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by

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Abstract

This report presents an overview of the issues related to the safe evacuation of personnel from offshore structures in ice-covered waters. The report discusses and evaluates the various approaches that have been used, or are being planned for use, on different platform structures in ice-covered waters. The report examines and classifies different evacuation scenarios and systems, reviews existing experiences from various ice-covered regions around the world, and identifies gaps where research and development could improve the safety of evacuation systems.

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1.0 Introduction

Safe emergency evacuation of personnel from offshore structures and vessels is of critical importance in the event of a major onboard problem. In addition to the issue of specific evacuation systems and their capabilities, the question of safe evacuation also involves the procedures and training that are necessary for personnel to systematically respond in emergency situations, and a clear understanding of the range of environmental situations that may be met

Various evacuation approaches have been developed for the offshore structures deployed in Canada’s frontier waters and in other parts of the world. In areas like the Beaufort Sea, the offshore Sakhalin region and the Caspian Sea, evacuation systems have necessarily been configured to deal with different emergency situations in both ice and open water conditions. Although it is not commonly stated, many practitioners recognize that most of these evacuation systems do have some limitations, depending on the specific conditions encountered. This is particularly true for offshore structures operating in ice.

There has been some R&D work done on improving evacuation from offshore platforms in open waters, but there have been few recent initiatives involving personnel evacuation from structures in ice conditions. With the exception of the ARKTOS escape vehicle, open water evacuation systems have generally been adapted (or accepted) for use in ice-covered waters. Evacuation in ice raises a number of different issues when compared to evacuation onto open water. In Canada’s frontier waters and in other ice-infested regions of the world, a wide range of ice conditions, ice dynamics, and “structure dependent ice interaction behaviours” can be seen at any particular point in time. Because of this, safe evacuation approaches must be capable of accommodating a full spectrum of different ice situations, which are often complicated by environmental factors such as low air and sea temperatures, blowing snow and icing.

Recognizing some of the present limitations, the National Research Council (NRC) and the Program of Energy Research and Development (PERD) have initiated work to evaluate emergency evacuation systems in ice-covered waters. The purpose of this work is to examine and classify different evacuation scenarios and systems, to review existing experiences from various ice-covered regions around the world, and to identify gaps where research and development could improve the safety of evacuation systems.

NRC has contracted B. Wright & Associates Ltd. to assist them with this evaluation work, with input from Capt. P. Dunderdale of Nobel Denton Canada Ltd. and M. Smith of PetroGlobe (Canada) Ltd. In this report, the results of the work are presented, with a good deal of the emphasis placed on the practical aspects of emergency evacuation from structures and vessels in ice-covered waters.

2.0 Objectives & Approach

The main objective of this work is to evaluate the expected performance of emergency evacuation systems in offshore regions where floating ice is present, and to identify any improvements that may be warranted.

More specific objectives of the work are:

- to review past and current experiences with evacuation systems in different ice- covered areas
- to examine and classify different “in-ice” evacuation scenarios and systems
- to identify gaps where research and development could help to improve the safety of evacuation systems for offshore areas where floating ice is present

The approach that was taken was subdivided into the following key tasks.

- gathering, organizing and classifying relevant information on emergency evacuation systems that have been used, are being used, or are being planned for use in various ice-infested regions
- identifying any potential problems areas or deficiencies in the use of these evacuation systems, given the wide range of emergency situations and ice scenarios that can be expected
- outlining the type of research and development initiatives that are needed to improve the safety and effectiveness of emergency evacuation systems in ice-covered waters, with the primary focus on Canada’s offshore frontiers, including the Grand Banks and northern Canada

The results are presented in subsequent sections of this report, with the various report sections sequentially organized along the lines of the key study tasks. However, some background information and general material about evacuation systems is given first, as a preface to the remainder of the discussion. This basic background material is provided in the next two sections of the report and is intended to provide some initial perspectives on the problem area.

3.0 Background

3.1 General

Although safe evacuation from offshore structures and vessels has always been an issue of concern, it has become an increasingly important consideration over the past decade or two, particularly for exploration and production platforms. Interest in both the evacuation topic area and in evacuation technology has become much stronger, given the realities of the major accidents that have been seen with offshore structures, where life was lost. One example is the Ocean Ranger, which was a semi-submersible used for offshore drilling on the Grand Banks in the late 1970s and early 1980s. This vessel sank during severe wave conditions in 1982, with more than 80 onboard workers perishing at sea. Another key example is the Piper Alpha, a bottom founded production platform that was lost in the North Sea in 1988. This offshore disaster was caused by a gas explosion on the structure, followed by a major fire, then a collapse of the platform (Figure 3.1). In this case, almost 200 workers lost their lives. Unfortunately, there are more examples of offshore accidents in which people have perished, but they are not highlighted here. It is noteworthy that all of the major accidents have occurred in open water situations, with the exception of the Titanic, which sank in the iceberg-infested waters of the Grand Banks.

In the recent past, most major companies have created sizable departments that deal with a wide range of Health, Safety and Environment (HSE) issues. In companies involved with offshore exploration, development and/or shipping activities, these HSE groups are generally responsible for designing and implementing appropriate emergency escape, evacuation and rescue (EER) systems for particular operations. The EER systems and procedures that are developed are then handed over to the personnel who operate offshore structures and vessels for subsequent use, on an as-required basis. Training of onboard staff, periodic evacuation drills, and routine safety audits are all part of this process.

As the question of safe evacuation from offshore facilities has risen in profile, there has also been a resurgence of interest in oil and gas activities in ice-infested regions. Recent development projects on the Grand Banks, in the Alaskan Beaufort Sea, in the offshore Sakhalin area, and in the Caspian Sea are all examples of this. New plans for exploratory drilling in the Canadian Beaufort and year round shipping to Voisey Bay are additional examples. Over the past few years, most of the resources that have been directed towards advances in the EER topic area have focused on open water technologies. Clearly, the open water consideration is by no means straightforward, and ongoing improvements are required. However, it seems that any significant efforts to improve evacuation approaches for ice-covered areas have not kept pace. In this regard, few new evacuation systems have been designed and "purpose built" for in-ice applications, nor systematically evaluated and tested in different ice situations.

Figure 3.1: In June of 1988, a major explosion and fire occurred on the Piper Alpha, a production platform that was operating in the North Sea. The platform was destroyed, with 167 of the 230 workers onboard losing their lives.

3.2 Considerations

Any evacuation system that is developed for use on an offshore structure or vessel should be capable of moving all onboard personnel "out of harms way" in the unlikely event a significant problem is encountered. The evacuation of personnel should be achieved in a timely and orderly manner, without a high potential for injury to anyone. The evacuation system should also be capable of moving people away from the problem to a location of temporary safety, then on to complete safety.

In moving through the basic logic of an evacuation, there are a number of considerations that are fundamental. They are:

- the particulars of the structure or vessel, including:
  - its geometry, dimensions and freeboard
  - its function (drilling, production, transportation, etc.)
  - the number of people that are onboard
  - facilities layouts and egress routes on the structure
  - muster and temporary refuge areas on the structure
- the range of causal problems that can be encountered, including:
  - major explosions and major fires
  - toxic gas releases and oil or gas blowouts (recognizing the possibility of H_2S)
  - loss of stability due to ship collisions.
  - loss of stability due to extreme ice events, storm waves, earthquakes, etc.
  - loss of stability due to unexpected structural failure, equipment malfunction, etc.
- the range of environmental situations in which evacuation may be required, including:
  - various wind and wave conditions, from benign to extreme
  - various visibility, air and sea temperature conditions, also from benign to extreme
  - various icing events and heavy snowfall situations that may occur
  - various ice conditions, from low to high concentrations, thin to thick ice, broken to unbroken ice floes, and stationary to highly dynamic ice movement situations
  - the types of ice/structure interaction behaviours that may be seen adjacent to the structure or vessel (for example, crushing, flexure, large scale fractures, downdrift wakes, grounded or floating ice rubble, etc.)
  - various combinations of wind, sea, ice and other weather conditions (for example, broken ice floes in large swells)
- the logistics systems that may be available to support any required evacuations from the structure or vessel, including:
  - the presence of a standby vessel
  - other structures or vessels operating in the general area
  - distances to support bases, heliports and airfields, etc.

- the range of on-site factors that can become very important when an evacuation may actually be required, including:

  - the amount of time that is available to react to a particular emergency situation
  - the interruption of loss of communication systems to summon assistance
  - the capability of support vessels that may be called on for assistance, for example, their maneuvering and stationkeeping abilities in ice
  - potential lack of training and experience of personnel in the use of and problems associated with specific evacuation systems, particularly in low temperatures
  - miscommunication during the evacuation process for various reasons, for example language problems with multi-national crews

All of these considerations should be recognized when different evacuation approaches are being evaluated. The most appropriate evacuation system for a particular structure or vessel must be capable of functioning effectively and reliably, while accommodating all of the foregoing factors. In most cases, a variety of evacuation options will be needed to satisfy the full spectrum of possible "problem scenarios", moreso in offshore regions that are subjected to ice, as well as open water conditions.

3.3 Recent Efforts

Over the past few years, there have been a number of initiatives within both industry and government to improve evacuation methods for offshore platforms and vessels and also, to raise awareness about the overall topic area. As noted earlier, most of these efforts have focused on improving EER systems in adverse open water situations, primarily with a view to production operations on the Grand Banks and Scotian Shelf.

At this stage, several recent "streams of activity" are highlighted, to provide the reader with a feel for some recent work of relevance.

NRC Database

The National Research Council of Canada has produced a database on "Offshore Escape, Evacuation and Rescue" that is available on the web at http://www.nrc.ca/imd/eer/home. NRC has undertaken this database development in conjunction with Transport Canada, Natural Resources Canada, and the Canadian Association of Petroleum Producers, as part of a larger collaborative effort between industry and some government departments into the EER topic area. The web site contains a large number of relevant reports, papers and references, many of which can be obtained from the NRC Canada Institute for Scientific and Technical Information (CISTI).

Transport Canada Studies

Transport Canada has supported a considerable range of studies related to safety systems, survival craft and personnel survival equipment for vessels operating in Arctic offshore conditions. A number of these studies, conducted by Canarctic and Melville Shipping in the 1980s and early 1990s, involved field tests of equipment in low temperatures and ice. These are listed in the Bibliography. The 1987 Report published by the Prairie and Northern Region, Marine of Transport Canada entitled "Cold Weather Marine Survival Guide" is especially useful.

It collates the results of the research into a readable manual that provides good guidance on the key issues and approaches that can be used for survival in the Arctic.

Arctic Shipping Guidelines

The International Maritime Organization is currently finalizing the "The Arctic Shipping Guidelines" (which was previously known as the Polar Code). Excerpts from these guidelines that are relevant to the issue of personnel evacuation from vessels in Arctic ice and open water conditions are given in Appendix A.

Bercha Studies

The Bercha Group, in association with a number of operating and safety companies, has developed a methodology to analytically model the EER process on offshore platforms and vessels, and probabilistically assess expected levels of "risk and performance". There are many elements to this work that have been described in detail in various reports and papers (Bercha 2000; Bercha et al. 2001). The analysis method has been applied to several evacuation scenarios in ice and, depending upon the assumptions made, suggests that a reasonable capability now exists (ie: relatively good performance of evacuation methods and fairly low risk to personnel). However, to date, the details about actually moving people off a platform and safely away in a variety of realistic ice situations have only been treated in a heuristic manner.

A significant outgrowth of the Bercha studies has been to "move along" the development of performance based EER standards for the Canadian East Coast oil and gas industry. These standards are currently being discussed in a task force setting, and a first working draft has recently been issued. This draft material is well worth reviewing, since it covers all pertinent aspects of the EER consideration for most East Coast situations.

Because of its relevance, the draft standard is included in Appendix B in its entirety. It is noteworthy, however, that there is no explicit mention of in-ice evacuation issues in this draft. Although the material it contains is appropriate for most of the environmental conditions seen in the current area of development on Canada's East Coast, it does not address the type of EER situations where pack ice conditions may be present.

Clearly, this draft should be recognized as potentially "precedent setting" for operations in the ice-covered waters lying further to the north of the Grand Banks region in Canada, and elsewhere. In this draft, some thought should be given to including a disclaimer that recognizes evacuation procedures and methods in ice conditions may necessarily require "different standard prescriptions".

Fleet Technology "Sheba" Facility

BMT Fleet Technology Limited has developed a computer simulation tool for ship evacuation that will allow users to explore beyond the cases that can be examined in controlled evacuation trials. This model allows comparison of evacuation arrangements at the ship design stage, and can be used to assist with determining the optimum layout of facilities, location of lifeboats, and even crew/passenger ratios. In order to collect data on the mobility of people moving along typical ship's passageways and up stairs, on the level and at an angle of heel, Fleet Technology have built a test rig in their Kanata, Ontario laboratory. The Ship Evacuation Behaviour Assessment Facility – SHEBA, comprises a cabin, passageway and a stair mounted on hydraulic rams that can tilt the rig to 20 degrees. Cameras and optical sensors time people moving along the rig, and this data is analyzed in a variety of ways in order to assess the role that human factors plays in both emergency evacuations and non-emergency traffic movement onboard ships.

CAPP Studies

The Canadian Association of Petroleum Producers (CAPP) has commissioned a three-part technical research study into East Coast offshore marine evacuation systems. Two parts of this CAPP study have been completed which deal with conventional lifeboat evacuation technology. The third part of the study which focusing on the freefall lifeboat technologies now in use on the Canada' East Coast is currently underway. While this work remains proprietary to CAPP, it should be noted that the performance of lifeboats and associated launching and recovery technologies in sea ice is not part of the study's focus. CAPP is also supporting the Performance Based Standards for offshore evacuation on Canada's East Coast that was highlighted above. Furthermore, CAPP is committed to personnel safety, and appears to be willing to be involved in important initiatives.

Industry Studies

As the foregoing work efforts have been progressing, certain oil and gas companies have been in the process of addressing different EER considerations, and putting specific evacuation plans and systems into place in reality. Of particular relevance are some the international operators who are now involved with developments in "truly ice-infested regions" such as the Alaskan Beaufort Sea, the Caspian Sea and the offshore Sakhalin region. These companies have all conducted technology and system evaluations, and are necessarily proceeding as they see fit. The EER approaches that they have been or are currently putting in place are felt to be reasonable, but all companies recognize that future improvements are warranted. Most of these companies are continuing to conduct R&D work in the "in-ice" EER area for their particular operational concerns, although the specifics of this work is proprietary. In general terms, all of these companies also appear to be supportive of any new initiatives directed towards improving evacuation methods for ice-covered waters.

In Canada, the operators of current East Coast development projects are at the forefront and, in terms of immediate needs, generally dispel most concerns about in-ice evacuation issues in their area of interest. Since sea ice can be encountered on the Grand Banks in some years, this position may be short sighted. From a broader frontier perspective and, in recognition of the possibility of new industry activities on the northern Grand Banks and Flemish Cap, off the Labrador Coast and in the Canadian Beaufort, this position also tends to "push off" the need for advances in evacuation methods for ice covered waters. The oil companies and shipping groups that are now involved with in-ice developments and marine activities more internationally all tend to more readily accept this need.

There have been a few reports and papers published on evacuation procedures from offshore structures in ice-covered waters. Zahn and Kotras (1987) did a study of the evacuation procedures from the offshore drilling and production units in the Bering, Chukchi, and Beaufort Seas. Poplin et al. (1998a, 1998b) did an excellent overview of the issues related to evacuation in ice-covered waters. Polomoshov (1998) discussed aspects of evacuation from a platform in the Sakhalin offshore region. There was a Special Session devoted to emergency evacuation in ice at the POAC'01 Conference in Ottawa. Bercha et al. (2001) presented a model for Arctic offshore EER systems. Barker et al. (2001) presented a numerical model that was used to investigate the range of safe zones around the Molikpaq structure for different loading directions. Cremers et al (2001) discussed the current status and development of emergency evacuation from ships and offshore structures in ice-covered waters. These papers are referenced in the Bibliography.

3.4 Importance

The importance of the evacuation topic area should not be underestimated. Quite clearly, the availability of evacuation systems and procedures that work is critical to all involved, when a major problem is encountered on an offshore structure or vessel. This has been recognized in various codes, regulations and guidelines that have been developed over the past number of years, as well as the draft EER standards now being developed for the East Coast. These requirements will guide the acceptability of the evacuation methods that are proposed in the future and, if not met, could well derail some major projects.

A case in point involves the drilling activities that are currently conducted in the Caspian Sea during the ice-covered period. Here, drilling operations are actually shut down, on a routine basis, if the ice conditions around the drilling platforms are not amenable to safe evacuation. In this regard, the possible release of deadly H_2S (should a blowout occur) is the underlying concern. However, the operator's approach reflects a true commitment to personnel safety and is a prudent yet costly approach, necessitated by the presence of ice.

Although there does not appear to be any direct legislative requirement for the provision of evacuation equipment that will *guarantee* safe evacuation of personnel from offshore structures in all weather and ice conditions, there is legislation that requires detailed plans to be developed to ensure the safe evacuation of onboard personnel. This legislation is not detailed here. However, some of the key clauses and points have been excerpted from a variety of sources and are summarized in Appendix C, with particular reference to EER requirements for systems operating in Canada's ice-infested waters. In this regard, few specifics are outlined that relate to evacuation approaches in ice, with details in the topic area being left to the discretion of the operator to pursue.

4.0 Some Fundamentals

4.1 General

The evacuation systems that are used on offshore structures and vessels are comprised of a number of basic and stepwise components, all of which should be recognized when the overall evacuation process is being considered. These components include:

- the escape route(s) that are available for personnel to move away from the location of a hazardous situation onboard a structure or vessel (eg: a toxic gas release, explosion or fire), then into a temporary refuge (TR) onboard the platform

- the temporary refuge itself (there may be one or more such refuge locations where people are mustered), and the time period over which they can safely stay there prior to leaving the platform (TR endurance times are generally in the range of 1 to 2 hours on most offshore structures, depending on the particular hazardous incident at hand)

- the route(s) that are available for personnel to move from the temporary refuge(s) to the appropriate point(s) of evacuation from the structure or vessel

- the evacuation options that are available to move personnel off the platform, whether by helicopter, transfer systems that can move people directly to a support vessel, or survival craft (or other more rudimentary means) that move people from the platform into open water, mixed ice and water, or more continuous ice coverage conditions for subsequent rescue

- the rescue craft (typically a standby vessel or helicopter) that retrieves personnel from the evacuation craft (or more directly, if they are individually in the sea or on the ice)

The basic logic that surrounds the overall EER process is summarized in Figure 4.1. In this report, issues concerning escape routes and temporary refuges onboard structures and vessels are not discussed. Similarly, the general question of rescue craft is not covered explicitly, only from the standpoint of vessel operations in ice, and means of directly transferring personnel from a platform to a support vessel. Also, the survival equipment that may be used by individual personnel (eg: immersion suits, breathing apparatus, cold weather gear, and so forth) is not discussed. In short, this work focuses on the various evacuation methods and survival craft that may be used to move people from an offshore platform to nearby safety in various ice conditions, and the key ice issues relating to their effectiveness.

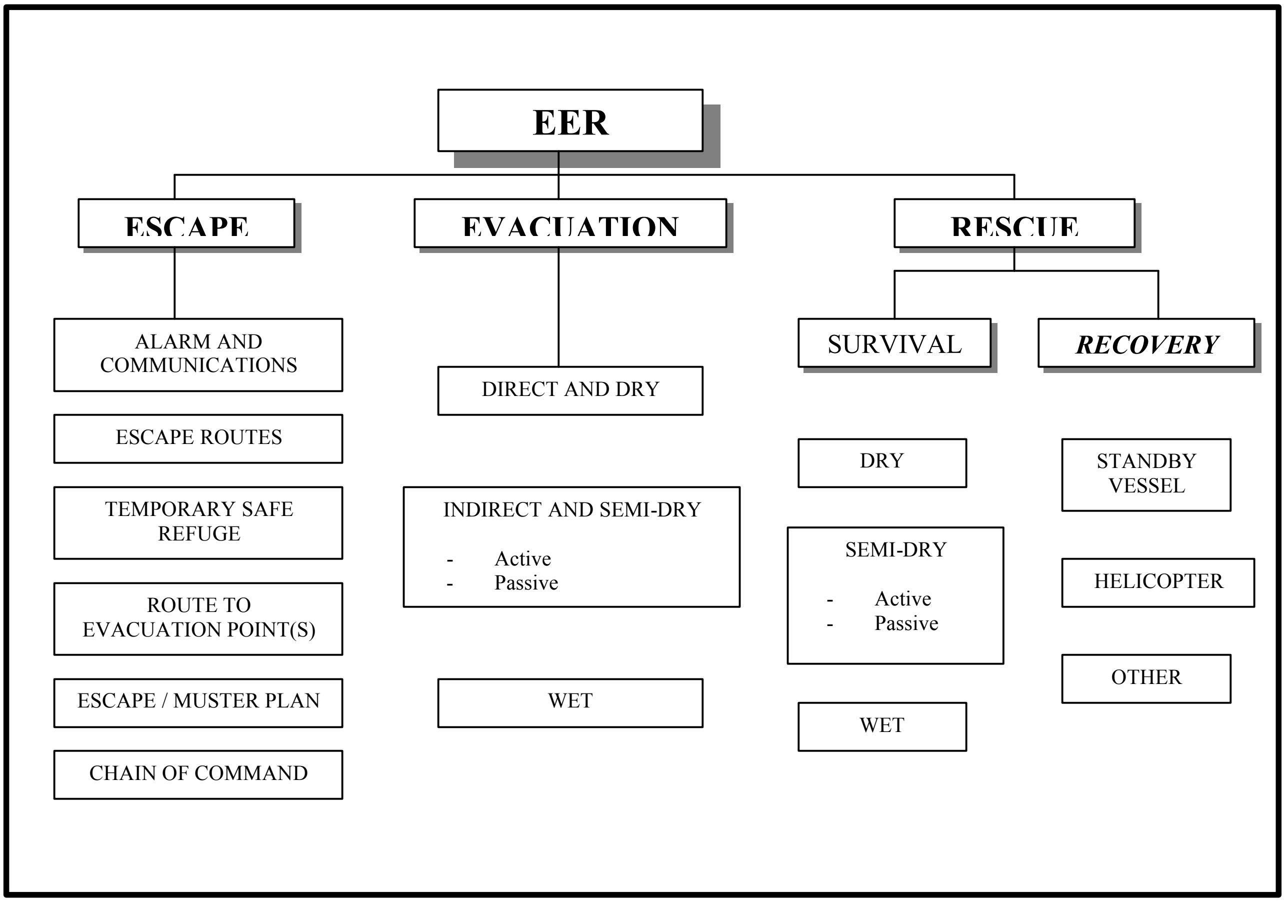


Figure 4.1: The basic logic of any escape, evacuation and rescue (EER) approach on an offshore platform or vessel in either ice or open water situations, based on information extracted from the first draft of the "EER Performance Standards" for the Canadian East Coast.

4.2 Evacuation Approaches

In broad terms, there are three fundamentally different evacuation approaches that can be identified to move people off endangered facilities. The first is commonly termed a direct or dry evacuation, wherein groups of people are moved off the platform directly to a safe haven, without having to be moved either into sea or ice conditions by various means, for subsequent pick-up by a rescue vessel. Evacuation options that involve helicopters or the direct transfer of personnel onto the deck of a support vessel are examples of this.

The second approach can be termed an indirect or semi-dry evacuation, where groups of people are moved into survival craft onboard a platform, then down to the sea or ambient ice conditions, and in turn, away from the platform to a nearby area for subsequent pick-up. Again, this evacuation approach is "dry" in the sense of people being enclosed in some type of survival craft and protected from direct exposure to adverse environmental conditions. Examples of indirect or semi-dry evacuations include the use of lifeboats, liferafts, or the ice-capable ARKTOS system.

The third approach is generally the least preferred, and involves more individual methods of personnel abandoning a platform, then reaching the sea or ambient ice environment. This is the most basic escape option and is usually only chosen when all other evacuation systems have failed. Typical examples range from the use of scramble nets, to individual personnel lowering devices, to people simply jumping off the platform. Clearly, this is a last resort approach that is both "wet" and dangerous, and requires subsequent pick up of separate individuals with rescue craft. However, in specific ice situations (eg: stable ice or a grounded rubble field around a structure), this basic type of abandonment approach may actually be preferred. For example, moving down the side of a structure by way of slides, gangways, ladders or scramble nets, and then walking away to a nearby enclosure on stable ice can be a simple, sensible and safe response in certain evacuation scenarios.

