical examination by the ship's doctor. This examination included assessment of mental status, measurement of core temperature (using bilateral infrared tympanometry, i.e. ear canal), blood pressure, oxygen saturation and heart rate.

In general, all subjects were alert and able to take care of themselves (including walking without support), although some were shivering. Shivering was in most cases reported to be triggered by the evacuation in open sea by the workboat. Most physiological measurements were within normal range; Fig. II–25 shows boxplots with median and quartiles (25/75 percentiles). While six participants had a measured core temperature at or below the conventional hypothermia threshold of 35°C (Fig. II–25: blue line), the lowest recorded ear temperature was 34.8 °C.

In conclusion, none of the participants were severely affected by hypothermia or showed other evidence of grave disturbances at the time they left the life-raft or lifeboat.

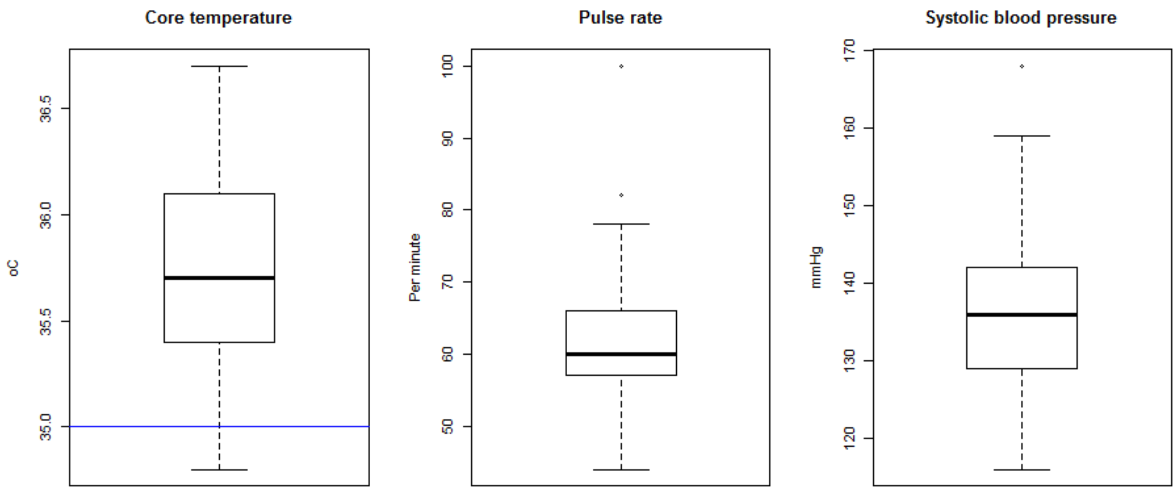

Fig. II–25: Core temperature, pulse rate and systolic blood pressure

II.2.17 Inspection of lifeboat survivors to plan the rescue operation

By: Pål Bratbak[1] and Adelheid Hopland[2]

[1] XO, *KV Svalbard*, [2] Medic, *KV Svalbard*

Background

KV Svalbard participated in the SARex from from 22nd to 29th April, 2016 during which one of the exercises was the evacuation of people from a lifeboat and the transportation of these to *KV Svalbard*, where they would be treated by medical personnel.

Planning phase

KV Svalbard received an emergency transmission from the Swedish passenger vessel Stockholm; it was reported that the vessel had taken in a lot of water and 38 of the 40 people onboard had been evacuated into a lifeboat. Two persons were missing. The captain also stated that four people were unconscious, three people had fractures and those remaining were at different stages of hypothermia.

From the exercise leader group on *KV Svalbard*, it was decided that the second in command onboard *KV Svalbard*, LT Pål Bratbak, should board the lifeboat and lead the evacuation of the people from Stockholm to *KV Svalbard*.

Bratbak began the detailed planning of the evacuation in conjunction with *KV Svalbard*'s medical team, led by LT Hallgeir Anuglen, and the two crews driving the Man-over-Board (MoB) boats. The following aspects were considered to have high priority:

- Evacuate the passengers with the worst injuries first. This covers unconscious passengers and those with serious injuries.
- Attempt to number everyone on his or her right hand with a black marker, indicating the seriousness of the injury. Serious injuries should be allotted the lowest number.
- Unconscious passengers and those with fractured bones should be evacuated on a stretcher.
- As medical support, one of the medics from *KV Svalbard*, Adelheid Hopland, should be a part of the boarding crew and handle the severely injured passengers, while LT Bratbak should lead the evacuation. Hopland is a trained nurse and has tape, splints, morphine spray, and fentanyl spray to reduce pain.
- Both MoB boats should be used in the evacuation.
- LT Bratbak to have communication with the medical team leader on *KV Svalbard* and with both MoB boats.
- LT Bratbak and Hopland to wear the coast guards' North Cape survival suit and safety helmets.

Initiating phase of evacuation – On the water

One of the MoB boats positioned itself away from the lifeboat to monitor the situation and also to have the option of rescuing passengers who might fall into the water. The other MoB boat positioned itself on the side of the lifeboat, and LT Bratbak boarded the lifeboat first to get an overview of the situation inside.