For direct (and dry) evacuations that involve moving people from a platform to the deck of a standby vessel in various ice situations, the primary considerations include:

- the performance capabilities of the vessel in the ice and ice interaction conditions that are present around the platform, specifically, its ability to quickly access a location adjacent to the platform, then stationkeep at this location within fairly tight tolerances over the time frame that is required to move large numbers of people onto its deck

- the type of transfer system that is used to quickly move large numbers of people from the platform to the vessel (eg: slides, chutes or stairways), and its "workability" in the range of environmental and vessel movement situations that can be anticipated

For the types of evacuation craft that may be selected for indirect (or semi-dry) personnel evacuations from platforms in ice-covered waters, primary areas of consideration include:

- the craft into which groups of people are placed, and its ability to safely function and, in fact, survive when deployed in the ambient ice conditions

- the means by which the craft is deployed from the platform into (or onto) the ambient ice environment, and where the craft should initially be placed to "be safe" relative to expected ice interaction conditions around the platform

- once deployed, the ability for the craft to move away from the hazard at the platform (eg: the heat and direct effects of a fire, smoke or gas plumes) in the ice conditions that are present, either actively (with propulsion) or passively (drifting in the ice and water), to a safe nearby location where the entire craft or its onboard personnel can be picked-up by a rescue vessel

4.3 Evacuation Options

A number of evacuation options are available to move personnel from offshore structures and vessels, either directly or indirectly. Most have been developed, tested and "put into place" for operations in conventional open water areas. However, some have also been selected for use on offshore structures and vessels that work in ice-covered waters.

With the exception of direct evacuation of personnel to helicopters or support vessels, or wet evacuations of individuals into the sea, there are several basic classes of systems for indirect or semi-dry evacuation. They include:

The Survival Craft

- lifeboats
- liferafts
- specialized craft, such as the ARKTOS

The Craft Deployment System

- standard davit launch and freefall systems
- methods to launch a craft in a specific direction and at some distance from a platform such as the PROD, TOES and Seascape systems

Personnel Transfer Systems

- slides and chutes
- stairways and bridges
- GEMEVAC

Some of the more common evacuation systems are highlighted as follows, along with a few initial comments about their application in ice-covered regions.

Helicopters

In the vast majority of cases, helicopters are the preferred means of moving people off a platform and, in fact, provide the means for most crew changes. In many evacuation plans, helicopters fulfil a primary role, provided they are available in the general area of operations and can safely access the platform in the environmental and "onboard hazard" conditions that are at hand.

In emergency situations that can be anticipated, the use of helicopters is amenable to evacuating large numbers of personnel from a platform in a staged manner, before the situation escalates. Most often, emergency alert schemes are defined and helicopters used to move non-essential personnel, then all onboard personnel sequentially, as a hazardous situation is starting to arise. This approach has been used to move people of Beaufort Sea structures on several occasions and works quite well, unless an unpredictable emergency situation occurs, for example, a major explosion or fire.

It is clear that helicopters cannot be effectively used in adverse environmental conditions, such as poor visibility, strong winds, very low air temperatures or atmospheric icing situations. In addition, there are certain hazardous situations in which helicopters cannot safely access a platform, for example, in the case of a major onboard fire or a gas plume around the facility. Therefore, the use of helicopters is only seen as a first line of response in most evacuation plans, provided they can successfully function. In this regard, the number of people to be moved, response and flight times, and the numbers and capacity of helicopters in the region are all key factors.

Clearly, the presence of ice around a platform has little impact on the use of helicopters as an evacuation method. However, some of the other environmental factors that are commonly experienced when working in ice-infested regions can often be consequential. Because helicopter evacuations are not reliable in all weather and emergency situations, supplementary means of evacuating personnel are essential.

Standby Vessels

In many cases, a standby vessel will be available around an offshore platform at all times, to provide a variety of as-required support and emergency response services, including personnel evacuation and rescue. In fact, a permanent standby vessel is a requirement for production platforms operating in Canada's frontier waters, according to federal oil and gas regulations.

In conventional open water areas, support vessels routinely approach and stationkeep at fixed and floating platforms, to transfer supplies and often people. It is well known that adverse factors such as strong winds, high waves or poor visibility sometimes preclude these types of support vessel operations. The presence of ice is an additional constraint. Any standby vessel used at a platform that is situated in ice must be capable of safely and effectively operating in the ambient ice conditions, otherwise, its ability to satisfy various support roles will often be compromised. This is an obvious statement but should be clearly recognized. What it means is that any standby vessel used in ice-infested areas should be a capable icebreaker in the range of conditions expected, including its ability to manoeuvre and stationkeep near a platform.

In certain scenarios, for example, the presence of grounded ice rubble around a structure, this type of vessel may also need specialized equipment like azimuth thrusters, to enable rapid clearance of the grounded rubble to allow access or egress. This is one attribute of the vessels that are currently being used to support drilling platforms in the Caspian Sea (Figure 4.2). Other capabilities, such as the ability of a standby to tow survival craft, to pick them up or retrieve them on deck over stern rollers, are additional considerations.

Evacuation to a standby vessel is a generally preferred approach, as compared to indirect evacuations that involve the deployment and subsequent pick-up of various survival craft. However, there are certain emergency situations in which a vessel cannot safely approach a platform, because of the nature of the hazard itself. A gas plume that could be ignited by shipboard systems, the presence of H_2S, the heat of a major fire, or falling debris are all examples. Although there is military technology available to aid in protecting ships from gases, fires and explosions, it is both expensive and specialized, and unlikely to be employed on a standby vessel.

Although the use of a standby vessel for personnel evacuation cannot be relied on in all emergency situations, the approach will often be a key ingredient in EER plans. The issue of evacuation from a platform to a standby vessel in different ice and ice interaction situations is discussed in more detail later in this report. There is little question that this evacuation option will have a central role in many offshore development projects in ice-covered waters.

Figure 4.2: Specially designed shallow draft icebreaking supply vessels were built to support winter drilling operations in Caspian Sea ice conditions. These vessels have azimuth drive propulsion systems that have proven to be very effective in clearing grounded ice rubble away from fixed platforms. In the upper photograph, one of the vessels is clearing grounded rubble from around the Sunkar drilling platform. This activity is carried out on an as-required basis, as a means of creating an exit route for ARKTOS survival craft that are carried onboard the platform. In the lower aerial view, a supply vessel is clearing grounded ice rubble from in front of an ARKTOS craft "egress hatchway" that (at the time) was blocked by ice rubble.

Totally Enclosed Motor Propelled Survival Craft (TEMPSC)

These lifeboats are the most common type of survival craft that is now found on offshore platforms and vessels. There are a wide range of manufacturers who offer TEMPSC of various sizes and capacities. Typical units on offshore facilities are generally capable of carrying roughly 50 people (or more). They are not particularly large or heavy craft, and are normally constructed from fibreglass. Once deployed, their propulsion systems allow them to move away from a platform, operated by trained marine personnel. In terms of transit speeds, they are required to be capable of travelling at 6 knots in calm open water conditions. Increasing sea states, currents and winds detract from this performance. The life support systems on standard TEMPSC units provide protection from fire, dangerous vapours and gases, for a limited period of time (typically tens of minutes). These survival craft are proven in many open water situations and are SOLAS approved, and therefore an attractive option for use on many offshore installations.

TEMPSC units are usually mounted on fixed davits that overhang the side of a structure or vessel (Figure 4.3). Various winching arrangements, which offer different degrees of control during lowering, set-down and release operations, are available. A free fall launch approach is also used in some TEMPSC applications. With these types of launches, the craft is usually set down in close proximity to the side of a platform and thus, can be susceptible to possible “wash back” against the platform in heavy seas. Recently, some alternate methods of placing a TEMPSC unit “further out” from a platform have been developed, such as the PROD, TOES, and Seascape systems. The intent of these newer launch systems is to improve the likelihood of successful TEMPSC deployments and movements well away from a platform.

Most TEMPSC units are designed for temperate regions, with little thermal insulation for very low air temperatures. Although their fibreglass hulls are satisfactory in open water conditions, they appear to be “quite flimsy” in terms of standing up to interactions with ice, particularly when their hulls are very cold. When a standard TEMPSC is deployed in ice, key issues include the local and global strength of their hulls under various ice loads, and their ability to move through the ambient ice conditions in a powered manner. In addition to the fact that ambient ice conditions will impede the craft’s transit, possible problems like slush ice ingestion into water-cooled engine designs are “indirect” factors to consider. In high concentrations of moving pack ice, the question of where to deploy a TEMPSC in relation to ice action on the platform is another important consideration.

Launch mechanisms and the efficiency of basic launch operations are also issues in cold and hostile ice-infested offshore regions. Equipment and people can often be subject to malfunction, due to low air and sea temperatures, wind and blowing snow, freezing spray or freezing precipitation, and where evacuees and marine operators may be combating high wind-chill, frostbite and hypothermia.

A simple analysis was performed to investigate the factors in launching a TEMPSC in ice-covered waters. The details are presented in Appendix D. The results of the analysis show that the loads are a very strong function of the impact velocity and the shape of the bottom of the lifeboat. The results show that:

- Very high forces can be transmitted to the lifeboat if it is dropped onto a thick floe if sea ice;

- The velocity of the impact is critical in determining the load. The forces are considerably reduced with a low impact velocity;
- The shape of the lifeboat can influence the load. Flat-bottomed boats can lead to very high impact loads

Figure 4.3: The hull of a typical TEMPSC lifeboat, in this case, one of 50 man units installed in standard davits on the Molikpaq caisson. Lowering the craft into the failing ice zone present at the time of this photo would crush it

Liferafts

Liferafts are another form of survival craft that is commonly found on offshore structures and vessels. They are typically compact, light, simple and low cost units, when compared to TEMPSC systems. The most rudimentary type of liferaft is the canister type, which is simply thrown into the sea, self-inflated, and then available for personnel to board. More sophisticated variants include raft systems with integral slides or chutes that allow large numbers of people to quickly move down from a platform to a "collector raft". They are generally made from robust rubber materials, have enclosed tops to protect onboard personnel from the elements, and are quite hardy when floating in the sea (Figure 4.4). Once deployed, they simply drift with the ambient wind and sea (or ice) conditions.

Liferafts are adequate as an evacuation option in many open water emergency situations. However, safe use of these units may be much more limited in various ice conditions. For example, the liferafts that are offered by most manufacturers appear to be susceptible to puncture and damage from any significant contact with ice. This is a fundamental issue.

Figure 4.4: A typical liferaft shown after deployment onto the sea. Self-righting units are also commonly available. Standard brands are not intended for use in very low air and sea temperature, and many issues surround the use and safety of liferafts in ice-covered waters.

ARKTOS

ARKTOS is a specialized survival craft that was developed by Watercraft International, specifically for use in ice-infested regions. Its development was carried out in the 1980s, supported by the Canadian oil industry and various government agencies. ARKTOS is comprised of a permanently linked pair of hull units, both of which are ice strengthened and designed for use in very low air and sea temperatures. Representative photographs of the ARKTOS craft are shown in Figure 4.5.

ARKTOS has treads extending around the vehicle on both sides that propel it on ice, and a water jet propulsion system to move it through water. This type of craft has been shown to be capable in most level ice, ridge and rubble conditions, and in many partial ice cover and open water situations, providing the sea state is not too rough. ARKTOS also has the ability to climb onto and off of various types of ice floes and rubble formations with the aid of a hydraulically controlled articulating arm between its twin hulls.

Figure 4.5: A view of the ARKTOS at the Northstar production island in the Alaskan Beaufort Sea (upper), and the ARKTOS craft transiting fairly thin broken ice in the Caspian Sea (lower).

However, ARKTOS units are quite large, complex and heavy, weighing about 25 tonnes. With a 50-man payload onboard, their gross weight increases to about 35 tonnes. They are usually launched from low freeboard platforms down ramps, but can also be lowered on large davits when dictated by platform geometries. In addition, their operators must be well trained and experienced to ensure that an ARKTOS vehicle is operated effectively in ice and open water situations. Should this type of craft capsize, it has no self-righting capability.

The ARKTOS is the only purpose built and field-tested evacuation craft that is currently available for comfortable use in ice, and is viewed as proven. It has been demonstrated to work in a considerable range of ice conditions, although there are specific situations (ie: thin ice) in which its weight causes the craft to break through the ice cover, and its ability to move at any reasonable speed in a self-propelled mode is compromised. More practical issues include its space and maintenance requirements, its cost and complexity, as well as how and where it could best be launched from high freeboard platforms in dynamic ice situations

Preferred Orientation and Displacement (PROD) System

The PROD system has been developed to move a TEMPSC unit outwards to a preferred orientation, and displace it "well away" from a platform prior to its launch. With this system, a conventional davit launched survival craft is assisted by a large boom to clear the platform (Figure 4.6). As the TEMPSC begins to descend, tension is induced in a tag line that causes the boom to bend outwards and downwards to take an approximately horizontal position away from the platform. As the craft continues to descend further, the tag line causes the boom to flex downwards like a giant fishing rod until the craft is waterborne. The tag line continues to exert a pull on the bow of the craft in both an upward and outward direction until the craft has navigated the length of the boom away from the platform. When the bow of the TEMPSC reaches the tip of the boom, the tag line is automatically released. This type of system is being used on the Hibernia GBS and Terra Nova FPSO platforms, and in tests and drills, has been demonstrated to work well across a range of open water situations.

In certain ice conditions, the PROD system may also have application in moving survival craft out from a platform, prior to deployment into or onto the surrounding ice cover. However, in dynamic ice conditions with high ridge and rubble sails, surface features could directly interfere with the use of this system. In addition, the presence of ice in the set down area could impede tow away of the TEMPSC by the tag line, once the craft was in contact with ice. Other issues to consider include its use in cold air icing conditions, and when there are mixed ice and swell situations.

Figure 4.6: The PROD system assisting the deployment of a survival craft on a standard davit, from an East Coast platform, in a preferred direction and "out and away" from the structure.

TEMPSC Orientation & Evacuation System (TOES)

TOES is another type of system designed to supplement the launch of TEMPSC units from conventional davits. The TOES approach relies on the energy of a submerged buoy to provide both direction and towing forces to the survival craft during its launch and clearance from a platform (Figure 4.7). With this approach, a towing cable is attached to a submerged buoy that passes through an anchor block on the seafloor (at some distance from the platform) to a hook and eye arrangement on the platform (near the waterline), then on to the bow of a davit mounted TEMPSC. When TEMPSC lowering operations begin, the eye slips from the hook, freeing the towing cable and releasing the submerged buoy to make its ascent to the water surface. The effect of the rising buoy is to orient the TEMPSC away from the platform and, after its release from the falls, to pull the survival craft away from the platform to a safe position.

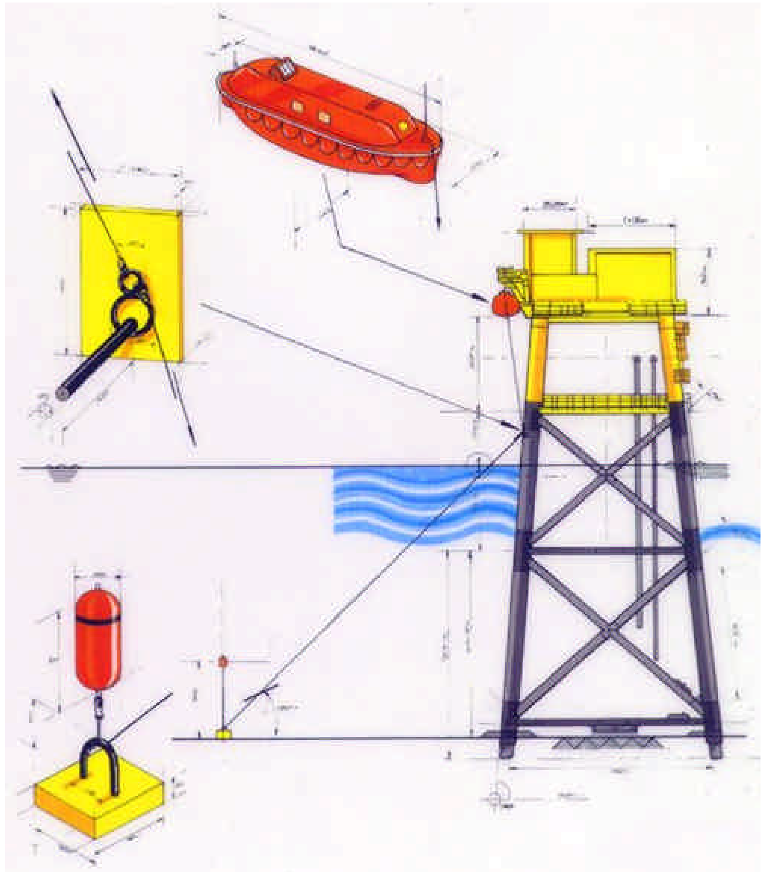


Figure 4.7: A schematic illustration of TOES, which is designed to supplement the launching and movement of a TEMPSC away from an offshore platform. This system would find little application in any significant ice conditions, because of adverse ice action on its cabling arrangements.

Although the TOES approach is workable in certain open water situations, there is little chance that it would reasonably function in ice-infested waters. In moving ice conditions, ice effects near the waterline and the presence of deep draft ice features (eg: ridge keels) would be problematic for the cabling and hook and eye arrangements. In addition, the occurrence of grounded ice rubble adjacent to a platform would simply destroy this type of system. The best place "to move the TEMPSC to" would also be a continual variable. In addition, factors such as icing of the hook and eye in cold water and air temperatures would be an ongoing concern. Concepts like the use of power dolphins have similar disadvantages in ice.

Seascape System

Seascape, a company based in Newfoundland, is in the process of developing a different type of TEMPSC launch system, as well as an alternative type of lifeboat. Their basic launch system lowers a survival craft from a platform by means of a large steel arm that pivots at a point near the waterline. The TEMPSC, which is yoke mounted at the end of the arm, is gravity lowered by a winch on the platform, and simply floats free of the yoke when it reaches the water. This approach has the advantage of placing a craft 20m to 30m away from a platform, as opposed to a davit launching closer to its sides. This Seascape launch system is intended for use in open water situations. Model tests and large-scale trials have shown that it functions well in various open water wave and “platform list” conditions.

Seascape also has a modified design for this basic launch system that should be of more use in ice conditions. In this regard, an external arm that is mounted near a platform’s waterline would likely be damaged by moving ice, and/or rendered useless in grounded rubble ice situations. The modified design relocates the arm’s pivot point to the main deck level, and uses an articulated arm arrangement to lower the TEMPSC from the platform. The prototype is shown in Figure 4.8. In ice conditions, this type of system maintains the benefit of placing a survival craft “out and away from” the broken ice zone that may be present around a structure in moving ice, or onto any grounded ice rubble that may have formed around it. With the craft’s descent being winch lowered and controllable, a TEMPSC unit could also be suspended slightly above the waterline prior to its final release, awaiting appropriate conditions in its landing area, should this be required. However, the presence of high drifting ridge sails is an issue to consider when evaluating this approach.

Seascape is also developing another type of TEMPSC, with various enhancements over many of the more standard units. The Seascape lifeboat is considerably larger and more highly powered than most, has a sturdy aluminium hull (rather than fibreglass), is very manoeuvrable, and provides good visibility for its operator. However, its overall size and weight (roughly 15m in length and 17 tonnes when 50 people are onboard) are practical disadvantages in many applications.

A prototype vessel has been constructed and performance tested in a range of open water conditions. Some testing of the Seascape lifeboat has also been carried out in late spring pack ice off Newfoundland (Figure 4.9). The steps that are required to obtain certification for this type of TEMPSC unit are now being followed with Transport Canada, but no certification is yet in place.

Figure 4.8: Views of the Seascape articulated launching arm, which is lowered on a winch and deploys a yoke mounted TEMPSC unit "out and away" from a platform.

Figure 4.9: Views of the Seascape prototype TEMPSC unit, taken at dockside (upper) and during trials in late spring ice conditions off Newfoundland (lower two photos).

In addition to the types of survival craft and deployment approaches highlighted above, there are a number of systems that have been developed to quickly transfer large numbers of people down from a platform. These systems are often linked to collector liferafts, but may also be capable of moving personnel to the deck of a standby vessel or, in some situations, directly onto the ice surface. Conceptually, the basic slide and chute systems now available are designed to unfurl, and transfer people to a collector raft or other landing area, at controlled rates of descent. These types of systems are schematically illustrated in Figure 4.10. In principle, the use of collapsible stairways or bridges to a landing area is similar.

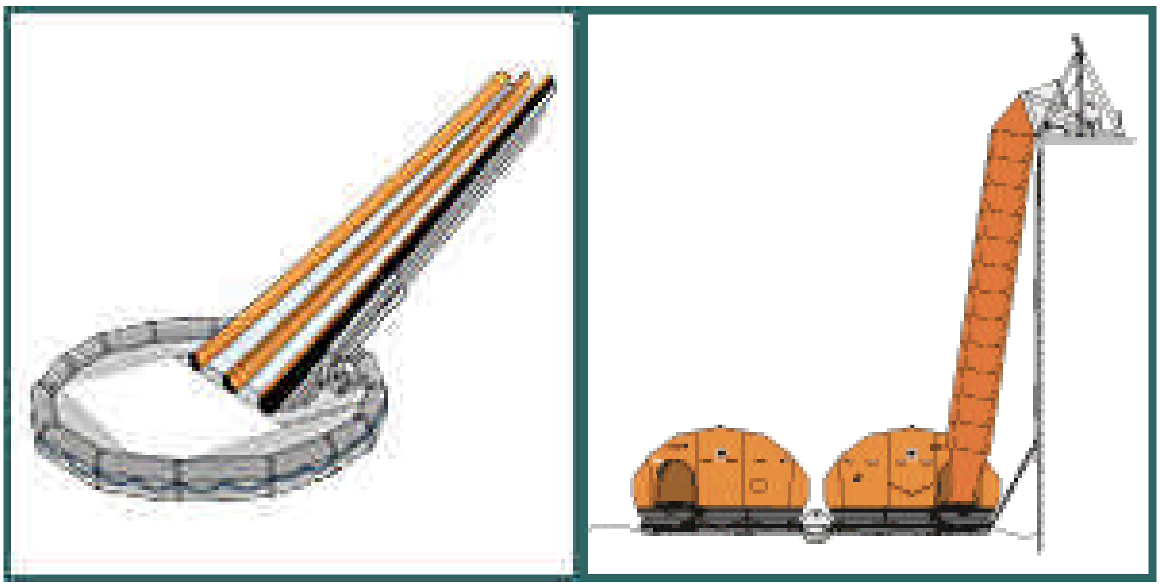


Figure 4.10:“Mass evacuation” systems that involve slides (left) or chutes (right) are now commercially available, and can move large numbers of people off a platform to a “landing area” quite quickly.

Some of the mass personnel transfer systems that are currently most topical and now in use on East Coast platforms, along with the GEMEVAC gondola approach, are briefly outlined as follows.

<u>*Skyscape System*</u>

The Skyscape system, manufactured by Selantic, is a Kevlar mesh chute that is intended to safely transport personnel down from a platform. When it is deployed, people wriggle their way down the chute at "controlled rates of descent", normally to a collection life raft in the sea (Figure 4.11). The collector raft is an integral part of this system, and is held in place by a stabilizing weight below the water surface. Once ample numbers of people reach the collector raft, additional liferafts secured to it are boarded, allowing groups of people to drift away from the platform. This escape system is now in place on the Hibernia GBS platform. In open water situations that involve heavy seas, possible "wash back" of the raft(s) is an issue with this scheme. Large wave and high wind conditions are also problematic for the use of this type of system, since their deployment is limited by "like conditions" to those that would shut down use of a crane.

Figure 4.11: A view of the Skyscape system being employed during personnel training exercises in "calm open water conditions".

The Skyscape system is a possible option to move people down from a platform to either the deck of a vessel in ice, or directly onto the ice surface. However, this would only be feasible if the support vessel or surrounding ice cover offered a reasonably stable landing area over the time period required to move substantial numbers of people onto them. As an example, rapidly moving ice would quickly "pull away" the bottom of the chute or the collector raft in the landing area.

For situations that may involve moving ice adjacent to a platform, Selantic has proposed a concept whereby the collector raft (or alternative) would be suspended several metres above the ice surface. In concept, this approach would eliminate the likelihood of drifting ice quickly carrying the collection "device" away, and also avoid possible interactions with sizable ridge and rubble sails. Subsequent personnel access to the ice would be by means of a short slide or other means. In "real ice situations", this approach may be a considerable stretch. In addition, other complicating factors such as strong winds, low air temperatures, blowing snow, icing and darkness must also be recognized, and may often detract from the practical application of this type of scheme.

Viking Marine Escape System (MES)

Another chute and raft system, which is offered by Viking, has been specifically designed for personnel escape from a range of low to high freeboard platforms. In concept, the MES is similar to the Skyscape system, although it is functional with installation heights of up to 35m above sea level. These units are comprised of multiple chutes that terminate at a collector raft, with chute components also designed to slow rates of decent of people. Again, additional liferafts attached to the collector unit are available to move groups of people away, once they have abandoned the platform. An illustration of this system is given in Figure 4.12. In ice conditions, this unit has the same general disadvantages, and advantages, as the Skyscape system.