In the lifeboat

Except for a select few passengers, who were complaining and actively causing disturbance, most were calm and several were shaking from the cold. The passengers onboard the lifeboat were mostly wearing survival suits, with the exception of one passenger, just beside one of the lifeboat entrances, who had a very painful fractured thigh bone. As this passenger was lying just by the entrance and effectively blocking the way in, it was very difficult to get an overview of the medical condition of the passengers onboard. The passengers were sitting very close together, and it was impossible to get a stretcher inside until more passengers had been evacuated. We therefore started evacuating the passengers closest to the entrance, regardless of their medical condition. LT Bratbak was made aware of some unconscious passengers onboard. These were singled out and, with the help of other passengers in the lifeboat, evacuated to the MoB boat. The first MoB boat was filled with three unconscious and five conscious passengers, and, when sufficient space was available, Hopland entered the lifeboat with a stretcher. A dose of fentanyl spray was given to the passengers who were in serious pain, and the remaining unconscious passengers were positioned in a stable side position to ensure open airways. The passenger with the serious thighbone fracture was in extreme pain and was given two doses before the pain was relieved. This took approximately 20 minutes. Splinting the leg was very difficult, particularly due to the space restrictions inside the lifeboat. To stabilize the fracture sufficiently, prevent further injuries to the leg and prevent further bleeding, the patient was put on a stretcher and transported in the MoB boat to *KV Svalbard*.

In parallel, LT Bratbak started the evacuation of passengers from the other entrance (one on the starboard and one on the port side). The second MoB boat contained the last unconscious passenger and seven other passengers. Another passenger assisted those who had fractures in their hands or legs during the evacuation to the MoB boat and during the transit to *KV Svalbard*.

By the time the second MoB boat was filled, the first MoB boat had returned, and the evacuation continued immediately. A total of four trips were made with eight passengers and one with six passengers in order to evacuate all passengers from the *Stockholm*. In the final trip, LT Bratbak and Hopland joined the MoB boat, and the lifeboat was abandoned. The entire evacuation process took 42 minutes.

Experiences

The people on board *Stockholm* were effectively and quickly evacuated with the use of both MoB boats. It was very good to have the security of one MoB boat acting as a lookout in the initial phase. Once the situation had been evaluated, and it was clear that the passengers in the lifeboat remained calm, this MoB boat could also be utilized in the evacuation, which significantly increased the evacuation speed. Another passenger who was medically fit to provide assistance to others assisted the passengers who were unconscious or had injuries.

The original plan was deviated from in the following points:

- The marking of the passengers was quickly dropped. All passengers had mittens or gloves, had damp hands and the permanent marker did not stick to their hands. It was also difficult to use the assessment system due to the lack of space, and the survival suits made it difficult to assess any damage. At times, both MoB boats were used in the evacuation process.
- It quickly became clear that there was little advantage in evacuating the most injured or coldest passengers first, as the passengers were spread out throughout the lifeboat, and it proved difficult to accommodate more than three unconscious passengers at a time. However, continuous assessments of the medical condition of the passengers were conducted, and the passengers with the greatest medical needs were evacuated as quickly as practically possible. In this exercise, *KV Svalbard* was positioned very close by, so the impact of this was not very great, as all passengers were evacuated quite quickly. If the MoB boats had had to travel further to reach *KV Svalbard* or other assisting vessels, a lot more effort would have had to be put into a prioritized evacuation.
- The unconscious were not put on stretchers. This was decided as there was very limited space inside the lifeboat, and preparing a patient on the stretcher took a very long time. One of the

> passengers who had a serious fracture was prepared on the stretcher, something which was very demanding.

For LT Bratbak, who led the evacuation, it was vital to have Hopland as medically responsible, as she could focus on administering first aid to the most critical patients. The evacuation would also have been more difficult if the MoB boat crews had not been trained as well.

II.2.18 Reports to media throughout the SARex Svalbard North exercise

By: Lars Gunnar Dahle, University of Stavanger

Adopted the 27.07.2016 from:

http://www.uis.no/news/evacuation-in-the-arctic-put-to-the-test-article105738-8865.html

Evacuation in the Arctic put to the test

How long could you survive if you became shipwrecked during a cruise in the Arctic ice? In order to find some of the answers to this the Norwegian Coast Guard vessel *KV Svalbard* served as the home and workplace to a week-long research mission, headed by the University of Stavanger, to the remote archipelago of Spitzbergen - or Svalbard - which is its Norwegian name.

Fig. II–26: Testing the life raft in the fjord ice © Lars Gunnar Dahle

Fig. II–27: Lifeboat drill © Lars Gunnar Dahle

Fig. II–28: Bjarte Odin Kvamme, University of Stavanger © Lars Gunnar Dahle

Fig. II–29: Debrief in the hangar © Lars Gunnar Dahle

Fig. II–30: Hot dogs on cold ice © Lars Gunnar Dahle

Fig. II–31: A curious neighbor © Lars Gunnar Dahle

Fig. II–32: Ove Tobias in charge © Lars Gunnar Dahle

Fig. II–33: KV Svalbard is a powerhouse of a ship © Lars Gunnar Dahle

Fig. II–34: From Sørgattet, North-Western part of Svalbard © Lars Gunnar Dahle

Fig. II–36: Midnight sun dusk © Lars Gunnar Dahle

Fig. II–35: Ove Tobias Gudmestad (left), Ove Njå and Knut Espen Solberg in Woodfjorden on Svalbard during SARex2016 © Lars Gunnar Dahle

"The increase in cruise traffic in the polar regions in recent years is the backdrop to the mission, and a major shipwreck in the waters around Svalbard is a realistic scenario" says professor Ove Tobias Gudmestad from the Department of Mechanical and Structural Engineering and Materials Science at the University of Stavanger, which is responsible for the scientific part of the voyage.