Figure 4.12: An illustration of the MES escape chute system, with people moving down it during a training exercise in a calm open water situation.

Selstair System

Selstair offers another type of personnel descent system. It is a collapsible spiral ladder that can be used to quickly move large numbers of people down platforms and vessels, from heights of up to 50m above the waterline. It has no inflatable parts and, in the lower portion of the staircase, has a flexible "stair zone" where people exit the unit. This system is designed so that the staircase is folded into a compact storage unit that can be moved from spot to spot. The Selstair does not perform well in any substantial waves or in high winds. In ice, its use would also be to move people onto the deck of a standby vessel, or onto the surrounding ice cover. Again, this type of applications would be predicated on the stability of the "landing zone" or either the standby vessel or the ice.

GEMEVAC

The GEMEVAC system has been developed as a means of directly transferring groups of people from the deck of a structure to a suitably equipped vessel. It is basically a gondola that is suspended on a temporarily established ropeway between a platform and a support vessel (Figure 4.13). The gondola travels back and forth on an arrangement of cables over a distance of about 75m, carrying up to 16 people in each haul. Rigging the GEMEVAC system is initiated by firing a shot line from the platform to the support vessel, where most of the equipment is located. Cable runs are then established between the two facilities, with the bridge of the support vessel acting as the control centre. Power for the operation of the system is also provided from the vessel.

Figure 4.13: A view of the prototype GEMEVAC system, moving a gondola from a platform to a vessel.

The GEMEVAC is being used as an evacuation option at the Hibernia GBS, on the Grand Banks. However, trials carried out with the GEMEVAC system in fairly quiescent open water conditions to date have been less than successful. Strong winds, significant storm waves and icing would add an additional level of operational complexity to the use of this system.

In ice conditions, a system like GEMEVAC (if proven to be operable) would be an option to directly move people to the safety of a standby vessel, located at some distance from a platform. However, the application of this type of system is predicated upon the ability of a standby vessel to reliably stationkeep at a location in close proximity to a platform over time periods in the order of an hour or more. In some moving ice situations, this would be a significant challenge. If stable ice or a grounded ice rubble field was reliably present around a structure for most of the winter, a similar concept could be adapted for use with some comfort.

Other Concepts

A number of other evacuation concepts have been suggested for offshore structures and vessels, in the extreme, ranging from airborne dirigibles to submarine systems. By way of summary, the shortfalls and practical disadvantages of most of these concepts generally outweigh any benefits that they may offer. Two of the "more grounded approaches" that have been considered to date include the use of a hovercraft and an archimedian screw vehicle. A few related comments about other concepts are given as follows.

Hovercrafts are sometimes considered as a possible option for evacuation from structures and vessels in ice-covered areas. It is well known that they can transit many open water, mixed ice and open water, and full ice cover situations. Various versions also operate in very cold climates, onshore and offshore. In terms of transiting ice, the only problem for hovercraft is their ability to move over "high" surface features such as ridge and rubble sails. Vertical clearances of 1m or so are typical with current powering and skirt designs, although this clearance level can be increased with more effort and cost.

As a practical evacuation method, the main drawback of hovercrafts is their considerable size and weight, their complexity and need for maintenance, and their cost. Launching from high freeboard platforms is also a key issue. In practical terms, hovercrafts are best viewed as an optional type of rescue craft to standby vessels in certain ice or open water conditions. They are being evaluated for use within this context for specific development projects in the ice-infested waters off Sakhalin Island. In the Caspian Sea, they are also being considered as an evacuation option for the large low freeboard platforms being used, where the release of H_2S is of concern and a "quick getaway" to a substantial (and) safe distance is required.

Various *Archimedian Screw Tractor* (AST) concepts were developed and tested by the U.S. military during the 1960s, mainly for applications in mud and swamp conditions. In the 1970s and the 1980s, Mitsui produced a number of ice-capable AST prototypes to address a range of needs, including platform evacuations in ice-covered waters. This type of system has two rotating pontoons that are mounted below a personnel cab, both having screw threads to move the vehicle through open water, over low relief ice and so forth. Several small prototype AST units have been demonstrated to work quite well within or on ice covers, although the technology is far from mature. There are a number of issues surrounding the application of this AST technology, including the size, complexity and weight of any AST evacuation craft that might be designed.

Once placed on or in ice conditions, the local and global strength of this type of craft in terms of its ability to accommodate various ice forces is of concern. In thin ice, where the weight of the craft may lead it to breaking through, its ability to propel itself is another issue.

Air-Propelled "Swamp Buggies" have also been suggested as a possible alternative for evacuations for offshore structures in some ice environments, where rapid over-ice transit away from a platform is a key. In reasonably smooth ice areas, this concept may have some merit. However, in rough ice, transits with this type of craft would be problematic.

4.4 Summary

The foregoing material has highlighted most of the evacuation approaches and systems that are now available or are currently being considered for use on offshore platforms and vessels. Some of these systems have been used in the offshore for many years, while others reflect relatively new technology, developed to satisfy certain needs for platform evacuations on the East Coast of Canada and in other open water areas of the world.

It is clear that few systems have been specifically designed for any intended uses in ice-infested waters, with the exception of the ARKTOS craft. In this regard, it is important to recognize that a "strong demand" for ice capable evacuation systems has not arisen until quite recently. It is also important to note that in-ice evacuation technology is very much a "niche market", since there are only a handful of projects being carried out or planned in ice-covered areas, as compared to the multitude of projects underway in conventional open water areas. Consequently, there are few incentives for manufacturers to develop and offer ice capable evacuation systems, from a business perspective.

Despite some of the apparent shortcomings in the evacuation systems that are available for use in ice, offshore operations have been conducted from structures and vessels in ice-infested areas for many years. The evacuation approaches that have been used in these operations are outlined in the following section of this report.

5.0 Review of Evacuation Systems

5.1 General

Here, information about the evacuation systems that have been used, are now being used, or are currently planned for use on offshore platforms in different ice-infested regions is summarized. This information is presented on a regional basis, with a major focus placed on the Beaufort Sea and Grand Banks areas. However, the evacuation systems that are being employed in other ice-covered regions of the world are also outlined. This material is organized according to the range of considerations that were highlighted in Section 3.3, which include:

- the particular structure, its function, and its manning levels
- the logistics support available, should a problem arise
- the ice scenarios that are relevant for operations
- the evacuation systems and approaches used, along with related comments

A number of different types of platforms, both fixed and floating, have been employed or are now being planned for use in exploration and production activities in the geographical areas covered. Because of this, there are many systems, ice conditions, and evacuation approaches to describe. For the sake of conciseness, the information that is provided in this section is provided in the form of tabular summaries and illustrative photographs. A more thorough description of the details of each platform in Canadian waters, their evacuation systems, and the various ice situations of relevance is given in Appendix E.

5.2 Canadian Beaufort Sea

5.2.1 Environmental Setting

The Beaufort Sea is well known as having one of the most hostile operating environments in the world. This region is ice-covered for about nine months of the year, with a short open water season in summer. The Beaufort's winter ice cover consists of a nearshore landfast ice zone that extends from the shoreline to water depths of about 20m, and a moving pack ice zone beyond this fast ice, stretching northwards to the permanent polar pack. In winter, the landfast ice is fairly stable, moving only a few metres to a few tens of metres in episodic events. In contrast, the pack ice is in near continual motion, with ice movements seen from all directions. A flaw lead, characterized by open water or thin ice, sometimes forms between the northern boundary of the landfast ice and the southern edge of the pack ice, depending upon wind directions at the time.
In winter, ice thicknesses in both the landfast and pack ice zones are substantial, with the first year ice cover generally reaching maximum thicknesses in the order of 1.5m to 2m. The winter ice cover is also typically rough, and contains significant areas of ridging and ice rubble. Average surface roughness features are in the range of 1m to 2m high, with extreme sail heights in the range of 10m to 15m.

Freeze-up, which typically occurs over the October to December time frame, sees newly growing, much thinner ice in the southern Beaufort Sea. During this period, ice coverage in the fast ice zone is continuous, while further offshore in the moving pack ice zone, ice concentrations are generally high and floe sizes usually large. Break-up normally starts in the late May to early June period and ends in late July, when open water is typically seen across most of the area. Over this time frame, the ice concentrations and thicknesses tend to decrease as break-up progresses, with floe sizes being quite variable. In some years, multi-year ice floes that have moved southwards from the more northerly polar pack can be found in the ice cover during freeze-up, winter and break-up. These floes are typically thick, ranging from 3m to 6m, and can be very rough with frequent ridges. Old ice intrusions can also occur during the summer open water season under the influence of storm winds from the north, bringing old ice into the southern Beaufort.

Although sea ice is the primary environmental constraint in the Beaufort Sea, there are other environmental factors to recognize. During summer, when open water conditions are experienced, the wave climate is generally mild and high storm waves are not a significant concern. However, low air temperatures in winter, extended periods of poor visibility over the break-up, summer and freeze-up periods, and influences such as high wind chill, blowing snow and occasional icing are also important constraints.

5.2.2 Logistics Setting

During the drilling operations that were conducted in the Beaufort Sea in the early to mid 1970s, from the first few artificial islands, there was little logistics infrastructure in place. Helicopters, ice roads, and a handful of small vessels that were only capable of working in open water were the norm. As levels of exploration activity increased over the late 1970s to mid 1980s period, large onshore base camps, more substantial helicopter fleets and various icebreaking support vessels were "put into place". For most of the drilling systems employed after the mid 1970s, this improvement in support logistics meant that helicopters were easily accessible within an hour or two, on a year round basis, weather permitting. In addition, ice capable vessels were generally available and not too far away in break-up, summer and freeze-up seasons. In winter, however, icebreaking vessels were not used (or "kept warm") and therefore, were not available. All of the drilling systems that were used were located within ≈250 km of Tuktoyaktuk, which was the main support centre for offshore operations in the Canadian Beaufort Sea.

5.2.3 Platforms Used

The different types of platforms that have been used for offshore drilling operations in the Canadian Beaufort Sea are summarized below. Here, they are categorized as either fixed or floating systems, and their water depth ranges and operating seasons broadly indicated. The tables and photos that describe and illustrate each of these platforms, their logistics support, the ice conditions in which they operated, and the evacuation systems they used are also highlighted.

Bottom Founded Structures

Artificial Islands

- intended for use in shallow to intermediate water depths, in landfast ice conditions (typically constructed in several metres to 12m of water, with the deepest artificial island built in 19m of water)
- typical operating season was in winter, usually from December until late April

- with some islands, drilling operations were also carried out in early summer open water situations and during freeze-up ice conditions
- see Table 5.1 and Figure 5.1

<u>Tarsiut CRI</u>

- intended for use in intermediate water depths and deployed in 20m of water where in winter, it was at the outer edge of the landfast ice zone
- designed and used for drilling operations on a year round basis
- see Table 5.2 and Figures 5.2 and 5.3

<u>Esso CRI</u>

- intended for use in intermediate water depths, and deployed at locations ranging from 12m to 25m in depth, which were also in landfast ice in winter
- designed for year round operations, but only used during freeze-up and winter ice conditions
- see Table 5.3 and Figure 5.4

<u>SSDC</u>

- intended for use in intermediate to deeper water areas (10m to 40m), in both pack ice and landfast ice conditions
- designed and used for operations on a year round basis
- see Table 5.4 and Figures 5.5 and 5.6

<u>Molikpaq</u>

- originally intended for use in the deeper water areas (20m to 40m) in moving pack ice and open water situations, but has also worked in landfast ice (12m)
- designed and used for year round operations
- see Table 5.5 and Figures 5.7 and 5.8

<u>*Floating Vessels*</u>

<u>Drillships</u>

- conventional drillships were ice strengthened, brought into the Beaufort, and used for drilling operations in deeper waters (roughly 25m to 60m) on a seasonal basis
- maintained location on a standard eight point mooring spread, supported by ice management vessels when required
- usually operated during the open water season, but also in some late break-up and early freeze-up pack ice conditions
- see Table 5.6 and Figure 5.9

<u>Kulluk</u>

- purpose built Arctic drilling barge, also intended for use in the deeper water areas (20m to 60m) on an extended season basis
- maintained location on a very strong 12 point mooring system that emanated from the bottom of its hull for protection against heavy ice
- supported by several highly powered Class IV icebreakers for ice management in heavy moving pack ice situations
- operated from early break-up through late freeze-up (May to late December) in a wide range of pack ice conditions (both thin ice and thick) and also in open water
- see Table 5.7 and Figures 5.10 and 5.11

Note: Spray ice islands have also been used for exploratory drilling operations in the Beaufort Sea, in water depths to 8m. These platforms are constructed in stable landfast ice and are only used in winter. Evacuation approaches for this type of structure are very similar to those used on artificial islands in winter (ie: walking off the ice platform to a nearby temporary enclosure) and are not explicitly covered here.

General

Location: Beaufort Sea

Platform: Artificial Island

Type: Bottom Founded

Water Depth Range: several metres to 19 m

Function: Exploratory Drilling

Manning: ≈ 80 people

Platform Characteristics

- large surface area (100m diameter)
- low freeboard (a few metres) & beaches sloping down to the waterline
- generally easy access for personnel to move onto the ice or sea surface
- generally simple routes from hazardous areas on the island surface
- in winter, egress (to stable ice) similar to leaving a land based operation

Logistics Setting

- helicopters usually available within several hours, on a year round basis (weather permitting)
- nearby ice roads and vehicles usually available "on-demand" in winter
- support vessels only available in the summer and early freeze-up periods, within time frames of a few hours to tens of hours

Environmental Scenarios

Winter: ***(Dec to late May)***

- during their winter operations, artificial islands were located in stable landfast ice, surrounded by a stable grounded rubble field
- these grounded rubble fields were of variable sizes and geometries, but were typically quite rough, with variable ice surface topographies

Freeze-Up: ***(early Oct to early Dec)***

- when manned during the freeze-up period, artificial islands were usually surrounded by a thin mobile first year ice cover, with active ice failures and rubble forming on their updrift side
- a partially open water or brash ice wake was often found on their downdrift side, with a broken ice zone several tens of meters wide on each side

Break-Up: ***(early June to mid July)***

- when manned during break-up, artificial islands were generally surrounded by thick, puddle and weak first year ice that, once the landfast ice had fractured, was mobile
- drifting ice floes interacting with the grounded rubble field on the island's updrift side, with cracks and failures occurring in the surrounding ice that was moving by, was typical
- brash and small ice floes were most characteristic in the downdrift area

Open Water: ***(late July to early Oct)***

- when manned and operating in the early summer season, artificial islands were surrounded by either fairly calm open water conditions or partial ice coverage situations
- high waves were not an issue

Evacuation Systems

- evacuation methods were generally rudimentary, and focused on winter operations
- included mustering, then walking off the island to a nearby stable ice area
- appropriate cold weather Arctic gear was "mandatory"
- no off-site shelters were available in the early years, but were put into place in later years, and contained appropriate survival supplies
- nearby vehicles and ice roads were seen as an obvious means of shelter and escape in winter, as were helicopters for rescue
- shoulder season evacuations in thin moving ice or in partial ice coverage conditions were more reactionary and involved the deployment of very simple liferafts that were on the island, the use of any support vessels that may be in the area, or from the island's surface with "helicopters lifts"
- evacuation in any adverse open water situations were similarly conceived

Key Points

- in practice, the evacuation options to move away from artificial islands were comfortable to all involved, in stable winter landfast ice conditions
- evacuation options in open water and low ice concentrations were also acceptable to on-island personnel
- evacuation options in thin moving ice conditions during freeze-up were not satisfactory, if the artificial island's working surface was "out of bounds" due to the nature of the hazard, the surrounding ice rubble field was not stable, and shallow draft support vessels were not available in the general area

Table 5.1: Evacuation approaches used for artificial islands in the Beaufort Sea.

an artificial island in calm open water conditions

an artificial island in moving ice during late freeze-up

an artificial island in stable winter landfast ice

Figure 5.1: Representative photographs of the type of open water and ice conditions that were typically seen around artificial islands in the Beaufort Sea, including the grounded ice rubble fields surrounding them.

General

Location: Beaufort Sea

Platform: Tarsiut Caisson Retained Island (CRI)

Type: Bottom Founded (shallow concrete caisson on a large dredged sand berm)

Water Depth: 20 m

Function: Exploratory Drilling

Manning: ≈ 120 people

Platform Characteristics

- moderate surface area on the Tarsiut CRI, about 70m in diameter
- vertically sided caisson walls with no large ice or wave deflectors on top
- a fairly low freeboard structure, about 5m from the top of the caisson and its working surface to the waterline
- generally easy access for personnel to move off the CRI to the surrounding ice or sea surface

Logistics Support

- helicopters were readily available year round within an hour or two (weather permitting)
- open water and ice capable support vessels were also locally available within time frames of a few hours during the summer and early to mid freeze-up periods
- there were no ice roads to the Tarsiut CRI location

Environmental Scenarios

Winter: ***(late Dec to late May)***

- during winter operations, the Tarsiut CRI was located in stable ice at the outer edge of the landfast ice zone, surrounded by a stable grounded ice rubble field
- the grounded rubble around the CRI was quite extensive and very rough in places, with a variable surface relief
- a large grounded ice pad, constructed for relief well drilling purposes, was also present in the rubble field, about 100m to the north of the CRI

Freeze-Up: ***(mid Oct to mid Dec)***

- during freeze-up, the Tarsiut CRI was surrounded by thin mobile first year ice, with active ice failures and rubble often forming on its updrift side
- a partially open water or brash ice wake was often seen downdrift, with broken ice conditions alongside
- low swell was occasionally seen in combination with thin broken ice

Break-Up: ***(early June to late July)***

- during break-up conditions, the CRI was surrounded by thick, puddled and weak first year ice that was mobile
- drifting ice interacting with the CRI's grounded rubble field on the updrift side, and "swirling" around its sides and downdrift areas was typical

Open Water: ***(early Aug to mid Oct)***

- generally mild wave conditions were seen around the CRI in summer
- however, occasional storm wave events did occur with spay, wave heights, and typical sea surface roughnesses around the CRI being amplified by its presence

Evacuation Systems

- basic personnel evacuation approaches were developed for full ice cover, partial ice cover and open water situations, but these remained quite rudimentary, with systems including:
- a helideck for large helicopters with an emergency refuelling capability
- 25 man inflatable life rafts (the portable canister type) with some basic survival supplies included, located on all four sides of the CRI, on top of its walls
- adjacent scramble nets to allow people to climb down the caisson walls
- 2 temporary shelters placed on the stable relief well ice pad to the north of the CRI (in late winter), with provisions for two weeks and an exit ramp off the NE side of the CRI
- support vessels as an option to the use of helicopters in open water and freeze-up conditions,, directly accessed (draft and ice rubble permitting) by scramble nets from any caisson wall, or indirectly by liferafts (or other) at sea or on thin ice
- an environmental alert system provided early warning of hazardous ice or wave conditions, and prompted a phased evacuation process, by helicopter or ship

Key Points

- evacuation options from the Tarsiut CRI to the surrounding rubble and fast ice cover were quite comfortable in stable winter ice conditions
- evacuation options in open water and low ice concentrations were also acceptable, as long as support vessels were nearby and the wave situation not adverse
- evacuation options in thin freeze-up ice conditions were not satisfactory
- one staged personnel evacuation was carried out by helicopter in summer, due to a forecasted high storm wave event

Table 5.2: Evacuation approaches used for the Tarsiut Caisson Retained Island.

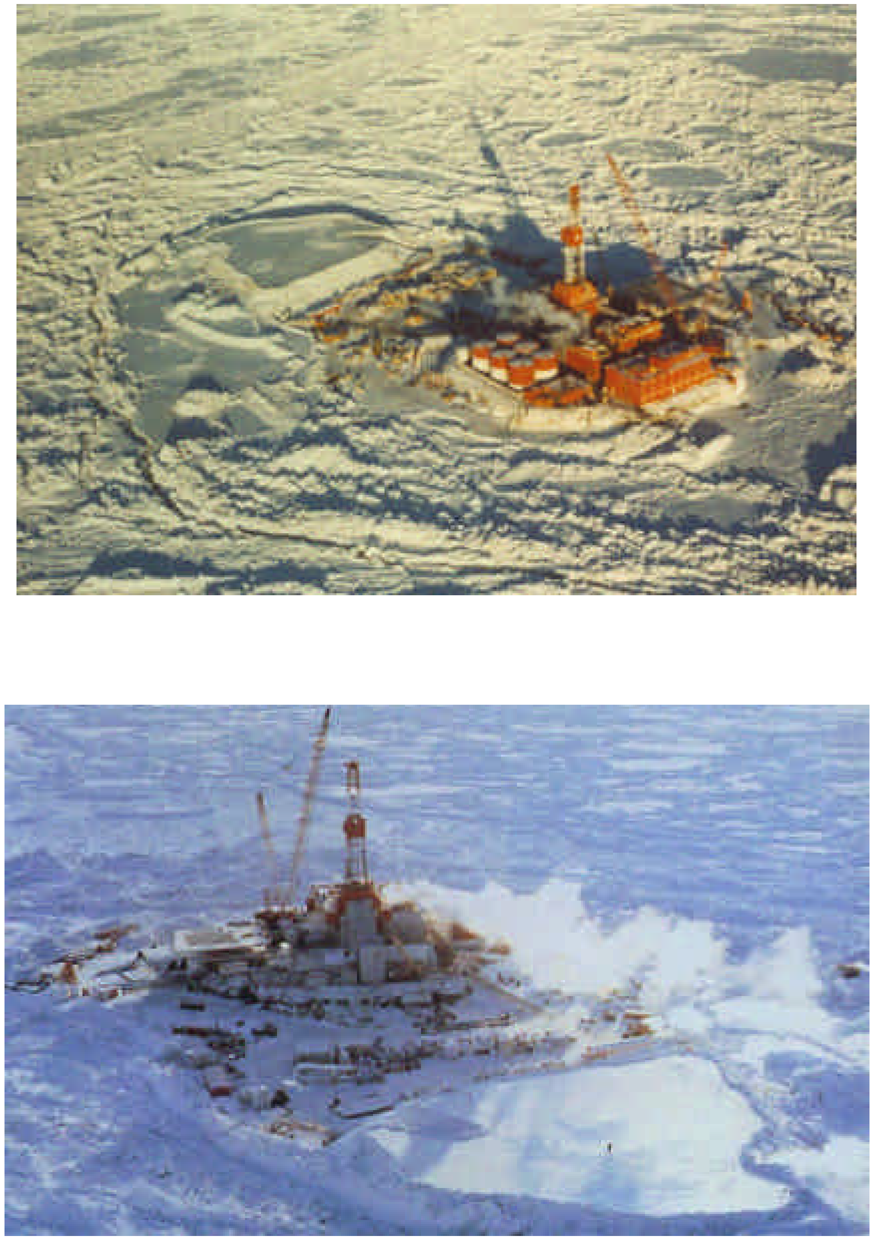


Figure 5.2: Representative views of the type of stable landfast ice conditions that were seen at the Tarsiut CRI during the winter period, including the grounded ice rubble annulus around it, and its relief well ice pad.

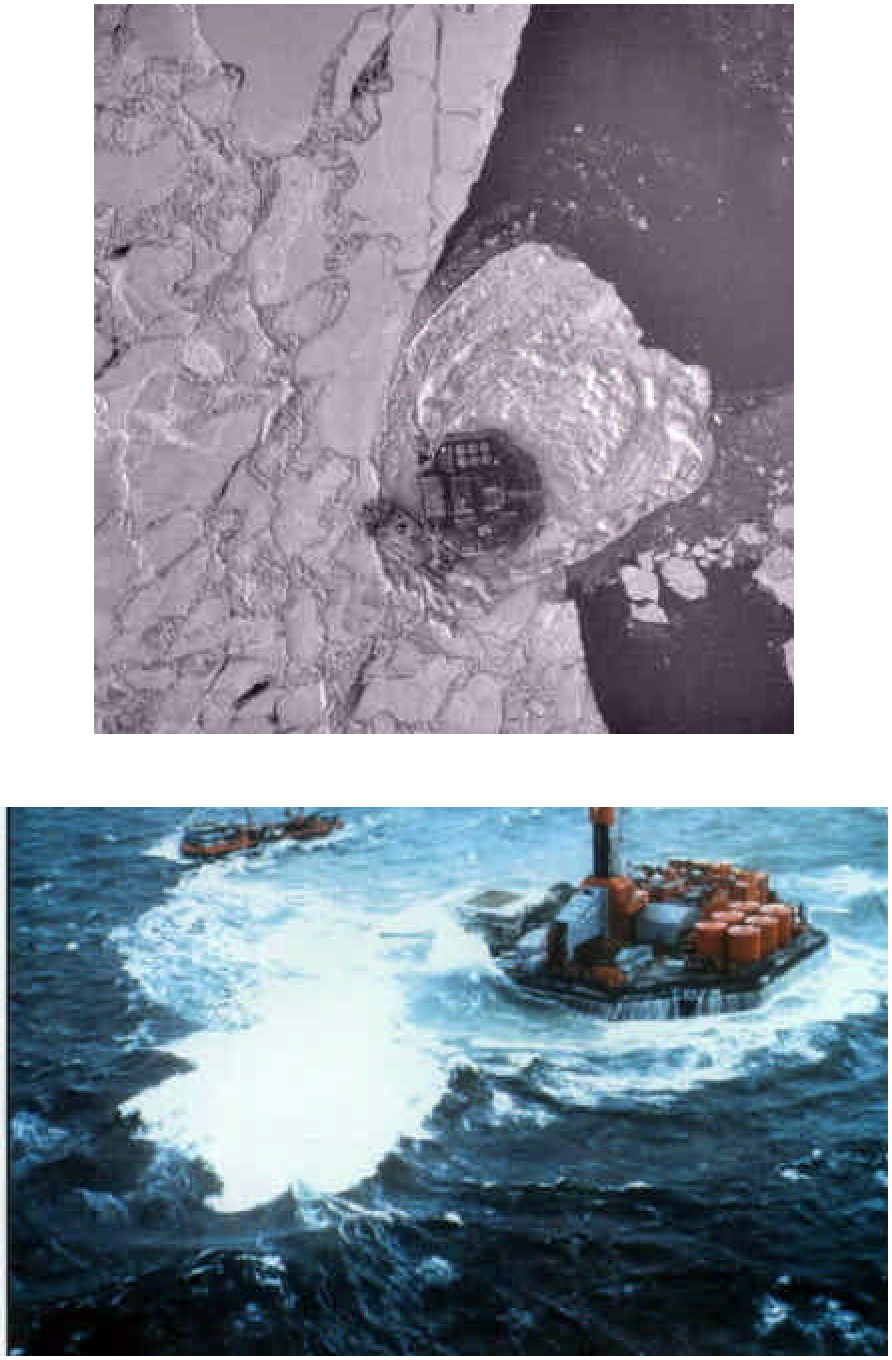


Figure 5.3: Representative views of the type of thin moving ice conditions that were seen around the Tarsiut CRI during freeze-up (upper aerial photo), and in storm waves during the open water season (lower).

General

Location: Beaufort Sea

Platform: Esso Caisson Retained Island (CRI)

Type: Bottom Founded (shallow steel caisson on a large sand berm)

Water Depth: 10 m to 25 m

Function: Exploratory Drilling

Manning: ≈ 80 people

Platform Characteristics

- moderate surface area on the Esso CRI, about 90m in diameter
- sloped caisson walls with an ice/wave deflector on the top of these walls
- also a fairly low freeboard structure, about 8m to the top of the deflectors
- generally easy access for personnel to move off the CRI to the surrounding ice or sea surface, via scramble nets, ramps, etc.

Logistics Support

- helicopters were readily available year round within an hour or two (weather permitting)
- open water and ice capable support vessels were also locally available within time frames of a few hours during the summer and early to mid freeze-up periods
- there were ice roads built to some of the Esso CRI deployment locations, but not the deeper water sites

Environmental Scenarios

Winter: ***(late Dec to late May)***

- during winter operations, the Esso CRI was located in stable ice within or at the outer edge of the landfast ice, and was generally surrounded by a large stable grounded rubble field
- the grounded rubble around the CRI was extensive and very rough in places, with variable surface relief
- a grounded ice pad was constructed for relief well drilling purposes in the rubble fields around the Esso CRI

Freeze-Up: ***(mid Oct to mid Dec)***

- very similar ice and ice interaction conditions to those seen around the Tarsiut CRI (see Table 5.2)

Break-Up: ***(early June to mid July)***

- also, similar to the basic ice and ice interaction conditions that were seen at the Tarsiut CRI (see Table 5.2)

Open Water: ***(late July to early Oct)***

- not manned and in operation during the summer open water season

Evacuation Systems

- personnel evacuation approaches very similar to the ones developed for the Tarsiut CRI for full ice cover, partial ice cover and open water situations:
- included a helideck, canister housed inflatable liferafts on four sides of the CRI, scramble nets, and temporary shelters on the stable rubble around the platform
- support vessels were also viewed as an option to the use of helicopters in open water and freeze-up conditions,, directly accessed (again draft and ice rubble permitting), or indirectly accessed by liferafts (or other)
- Esso did not use a rigorous alert system to provide early warning of hazardous ice (or wave) situations, to prompt a staged evacuation process
- their operational approach was generally more reactive than proactive

Key Points

- evacuation options from the Esso CRI were perceived in a similar manner to those from the Tarsiut CRI
- personnel movements to the surrounding rubble and fast ice cover were comfortable in stable winter ice conditions
- evacuation options in open water and low ice concentrations were also acceptable, as long as support vessels were nearby, and the wave situation not adverse
- evacuation options in thin freeze-up ice conditions (again) were not satisfactory
- one evacuation "alarm" came from the Esso CRI when a landfast ice movement event began to create ice overtopping of its surface
- radio calls went out for helicopter support and to an icebreaker in the general area, but the overtopping event quickly subsided and there was no need for anything more than caution on the platform's surface

Table 5.3: Evacuation approaches used for the Esso Caisson Retained Island.

Figure 5.4: Representative views of the conditions generally seen around the Esso CRI during the ice-covered period, and the type of large grounded rubble fields that usually formed around it.

General

Location: Beaufort Sea

Platform: Single Steel Drilling Caisson (SSDC)

Type: Bottom Founded (a segment of a tanker hull set down on a large sand berm, or on a steel base MAT in Alaska)

Water Depth: 10m to 40 m

Function: Exploratory Drilling

Manning: ≈ 100 people

Platform Characteristics

- the SSDC has a ship-shaped surface area with a length of 160m and a beam of roughly 50m
- it is basically vertically sided with no large ice or wave deflectors on top
- it has a fairly high freeboard, about 17m from the waterline
- egress for personnel from the deck of the SSDC to the surrounding ice cover or sea surface is not easy due to the heights involved

Logistics Support

- helicopters were readily available on a year round basis, within several hours (weather permitting)
- open water and ice capable support vessels were also locally available within time frames of a few hours, during the summer and freeze-up periods, but not in winter

Environmental Scenarios

Winter: ***(late Dec to mid May)***

- during winter drilling operations in the Canadian Beaufort Sea, the SSDC was located in the moving pack ice zone, surrounded by a grounded ice rubble field on its submerged berm
- the grounded rubble was tens of metres wide on all sides of the SSDC and in many places was quite smooth, as it was flooded to be a protective barrier
- drifting pack ice created ice failures and floating ice rubble against the grounded rubble on the updrift side of the SSDC, fractured and clearing ice along its sides, and an open water or brash ice wake downdrift
- although the surrounding pack ice cover was usually in motion, there were time periods when the ice did not move for a few days

Freeze-Up: ***(mid Oct to mid Dec)***

- during the freeze-up period, the SSDC was surrounded by thin mobile first year ice, with active ice failures and rubble often forming on its updrift side, and a broken ice zone alongside
- again, a partially open water or brash ice wake was often seen downdrift
- at this time, grounded rubble around the unit was either absent or unstable

Break-Up: ***(late May to late July)***

- similar to winter, but puddled ice

Open Water: ***(early Aug to mid Oct)***

- generally mild wave conditions were seen around the SSDC in summer
- however, occasional storm wave events did occur, with wave heights and sea surface roughnesses around and "up its sides"" being amplified by the structure's presence

Evacuation Systems

- the personnel evacuation approaches developed for the SSDC, included:
- a helideck for large helicopters
- 50 man lifeboats on davits fore and aft, on both sides of the platform
- standard 25 man inflatable life rafts on single point davits, also fore and aft and on both sides
- personnel baskets to be used with the SSDC's cranes
- exterior ladders rigged on the sides, and scramble nets and lowering ropes
- support vessels as an option to helicopters in open water and freeze-up conditions
- an environmental alert system to provide an early warning of hazardous ice or wave conditions, and to prompt a timely staged evacuation process (by helicopter or ship)

Key Points

- evacuation from the SSDC to the grounded rubble & ice pad around it once it became stable winter was quite comfortable
- moving off the grounded rubble and to the surrounding mobile pack ice was not
- evacuation options in open water and low ice concentrations were also acceptable, as long as support vessels were nearby and the wave situation was not adverse
- evacuation options in thin freeze-up ice conditions were not satisfactory
- one staged personnel evacuation was carried out by helicopter in summer, due to a forecasted high storm wave event
- how a lifeboat or liferaft would actually perform if placed on or in ice (or in the downdrift wake in ice) was always an issue due to the strength of their hulls
- support vessel access over the 8m deep berm and when grounded rubble was present was also a concern for direct personnel evacuation to the vessel's deck (in this regard, crane reaches were limited)
- also "good lee conditions" were not always present at the lifeboat and liferaft locations in many open water and ice situations

Table 5.4: Evacuation approaches used for the SSDC.

Figure 5.5: Representative views of thin pack ice around the SSDC during the freeze-up period, and the type of ice rubble and downdrift wakes often seen adjacent to it. The lower photo, taken during late freeze-up, shows a cut-away of the MAT base used during later SSDC deployments in the Alaskan Beaufort Sea, in its landfast ice zone.

Figure 5.6: Representative views of pack ice moving past the SSDC and its grounded ice rubble annulus (and its flooded ice berm) in winter. These photos were taken when the SSDC was deployed on a sand berm at locations in the moving pack ice zone the Canadian Beaufort Sea.

General

Location: Beaufort Sea

Platform: Molikpaq

Type: Bottom Founded (a deep mobile Arctic caisson deployed on a sand berm

Water Depth: typically 20m to 40 m

Function: Exploratory Drilling

Manning: ≈ 100 people

Platform Characteristics

- the Molikpaq is an octagonal steel structure with a hollow central core, that was placed on a small berm on the seafloor, then filled with sand
- as-deployed at most of its Beaufort drilling locations, the caisson had a draft of about 20m (when set down) and a freeboard of about 15m to the top of the deflector on its outer walls
- it was basically vertically sided through the waterline, and its deflector did not provide much overhang, only a metre of two
- it was about 100m in diametr at the waterline
- egress for personnel from the Molikpaq to the surrounding ice cover or sea surface was not easy, because of the heights involved

Logistics Support

- helicopters were readily available on a year round basis, within several hours (weather permitting)
- open water and ice capable support vessels were also locally available within time frames of a few hours to a day or so, from late break-up to late freeze-up, but not in winter

Environmental Scenarios

Winter: ***(late Dec to mid May)***

- during winter drilling operations in the moving pack ice zone, the Molikpaq was not surrounded by a permanent grounded ice rubble field, due to the deep draft of the structure
- drifting ice failed directly against its updrift side in many ways, sometimes with very little broken ice debris seen against this face and, at other times, considerable floating ice rubble
- a broken and fractured ice zone was usually present alongside (typically 5m to 20m in width) as the moving ice cleared around it, and a partially open water or brash ice wake downdrift
- although the surrounding ice cover was usually in motion (from various directions) there were periods when the ice did not move for a few days

Freeze-Up: ***(mid Oct to mid Dec)***

- during the freeze-up period, the type of ice action seen on the Molikpaq was similar to winter, although the pack ice was much thinner
- a long and (largely) open water wake was more consistently seen downdrift during thinner ice conditions
- storm winds in fall sometimes created a combination of sea swell and thin broken ice around the Molikpaq

Break-Up: ***(late May to late July)***

- similar to winter but puddled ice
- in lower concentration and small floe situations, ice often rotated around the structure rather than failing against it

Open Water: ***(early Aug to mid Oct)***

- generally mild wave conditions
- occasional storm waves amplified around the caisson due to its presence

Evacuation Systems

- the evacuation approaches developed for the Molikpaq for year round use included:
- a helideck for large helicopters, with year round refuelling onboard
- four 50 man Watercraft TEMPSC lifeboats lowered on davits (slightly overhanging the deflectors), on all four sides of the platform
- 3 RFD escape slides with 3 RFD 50 man inflatable liferafts (all mobile), that could be deployed from all 4 sides of the caisson
- 3 cranes with personnel baskets, scramble nets, and cold water survival suits, plus a Hurricane Model D-70 fast rescue boat
- support vessels an option to helicopters in the late break-up through late freeze-up period, accessed directly by escape slides, cranes and baskets, or scramble nets or indirectly by the lifeboats or liferafts
- an environmental alert system was used to provide an early warning of hazardous ice or wave conditions, and to prompt a staged evacuation process (by helicopter or ship)

Key Points

- evacuation from the Molikpaq by lifeboat or raft was seen as acceptable in most open water and low ice concentration situations
- getting down from the caisson in these craft in higher concentrations of thin moving ice and in most moving winter ice situations was never a practically accepted option
- staged evacuations were twice carried out by helicopter in winter, due to potentially high forces from drifting multi-year ice
- lifeboat and raft performance in or on ice, and where and how to deploy these craft in various moving and breaking ice situations near the caisson were key issues
- support vessel access and stationkeeping for direct personnel evacuation in some heavy ice and ice pressure situations was also a concern, although getting onto a ship was always seen as better than getting into the ambient ice conditions

Table 5.5: Evacuation approaches used for the Molikpaq.

Figure 5.7: Representative views of moving pack ice around the Molikpaq in both thin and thick ice conditions showing the downdrift wakes that were often seen behind the structure.

Figure 5.8: Representative views of the type of ice interaction behaviours that were seen immediately adjacent to the Molikpaq in moving pack ice conditions.

General

Location: Beaufort Sea

Platform: Ice-Strengthened Drillships

Type: Floating & Moored

Water Depth: typically 20m to 80 m

Function: Exploratory Drilling

Manning: ≈ 90 people

Platform Characteristics

- the drillships that were used in the Beaufort Sea were fairly conventional with dimensions of about 100m x 20m x 9m, displacements of about 15,000 tonnes and freeboards to their main decks of about 4m
- they were strengthened to Baltic Class 1A Super levels, and moored with an 8 point mooring system (4 forward and 4 aft), with wire lines coming off their deck and through the waterline
- these drillships all had helidecks for large helicopters
- they were supported by a number of Arctic Class II supply vessels and the Class IV Kigoriak for as-required ice management

Logistics Support

- helicopters were readily available to drillships within several hours (weather and vessel motions permitting)
- during drillship operations, ice capable (and other) support vessels were also either locally available, or could be called for within time frames of a few hours to a day or so

Environmental Scenarios

Winter: ***(early Nov to mid July)***

- drillships operated in late break-up (low to moderate ice concentrations), open water, and early freeze-up (very thin ice), and not in heavy pack ice
- in short, the "effective" winter period for these platforms was usually from early November to mid July, and they were shut down during this time frame
- because of this, they did not encounter a "full range" of pack ice conditions in the area, but did experience a wide variety of different ice situations

Early Freeze-Up: ***(early to late Oct)***

- during early freeze-up, the drillships generally work in a thin, mobile, and near continuous ice cover, to about 15 cm in thickness or slightly more
- the ice around them was always managed, and present in the form of very small broken floes and brash
- this ice flowed around them as a slurry, but when moving beam on, sometimes formed floating rubble along a side (and high mooring loads)
- storm winds sometimes created a combination of sea swell and thin broken ice around the drillships
- periods of stationary ice, thick areas of managed ice that refroze and moved back over location, and ice pressure situations were all challenging

Late Break-Up: ***(mid to late July)***

- conditions usually involved lower ice concentration and small floes or managed floe fragments that drifted by or around the moored drillships

Open Water: ***(early Aug to mid Oct)***

- generally mild wave conditions, with occasional storm wave events and some summer ice intrusions

Evacuation Systems

- the evacuation approaches developed for the drillships included:
- a helideck for large helicopters
- TEMPSC lifeboats on davits forward and aft on both sides of the vessel
- liferafts (canister type) manually launched from any position(s) of choice
- cranes with personnel baskets, scramble nets, and ropes
- support vessels an option to helicopters, accessed directly by normal ship to ship methods (eg: gangway or scramble net), crane and baskets, or indirectly via pickup of lifeboats or rafts
- an environmental alert system was used to provide an early warning of hazardous ice or wave conditions, but this prompted a move-off location (rather than evacuation)

Key Points

- evacuation from drillships by lifeboat, raft or direct transfer to support vessels, was quite acceptable in most open water and low ice concentration situations
- limitations on safe launching of lifeboats and rafts in high seas and strong winds was well recognized
- close access and stationkeeping of support vessels in high seas and in many pack ice conditions was known to often be difficult, with the threat of collision, complicated by the above water mooring lines on the drillships
- direct personnel transfers to support vessels by crane and basket were seen as slow (4 to 6 people per load) and limited by strong winds and high seas
- lifeboat and liferaft performance in or on either thin or thick ice, and where, how and whether to deploy these escape craft in certain ice situations (eg: rapid ice drift speeds, pressure, thin ice and swell) were important issues
- icing of the lifeboat and liferaft equipment was sometimes a problem due to sea spray in cold temperatures, freezing rain, etc.

Table 5.6: Evacuation approaches used on Beaufort Sea drillships.

Figure 5.9: Representative open water and "in-ice" operating conditions for drillships in the Beaufort, including the type of thin managed ice conditions seen around them (lower photo).

General

Location: Beaufort Sea

Platform: Kulluk (a conical drilling barge)

Type: Floating & Moored

Water Depth: 25m to 60 m

Function: Exploratory Drilling

Manning: ≈ 100 people

Platform Characteristics

- the Kulluk is a conical drilling unit with a circular and downwards sloping hull
- it is a barge and therefore not propelled, and had to be towed from location to location
- the drilling vessel has a main deck diameter of about 100m, a waterline diameter of about 70m, a freeboard of about 5m, and a fully loaded displacement of roughly 28,000 tonnes
- it was strengthened to Arctic Class IV levels, and was moored with a radially symmetric 12 point mooring system
- the mooring lines were well below the sea and ice surface, emanating from the bottom of the Kulluk's hull at a depth of about 11.5m
- during drilling operations, one support vessel was almost always present around the Kulluk and in heavy ice conditions, it was usually supported by two to three Arctic Class IV icebreakers vessels for as-required ice management support

Logistics Support

- helicopters were readily available to the Kulluk within several hours (weather and vessel motions permitting)
- during operations, ice capable vessels were available at the drilling site, or could be called for within time frames of a few hours

Environmental Scenarios

***<u>Winter:</u>* (early Jan to mid May)**

- the Kulluk operated from break-up to late freeze-up, but not in heavy winter pack ice (often due to relief well drilling requirements)
- although it was shut down from early January to mid May, the Kulluk did encounter a "near full range" of Beaufort pack ice conditions during its extended season operations

***<u>Early Freeze-Up:</u>* (early to late Oct)**

- during freeze-up, the Kulluk worked in a thin to moderately thick (1.2m) mobile pack ice, with frequent ridges
- the ice around it was always managed, and usually present in the form of small broken ice floes
- this ice flowed around the circular hull as a slurry, with no discernable "open water" wake seen downdrift
- in pressure, a floating rubble wedge (up to about 50m in length) was often seen on its updrift side
- storm winds sometimes created a combination of sea swell and thin broken ice around the Kulluk
- periods of stationary ice, heavily ridged ice areas and old floes moving at high speed thick and ice pressure situations were all challenging

***<u>Break-Up:</u>* (mid to late July)**

- ice conditions were similar to late freeze-up, but involved thicker and rougher pack ice, in progressively diminishing concentrations and floe sizes

***Open Water:* (early Aug to mid Oct)**

- generally mild wave conditions, with occasional storm wave events and some summer intrusions of old ice

Evacuation Systems

- the evacuation approaches developed for the Kulluk included:
- a helideck for large helicopters
- 4 fifty man Whttaker TEMPSC lifeboats on davits, on all four "sides" of the vessel
- 2 stations, each with 2 inflatable RFD slides and liferafts, on two sides of the vessel (they could be moved to other sides)
- 3 cranes with EMPRA personnel baskets, plus scramble nets, ropes and survival suits
- 1 Hurricane Model 700 D fast rescue boat
- support vessels an option to helicopters, accessed directly by normal ship to ship methods (eg: gangway or scramble net), the RDF slides, crane and baskets, or indirectly via pickup of lifeboats or rafts
- an environmental alert system was used to provide an early warning of hazardous ice or wave conditions, but this prompted a move-off location (rather than evacuation)

Key Points

- evacuation from the Kulluk by lifeboat, raft or a direct transfer of personnel to support vessels was acceptable in most open water and low ice concentration situations, and drills were conducted in these conditions
- in high seas and certain ice situations (eg: high drift speeds (> 0.7 m/sec) in heavy pack ice, or significant ice pressure), close approach and sustained stationkeeping of a support vessel was known to be limited
- lifeboat and liferaft performance in or on either thin or thick ice, and where, how and whether to deploy these escape craft in certain situations (eg: rapid drift speeds, pressure, thin ice) were also key issues
- one actual evacuation of all personnel was carried out during break-up in low ice concentrations, when a large gas release occurred, by moving people to the rescue boat then on to a support vessel in groups
- in one case of storm waves and heavy icing, a lifeboat was swept overboard, then recovered damaged and partially flooded

Table 5.7: Evacuation approaches used on the Kulluk.

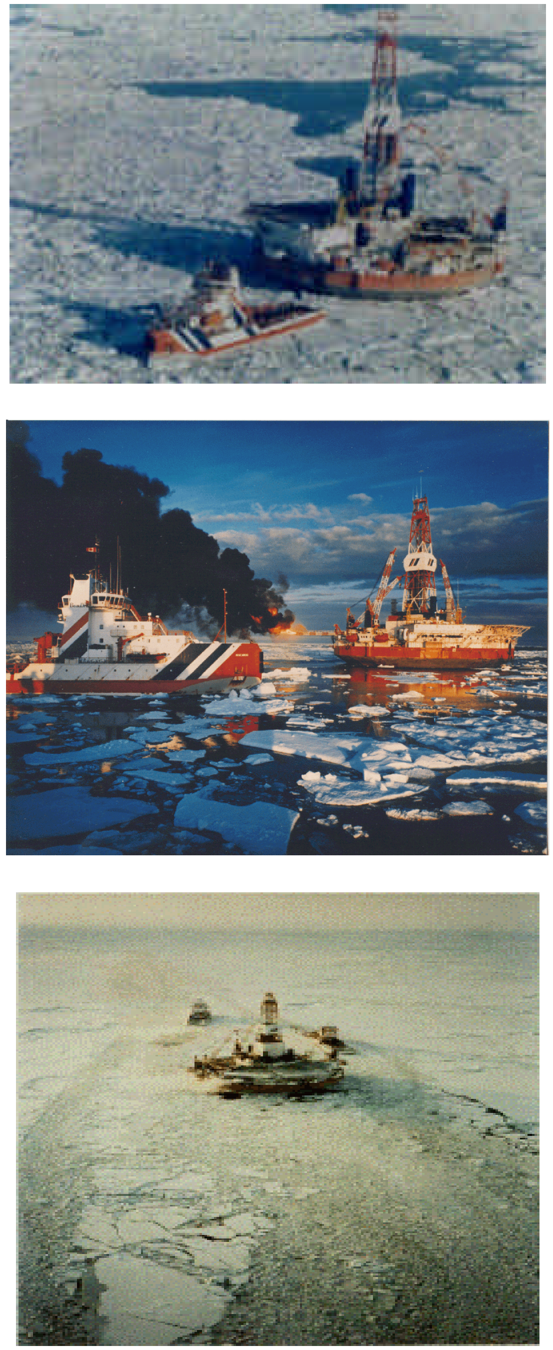


Figure 5.10: Representative views of the Kulluk in heavy pack ice conditions during summer ice intrusions (upper), in partial ice coverage situations (middle), and in thin freeze-up situations, including the type of managed ice floes typically seen around the platform.

Figure 5.11: Views of the type of managed pack ice conditions often seen immediately adjacent to the Kulluk. The lower photo shows an updrift rubble wedge that formed during an ice pressure event.