Gudmestad is head of the exercise, which purpose is to evaluate parts of the IMO (International Maritime Organization) guidelines on operations in polar regions. According to these, on-board emergency equipment should be sufficient to help passengers and crew survive for at least five days while waiting for international rescue capacities.

Being realistic

In order to test the equipment that is currently in use, volunteers are left in a lifeboat and a life raft in the ice. Medical personnel supervise the study subjects, who are water-jetted back to the mother ship at their own request this or when instructed by the medical coordinator to break up.

Keep in mind that the exercise takes place at 79° 30′ N in the freezing waters of the Woodfjorden in North-Western part of Svalbard - out of satellite range and with armed guards constantly on the outlook for polar bears.

The research project is taking place under the auspices of the University of Stavanger in co-operation with NTNU (the Norwegian University of Science and Technology), the University of Tromsø, the Arctic University of Norway, St. Olav Hospital in Trondheim, a number of research institutions, the Norwegian Petroleum Safety Authority, the Norwegian Maritime Authority, the Norwegian Armed Forces, equipment suppliers and the oil company ENI Norge.

Pioneering work

"As far as I am aware, such a scientific approach to hypothermia in rafts or lifeboats in ice infested waters has never taken place before" says Gudmestad. Even at an early stage of the experiment, he notices that there are major benefits to imposing more stringent requirements to the equipment and procedures in order to reduce the risk of hypothermia and loss of life.

Gudmestad is very pleased with the co-operation between the many parties in the project and with the crew on *KV Svalbard*, who are also taking care of the safety of the expedition. Luckily the polar bears never came close to the exercise area, while a walrus in particular was very interested in the orange-clad creatures on the ice. Take notice that the walrus is the only animal that a polar bear actively avoids on its long wanderings in the Arctic.

Practical research

Professor Gudmestad is also taking part in the experiment himself and considers himself as the study subject that best represents the target group of the research expedition - mature cruise passengers. Like the other participants, he appreciates a hot shower and a good meal in the mess on *KV Svalbard* after a cold stay in the life boat.

"There has been far too little practical research aimed at maritime safety and rescue" says Gudmestad, who believes that the findings of the expedition will help make everyday life safer for more than just cruise passengers and ship crews.

Important information

UiS professor Ove Njå from the Department of Industrial Economics, Risk Management and Planning couldn't agree more. Njå also spent a day on board a cold and wet life raft. In addition to being a guinea pig himself, he has equipped the captains on the life boat and the raft with mini cameras that records everything that is happening on board.

"This gives us important information on how people cope with crisis situations and whether they change their behavior over time and when they start to develop hypothermia" Njå says.

Unique co-operation

Knut Espen Solberg, a PhD research fellow at the University of Stavanger, thinks that what will be learned from the Svalbard mission will help reduce the risk of shipwrecks and major accidents in polar waters.

"Having a group with a broad academic range and such a level of expertise work so closely together on search and rescue and survival in the Arctic is unique" he says.

Solberg normally works as an engineer for GMC Maritime AS in Stavanger. He has wide experience from Det Norske Veritas (DNV) and is responsible for the technical part of the programme at Svalbard, where winter has still not released its icy grip. Daytime temperatures vary between minus 10 and minus 15 degrees Celsius. On the other hand, the sun is not due to set until sometime in the autumn.

Catastrophic potential

"A shipwreck in this area, particularly during the winter months, could have a catastrophic outcome and would generate great demands on other vessels in the area and on the search and rescue workers" says Solberg, who is also familiar with the cold, icy waters of the Arctic from sailing trips and winters spent in Greenland.

"Hardly any research has been done on survival in the cold following a shipwreck, so our goal, therefore, is to get the answers ourselves from doing realistic research in the Arctic. Equipment suppliers, industry, the authorities and other research bodies all expressed interest in participating" says Solberg.

Arctic voluntary work

"The fact that The Norwegian Coast Guard made *KV Svalbard* available for the project was crucial for our mission" he says, full of praise for the way in which the voyage was conducted.

During the voyage, evacuation exercises were conducted with life rafts and lifeboat in different types of clothing and with different types of equipment. Medical personnel interviewed all the participants afterwards and the results will be applied in further research on survival in cold regions.

"Must work in the cold"

Bjarte Kvamme, a student at the Department of Mechanical and Structural Engineering and Materials Science at UiS, is doing a master's degree on the winterization of pipes and deck structures.

"Fire extinguishing equipment must work in all conditions and passengers and crew must be able to operate the equipment in temperatures below minus twenty degrees" he says, adding that this practical experiment is important for future studies in the Arctic.

The research expedition, also dubbed SARex2016 (SAR for search and rescue) is co-operating with the Maritime Forum of Norway's SARiNOR initiative, the objective of which is to improve the quality of the search and rescue capacity in the Arctic. The findings of the exercise will be presented at the International Association of Hydro Environment Engineering and Research Symposium in Michigan, USA, later this year.