5.2.4 Key Points

Based on the foregoing information, it is clear that a wide range of experience was gained with offshore drilling operations in the Beaufort Sea, including various in-ice evacuation approaches. It is also clear that operations were carried out in many different types of ice and environmental situations, from a variety of platforms. Despite all of the details and particulars that can be associated with specific combinations of platform type, nature of hazard, evacuation approach, and the ambient ice and other environmental conditions, the basic evacuation scenarios, relevant limitations and issues derived from this Beaufort Sea experience are broadly “classified” as follows:

1) Platforms surrounded by stable landfast ice and grounded ice rubble in winter

- this is the most straightforward evacuation scenario to deal with
- moving personnel off a platform and onto the surrounding stable ice cover is the most reasonable approach to adopt, if evacuation by helicopter is not feasible
- simple personnel transfer methods such as the use of pre-established pathways or ramps for low freeboard structures, or the use of ladders, slides or chutes for high freeboard structures are quite sensible to employ
- prior to getting onto the ice, people must have appropriate cold weather survival gear and should also be educated to recognize that “the surrounding ice cover is a friend” in this type of circumstance
- once on the ice, there should be one or more temporary shelters available nearby (as options to be clear of gas plumes, smoke from fire, etc.), in which people can stay until “rescue and transport” by helicopter, nearby vehicles on ice roads, or other pick-up methods can be implemented

2) Platforms in high concentrations of thin moving pack ice during freeze-up (or at other times during the ice season)

a) <u>Direct Personnel Evacuation to a Support Vessel</u>

- this is the preferred personnel evacuation approach if helicopters cannot be used, provided a support vessel is readily available, and there are means of quickly and safely moving people to its deck
- the ability for a vessel to approach a platform and stationkeep in close proximity to it is normally acceptable in this scenario (depending on the vessel’s capabilities and any draft restrictions), but can be limited by high swell, strong winds, poor visibility and certain ice situations
- these include rapid ice drift speeds, significant ice pressure, combined swell and ice, and/or the threat of the support vessel being squeezed against the platform (by ice)in the location where people are trying to disembark
- when available, the lee and downdrift wake area behind a platform is normally the best location for a support vessel to approach and stationkeep
- low air temperatures, high wind chill, polar darkness, and other adverse factors like icing or blowing snow (when present) are all concurrent conditions that can influence the efficiency of people moving from the platform to a support vessel by various transfer means

- scramble nets, gangways, slides, chutes and so forth are viable methods to transfer fairly large numbers of people to a vessel quickly, although the degree of ease in deploying and using these systems tends to decrease as the platform's freeboard increases
- personnel transfer systems with enough "reach" to allow a vessel to stationkeep anywhere from a few metres to several tens of metres away from the side of a platform offer advantages in many situations
- high winds, severe icing and excessive support vessel movements are all factors that can preclude safe use of most personnel transfer systems

b) Indirect Personnel Evacuation to the Ice

- this is the least preferred evacuation approach, except for the last resort option of having people make their way off a platform and to the surrounding ice conditions individually
- lifeboats and liferafts must be deployed at locations around a platform where they will not be subjected to:
  - o high ice forces (even in thin ice conditions) and the potential for damage
  - o any potential to be overturned and/or overtopped by ice rubbling (or other types of ice failures)
  - o any ice movement or ice interaction situations with the potential to push them back against the platform
- survival craft lowered on standard davits (as most are) have landing zones in very close proximity to the side of most platforms, which is a often a limitation in ice (and open water) conditions
- in this regard, deployment systems that have enough reach to put a survival craft "out and away from a platform", beyond the broken and active ice zone around it, are preferred but are neither developed for nor used in ice conditions
- the possibility of a craft lowered onto the moving ice being "torn away" by the moving ice prior to being released is also an issue
- the practicality of lowering lifeboats or deploying liferafts in low air temperatures, strong winds, and/or icing situations is another issue, since these types of adverse factors can sometimes be problematic
- once placed in thin ice adjacent a platform, TEMPSC units should have the ability to move away from it to a nearby area of safety in a self propelled mode, ideally
- however, "typically powered" lifeboats have little capability to actually transit and manoeuvre, even in very thin ice, when it is present in high concentrations
- because of this, a standard TEMPSC is essentially the same as a liferaft in ice, and must rely on the ambient ice drift, wind and current conditions to carry it away
- if placed on top of a thin level ice area, it is noteworthy that the overall weight a fully loaded lifeboat or liferaft (carrying 50 man) will generally cause it to "break through", in ice thicknesses to about 0.3m
- concerns about significant ice damage to conventional lifeboats and liferafts when they are afloat in moving high ice coverage conditions are obvious
- in short, the technology for indirect evacuations into high concentrations of thin ice using TEMPSC and liferaft units is not well developed, and far from proven

3) Platforms in high concentrations of thick moving pack ice during winter (or at other times of the year)

- in this scenario, the same limitations and issues apply for both direct and indirect personnel evacuation approaches as those outlined in 2) above
- the ability for a standby vessel to approach and stationkeep at a platform, and the safety and “doability concerns” surrounding the deployment of a standard survival craft into high concentrations of moving winter pack ice is simply exacerbated by the thicker and heavier ice conditions that are present
- however, survival craft that are placed on top of the thick winter ice and drift will often be susceptible to ice damage while “afloat”

4) Platforms in mixed ice and open water conditions during break-up involving low to moderate concentrations of mobile thin or thick ice (or similar conditions at other times of the year)

- this evacuation scenario is more straightforward than in higher ice concentration situations, since ship access and stationkeeping near a platform is easier
- similarly, standard TEMPSC units can be deployed into open water areas around a platform, then transit away by navigating around ice floes
- also, the use of liferafts is not uncomfortable in this low to moderate ice coverage situation, to ice concentrations of about 5/10ths

It is noteworthy that deficiencies in evacuation approaches in high concentrations of thin and thick pack ice led to the development of the ice capable ARKTOS system in the late 1980s.

5.3 Grand Banks

5.3.1 Environmental Setting

The Grand Banks is situated at the outer edge of the continental shelf off the East Coast of Canada, and extends out into the North Atlantic. Water temperatures are cold due to the Labrador Current flowing south from the Arctic. This current transports icebergs from Greenland and the Baffin Island area onto the Grand Banks and, with prevailing northerly winds in February and March, can also bring pack ice down onto the southernmost banks. When this occurs, pack ice concentrations in the operational area can be as high as 8 to 9/10^{ths} in wide bands, consisting mostly of small floes. Level ice thicknesses are typically in the thin first year (0.3m to 0.7m) and grey white (0.15 to 0.3m) ice categories, but most of the pack ice cover has some level of deformity caused by ridging or rafting. Traces of old and glacial ice are also present in the pack. Pack ice intrusions are only seen once in every few years on the southern and central Grand Banks, where development activities are now underway. Further northwards and eastwards on the banks, and on the Flemish Cap, pack ice intrusions are much more frequent. Exploratory drilling programs are being considered in these areas and may be initiated in the near future.

Storms are frequent on the Grand Banks during the late fall and winter months, especially between November and March, when maximum winds of hurricane force (>80 knots) and waves up to 30 meters have been experienced. A storm of similar intensity to the one that sank the Ocean Ranger semi-submersible in 1982 was experienced on the Grand Banks on January 22 of this year (2002). At least one tropical storm (hurricanes) also tracks over the southern Grand Banks annually, most often during September or October.

In winter, air temperatures in the area can vary between +10°C when winds are from the south, to – 17°C in northerly winds, while sea surface temperatures can be as low as –1.7°C. The combination of strong winds and low air temperatures can cause extreme wind chills, and can also produce significant structural icing. In winter, precipitation may be in the form of snow, fog, freezing rain, freezing fog, or rain and typically results in reduced visibility conditions about 40% of the time. In summer, air temperatures can rise to 27°C and sea surface temperatures to 15°C. Southerly winds in summer bring warm moist air in contact with the cold ocean currents, creating advection fog. The southern Grand Banks of Newfoundland is well known as one of the foggiest places on earth, with reduced visibility occurring up to 80% of the time in June and July.

From the brief description given above, it should be clear that various combinations of environmental conditions can make personnel evacuation from offshore structures and vessels challenging. The range of environmental conditions that can be encountered also suggests the need for more than one method of evacuation.

5.3.2 Logistics Setting

Two production systems and a semi-submersible exploration rig are now operating in the Grand Banks region on a year round basis. One of the production systems is the gravity base structure (GBS) at Hibernia, and the second is the Terra Nova FPSO. The other vessel that is now drilling exploration and delineation wells in the area is the semi-submersible "Henry Goodrich". All of these offshore platforms are being operated in fairly close proximity to one another, within a radius of about 50 kilometres.

Each unit has a standby vessel, so that within a 50 km radius, there are at least three support vessels. The standby vessels are generally “ice type” and as such, they are able to transit limited pack ice regimes. They are also equipped with iceberg towing hawsers for iceberg management. All of the support vessels are outfitted with the required rescue equipment (including FRC) for Canadian standby ships, and all have davit launched TEMPSC lifeboats and manually launched liferafts for personnel evacuation. They also have survival suits for all onboard.

All exploration and production systems are required to have an ice alert strategy and a contingency plan in place, according to prudent operating practice, as well as government regulations. Their operators share real-time ice information and in most situations, the ice management systems and activities used to support operations. In addition to standby vessels, there are various resupply ships that commonly move through the area.

The Hibernia and Terra Nova locations are approximately 350 km ESE of St John’s, Newfoundland, where commercial helicopters are based, about 2 hours away from the Grand Banks distant in terms of flying time. These two production sites are also about 3 hours flight time from Gander, where Coast Guard search and rescue (SAR) helicopters are based.

All of the exploration and production systems on the Grand Banks have helidecks. In this regard, one of the benefits is that helicopters have alternate locations to use for shuttling personnel, and as re-fuelling stations, during an emergency. Each floating system (ie: the FPSO and semi-submersible) has different motion characteristics in heavy sea states, while the GBS platform offers a landing area that is stable and unaffected by seas. On the downside, with all of the offshore platforms being in close proximity to one another, weather conditions that can restrict helicopter flights will usually be similar. In recent years, a number of advancements have been made in the use and safety of helicopter travel in the harsh Grand Banks environment, including better communications, flight tracking, increased flight range, de-icing systems, and a helicopter flight simulator for practice landings on various vessels with different motion characteristics.

5.3.3 Platforms Used

The offshore platforms that are now being used for exploration and production operations on the Grand Banks are briefly highlighted below. The tables and figures that describe and illustrate each one of them, their logistics support, the ice conditions in which they may operate, and the evacuation systems they now employ are also identified.

<u>Hibernia GBS</u>

- this is the first production structure that was deployed on the Grand Banks and is operating in 80m of water, on a year round basis
- it was designed to withstand extreme storm waves and iceberg impacts and have been very effective since being installed in 1996
- the forces that can be applied by any moving pack ice in the region are very small, in comparison to the storm wave and iceberg impact design loads for the GBS
- see Table 5.8 and Figure 5.12

Terra Nova FPSO

- the Terra Nova FPSO is a very large turret moored vessel that houses production facilities on its deck, has integral oil storage for almost 1 MM bbls within its hull, and has loading systems to transfer oil to tankers at high rates on its stern
- it was installed at the Terra Nova oil field in 2001 in about 100m of water, and connected to pre-drilled wells and gathering facilities on the seafloor
- the FPSO is designed to maintain location in extreme waves, but must move off location if threatened by a large iceberg that cannot be towed
- this moored FPSO vessel is also capable of maintaining location in expected pack ice conditions, in concentrations that are in the range of 8 – 9/10ths
- see Table 5.9 and Figures 5.13

Semi-Submersibles

- the Henry Goodrich is typical of the type of conventional semi-submersibles being used on the Grand Banks
- this vessel, and similar semi-submersibles that may used in the area, are floating drilling units with the capability to operate in water depths from about 60m to hundreds of metres
- they are capable of maintaining location in extreme storm waves, but must move off location when threatened by icebergs or when pack ice intrusions occur
- see Table 5.10 and Figure 5.14

General

Location: Grand Banks

Platform: Hibernia GBS

Type: Bottom Founded

Water Depth: 80 m

Function: Drilling & Production

Manning: ≈ 100 people

Platform Characteristics

- the Hibernia GBS consists of a large concrete substructure that extends from the seafloor to slightly above the waterline, and a large deck with topsides facilities supported by vertical columns that emanate from the substructure
- the concrete substructure is circular in plan and has small wedge-shaped "teeth" on its outer walls that are intended to reduce iceberg impact loads
- the height of its main deck is more than 30m above the waterline and overhangs the base of the structure
- the GBS has integral storage for 1.3 MM bbls of oil in its concrete base
- shuttle tankers load oil that is produced and stored on the GBS every few days, through a flowline and transfer system distant from it
- personnel movements from the deck of the GBS to the sea surface is not easy, due to the heights involved

Logistics Support

- helicopters are readily available year round within a few hours (weather permitting)
- a standby vessel that has some capability in pack ice (albeit limited) is always available near the GBS, plus additional support vessels that operate in the general area

Environmental Scenarios

Open Water: (the normal condition)

- the Hibernia GBS is normally in open water conditions year round
- strong winds, high storm waves, and poor visibility are key constraints
- icing from atmospheric and marine influences is sometimes a factor

Icebergs: (usually seen in spring)

- icebergs sometimes drift through the Hibernia area, with masses ranging anywhere from tens of thousands to millions of tonnes
- growlers and bergy bits that calve from these iceberg may also be seen
- when present, iceberg and "small ice mass" densities are usually low, and they are simply ice features to be avoided from a vessel transit and evacuation system perspective

Pack Ice: (occurrences are infrequent)

- pack ice occurrences at the Hibernia GBS location are rare, and are only seen every few years
- when pack ice does spread down onto the Grand Banks, it can stay anywhere from a few days to a few weeks
- during pack ice intrusions, typical ice concentrations are in the low to moderate range, although high ice concentrations can also be seen
- pack ice thickness and floe sizes are generally in the range of tens of cm and tens of metres (respectively), with low relief ridges and rubble around floe edges, and some multi-year and glacial ice fragments in the pack
- the ice is in continual motion at drift speeds in the order of tens of cm/sec
- high swell can also be present when pack ice occurs
- in cases of high ice coverage, a small downdrift wake would be seen behind the GBS structure, with some small ice floes in it

Evacuation Systems

- the evacuation approaches now in place for year round use on the GBS include:
- a heliport for large helicopters, with refuelling onboard
- eight 72 man TEMPSC lifeboats (sufficient for 200% of the total onboard complement) all equipped with PROD launch assistance (6 attached to the accommodation module, south, and 2 to the process module, north)
- 3 Skyscape chutes with 4 tethered liferafts (each with a 25 man capacity), 2 chutes on the south side and 1 on the north
- the prototype GEMEVAC system (not yet certified for use)
- one 9 man fast rescue craft
- 2 cranes with personnel ("Billy Pugh") transfer baskets
- cold water survival suits and lifejackets for all onboard
- a standby vessel at all times, equipped as required by the regulatory authorities (Transport Canada, CCG and CNOPB)

Key Points

- the evacuation systems on the GBS are designed to contend with all expected emergency situations
- an evacuation capability for ice-covered waters is not seen as a key need, due to the rarity of pack ice occurrences
- in the extreme case of high concentration pack ice conditions being present when an evacuation was required, use of TEMPSC or raft systems would be challenging
- similarly, direct evacuation to the standby vessel (eg: by chute) would not be easy, because the structural and performance capabilities of such a vessel in any "heavy" ice situations is marginal at best
- in fact, in "heavy" ice, the support vessel could be in jeopardy itself
- should moderate to high swell conditions be present in combination with pack ice, safe use of TEMPSC, liferafts or a standby vessel for personnel evacuation would be even more difficult

Table 5.8: Evacuation approaches used on the Hibernia GBS.

Figure 5.12: A view of the Hibernia GBS (upper), and representative pack ice conditions on the Grand Banks (lower photo).

General

Location: Grand Banks

Platform: Terra Nova FPSO

Type: Floating

Water Depth: ≈ 100 m

Function: Production

Manning: ≈ 80 people

Platform Characteristics

- the Terra Nova Floating Production, Storage & Offloading (FPSO) vessel is large, with a length of nearly 300m, a 45.5m beam, and a displacement of roughly 200,000 tonnes
- the FPSO is turret moored so that it can vane into "environment forces", and is DP assisted
- production and accommodation facilities are located on its large deck, almost 1 MM bbls of oil can be stored in its hull, and it has systems to transfer oil to tankers at its stern
- the FPSO's main deck is quite high, about 20m above the waterline
- shuttle tankers load oil that is produced and stored on the FPSO every few days
- the FPSO is designed to maintain location in extreme wind and wave conditions, and it is also capable of operating in moderate to high pack ice concentrations (ie: 5 to 8/10ths)
- it must disconnect and move off location if threatened by sizable icebergs

Logistics Support

- helicopters are readily available year round to the FPSO within a few hours (weather permitting)
- a standby vessel that has some capability to operate in pack ice (albeit limited) is always available near the FPSO, plus additional support vessels in the general area

Environmental Scenarios

Open Water: (the normal condition)

- the Terra Nova FPSO is normally in open water conditions year round
- strong winds, high storm waves, and poor visibility are key constraints
- icing from atmospheric and sea spray influences is sometimes a factor

Icebergs: (usually seen in spring)

- icebergs sometimes drift through the Terra Nova field area, with masses ranging anywhere from tens of thousands to millions of tonnes
- growlers and bergy bits that calve from these iceberg may also be seen
- when present, iceberg and "small ice mass" densities are usually low, and they are simply ice features to be avoided from a vessel transit and evacuation system perspective

Pack Ice: (occurrences are infrequent)

- pack ice occurrences at the Terra Nova location are rare, and only experienced once every few years
- when pack ice does spread down onto the Grand Banks, it can stay anywhere from a few days to a few weeks
- during pack ice intrusions, typical ice concentrations are in the low to moderate range, although high ice concentrations can also be seen
- pack ice thickness and floe sizes are generally in the range of tens of cm and tens of metres (respectively), with low relief ridges and rubble around floe edges, and some multi-year and glacial ice fragments in the pack
- the ice is in continual motion at drift speeds in the order of tens of cm/sec
- high swell can also be present when pack ice occurs
- in cases of high ice coverage, a small downdrift wake would be seen behind the Terra Nova FPSO, with some small floes and brash ice in it

Evacuation Systems

- the evacuation approaches now in place for year round use on the FPSO include:
- a heliport for large helicopters, with refuelling onboard
- three 80 man TEMPSC lifeboats, 2 forward and 1 starboard aft (the aft boat is fitted with a small bow thruster to assist with manoeuvring)
- they are aligned fore and aft for traditional davit launch but are also equipped with specially designed PROD fittings
- ten 25 man davit launched liferafts in two forward locations (5 rafts each) and three aft, 2 port and 1 starboard
- two 10 man (hand launched) liferafts located each side amidships
- 20 "Decender units" (10 spaced equally on each side) for the controlled lowering of people (one at a time) down into the sea
- 2 cranes with personnel ("Billy Pugh") transfer baskets
- cold water survival suits and lifejackets for all onboard
- a standby vessel at all times, equipped as required by the regulatory authorities

Key Points

- the evacuation systems on the FPSO are designed to contend with all expected emergency situations
- an evacuation capability for ice-covered waters is not seen as a key need, due to the rarity of pack ice occurrences
- in the extreme case of high concentration pack ice conditions being present when an evacuation was required, use of TEMPSC or raft systems would be challenging
- similarly, direct evacuation to the standby vessel would not be easy and the support ship itself could be in jeopardy in ice, due to its structural and performance limits
- should moderate to high swell conditions be present in combination with pack ice, safe use of TEMPSC, liferafts or a standby vessel for personnel evacuation would be even more difficult

Table 5.9: Evacuation approaches used on the Terra Nova FPSO.

Figure 5.13: Views of the Terra Nova FPSO vessel.

General

Location: Grand Banks

Platform: Henry Goodrich *(a semi-submersible)*

Type: Floating

Water Depth: ≈ 100 m

Function: Drilling

Manning: ≈ 150 people

Platform Characteristics

- the Henry Goodrich is a large (but typical) semi-submersible that is now being used for drilling operations on the Grand Banks
- this particular vessel has deck dimensions of about 100m x 75m, and four equally spaced columns running down from the deck to two full length 14m pontoons
- at its 28m operating draft (while drilling), its displacement is roughly 50,000 tonnes
- the Henry Goodrich is moored by a 12 point all chain spread, and has two 7,000 HP thrusters to assist in waves and winds
- when operating, its main deck is quite high, about 25m above the waterline
- it can maintain location in extreme wind and wave conditions in a survival mode, but must disconnect from its mooring and move off location if threatened by icebergs or pack ice intrusions
- in short, it is intended only for open water use

Logistics Support

- helicopters are available to the semi within a few hours, on a year round basis (weather permitting)
- a standby vessel is available nearby, and other support vessels in the general area

Environmental Scenarios

Open Water: (the normal condition)

- semis like the Henry Goodrich are only intended for use in open water conditions, which typify the Grand Banks area
- strong winds, high storm waves, and poor visibility are key constraints
- icing from atmospheric and sea spray influences is sometimes a factor

Icebergs: (usually seen in spring)

- an iceberg that is moving towards a semi will cause a move off location, as dictated by an ice alert system
- iceberg towing by support vessels is often successful in dealing with threatening icebergs
- from an evacuation perspective, any icebergs or small ice glacial masses in the local vicinity of a semi should simply be avoided
- the areal densities of these ice features are typically very small

Pack Ice: (occurrences are infrequent)

- pack ice occurrences force semis to shut down drilling operations and move-off location, away from the pack ice edge
- as a result, in-ice evacuations are not a real concern (or issue) for these types of drilling vessels

Evacuation Systems

- the evacuation approaches that are now in place on the Henry Goodrich are representative for semis working on the Grand Banks, and include:
- a heliport for large helicopters, with refuelling onboard
- four 75 man TEMPSC lifeboats, optional "free fall" or davit launched
- six 25 man davit launched liferafts
- one 9 man fast rescue craft
- 2 cranes with 4 man ("Billy Pugh") transfer baskets
- cold water survival suits and lifejackets for all onboard
- a standby vessel, equipped as required by the regulatory authorities

Key Points

- the evacuation systems on the Henry Goodrich (and similar semi-submersibles) are capable of dealing with all expected emergency situations in open water conditions on the Grand Banks
- an evacuation capability for ice-covered waters is not required for this type of unit, because semis do not operate in pack ice
- however, should a semi find itself in a pack ice situation and in need of an evacuation, the same limitations would apply to its systems as those noted for other Grand Banks platforms

Table 5.10: Evacuation approaches used on a typical semi-submersible drilling unit.

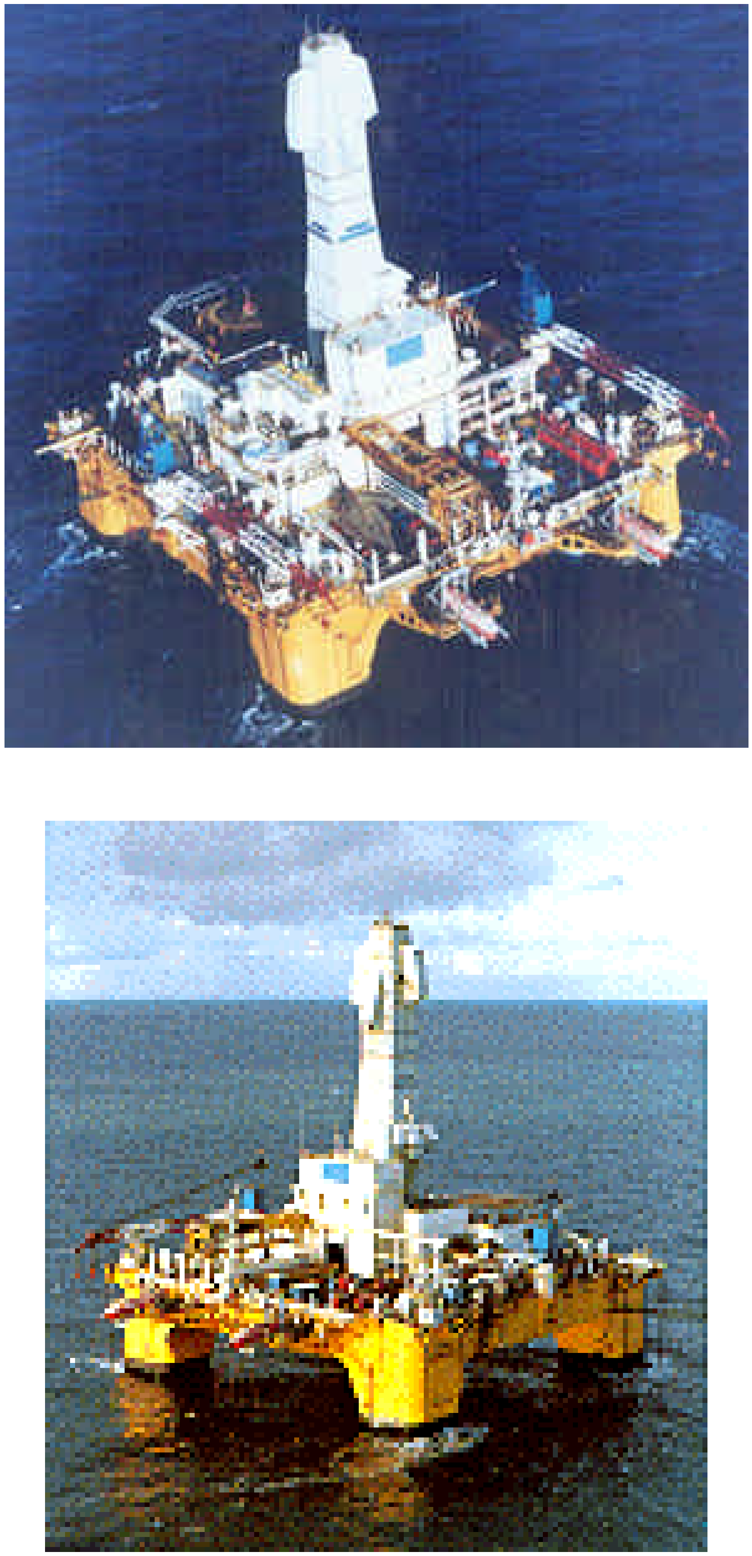


Figure 5.14: Views of the Henry Goodrich semi-submersible.