Text and pictures: Lars Gunnar Dahle

Published 04/05/2016

Other media coverage:

http://forskning.no/turisme-sikkerhet-arktis/2016/05/forskarar-i-isen-skal-gje-tryggare-cruisetrafikk

http://phys.org/news/2016-05-evacuation-arctic.html

http://www.uarctic.org/events/congress-2016/science-section/sessions/5-2-arctic-tourism-29724/29922/

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II.3 Learnings from SARex 2016

II.3.1 Experiences following participation in SARex

By Erik Johan Landa[1] and Jan Erik Jensen[2]

[1] Norwegian Maritime Authority, [2] Petroleum Safety Authority Norway

Introduction

This memorandum is summarizing the experiences we had during SARex, held 22 – 29 April 2016.

Objective

SARex was a full-scale exercise that aimed to identify and explore the gaps between the functionality provided by existing SOLAS approved safety equipment and the functionality required by the Polar Code. This was done through an exercise conducted together with the Norwegian Coast Guard, leading experts from industry, governmental organizations and academia.

Methods

SARex was conducted north of Spitsbergen within sheltered areas with variable ice conditions. Air temperature around -10 °C and sea temperature around -1°C. The exercise was conducted with the aid of the coast guard vessel *KV Svalbard*.

The practical parts of the SARex was split into three phases:

1. survival in liferafts and lifeboat, where people was dressed up with different types of immersion suits, and lifejackets with thermal protection.
2. Mass evacuation from lifeboat to *KV Svalbard* involving personnel with different types of injuries.
3. Towing of life raft and lifeboat in areas with first year ice, paddling of life rafts in first year ice/slush, operation of lifeboats in ice condition, demonstration of personal survival equipment/group survival equipment, and evaluation of de-icing arrangements.

A HAZID/risk analysis was performed with all personnel taking part in the exercise involved. The exercise was coordinated and performed in a prudent and safe manner, by the support of naval personnel on board *KV Svalbard* and extra medical personnel.

Regulatory requirements

The functional requirements following the Polar code, which enters into force 01.01.2017, involves an increased demand to the lifesaving equipment placed on board vessels intended to operate in Polar areas as it amongst others, requires survival for at least 5 days.

Results and discussion

The practical exercises indicated a significant gap between the performances of available lifesaving/evacuation equipment and the requirements of the Polar Code. There were amongst others, issues concerning thermal protection and functionality of de-icing.

There are many challenges ahead related to design and optimization of life saving equipment and de-icing arrangements.

Lifesaving equipment

The personnel in this exercise was equipped with different type of life wests and survival suit combinations, i.e. standard life vests, naval life vests, uninsulated and insulated one-size-fits-all survival suits. There was, as expected, a major difference in performance between these types of equipment. Under any circumstances, we can assume that none of these types of equipment could sustain survival in the prevailing conditions experienced during this exercise.

Evacuation equipment

The life raft was a single bottom standard 25-person life raft. There were 20 persons in this raft. A capacity of 25 seemed unrealistic, but the design was in accordance to the IMO required 82,5 kg person average design basis.

The main challenge on board was handling the cold from the seawater (-1,5 °C) due to the single sheet being the only separation between the personnel on board and the seawater. It was a constant challenge to keep warmth, e.g. by moving and avoiding the cold at pressure points where the body was touching the bottom of the raft.

To increase the probability of survival it was also clear that sound leadership on board the raft is of the utmost importance. For instance, keeping track and order of all equipment on board (e.g. signal flares), food and water rations, being able to move to keep warmth and general practicalities.

We were not present in the lifeboat, so we need to refer to the main report for similar experiences related to lifeboat.

Personnel and group survival equipment

This equipment consisted of a variation of clothing and survival equipment of various quality and practicality, including a tent for six persons, which was a challenge to put together. The content of such survival kits and the quality of the various items selected needs to be thoroughly evaluated. Examples are torches without batteries and unpractical packaging on several items.

Conclusion

SARex has contributed to increase the understanding of the challenges that will be faced during operations of vessels under such harsh environment, and with valuable knowledge both for the industry and governmental bodies. The *industry* should be able to use the results to:

- further develop evacuation and lifesaving systems and equipment better adapted to the polar region
- choosing suitable lifesaving and evacuation systems/equipment by utilising best available technology on the market today
- training of personnel to lead the evacuation and survival period at sea

The *regulatory bodies* have gained experience to be used in further work related to implementation of the Polar Code. Overall, the experience should also prove useful for adapting regulations to other areas exposed to seasonal cold and harsh environmental conditions with relation to the functionality of life saving appliances and evacuation systems.

II.3.2 Relevance of the Svalbard SARex to the oil and gas industry in the Barents Sea

By Ove T. Gudmestad, Professor, University of Stavanger (2008 to date). Former Technical Advisor in Arctic Technology, Statoil ASA (1975 to 2008).

Search and rescue operations from exploration or production platforms are ensured by vessels in stand-by located near the platform. The Polar code does not apply for the oil and gas industry and the requirements of five-day survival in a life boat or raft may not be particularly relevant, as the preparedness for emergency scenarios are much higher compared to the cruise and shipping industry. Furthermore, the operations have, so far, been carried out closer to the shoreline where support vessels can reach from harbours to the offshore locations within hours, and helicopter availability is sufficiently high.

The new oil and gas licenses granted by the Ministry of Petroleum and Energy are located much further from the shore (for example at 74° 44’ N and 35° 89’E, up to 450km from shore). Therefore, the learnings from the Svalbard SARex could represent valuable information in case it would be necessary to evacuate vessels or helicopters along the route from shore to the field. It should be noted that seawater temperatures might be as low as 1 °C along parts of the route and that air temperatures could be as low as -30°C.

Assuming evacuation from a vessel, it may be assumed that lifeboats or rafts be readily available and that a rescue vessel could be on location within 24 hours. The stress on board a life raft after, say 6 hours might however be large, particularly when the seawater is very cold and in case the evacuees have been in the water without proper thermal survival suites. The following recommendations are made: Keep survival suits easily available, use life rafts with insulated bottoms and ensure rapid evacuation from the raft. If the personnel can escape in lifeboats, it is important that the lifeboat is winterized as discussed elsewhere in this report; with insulated seats and a proper heat generation unit. Personnel onboard the vessel will have the responsibility to take charge onboard the lifeboat or raft, as found in the exercise, the leader onboard the lifeboat or raft is important for the survival of the evacuees.

In case of evacuation from a helicopter, it could be assumed that all personnel are wearing standard protection suites and that life rafts are available. The conditions on board the lifeboat could however be stressful with some persons losing temperature quickly. The rafts should, therefore implement the suggestions of the exercise.

Disclaimer: One person from the petroleum industry (representing ENI Norge AS), and one person with long experience from the petroleum industry participated in the SARex Spitzbergen. Gudmestad is the author of this brief report and all statements are given in his own capacity and might not represent the view of the oil and gas industry or the University of Stavanger.

II.3.3 Recommendations from the medical support team

By Svein Erik Gaustad[1], Ulrik Wisløff[1], Eirik Skogvoll[1] and Gunnar Vangberg[2]

[1] Norwegian University of Science and Technology (NTNU), [2] St. Olav's Hospital in Trondheim / Norwegian Armed Forces

Optimal function of the human body requires a body temperature maintained within narrow temperature limits, with a core temperature of approximately 36.5 °C. In cold temperatures, an initial physiological response to reduce heat loss is reduction of blood flow (vasoconstriction) to the peripheral parts of the body. If core temperature drops to about 35 °C, heat production through shivering will occur to prevent further drop in core temperature. If core temperature falls below 35°C, subjects are defined as hypothermic.

To maintain a stable core temperature, heat production must equal heat loss. In cold conditions there may be mismatch between heat production and heat loss and the factors responsible for heat loss are:

- Conduction: Heat is lost from the body to the surroundings that are in direct contact with the body's surface. Air conducts heat poorly, while solids objects conduct better depending on the material. Additionally, water conducts heat much better that air, where the body loses heat 20-30 times faster in water than air.
- Convection: Heat is lost by movement of air or water close to the shin. In air, conduction is influenced by wind speed, where increasing wind increases the heat loss. This is named the wind chill factor.
- Radiation: All objects emit heat in the form of electromagnetic waves to colder surfaces. The rate of emission is determined by the temperature of the radiating surface.
- Evaporation: When water evaporates, the transition from water to gas requires energy. In cold, most evaporative heat loss is through respiration.

When constructing clothes and emergency life rafts/boats for Arctic conditions, all the four abovementioned ways of heat loss must be taken into account. According to the Polar Code, lifeboats/rafts and thermal protection should be designed for survival up to 5 days. In SARex, thermal protective aid with different insulation properties was verified during stay in both lifeboat and life-raft for up to 24 hours. In both lifeboat and life-raft, subjects dressed in minimal thermal protection (Kampvest) withdrew due to cold and discomfort significantly faster that subjects dressed in best available thermal protection during SARex (insulated survival suit, SSliner). A key element to reduce heat loss is to minimize the temperature difference between skin and the surroundings (radiation). In the insulated survival suit, the temperature difference between the surface of the suit and the surroundings will be smaller than an uninsulated, thus insulated suit will reduce heat loss through reduced radiation. However, heat loss in subjects dressed in SSliner in lift-raft versus lifeboat showed significant greater heat loss. In the life boat, the thermal protection properties of SSliner seemed to be adequate for a 24 hour stay in the lifeboat without evidence of discomfort nor of overt hypothermia, while all subjects in the life-raft withdrew within 24 hours. The increased heat loss in the life-raft was most likely due to conduction from the bottom/floor as the subjects reported that areas exposed to the floor/bottom became cold. To reduce the conduction heat loss from the floor, the life-raft floor should be better insulated. In addition, there may have been some heat loss due to moist building up in the life-raft and life boat, whereas convection was minimal since both the life-raft and life boat was totally enclosed.

In conclusion, our observations suggest that subjects dressed even in the best available thermal protection (here: SSliner) would probably not survive 5 days in a life-raft at a sea temperature of -1.5°C and ambient temperature of -10°C due to cold stress and hypothermia development. On the other hand, it is possible that subjects may survive for 5 days in a life boat if dressed in SSliner – this however remains a speculation as the observation period was limited to 24 hours. It is worth mentioning that our test subjects were young and healthy, in contrast to the average cruise ship passenger. Based on the known relation between fitness and tolerance to cold, the average older and less fit cruise passenger would suffer from discomfort and hypothermia faster than our study subjects. Our recommendation is that ships should be equipped with lifeboats rather that life-rafts and that all ships should bring insulated survival suits in appropriate sizes.

II.3.4 The Polar code – the issue of training and exercises

By Odd Jarl Borch[1] and Johannes Schmied[1]

[1] Nord University

As previously discussed, the Polar Code covers all shipping-related subjects and shall provide additional requirements for marine vessel operations in polar waters. This means that ice-strengthened vessels as well as those intended to operate in ice need to comply with the Polar Code in addition to the other regulations within the STCW, SOLAS and MARPOL conventions of the International Maritime Organization (IMO). This also includes safety measures, safety equipment, and search and rescue (SAR) competence.