5.3.4 Key Points

Based on the foregoing information, it is clear that in-ice evacuation approaches are not seen as a significant issue for current exploration and development projects on the Grand Banks. It is also clear that little experience has been gained with offshore operations in Grand Banks pack ice conditions to date, with the exception of the breadth of ice-related knowledge possessed by East Coast mariners. As industry operations move northwards and eastwards, where pack ice is more frequently encountered, a stronger requirement for improving "in-ice evacuation technologies" will likely arise.

Nevertheless, the basic in-ice evacuation scenarios for Grand Banks systems, along with relevant limitations and key issue areas, can be broadly classified as follows:

1) Platforms in mixed ice and open water conditions during pack ice intrusions involving low to moderate concentrations of mobile ice

- this evacuation scenario is fairly straightforward and most evacuation systems on Grand Banks platforms should be capable of contending with it
- standby vessel access and stationkeeping near a platform should be achievable in most of these ice situations, to acccomodate direct evacuation of personnel
- similarly, standard TEMPSC units can be deployed into open water areas around a platform, then transit away by navigating around ice floes
- also, the use of liferafts is not uncomfortable in this low to moderate ice coverage situation, to ice concentrations of about 5/10ths
- however, strong winds, high swell and/or possible icing conditions could make safe personnel evacuation in these conditions much more challenging

2) Platforms in higher concentrations of moving pack ice

a) <u>Direct Personnel Evacuation to a Support Vessel</u>

- again, this is the preferred personnel evacuation approach if helicopters cannot be used, provided an ice-capable support vessel is readily available and there are means of quickly and safely moving people to its deck
- the ability for a vessel to approach a platform and stationkeep in close proximity to a platform remains the main issue, and depends on the capabilities of the vessel in ice, the presence of high swell, strong winds, poor visibility and so forth
- personnel transfer systems with enough "reach" to allow a vessel to stationkeep anywhere from a few metres to several tens of metres away from the side of a platform offer advantages in many situations
- high winds, severe icing and excessive support vessel movements are all factors that can preclude safe use of most personnel transfer systems

b) <u>Indirect Personnel Evacuation to the Ice</u>

- this is the least preferred evacuation approach in significant ice situations, except for having people make their way off a platform to the surrounding ice conditions, individually

- the use of lifeboats and liferafts as an evacuation method is less than comfortable in high pack ice coverage circumstances, because of the issues outlined in Section 5.2.4
- by way of summary, key areas of concern include:
    - where to best place a survival craft in relation to the ambient ice drift and ice interaction conditions around a platform
    - the ability of a survival craft to move away from a platform under its own power in ice or, if not self-propelled, where the ice will carry it
    - the strength, integrity and safety of a survival craft when it is afloat in moving ice conditions
- evacuation systems on Grand Banks platforms are more advanced than most in terms of their ability to place survival craft "out and away" from platforms
- however, some basic safety and performance issues remain, once a survival craft is placed into the ambient ice conditions

5.4 Other Regions

A variety of offshore platforms have been used (or are now being considered for use) in other ice-infested areas of the world. Here, a brief description of these platforms and the evacuation approaches employed on them is provided, on a regional basis. This material is generally less detailed that the previous summaries for platforms in Canadian waters. However, an attempt has been made to capture most of the relevant factors, and give the reader some feel for these other activities.

Descriptions are provided in relation to offshore platforms and evacuation approaches in the following regions.

- the Alaskan Beaufort Sea
- the Cook Inlet area
- the offshore Sakhalin area
- the Caspian Sea
- the Gulf of Bohai
- the Pechora Sea

5.4.1 Alaskan Beaufort Sea

Over the past several decades, a large number of wells have been drilled in the shallow nearshore waters of the Alaskan Beaufort. Almost all of them were drilled from artificial islands that only operated during the winter period. Since these structures were located in stable landfast ice and typically had ice roads running to them, evacuation approaches were similar to those used on artificial islands in the Canadian Beaufort Sea (Table 5.1). By way of summary, evacuating people to the surrounding ice cover was considered to be safe and practical, and was the preferred option. Two other platforms used in the Alaskan Beaufort Sea, which are considered to be more noteworthy, are highlighted as follows.

Concrete Island Drilling System (CIDS)

CIDS was used for exploratory drilling operations in the Alaskan Beaufort during the mid 1980's (by Exxon), and was capable of working in water depths from 11m to 17m. It is a bottom founded GBS platform comprised of three stacked "bricks". The lower steel mud base is 90m by 95m in dimension and sat directly on the seafloor, eliminating the need for a subsea berm. The middle concrete part penetrated the waterline, and was about 80m by 80m in size. The top steel module formed the main deck and housed the drilling and accommodation facilities. Depending upon the water depth in which CIDS was deployed, the unit's freeboard ranged between 12m and 18m. The top portion of the deck overhung the middle brick unit and had an outward sloping flare on its outer walls, to act as an ice and wave deflector.

The CIDS was designed to withstand forces from first and multi-year ice interactions, as well as storm waves. It was deployed at two drilling locations off Alaska's Beaufort Sea coast, both lying in about 13m of water, in the middle reaches of the landfast ice zone in winter. During its first deployment, the CIDS unit was also protected by a large spray ice annulus to further mitigate the potential for high ice load levels (Figure 5.15). Relevant in-ice operating scenarios for the CIDS are summarized as follows.

- moving pack ice in fall
  - high concentrations of thin moving ice with variable floe sizes
  - occasional leads and open water areas, and some stationary ice occurrences
  - occasional ice pressure events during onshore ice drift situations
  - floating rubble and some unstable grounded rubble intermittently forming on the structure's updrift side (in moving ice)
  - a narrow broken ice zone alongside the structure and usually, a downdrift wake
- winter landfast ice
  - a stable ice cover surrounding the structure, with a grounded rubble field adjacent to it (in one case, supplemented by grounded spray ice)
- moving pack ice during break-up
  - high concentrations of large thick ice floes in early break-up
  - decreasing ice concentrations and floe sizes as break-up progressed
- concurrent influences
  - strong winds, low air and sea temperatures
  - snow, blizzards & occasional icing events
  - poor visibility (fog, blowing snow, polar darkness, etc.)

Figure 5.15: Typical views of the CIDS in ice. The upper photo shows the drilling unit in thin ice during freeze-up, with a protective spray ice berm under construction. The lower photo shows the structure in more stable winter landfast ice conditions.

The evacuation systems that were used on CIDS are similar to those employed on other Beaufort Sea structures like the Molikpaq and SSDC. They included:

- a helideck for large helicopters
- 4 standard TEMPSC lifeboats on davits, one on each side of the unit
- standard liferafts (canister type) that could be moved to selected locations for use
- ladders and scramble nets on the side of the CIDS (in stable winter ice), to access the ice or sea surface

- no support vessels were available to aid with evacuations in any ice conditions, with the exception of the type of small "open water only" launches and ships used on the Alaskan north slope, which have some capability to operate in very low ice concentrations in summer

Ice situations that were recognized as being the most problematic for evacuation from the CIDS were those involving moderate to high concentrations of moving ice, either thin or thick. In the area where the CIDS operated, these conditions were seen during the freeze-up and break-up periods. The reasons for considering evacuation options from this unit to be limited are similar to the concerns identified earlier, in Section 5.2.4.

Northstar Development Project

Northstar is the first real offshore development project in the Alaskan Beaufort, in water depths beyond several metres. The production platform is a large artificial island that was built in about 12m of water, by adding onto the pre-existing "discovery island" (Seal Island), originally constructed in 1982. First oil was produced by the Northstar project in 2001, through a subsea pipeline that was built to shore and a short onshore trunk line that runs to Prudhoe Bay.

The production island is about 140m x 130m in size, and has a relatively low freeboard sloping down to the waterline. There are docking facilities on its south side for shallow draft vessels. It is designed to withstand the load levels associated with first and multi-year ice interactions, and the effects of extreme wave events.

The ice situations that can be experienced at Northstar are similar to those outlined in the summary above, for the CIDS unit. Representative views of the production island in various ice conditions are given in Figure 5.16. In winter, the island is located in stable landfast ice. Again, personnel evacuation to the ice cover around the platform is seen as the most sensible approach at this time, should emergency events like a major fire, explosion, or gas release occur. Also, an ice road is routinely built between Prudhoe Bay and the island each winter, which offers a straightforward means of rescue (or pick-up) by standard vehicles.

Figure 5.16: Typical views of the Northstar production island during freeze-up and break-up ice situations (top and middle photos). In winter, the ice cover and grounded rubble around this platform is stable The lower photo shows an ARKTOS craft moving over nearby rough ice in winter, during a training exercise for a driver. The ARKTOS craft has been selected as the primary means of evacuation in certain ice and emergency situations.

Personnel evacuations in the type of moving ice and ice interaction situations that can be seen around the island during the freeze-up and break-up periods, and in heavy summer pack ice intrusions, are somewhat more difficult to contend with. ARKTOS units have been selected as the primary option for evacuation in these ice scenarios, and are in place on the island. In this regard, the operators of the Northstar development project feel that the ARKTOS can safely deal with most of the ice and open water conditions expected, given the testing carried out with it in the Beaufort Sea area to date.

The use of ARKTOS at Northstar is an example of how evacuation technology that is specifically designed for ice can be applied. However, some of the practical factors that should also be recognized are:

- the surface area on the production island is large and there is "plenty of room" to house ARKTOS craft, which are quite large and also heavy
- the freeboard of the production island is fairly low, and its geometry is amenable to driving an ARKTOS craft off the platform and onto the surrounding ice or open water conditions

With respect to using the ARKTOS in "all conditions", three possible limitations to note are highlighted as follows:

- in situations where the ARKTOS craft is being driven directly onto a moving ice cover from the island's edge, there is potential for its front unit to move laterally when "first arriving on the moving ice", and for its rear unit to be flipped over prior to getting to the ice, due to relative movements between the two
- once deployed in certain thin ice situations (tens of centimetres), where the weight of ARKTOS may cause it to break through, the craft's ability to propel itself can be limited and its effective speed of advance may be very low
- if an ARKTOS craft rolls over when traversing steep ridge or rubble features (or in any significant waves), it does not have any ability to self-right itself

5.4.2 Cook Inlet

Production platforms have been operating in Cook Inlet, which lies along the northwest coastline of Alaska, since the late 1960s. A relatively thin first year ice cover is present in this area for several months in winter, cyclically moving up and down the inlet under the influence of tides, often at high drift speeds. Multi-legged platforms are most typically employed here, with deck freeboards in the range of 20m, and deck sides that overhang the structures' legs. A representative view of a Cook Inlet platform in thin moving pack ice conditions is shown in Figure 5.17.

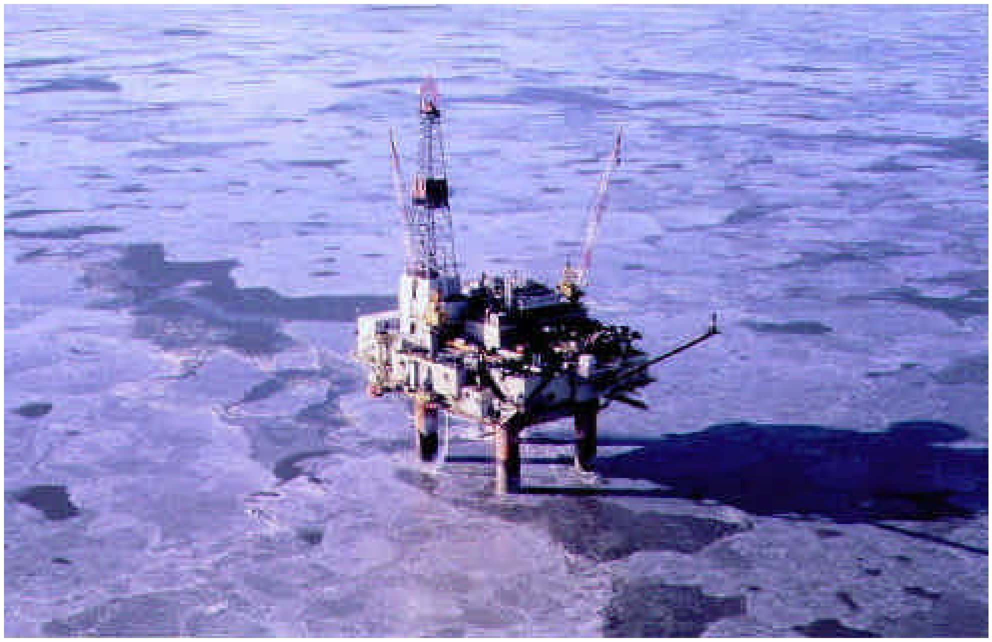


Figure 5.17: A typical Cook Inlet production platform in thin pack ice conditions. Note the TEMPSC unit mounted along the side of its deck.

Standard davit launched TEMPSC units are commonly installed on these platforms, while conventional liferafts are also available onboard. To date, there have not been any direct experiences with the use of these type of survival craft in the ice conditions encountered. However, there is an anecdotal case of a TEMPSC accidentally falling onto the pack ice cover in winter. Although it quickly disappeared in an overturned state, it was recovered sometime later, damaged but not sunk

There do not appear to be any regulations concerning in-ice evacuation methods in Cook Inlet, only the approaches adopted by the platform operators of their own volition. It is likely that platform operators made due with the evacuation approaches available at the time, with these becoming the "status quo" over time in the area. Here, it should also be noted that all of the Cook Inlet platforms are located within a few kilometres of the shoreline, where substantial infrastructure is in place. For example, large helicopters can be quickly mobilized to a platform, while support vessels (with "some" capability to operate in ice) can also be dispatched.

5.4.3 Offshore Sakhalin Island

Two major development projects are now underway off Sakhalin Island, a Russian region that lies to the north of Japan and to the east of the Siberian mainland. They are termed the Sakhalin 1 and Sakhalin 2 development projects, operated by Exxon Neftegas (ENL) and Sakhalin Energy Investment Company (SEIC), respectively. The Sakhalin 2 project is presently the furthest advanced. Within the scope of this development, the Molikpaq was modified for use as a drilling and production platform, and then deployed off the northeast Sakhalin coastline in 1998. Oil is now being produced from this structure to a floating storage system (FSO) on a seasonal basis (in open water and thin ice), and exported to market by tankers. Two multi-legged production platforms are also being designed for installation as the SEIC development project expands. These platforms will be constructed and deployed at two other locations on the northeast Sakhalin Shelf over the next few years. Subsea and onshore pipelines, along with LNG and oil export systems are also under design, to move hydrocarbons produced from the three platforms to tankers and then on to market, on a year round basis.

The initial stages of the Sakhalin 1 project are not as large, but also involve an oil field development off the northeast shelf of Sakhalin Island. Within the scope of this project, the CIDS platform, now renamed the Orlan, is being modified for use as a production platform and will be deployed in 2004. Pipelines will carry oil from the Orlan to the shoreline, across Sakhalin Island, and then across the Tartar Strait to a small port on the Russian mainland, where a tanker export facility will be constructed.

The offshore Sakhalin area, where the Molikpaq is located and the three new production platforms will be installed, has an extremely hostile operating environment. During the open water season (typically from early June to late November), large storm waves are often seen, particularly in the fall. The wave climate is severe, with extreme wave heights approaching those experienced on the Grand Banks and storm waves being steeper, due to shallower water depths in the area of operations (15m to 50m). During the ice season, which generally lasts for about six months of the year, the northeast Sakhalin shelf is usually covered by thick and heavily deformed first year pack ice that is very dynamic. This Sakhalin ice cover is not dissimilar to the type of ice seen off Labrador (excepting the presence of icebergs and multi-year ice) and in many ways, presents difficulties that rival those in Beaufort Sea pack ice conditions. In addition to high waves in late summer and fall, and heavy rapidly moving pack ice conditions in winter, the offshore Sakhalin region is also subject to very strong seismic activity. Other environmental constraints to note include high winds, low winter air and sea temperatures, frequent periods of poor visibility and fog, rain and snow, and various forms of icing. Representative views of the type of wave and pack ice conditions that are seen in the area, in this case around the Molikpaq platform, are shown in Figure 5.18.

Figure 5.18: Representative open water storm wave and winter pack ice conditions seen in the offshore Sakhalin area, in this case around the Molikpaq.

At the present time, the Molikpaq is the only platform operating off Sakhalin Island on a year round basis. However, it is periodically resupplied by icebreakers in winter and usually has vessels near it in the open water season, including the FSO unit. The platform is located roughly 20 km off the coast in about 30m of water. Helicopters can be made available within an hour of flying time, although the more major cities on Sakhalin Island are located hundreds of kilometres away. When SEIC's two new production platforms are deployed, and as their onshore pipelines and facilities are constructed, the logistics infrastructure will increase. One of the new platforms will be located some 25 km to the north of the Molikpaq and the second about 150 km south in a different hydrocarbon field. These new platforms will also be located within roughly 20 km of the coastline, one in about 30m of water and the other in a water depth of about 50m. Each platform will have a standby vessel, and supply vessel transits through the general area of operations are expected to be frequent on a year round basis.

The Orlan platform will be closer to the coastline, some 10 km offshore, in about 15m of water. This structure may or may not have a year round standby vessel, but will certainly have helicopter support available to it within an hour or so. As these two development projects progress, it is clear that significant logistics support systems will be put into place, many of which will probably be utilized by the two operators on a shared basis.

Molikpaq

Although the Molikpaq caisson and its topsides were modified for its deployment off Sakhalin Island, the structure has the same basic characteristics as described in Section 5.1. However, for its Sakhalin application, it was mated with a large steel base called the spacer, then set down directly on the seafloor (this spacer essentially replaced the dredged sand berms that were required in the Canadian Beaufort Sea). The ice deflectors on the Molikpaq's upper walls were also increased in height on its seaward sides, to prevent significant wave overtopping in storm wave events.

These changes have resulted in some subtle differences, which are highlighted as follows.

- the structure's as-deployed freeboard off Sakhalin Island is slightly higher than in the Beaufort Sea, about 20m above mean sea level
- because of the 30m water depth in which the structure is located and its spacer (rather than a large "shallower" berm), there is never any stable grounded ice rubble around the Molikpaq, only moving and actively failing pack ice

In its drilling and production application off Sakhalin Island, manning levels on the Molikpaq are consistently high, and its 110 beds are always full. In fact, a jack-up rig is usually located close to it in summer, to house additional personnel.
The evacuation systems that are now in place on the Molikpaq are the same as those used when the structure was operating in the Canadian Beaufort Sea, and are not augmented in any way. As outlined in Table 5.5, they include:

- helideck for a large helicopter, with a year-round refuelling capability onboard
- 4 fifty man Watercraft lifeboats on 4 sides of the Molikpaq, lowered on davits
- 4 RFD inflatable escape slides and RFD liferafts
- 1 fast rescue boat – Hurricane Model 700-D
- 3 cranes and personnel baskets, scramble nets and cold water survival suits

- icebreaking support vessels, although not continuously available year round, directly accessed by escape slides, crane and baskets or scramble nets (when stationkeeping is possible nearby), or indirectly by pick-up of lifeboats or liferafts after they have been placed into the sea or pack ice

Off Sakhalin, the challenge for these evacuation approaches is to contend with the wide range of moving pack ice conditions that are seen during the ice-covered period, and the continually varying ice-interaction conditions adjacent to the platform. These situations are substantially more dynamic and changeable than those commonly encountered in the Canadian Beaufort Sea. For example, typical ice drift speeds off Sakhalin are about five times higher than mean winter drift speeds in the Beaufort, with means in the range of 0.5m/sec and extremes in excess of 2 m/sec (ie: > 4 knots). This has the effect of making “ice action” on and around the Molikpaq “very rapid” most of the time. Combined with the very rough and thick first year ice that is typically seen, safe deployment of survival craft adjacent to the structure and the ability for a support vessel to stationkeep nearby are both key considerations. Figure 5.19 provides views of the type of broken and dynamic ice conditions often seen immediately adjacent to the Molikpaq. In the Sakhalin pack, there are typically few expanses of level ice to move away on, unlike the Beaufort Sea.

Ice drift reversals (caused by tides) are usually seen twice daily, often bringing the pack ice back and “near-to or over” its former location. During these reversals, some in-ice pressure often occurs. The pack ice may also remain stationary for short periods, at times. These factors raise questions about the safety of a survival craft once deployed in or on the pack ice cover, and its ability to “get away and stay away” from the platform should adverse ice drift situations occur around the time of its deployment. An additional scenario of note for the offshore Sakhalin area, usually in the late freeze-up, early winter and break-up periods, is the combined occurrence of high concentrations of small broken ice floes and significant swell, sometimes up to 5m or 6m in height. This is a difficult situation for vessel stationkeeping near the Molikpaq (because of vessel motions), and for the deployment of survival craft. The important points and issues for in-ice evacuation from the Molikpaq are similar to those outlined in Section 5.2.4, only exacerbated by the dynamics and typically rough nature of the Sakhalin pack ice cover.

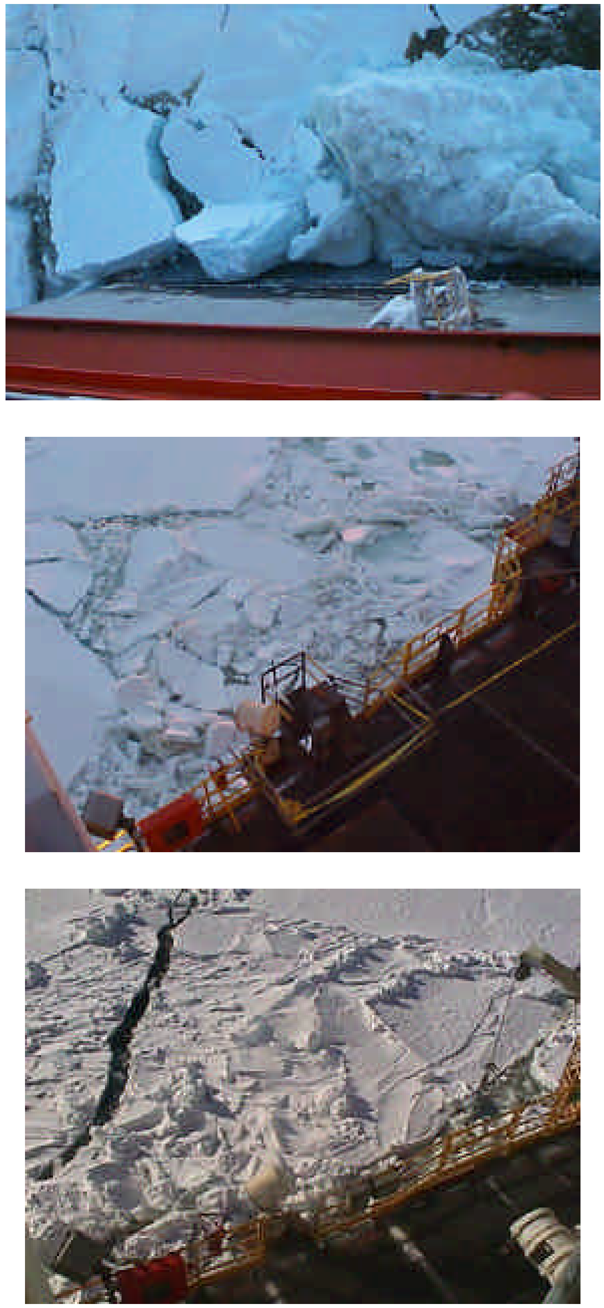


Figure 5.19: Examples of the type of ice action that is often seen immediately adjacent to the Molikpaq, on its updrift and "alongside" faces.

Multi-legged Platforms

The two new production platforms now being designed by SEIC for the next phase of their offshore Sakhalin development project are both multi-legged GBS structures. They consist of a large base section (or raft), four columnar legs emanating from the base and penetrating the waterline, and an elevated deck on the columns supporting the topsides facilities. One of these structures will be deployed in about 30m of water and the second in about 50m of water. The length of the columnar legs will be increased on the second platform to compensate for water depth, but the deck freeboard of each structure will be similar, about 20m. The decks of each structure will also overhang the columns beneath them by 10m to 15m, all around. In broad terms, they will not look much different to the platform shown in Figure 5.17. The main incentive for designing a multi-legged structure is to reduce the global design wave load, as compared to the wave load levels on wide monolithic platforms like the Molikpaq. From an ice perspective, the design ice loads are not dissimilar, because ice may jamb between the legs and create a “wide solid zone” over which the oncoming pack ice can fail.