The greatest share of the Polar Code defines specifications for technical capabilities and norms of the vessel, design and equipment. Yet, proper education as well as correct training in maritime operations and the use of all equipment is an important factor as to SAR-preparedness. This includes efficient and effective use of all available measures in order to prevent incidents but also to mitigate the negative outcomes through competent action during all phases of a SAR-operation.

In the aforementioned context three chapters from the Polar Code need to be highlighted here:

THE POLAR WATER OPERATIONAL MANUAL (PWOM)

Polar operating ships are required to handle a Polar Water Operational Manual which contains sufficient information on capabilities and limitations of the vessel (Chapter 2). This operational manual shall provide guidance and preparation for owner, operator, master and crew. Important elements within this manual are procedures based on risk assessments for:

- Ice avoidance
- Receiving of weather/environment forecasts
- Limitation of available information
- Operation of equipment
- Special measures to maintain equipment and system under cold temperatures and ice conditions
- Contacting emergency response providers (incl. SAR)
- Maintaining life support for extended time periods

Appendix 2 of the Polar Code provides a model set up for the Polar Water Operational Manual (PWOM). It becomes clear that its aim is to increase overall preparedness and risk mitigating measures and to define crew-actions and procedures to do so. From a SAR-perspective particularly Division 3 on risk management should be highlighted. Its chapters are on *"Risk mitigation in limiting environmental condition", "Emergency response, Coordination with emergency response services"* and *"Procedures for maintaining life support and ship integrity in the event of prolonged entrapment by ice".*

When considering the demand of the Polar Code for five-day survival time in case of an emergency especially *"Procedures for maintaining life support and ship integrity in the event of prolonged entrapment by ice"* should receive special focus. The demand for five-day survival capacity in the case of ship evacuation represents a very challenging task that need special competence, not the least of handling crowded life boats and life rafts in very demanding environments.

LIFE SAVING APPLIANCES AND ARRANGEMENTS

This chapter 8 highlights, that it is mandatory to be prepared for cold climate, expected time of rescue (never less than 5 days), additional protection for all persons, and that the ship is adequately prepared for evacuation in icy waters.

The safety crew of the vessel needs to be prepared to be ready in the case of escape-, evacuation- and different survival- scenarios in sea using survival equipment. This includes particularly highlighted training requirements such as:

- *"Passengers shall be instructed in the use of the personal survival equipment and the action to take in an emergency; and*
- *The crew shall be trained in the use of the personal survival equipment and group survival equipment."*

These two points highlight not only handling the personal equipment itself. They are also focusing on instruction of people in distress on proper actions during the emergency. The key aspect here is handling the group survival equipment including emergency radio equipment, first aid kits, food supplies, MOB-boats, life rafts and life boats.

MANNING AND TRAINING

Chapter 12 has direct SAR-training implications. It seeks to ensure that ships operating in polar waters are manned by appropriately educated and trained people who have the necessary experience. Masters, chief mates and officers are required to have completed training according to the STCW Convention. A small number of specifications and exemptions are given. This table taken from the Polar Code provides overview on the training requirements:

Tab. II-7: Crew training requirements for Polar code waters

Ice Conditions	Ship Type		
	Tankers	Passenger Ships	Others
Ice free (ice free of any kind)	Not applicable	Not applicable	Not applicable
Open waters (large area of freely navigable water where sea ice is present to less than 10%; not from ice of land origin)	Basic training for master, chief mate and officers in charge of navigational watch	Basic training for master, chief mate and officers in charge of navigational watch	Not applicable
Other waters (ice concentrations over 10% or glacial ice, ice bergs and bergy bits present)	Advanced training for master and chief mate. Basic training for officers in charge of a navigational watch	Advanced training for master and chief mate. Basic training for officers in charge of a navigational watch	Advanced training for master and chief mate. Basic training for officers in charge of a navigational watch

Among the extra requirements chapter 12.3.4. should be highlighted:

"Every crew member shall be made familiar with the procedures and equipment contained or referenced in the PWOM relevant to their assigned duties."

This chapter increases the importance of the operational manual and in consequence also calls for measures such as training and exercises so the crew is actually capable of following their responsibilities according to the manual also in SAR contingencies.

REFLECTIONS CONCERNING THE PRESENTED CHAPTERS OF THE POLAR CODE

PWOM:

A manual is an important tool to mitigate risks, however it may only be seen as an additional means. Proper education and on-board training may not be replaced and are most important to provide safe operations.

LIFE SAVING APPLIANCES AND ARRANGEMENTS:

The points presented in this chapter are crucial in order to ensure that equipment and appliances are used in the right way and as efficiently as possible. To secure this, there may be two ways that should be used:

1. Training courses at academies
2. On board training by ship officers that have passed the IMO Train the Trainer (TTT) course

The latter here is to make sure that new crew members will also get proper skills taught, in order to meet the challenges of safe operation in polar waters. This may obviously especially be an issue as to safe handling of emergencies.

MANNING AND TRAINING:

The chapter only mentions masters, chief mates and officers when it comes to training according to the STCW convention.

It may be crucial that all safety crew obtain the skills that are needed beyond of what is required by chapter 12.3.4 on familiarization concerning the PWOM. Familiarization with procedures and equipment may not be sufficient to provide all necessary skills to secure safe operation. Furthermore, all crew members – and this includes the whole range from engine-officers, via ratings to catering-staff may end up in situations where they are forced to make independent decisions and should have some relevant training.

In an Arctic context, the use of firearms may also be an issue.

With respect to the table on training requirements depending on the ice-conditions there is some concern. Experience from these waters is that ice-conditions may changer very rapidly. This means, that time from open waters to various densities of ice may be extremely short. The approach should be to always prepare for the “worst possible condition” to ensure safety and restrict unexpected incidents.

II.3.5 Implications for SAR relevant competence development

By Odd Jarl Borch[1] and Johannes Schmied[1]

[1] Nord University

As noticed, there are several areas where the Polar Code or its consequences will require specific action and development of competence. In the following, the most important areas where these specific competences should be established are listed on the basis of the "value-chain" of a SAR-operation. The chain includes escape and evacuation, survival at sea and rescue, including thorough knowledge of the vessel's SAR contingency plan.

A. SAR contingency planning

- Development and knowledge of the polar operational plan contents
- Preparedness through thorough polar context description (ice maps, weather data)
- Preparation and establishment as well as training, exercising etc. with proper rescue equipment (personal, life rafts/boats)
- Designing, application and training of evacuation plans
- Training and exercises to improve interaction, increase efficiency and raise awareness of all stakeholders and personnel
- Design, update and rehearsal of SAR contingency plan with clear procedures

B. Evacuation from distress vessels

- Steady improvement and establishment of evacuation plan adjustments and implementation
- Create competence of appropriate design and selection of life rafts and life boats to be used
- Equipping life rafts and life boats with necessary tools for survival as well as create competence on their use
- Correct procedures of alarming and checking out quarters and cabins as part of the evacuation plans
- Management of the passengers and crew lines and keeping overview at the mustering stations

C. Survival at sea

- Develop and train leadership roles on board and increase awareness on the important skills needed
- Checking health status and taking care of each evacuee
- Activating people to keep body temperature and motivation up
- Management of water and food as well as organization of waste and additional resources
- Communication with other life boats/rafts
- Communication with rescue units

D. Rescue phase

- Development as well as following procedures according to rescue plan and check list including all SAR-stakeholders
- Management and preparedness for on-scene coordination of rescue units
- Situational adaptation of previously trained activities on search for survivals

- Communication with life boats and life rafts in order to share and use information on evacuated persons
- Have the competence and capabilities to perform triage (making priority) both within life boats and life rafts (people in distress) as well as triage from MOB boats (triage of rafts in distress) etc.
- Proper medical treatment and safe transfer of rescued persons from raft/life boat on board rescue vessel
- Receiving rescued persons from rescue-helicopter onto the ship, stations etc.
- Performing health triage with the rescued persons in the established medical facilities
- Treatment of wounded persons, potentially under stress conditions
- Outbound logistics to the mainland hospital

New course recommendations

The challenges outlined above with emphasis on the different parts of the SAR value chain call for a broader range of training efforts than the ones mentioned in the IMO model course. In consideration of the educational requirements mentioned in the Polar Code as well as the previously discussed in-depth competence needs along the "value chain" of SAR-operations the following IMO courses have been revised and were complemented with additional Polar code training modules:

1. All safety crew on board distress vessels

All members of the safety crew need to have the IMO Safety Course at operational level. Also it needs to be discussed, that all other crew members should also have at least a basic-safety education. For passenger ships an additional Crowd and Crises Management course is required. For both these courses, there is a need for additional modules:

- **Polar code operational level safety course module** on escape/evacuation, use of collective rescue equipment, lifeboat/raft management and rescue processes in icy waters
- **Polar code crowd and crisis additional module** on taking care of a broad range of passengers (young, old, weak and sick passengers) within life rafts/life boats in icy water

2. Officers on board vessels in distress

According to the STCW-convention and the Polar Code the deck officers on board need the following training:

- IMO Safety course at management level
- IMO Polar code navigator course
- IMO Polar code master course

This training should not be exclusive for deck officers. The engine officers play a vital role in the operation of ships, not the least in polar waters. Therefore, there should be a basic and advanced course for chief engineers and 1st engineers on board vessels in polar waters. In addition, for passenger ships with many passengers on board, there are special considerations to be taken as to evacuation in polar regions. Therefore, an additional course in polar water mass rescue operations should be available for officers.

We are therefore in need of the following additional courses:

- **Basic and advanced Polar Code course for chief engineers and 1st engineers**
    - should include polar water risk assessment of technical systems and taking care of collective rescue equipment such as life boats, MOB boats in cold climate

- **Polar code Mass rescue operation safety course**
  - should include alternative escape routes, large crowd management, improvisation management in different emergency situations
- **IMO Safety course at management level additional modules:**
  - evacuation, survival at sea and rescue operations in polar waters
  - Polar region contingency planning for SAR operations in polar waters

3. Masters and navigators onboard rescue vessels

Taking part in a search and rescue operation in polar waters is a very challenging task for masters and navigators. One of the polar water rescue challenges may be that the role and potential support by samaritan vessels has not been stressed within the Polar code. For example, limitations in the GMDSS-radio communication capacities create an extra need for improvisation and calls for less directions from the SAR mission coordinator.