The pack ice situations these platforms will operate in are similar to those highlighted for the Molikpaq above. Clearly, evacuation systems that can contend with the full range of ice and ice interaction conditions expected is important.

SEIC is now evaluating a number of evacuation options for these two platforms but has not yet decided on the systems that they will use. Clearly, a dry evacuation by helicopter is the preferred option, when weather and “onboard emergency” conditions permit. Since an icebreaking standby vessel will be present near each platform during the ice-covered period, SEIC is reviewing methods that are capable of moving personnel to the vessel’s deck. Alternatives like the Skyscape system, and other types of chutes and slides are all being considered. With this evacuation approach, which is based on the use of a standby vessel during the ice season, some of the key issues being addressed include:

- the ability for the vessel to approach the platform and stationkeep in all ice situations
- how many egress locations should be “installed” on the platform and where best to late them, to accommodate different ice drift direction and ice interaction situations
- cases in which significant in-ice swell may cause excessive vessel motions that could impede safe personnel transfers onto their deck
- restrictions on vessel approaches that may be caused by gas releases, fire, smoke plumes and so forth

The deck overhangs on these platforms offer some vessel access advantages, as compared to wide near vertical structures like the Molikpaq. However, the movement of broken ice through and around their legs, and the absence of a downdrift wake in many cases, is a possible disadvantage for vessel access and stationkeeping.

Various indirect evacuation systems are also being evaluated, to provide personnel escape options on these multi-legged platforms in situations where helicopter and standby vessel access is not possible. A number of survival craft and deployment systems are now under consideration but, for the most part, are alternatives that have been developed for use in open water environments. In this regard, key issues include:

- how many evacuation stations to install and where, to accommodate variability in ice drift directions and ice action around the structure
- how and how far out to lower a survival craft to avoid the active broken ice zone (when necessary), and how to have control over where and when the craft is placed
- appropriate craft geometries and hull shapes to prevent “roll over” during launch
- the ability for the craft to move away in various ice situations in a powered mode, and to safely move away with the ambient ice drift in certain cases
- the need for an ice resistant survival craft that can be carried away on (or in) the pack ice, and is capable of safely resist local and global ice forces on it

Orlan

When the Orlan is deployed as a drilling and production platform off the northeast coast of Sakhalin, it will be exposed to the same range of moving pack ice situations as SEIC's structures. However, it will be located at a shallower site, in 15m of water, and will be partially or fully surrounded by grounded ice rubble at times. The extent, stability and longevity of the rubble formations that may be seen around it can only be speculated on at present, pending actual full-scale experience. However, the presence of rubble adds another element to the range of evacuation scenarios that have to be addressed.

In terms of its overall size and basic geometry, the Orlan is quite similar to the Molikpaq. When deployed, it will have a waterline diameter of roughly 80m, a freeboard of 22m, a slight deck overhang, and vertical sides though the waterline. Exxon is now evaluating various evacuation systems for the Orlan to cover both ice and open water situations. All of the in-ice factors identified for SEIC's Molikpaq and multi-legged platforms are being considered, plus the potential complications (and benefits) relating to evacuations when ground rubble is present.

The evacuation systems that are currently in place on the Orlan (originally the CIDS) will likely be kept, including its TEMPSC lifeboats and liferafts. However, Exxon is also pursuing means of augmenting the present evacuation capability on it, to better deal with the full range of situations that are foreseen. In this regard, some of the methods Exxon are now considering that have not already been mentioned, and some related concerns, include:

- how best to get large numbers of people down and onto stable grounded ice rubble that may be present around their high freeboard platform quickly and safely (slides, etc.)
- the safety of people once on the ice (in conditions unfamiliar to them), and the ability for large numbers of people of different shapes, ages and fitness levels to effectively move away from the platform without injury in various ice situations, for subsequent rescue
- the use of a large cantilevered walkway and TEMPSC launch structure, permanently mounted on (or swung out from) the platform at a high elevation, that would allow survival craft and/or people to be lowered onto grounded ice rubble or moving pack ice at a predetermined preferred location, some 20m to 30m distant from the Orlan's side
- survival craft that like the ARKTOS, have the ability to climb up onto large ice floes deemed safe, thereby getting out of potential situations where they could be crushed between floes
- the use of hovercraft for rescuing people located either on the ice or in survival craft, as an alternative to an ice capable standby vessel

5.4.4 Caspian Sea

A major offshore development project is now underway in the northern Caspian Sea. This development is operated by the Offshore Kazakhstan International Operating Company (OKIOC), with AGIP as the prime western participant. Very large oil reserves have been found in this area. As the project proceeds, as many as ten production structures will be installed, together with subsea pipeline systems. This offshore development will, by far, be the largest of any in the world.

The northern Caspian Sea has a unique set of environmental conditions. In the area that is of interest for the OKIOC development, water depths are shallow, from several metres to 10m. Large and persistent water level changes may be seen at any time of the year, which can reduce water depths by up to several metres. Sometimes, vessels that are operating in the region can be grounded for periods of days to weeks. Open water is typical from mid April to late December. During this period, storm waves are not particularly high because of limited water depths. From late December through early April, OKIOC's operating area is normally ice covered. This ice cover is comprised of relatively thin first year ice that is generally quite smooth. It can experience significant movements, which sometimes lead to intermittent open water occurrences on-site in winter. At times, the ice can also be stationary. Pressure ridges and rubbled ice areas are found within the ice cover. Grounded ice rubble piles (stamukha) are also seen, most frequently in the 2m to 6m water depth range. Rubble pile heights in excess of 10m are not uncommon.

Offshore drilling operations have been conducted in the northern Caspian Sea for the last several years, including activities during the ice season. A purpose built drilling barge named the Sunkar has been used for this purpose, and deployed at different locations. It is a low freeboard bottom founded structure that sits on the seafloor or on a small berm, depending on water depth (Figure 5.20). Methods designed to reduce ice load levels on the barge and mitigate the potential for ice overtopping have been employed, including the use of piles and rubble generators placed around it. Artificial islands are additional structures now being constructed for drilling operations at other Caspian Sea locations. In additional to challenging environmental condition, the presence of H_2S in the reservoirs being drilled is a very key factor. Any release of this toxic gas on-site could be deadly.

The evacuation approaches that have been put in place on the Sunkar are intended to deal with emergencies in all expected ice and open water situations. The ability for evacuation systems to quickly move personnel away from the platform to a safe distance (and in any required direction) is particularly important, given the potential for an H_2S release and a toxic "downwind" plume. The systems now being used on the Sunkar are highlighted as follows.

- 3 ARKTOS units housed in a large bay within the hull of the Sunkar barge, as the main evacuation system for all eventualities (particularly in ice)
- doors that can be opened and ramps that can be lowered on both sides of the bay, to allow the ARKTOS units to drive out on either side (ie: to provide an option should one side of the platform be blocked by grounded ice rubble, or otherwise adverse)
- standard inflatable liferafts on both sides of the Sunkar fore and aft, and scramble nets and ropes in these locations
- a gangway that can be placed to span the width between the Sunkar's deck and a support vessel stationkeeping alongside

Some of the issues and limitations that have been identified in conjunction with in-ice use of the ARKTOS, based on full-scale trials and field experiences in north Caspian Sea ice conditions, are summarized as follows:

- the presence of grounded ice rubble around the Sunkar structure is an ongoing constraint on egress of ARKTOS vehicles, and must be cleared when it occurs
- the use of icebreakers with azimuth drives has proven to offer an effective means of quickly clearing grounded ice rubble around the bay doors for the ARKTOS

- although an uncommon situation adjacent to the Sunkar structure in the Caspian Sea, in theoretical cases where the ARKTOS craft is being driven directly onto a moving ice cover, there is potential for its front unit to move laterally when "first arriving on the moving ice", and for its rear unit to be flipped over prior to getting to the ice, due to relative movements between the two
- once deployed in certain thin ice situations (tens of centimetres), where the weight of ARKTOS may cause the unit to break through (Figure 5.21), the ability for an ARKTOS craft to propel itself is limited and its effective speed of advance can be very low (this is a significant and problematic limitation in the event of a major H_2S release, where rapid escape to a safe area is key)
- additionally, effective use of the ARKTOS vehicle in ice is highly dependent on the skill of its operator in the particular situation that is at hand, and ongoing training and learning is required
- experience in training and demonstration exercises with the ARKTOS in the Caspian Sea has shown the problems with an ARKTOS craft rolling over, for example when traversing steep ice rubble features, and the dangers associated with its inability to self-right itself

OKIOC is continuing to look for and develop improved in-ice evacuation methods for their offshore operations (and particular problem areas) in the Caspian. The evacuation approaches they develop in the future could well be linked to the specifics of the platform arrangements that they put into place, rather than being based on generic technologies.

5.4.5 Bohai Bay

Offshore oil and gas activities have been underway in China's Bohai Bay for a number of years. There is not a lot of information readily available about conditions in the area, or details about the platforms and systems being used. However, it sis well known that Bohai Bay does experience thin moving pack ice conditions for several months during the winter period. Rather simple jacket platforms, with narrow vertical sided legs through the waterline, have been traditionally used for drilling and production operations in this area, year round (Figure 5.22). At least one of these platforms is known to have failed due to ice-induced vibrations experienced in thin moving ice. More recently, FPSOs have been installed for production operations in some of the deeper water parts of Bohai Bay.

Information was received from the Bohai Company, now renamed the Tianjin Branch of the China National Offshore Oil Company (CNOOC), about the safety regulations for and emergency evacuation procedures used on Bohai platforms. Their response indicated that safety requirements for the Chinese offshore have become more stringent and have been improved over the past few years, due to CNOOC initiatives. Based on ISO standards, the Tianjin Branch has established requirements and regulations for safety in the offshore environment, involving the protection of personnel and equipment against factors such as fires and explosions, storms and typhoons, and sea ice effects.

Figure 5.20: Two views of the Sunkar barge in Caspian Sea ice conditions.

Figure 5.21: Relatively thin ice conditions in which an ARKTOS craft has considerable difficulty in making any significant forward progress. In this photo, it is "wallowing" at a very low speed of advance.

Figure 5.22: A typical Bohai Bay production platform that, comparatively, looks quite basic.

The approach that appears to be used is to set up a working group for each platform in charge of safety requirements and emergency evacuation procedures, from the design through the operation phases. This group periodically does checks of how safety systems are being implemented, and arranges field exercises for fire extinguishing, personnel evacuation operations and so forth. A special working organization system in the Branch is also established every winter for monitoring, forecasting of ice conditions and also for evacuation procedures in case of an in-ice emergency.

In terms of evacuation approaches, standard lifeboats of adequate capacities and numbers are provided onboard each platform, and all are fire-isolated. For personnel evacuation in situations caused by ice, helicopters are to be used, and it is assumed there is enough forewarning time (through ice forecasting) to implement this type of evacuation. Escape in ice conditions when required by onboard fire or explosions was not mentioned. However, it is likely that support vessels (if available) would play an important role in these emergency scenarios.

5.4.5 Pechora Sea

In this report, possible offshore development activities in the Pechora Sea are simply noted. This region lies off the western part of Russia's Arctic coastline, to the east of the Barents Sea and northeast of Murmansk. The Pechora Sea is covered by first year ice for about half of the year, and is characterized by rough mobile pack ice conditions in winter. Development studies have been carried out by various groups over the past ten years, but have focused on production and export system concepts and their basic economics, moreso than the details that come after feasibility is established such as in-ice evacuation. However, when last visited, the evacuation concepts that were most topical for a drilling and production caisson being planned for an oil field development (Prirazlomnoye) in 20m of water included:

- direct personnel evacuation from the high freeboard caisson structure (about 20m above the waterline) to a year round ice capable support vessel
- use of the ARKTOS for indirect evacuation of personnel to the surrounding ice conditions (however, topsides area requirements and craft weights, as well as how best to deploy this type of heavy units were under debate)

Concerns and issues surrounding the use of these evacuation approaches in moving Pechora pack ice conditions were similar to those already identified for other regions.

6.0 Assessment of In-Ice Evacuation Approaches

6.1 General

The foregoing sections have outlined the various evacuation approaches that have or are currently being used on offshore platforms in different ice-covered regions, along with some of the systems now being considered for use on future structures. The ranges of ice situations in which these evacuation approaches are expected to perform have also been highlighted, and the main areas of concern about their adequacy identified. It is clear that there are many combinations of platform type, ice and ice interaction conditions, and emergency situations possible. In this section of the report, an attempt is made to draw the in-ice evacuation material that has been presented thus far together, in a generic way, and highlight important factors, apparent deficiencies and key issue areas.

6.2 Ice Scenarios

The most basic in-ice settings that can be defined for various evacuation considerations include:

- a platform that is located in stable landfast ice conditions and/or surrounded by a large stable grounded ice rubble field
- a platform that is directly exposed to high concentrations of moving pack ice
- a platform that is operating in low to moderate concentrations of moving pack ice (ie: in mixed ice and open water conditions)

Within these basic settings, there are many different ice parameters, other environmental factors, and emergency situation specifics of importance, as outlined in Section 3.2. The ranges of ice interaction conditions that can be seen around a platform introduce another level of variability.

The case of a platform surrounded by stable ice or rubble is straightforward, as compared to high coverage, moving ice situations. In the case of stable ice, the main issue is how to get people onto the ice, their protection and safety while there, and how best to pick them up. Since structures that are located in stable ice or rubble normally experience varied concentrations of moving pack ice during the freeze-up and break-up periods, they should also be capable of personnel evacuations in these types of conditions. Because of this, the main focus of the discussion that is given here is on moving ice scenarios. The stable ice case is not addressed further, at least in an explicit way.

A generic summary of the key scenarios that can be identified for platforms operating in moving ice conditions is given in Table 6.1, together with a broad brush assessment of the relative degree of ease (or difficulty) for evacuations in these situations. The intent of this summary is simply to provide a general overview. The “ease of evacuation” rankings shown are considered to reasonably cover both direct evacuations to a support vessel and indirect evacuations by typical survival craft, as a first level cut. However, it is readily acknowledged that these types of rankings will vary with specific details of the platform and the situation at hand. Other influences that may occur concurrently with these basic ice scenarios and impact the effectiveness of any evacuation approach include strong winds, low temperatures, darkness or poor visibility, blowing snow or icing, and so forth.

Ambient Ice **Situation**		**Ice Drift Speed**			**Other Factors**	
		low	→	*high*	High Swell	In - Ice Pressure
Initial Ice Forms *	0 – 5 cm	green /////	green /////	green /////	orange	only a factor in very high concentration situations
New Ice Forms *	5cm – 15cm	green /////	green /////	yellow	orange	
Grey White Ice *	0.15m – 0.3m	green /////	yellow	orange	orange	
Very Low Ice Concentrations (1 – 2/10ths)	Thin	green	green	green	yellow	
	Medium	green	green	green	yellow	
	Thick	green	green	green	yellow	
Low to Moderate Ice ***Concentrations*** 3 – 4/10ths	Thin	green	green	green	yellow	
	Medium	green	green	green	yellow	
	Thick	green	green	yellow	yellow	
Moderate Ice ***Concentrations*** 5 – 6/10ths	Thin	green	yellow	yellow	orange	
	Medium	yellow	yellow	yellow	orange	
	Thick	yellow	yellow	orange	orange	
High Ice ***Concentrations*** 7 – 8/10ths	Thin	yellow	orange	orange	red	
	Medium	orange	orange	orange	red	
	Thick	orange	orange	red	red	
Very High Ice ***Concentrations*** 9 – 10/10ths	Thin	orange	red	red	red	red
	Medium	red	red	red	red	red
	Thick	red	red	red	red	red

Notes:

(green) not difficult (hatched by yellow suggests not straightforward for some types of survival craft placed onto or into the ice)

(yellow) not straightforward

(orange) quite difficult

(red) very challenging

* These ice types are normally present in high concentrations (8 – 10/10ths)

Ice Thickness Ranges:

Thin	0.3m to 0.7m
Medium	0.7m to 1.2m
Thick	> 1.2m

These are assumed as typical first year pack ice types, with areas of ridging and rubble, and variable floe sizes.

Table 6.1: A generic summary of key scenarios involving moving ice conditions, and a broad brush ranking of the relative ease of evacuation in these conditions.

6.3 Ice Interaction Scenarios

The range of ice conditions that may be seen in the general vicinity of an offshore platform must be considered when evaluating the functionality and probable success of any evacuation approach used. However, the type of ice interactions that a platform can experience, and the ice conditions created immediately adjacent to it as the result of these interactions, are also important factors to recognize. Observations from the Molikpaq can be used to illustrate a number of related points.

6.3.1 Broken Ice Zones around the Molikpaq

A considerable amount of information about ice conditions around the Molikpaq was acquired during its deployments in the Beaufort Sea (Timco, 1996). Photos, like the one given in Figure 6.1, show the general ice conditions around the Molikpaq in moving ice. In addition, and more importantly, frequent records of ice conditions near the structure were obtained, and numerous overview ice charts prepared throughout the winter months. Figure 6.2 shows a typical overview ice chart from December 9, 1984.

Figure 6.1: Photograph showing ice action on the updrift sides of the Molikpaq in moving pack ice, and the brash ice wake behind it.

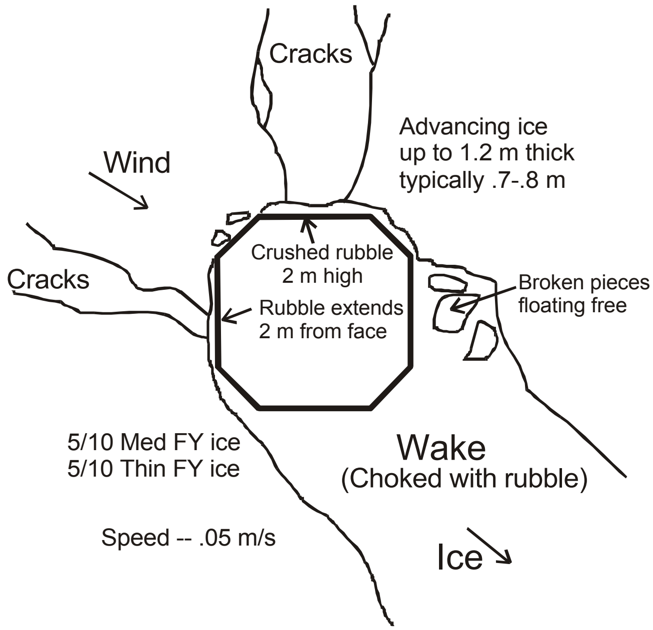


Figure 6.2: A sketch showing the ice and ice interaction conditions around the Molikpaq on December 9, 1984. Note that the zone of broken ice is close to the structure, and there is a open area along one of its side and in the downdrift direction.

For a caisson-type structure like the Molikpaq, the ice conditions immediately adjacent to it can be highly variable, and safe approaches for evacuation must cover a wide range of ice situations. When launching a lifeboat or any other type of escape craft from the Molikpaq, it is important to ensure that the craft does not get "caught" in the broken ice zone on its updrift side(s) resulting from ice interactions with it.

In general terms, there are three basic ice zones normally seen around the Molikpaq in moving ice conditions. They are briefly summarized as follows, and illustrated in Figure 6.3.

1. **Updrift Direction** – In this region, "in front of the structure", dynamic ice conditions and active ice failure processes are usually observed. In most cases, it would be extremely dangerous to launch a lifeboat in the updrift direction or allow personnel access to it.
2. **Longside Direction** – Along the sides of the structure, ice conditions can also be quite dynamic, as the moving ice clears around it. A lifeboat launched into this region would have to be placed far enough away from the structure to avoid the broken ice zone. Allowing personnel to leave through this alongside region may at times be safe, if the ice is not moving too fast. The width of this broken ice zone in this region is a function of the ice thickness and the type of ice failure processes occurring at the time. Figure 6.4 shows typical values for a 1 m thick ice sheet, for both crushing and mixed modal ice failure.
3. **Downdrift (Wake) Direction** – In the region "behind" the structure, an open water wake or broken ice area is often present. A lifeboat could be launched in this wake area, in close proximity to the structure. It should be noted, however, that this region is usually located in the downwind direction in moving ice, so it could inaccessible due to fire, heat, smoke or gas plumes, and so forth.

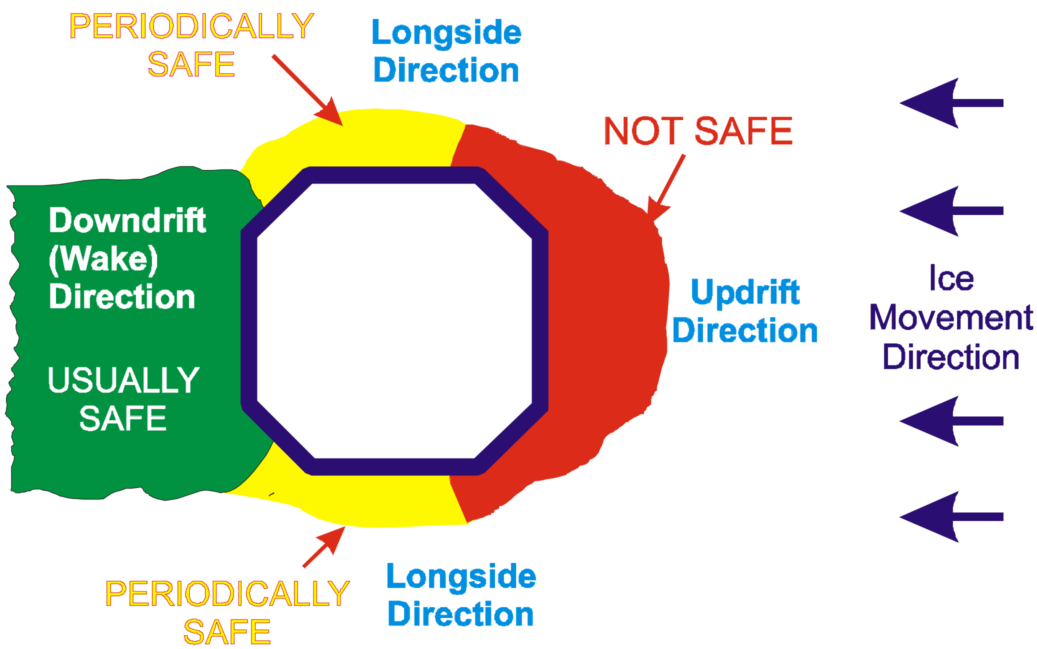


Figure 6.3: Schematic illustration showing the 3 zones for evacuation in ice-covered waters.

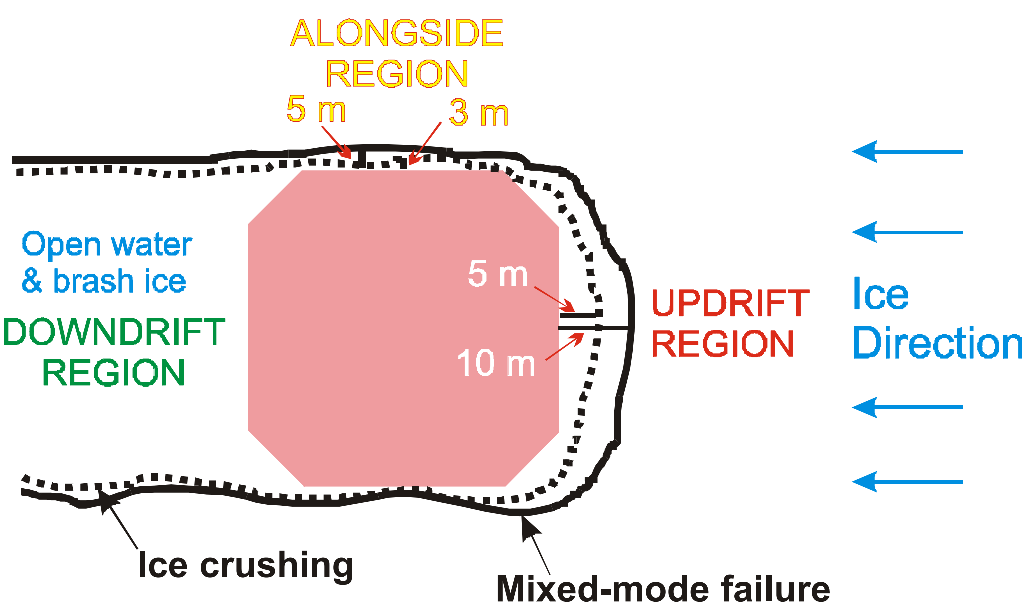


Figure 6.4: Schematic illustration showing the typical size of the "active ice zone" alongside the Molikpaq in 1 m thick ice. The zone sizes are indicated for both crushing (dashed line) and mixed modal (solid line) ice failures on the updrift side.