With limited professional capacity in polar waters, even smaller vessels may have to serve as on-scene-coordinators (OSC) on behalf of the SAR mission coordinator. The OSC-role is given only a superficial place in the traditional GMDSS-training. Additional polar water modules should therefore be included in the GMDSS-course. Limited basic training is also the case for the IMO medical course. There is a need for special training in medical issues related to cold climate conditions, especially as the crew and passengers may be stuck in icy waters for several days.

Therefore, the following modules should be added to the IMO courses for deck officers:

- **GMDSS course additional modules**
  - Polar Code additional module on OSC (On scene coordinator) / ACO-air coordinator roles
- **IMO Polar Code additional medical course**
  - Frost wounds, hypothermia, triage and emergency logistics

Conclusions

The polar water SAR context calls for additional training efforts. The demands have to be followed up by both specialized courses and additional modules included in the IMO courses for officers and safety crew. The courses have to provide knowledge covering the whole search and rescue value chain including both vessels in distress, “samaritan” vessels and vessels serving as on-scene coordinators. It is important that the training includes all key personnel of the vessels. In the present Polar Code, the key role of the engineers has been ignored. However, both the ship owners and the coastal states should provide additional courses for all their officers and crew. In polar waters, the SAR capacities are limited. Mass rescue situations will therefore call for a lot of improvisation. For larger passenger vessels as well as professional SAR operators such as the Coast Guard, additional training efforts should be directed towards mass evacuation operations.

II.3.6 On risk reduction of cruise traffic in polar waters

By Ove T. Gudmestad, University of Stavanger

During SARex Svalbard, we have investigated the mitigation of consequences of the evacuation from a cruise ship in polar waters: the subsequent stay and survival in lifeboats and life rafts, the rescue operation and the handling of rescued persons onboard the rescuing vessel. We have in particular assessed the requirements of the Polar Code, coming into force from January 2017.

From a high level perspective successful rescue of casualties depend on two actions:

1. Survival in the rescue crafts until arrival of SAR infrastructure
2. Availability of SAR infrastructure.

The Polar Code requirements with regards to life saving appliances has the potential to improve the probability for survival in the rescue craft when being fully implemented. However, other aspects of the risk of traversing in polar waters should be investigated as well;

- the probability of a cruise ship with a large number of passengers running into severe problems in polar conditions/ remote locations, necessitating evacuation

Risk reducing measures could be evaluated qualitatively or quantitatively, possibly leading to implementation of new international requirements. While the international Law of the Sea have few restrictions related to voyages in international waters, some suggestions to future discussions are presented. Most of these suggestions have already been discussed amongst international experts; the author would however like to finalize this report by presenting the suggestions considered to be best suited to reduce the risk of incidents in polar waters:

Increased requirements for training

- For evacuation, search and rescue of persons leaving a vessel in distress, experience and training are particularly important. These factors may be even more important in polar waters, in particular for cruise vessels hosting a large number of passengers, many of them not particularly mobile due to age. The authorities should require ***special certificates documenting training*** in polar waters for key persons, which could be involved in the evacuation of a vessel under the Polar Code.

Design of equipment

- Standard life saving appliances approved by SOLAS does not provide adequate protection along the lines defined in the IMO Polar Code. It is difficult for the Flag State or classification societies to implement requirements that is impossible to fulfill utilizing standard technology. Further work is required to develop technology that enables a minimum of 5 days survival time.

Limit the number of passengers onboard a cruise vessel in polar waters

- The exercise showed that evacuees residing in life rafts would be highly uncomfortable after 12 hours onboard in subzero temperatures. For evacuees in lifeboats, they are likely to struggle after a 24-48 hours. As a minimum it is to be expected that the capacity of all lifesaving appliances is down rated to accommodate both survivors and survival equipment.

- It is important to note that even with the capacity and capability of a well-equipped SAR vessel like *KV Svalbard*, there is a limit of around 800-1000 persons that could be brought onboard the vessel. The number of heavily injured casualties the vessel is able to rescue is considerably less. As a result, we are recommending that ***any cruise vessels leaving for distant locations in polar waters should have a limited number of persons (staff and passengers) onboard*.**

Availability of rescue vessel

- Availability of SAR infrastructure is a political question. The Ilulissat Declaration states that all parties are to cooperate across national borders in a SAR scenario. It does however not state any minimum requirements with regards to availability of SAR infrastructure or response time. The availability of SAR vessels in polar waters is scarce and the travel distance from the location of the incident to where the SAR vessel is located is potentially very long, and could be further restricted due to bad weather. The availability of a large capacity vessel with performance characteristics like the *KV Svalbard* (ice going, high speed, high capacity, well-equipped, well-trained staff, etc.) should be considered: ***Norwegian authorities should consider stationing a suitable SAR vessel in the area around Svalbard during the cruise vessel season*.**
- Cruise vessels travelling together represent a huge potential for assisting each other and authorities should consider requiring that ***cruise vessels travel together***, never being located more than a certain distance (in time) from each other. Such requirement would potentially represent an extremely efficient SAR capacity.
- The ice limit is retracting northwards and the waters in-between the islands get ice-free. This situation represents a dangerous situation where grounding could occur in unchartered waters. In case of hitting underwater reefs, the vessel could quickly start to heel, representing the danger that evacuation becomes very difficult. ***The authorities might therefore consider limiting the free movement of cruise vessels to chartered waters only***.

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