6.3.2 Generic Comments for Wide Structures

A few generic comments about ice interactions with the type of wide deep draft platforms that are typically used in pack ice environments are given as follows.

- in high concentrations of moving pack ice, the oncoming ice cover will always fail against the updrift side(s) of a platform, with some failures and fractures often seen in a broken ice zone along the structure's sides. When the drift direction is perpendicular to one of the platform's broad sides, only the updrift face will experience "severe ice action and ice forces". However, when the ice drift direction is diagonal to a platform's broad side, significant ice action and forces can be experienced on its two updrift faces.

- a band of floating ice rubble of variable extent (typically a few metres to many tens of metres) will normally be seen across the platform's updrift width in the perpendicular ice drift case. In diagonal ice drift situations, this rubble will span its larger diagonal width, but will taper off in extent towards the structure's corners.

- Ice action and fractures will also be seen in a broken ice zone along the sides of a structure, as the ice clears by it. Typically, this broken and active ice zone will be between 3m and 30m wide along its sides, depending on the pack ice thickness and roughness, and the ambient ice failure situation st the time.

- on the downdrift side of a platform, in high ice coverage situations, an open water or brash ice wake will normally be seen. This wake will form behind one side of a wide platform in perpendicular ice drift direction cases, and over a wider width behind its two downdrift faces when the ice movement direction is diagonal.

- this type of ice interaction scenario will be favoured in pack ice situations where floe sizes and "the overall continuity of the ice cover" are large in comparison to the width of the platform. Thinner ice tends to favour a more open and less brash filled wake, while thicker and rougher pack ice conditions usually result in heavier ice debris in the wake area.

- Figure 6.5 provides another schematic illustration (similar to Figure 6.3) of the type of ice interactions that should be expected around wide platforms in high concentrations of moving pack ice. The length of the downdrift wake will vary with the ice drift speed, while its width will narrow as a function of pressure (or convergence) in the ice cover. In high ice pressure situations, the wakes (if seen) behind structures are often very short and in low drift cases, they may be virtually non-existent.

- when ice floe sizes are fairly small (tens of metres, for example, during the break-up period or in managed ice) and ice concentrations are still high, the ice cover can flow past a platform as a "slurry", without significant failures on the updrift side. In these types of situations, the downdrift wake that is seen behind a platform is usually minimal.

- representative examples of the downdrift wakes that can be observed behind wide platforms, ranging from open to not present, are shown in Figure 6.6

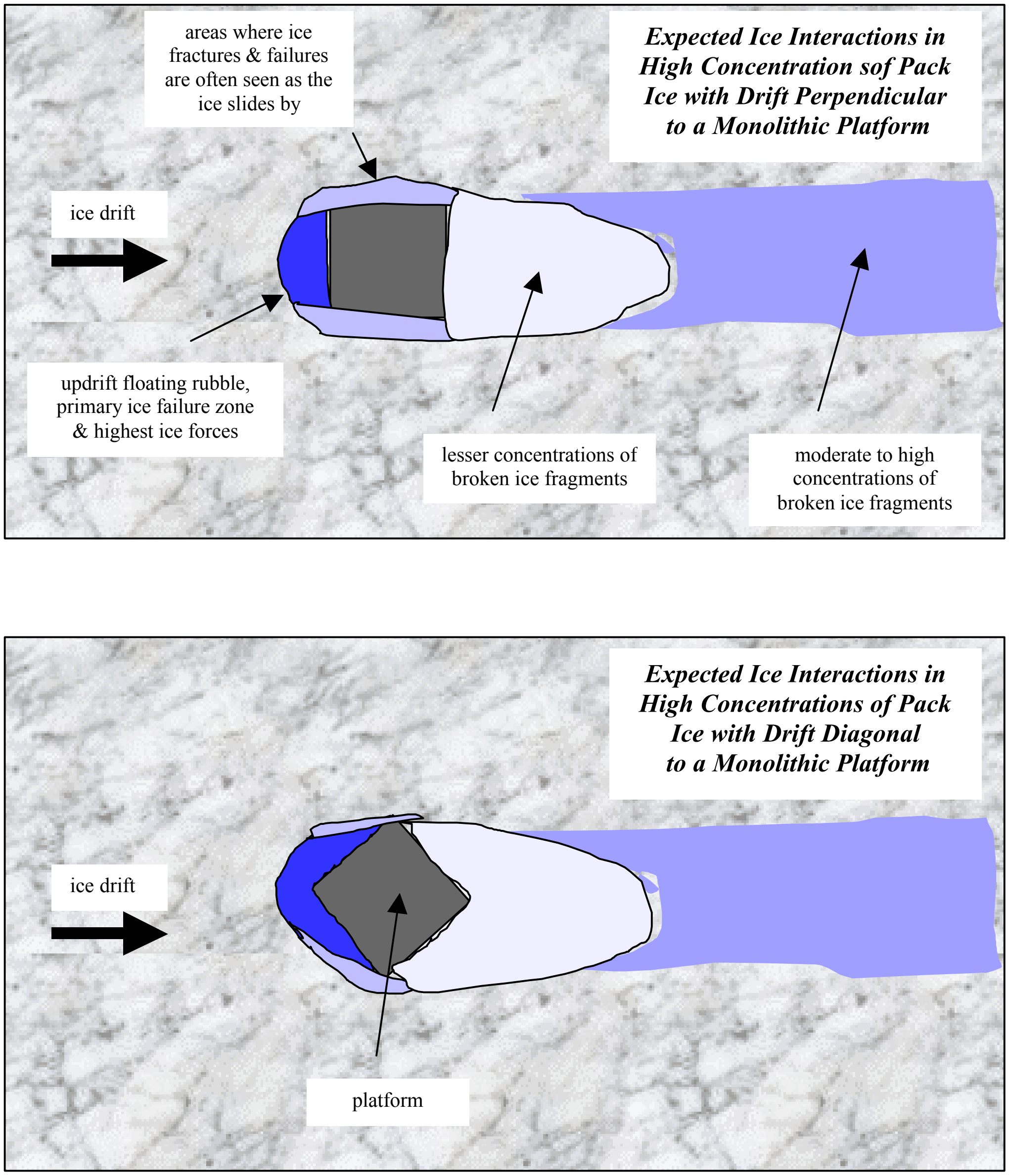


Figure 6.5: Another illustration of typical ice interactions around wide offshore platforms in high moving pack ice concentrations. The top schematic is similar to Figure 6.3, while the lower one shows the diagonal ice drift case.

Figure 6.6: Downdrift wakes can sometimes be quite open (upper - in thin moving ice) and at other times full of brash and broken ice fragments (lower - in small floes). Although these photos were taken around the Molikpaq off Sakhalin Island, observations in the Beaufort Sea were similar.

The manner in which ice interacts with a platform and clears around it will have a very strong influence on where it is possible to effectively stationkeep with a support vessel, or safely deploy a survival craft. Figure 6.7 provides a simple conceptual illustration of “safe evacuation zones” around a platform that is located in moving high concentration ice conditions. The suitability of vessel stationkeeping or survival craft deployment into the alongside area will depend on the particulars of the ice situation present at the time. If the nature of the onboard emergency (eg: a major fire on one side of the platform or a significant gas plume in the downdrift direction) takes away access to the “safe evacuation zone(s)”, clear problems may arise. Lesser ice concentration situations become progressively easier to contend with.

6.3.3 Generic Comments for Other Platform Types

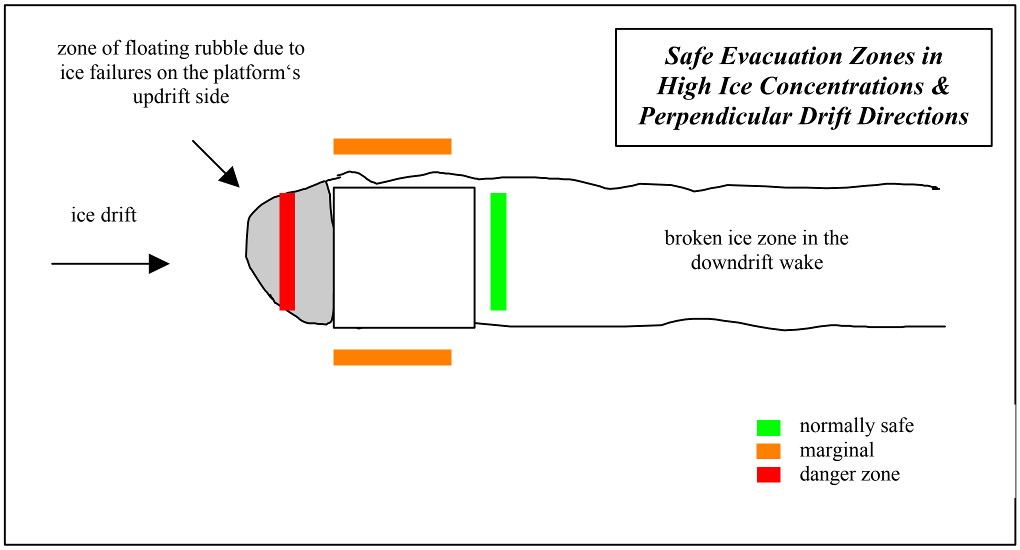
The comments that have been provided in the last two subsections are relevant for wide platforms with a fairly deep draft (ie: structures with no grounded ice rubble around them). Other types of platforms will experience different ice interaction behaviours, usually with lesser degrees of “shielding” for both standby vessel stationkeeping operations and evacuation craft deployments.

For example:

- conical structures will usually fail the oncoming ice cover “further out” from them than wide near vertically sided platforms like the Molikpaq. However, there will generally be less (if any) floating ice rubble on the updrift side of conical platforms. Along their sides, the ice will be actively failing out from the cone, moreso than in the case of wide vertical structures. Broken ice pieces will also clear by moving up and over the cone near the waterline, virtually eliminating any clear wake conditions on the downdrift side.

- multi-legged structures will normally have relatively narrow columnar legs down through the waterline. In most cases, the oncoming ice will fail against the individual legs locally, with a a narrow downdrift wake forming behind each one. Less rubble will be seen on the updrift side of each leg and the broken ice zone along the legs’ sides will typically be less wide than in the case of a wide platform. The ice in the area between the legs will usually be comprised of broken ice pieces that “drift through”. Deck overhangs “out over” the supporting legs (if present) may simplify the deployment of evacuation craft away from the broken ice zone. However, this type of platform would offer little protection on it downdrift side for standby vessel stationkeeping operations. In some cases with multi-legged structures, thick rough ice areas may jamb, temporarily leading to ice interactions and wake occurrences similar to those for wide platforms.

- ship-shape platforms will be different again. Little updrift rubble, narrow broken ice zones down their sides, and a brash ice wake would be characteristic in unmanaged ice conditions. If a ship-shape platform was operated in conjunction with ice management support vessels, the normal ice interaction scenario would involve small broken ice floes and floe fragments moving around it as a slurry.



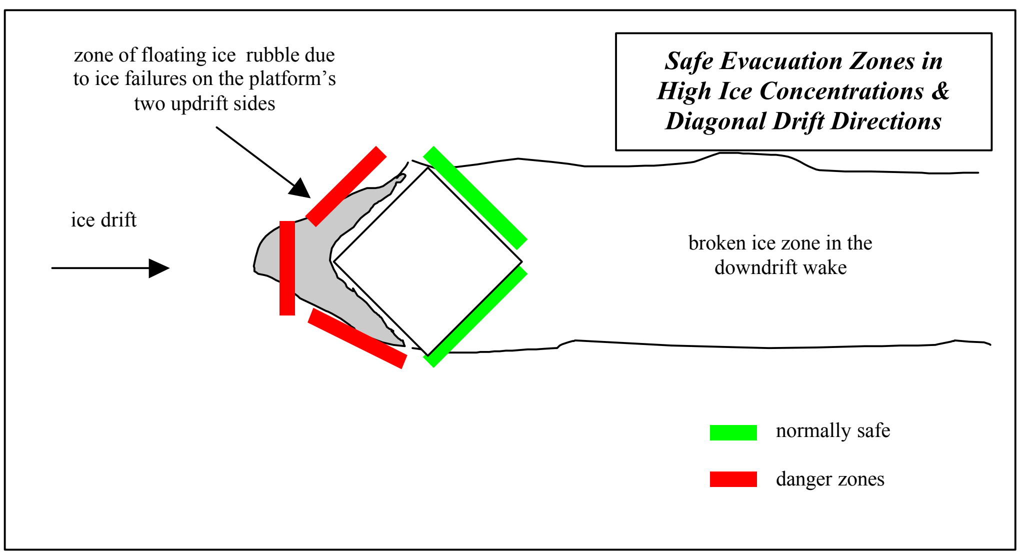


Figure 6.7: Safe evacuation zones for standby vessel stationkeeping operations or survival craft deployments in high concentrations of moving ice. The upper schematic is for perpendicular ice drift cases and the lower for diagonal ice drift situations.

It is of interest to note that NRC-CHC has developed an analytic model to determine expected ice interactions, broken ice zone dimensions, downdrift wakes and ice force levels around various platforms in moving pack ice. This model has been applied to the question of safe evacuation zones around offshore structures and is available for future use. A description of the model and its application to the in-ice evacuation topic area is given in Barker et al. (2001) and in Appendix F.

The results this model produces are very much in line with ice interaction scenarios that can be developed on the basis of full-scale experiences. However, the model can be applied to a wide range of platform geometries and ice conditions. Consequently, it can be used to obtain various insights about in-ice evacuations for different structures, in a variety of moving ice conditions.

6.4 Key Issue Areas

In order to properly evaluate the various in-ice evacuation approaches that are currently available, it is important to identify some of the key issue areas associated with their use. These issues form a basic checklist for particular evacuation system assessments. They are simply listed as follows.

6.4.1 Direct Transfer of Evacuees to a Standby Vessel

- ice strengthening and in-ice performance of the support vessel
- ability to stationkeep adjacent to a platform within required tolerances, for the time period needed for evacuation
- personnel boarding methods, and their sensitivities to vessel movements, including vessel behaviour in adverse ice and combined ice / swell situations

6.4.2 Indirect Transfer of Evacuees by Survival Craft

- ability to deploy a survival craft into a “safe ice zone” away from a platform, where the ice action and ice forces are not adverse
- ability for the survival craft to move away from the hard on (and around) the platform to an area of safety
- safety and integrity of the survival craft when located within (or on top of) the ice conditions that are at hand, after deployment
- safe and efficient rescue (pick-up) of the survival craft and its onboard personnel after it has moved away from a platform in the ambient ice conditions

6.4.3 Practical Design and Operational Considerations

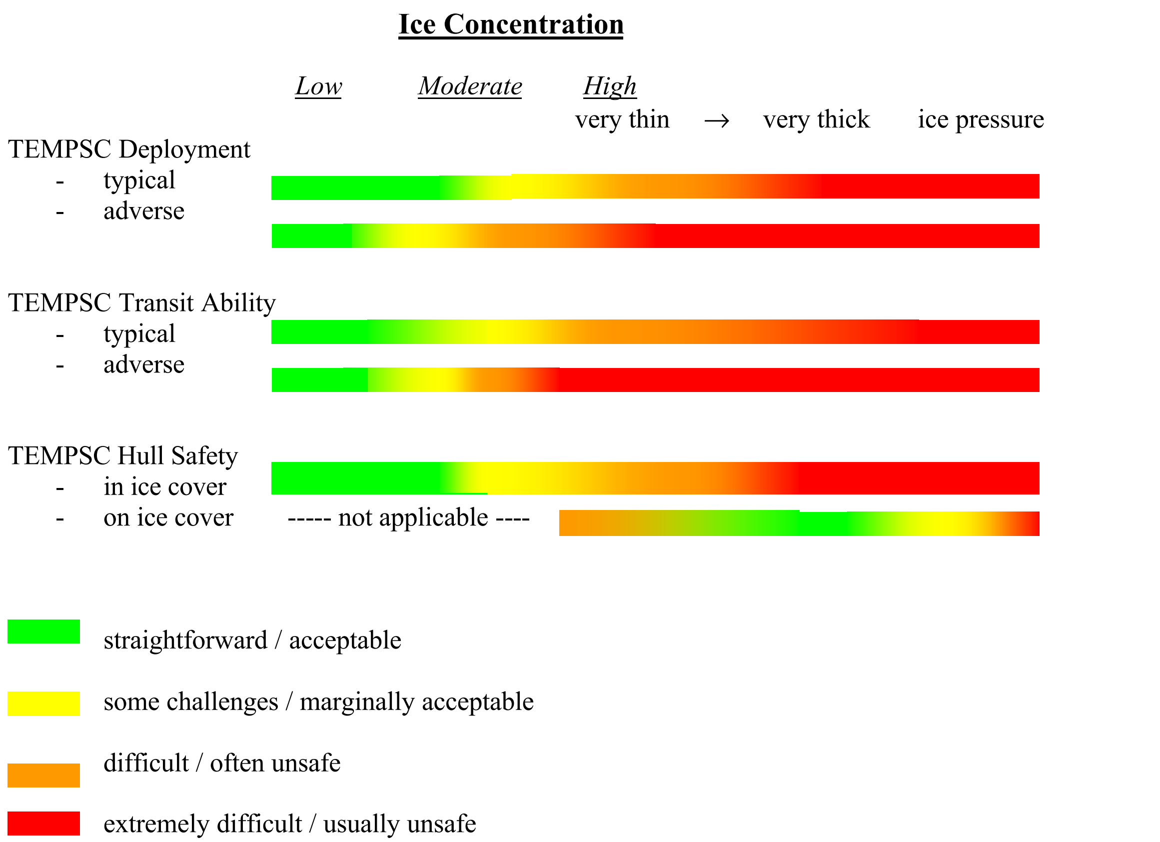
Design

- size, weight and cost of the evacuation system(s)
- topsides space requirements for the evacuation system(s)
- number(s) required, and locations around a platform
- means and complexity of deployment, and related details
- level of certification for the system(s), and experience base
- availability, reliability and "track record"
- cold weather and in-ice operating features

Operations

- simplicity of evacuation system(s) deployment and use
- suitability for use in both ice and open water conditions
- ability to move the system to a preferred deployment location on the platform
- throughput or speed of "mass personnel transfer"
- actual (as opposed to design) functionality in real emergency scenarios
- level of maintenance required
- level of operator training required
- ability to accommodate injured personnel and those carried on stretchers
- degree of risk to evacuees
- general practicality in hostile conditions

The foregoing key issue areas are basically evaluation criteria that can be used to assess various evacuation approaches. An example of a generalized evaluation of the likely performance and risks associated of the deployment of a standard TEMPSC in moving ice is given in Figure 6.8. The information that is suggested in this figure is by no means definitive, but is simply intended to promote some thought and discussion



Notes:

Typical: implies the nature of the onboard hazard allows survival craft deployment from any side of the platform and move away in a direction of choice

Adverse: implies the nature of the hazard restricts survival craft deployment to "poor" locations around the platform, for example, on its updrift side(s) and forces it to move away "into the ice and weather"

Ice drift speed and significant swell are not explicit factors here. However:

- increasing ice drift speeds will make deployment more difficult in typical and adverse situations
- increasing ice drift speed will make transit away easier in some of the typical situations and more difficult in most adverse situations
- increasing swell will make all deployment, transit and in-ice safety aspects more challenging

Figure 6.8: A generalized evaluation of the capabilities of a typical TEMPSC deployed by traditional (controlled) launch methods, in close proximity to the sides of an offshore platform, then moving away by virtue of its own propulsion system, or drifting with the ambient ice and other environmental conditions.

6.5 Basic Assessment

All of the information that has been presented thus far suggests that in-ice evacuation methods are neither well developed nor well proven, with the possible exception of the ARKTOS craft. However, use of the ARKTOS units does not meet many of the practical design and operational needs that are seen as mandatory for various offshore platforms and, as a result, it is certainly not viewed as a "global solution". One clear conclusion is that there is no one "in-ice evacuation system" that can meet all needs. The various proponents surveyed as part of this study all agree that more work is required on evacuation systems for ice-infested areas.

There are a number of limitations common to the evacuation methods that various companies are now using or considering for use in ice-infested waters. Most often, attempts are made to employ or "force fit" fairly conventional open water evacuation systems, to satisfy different evacuation scenarios in ice. The main themes that appear to be topical include:

- the availability of certified, proven and workable "off the shelf" escape systems that can be used in ice
- the dual utility of these systems in both ice and open water conditions

- the best distance at which to deploy an escape craft away from a structure, and how best to deploy them
- the safety of the escape craft, once it is deployed in ice

- the suitability of the option of transferring personnel to a standby vessel
- the reliability of this option, and the conditions in which it would be impractical

Most of these items are best addressed on a structure specific and "regional ice conditions" basis. Nevertheless, there are a number of generic problems regarding in-ice evacuation technologies that should be pursued.

7.0 Research & Development Needs

7.1 General

The foregoing sections have provided a wide range of information about evacuation approaches and systems either used or being considered for use on structures and vessels in ice-infested waters. On the basis of this information, it should be clear that there are some deficiencies in the "in-ice" evacuation technologies now available, for particular situations that can be encountered around platforms operating in ice-covered waters.

In the absence of the option of moving personnel off a platform by helicopter, there are two basic evacuation approaches to recognize. The first involves the direct transfer of people to a standby vessel, while the second involves the indirect transfer of personnel into the ice and sea conditions at hand, by various types of escape craft or systems for subsequent pick-up. Methods that will actually work with a reasonable degree of efficiency and reliability depend on the particulars of the ice environment, the platform, and the nature of the onboard problem causing the evacuation. Nevertheless, there are a number of "generic gaps" that should be pursued.

7.2 Recommended Initiatives

As a means of bringing this report to a closure, a number of the key R & D thrusts that should be considered are briefly summarized as follows.

- systematic evaluation of the safety and performance limits of both traditional and new survival craft, once they are placed in various ice conditions, with **full scale tests and trials**

- systematic evaluation of different deployment methods for various survival craft from representative offshore platforms across a range of ice and ice interaction conditions, with *model tests* and where possible, **full scale trials**

- systematic documentation of the capabilities and limitations of standby vessels to stationkeep adjacent to platforms that are operating in pack ice, in **full scale** on an opportunity basis

- initiatives to improve methods to quickly move large numbers of people to a standby vessel's deck, including compensation for sizable heave, surge and sway motions

- communication, planning and cooperative projects involving R&D groups and key industry and government stakeholders, to improve in-ice evacuation methods

- transfer of information about "in-ice evacuation technologies", and interactive discussions with operating personnel, in workshops and various training sessions

8.0 Acknowledgements

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Appendix A

The Arctic Shipping Guidelines

The Arctic Shipping Guidelines

The International Maritime Organization is in the final stages of approving the Arctic Shipping Guidelines[1]. The Guidelines are under final review and it is expected that the final document will be published as a joint circular by the Maritime Safety Committee and the Marine Environmental Protection Committee. The Guidelines cover all aspects of shipping in the Arctic including structural and machinery requirements, equipment and operational procedures. There are comprehensive sections related to evacuation procedures and safety measures. Chapter 4 relates to the Accommodation and Escape Measures, Chapter 11 deals with Life-Saving Appliances and Survival Arrangements, and Chapter 14 deals with Operational Standards. Also, Annex III provides, in detail, information on the Life-saving Appliances and Survival Equipment for both the Summer Season Standards, and the Unlimited Season Standards.

The salient features of the Arctic Shipping Guidelines related to evacuation in the Arctic are presented in the following sections.

Chapter 4 - Accommodation and Escape Measures

4.1 General

4.1.1 Passenger and crew accommodation should be designed and arranged to protect the occupants from unfavourable environmental conditions and minimize risk of injury during normal (including ice transiting or icebreaking) operations and emergency conditions.

4.1.2 The public spaces, crew accommodation and the equipment installed in them should be designed so that each person making proper use of them will not suffer injury during normal open water operations, designed ice transiting modes of operation, and emergency manoeuvring conditions.

4.1.3 Ships of Polar Classes 1 to 5 inclusive should be designed and insulated to retain adequate heat within a portion ("citadel") of the accommodation to maintain essential services if the main power source is lost. Emergency heating for this portion of the accommodation should be provided from an emergency power source. The portion of the accommodation so configured should be of sufficient size to shelter the ship's full complement.

4.1.4 All ships of Polar Classes 1 to 5 inclusive should have sufficient facilities to maintain a life sustaining environment in that portion of accommodation indicated in 4.1.3 in the event of extended ice entrapment.

4.2 Public Address and Other Safety Systems

4.2.1 The public address system and the general emergency alarm system should be audible over the loudest ambient noise level occurring during ice transiting, ice breaking or ramming.

[1] This was previously known as the International Code of Safety for Ships in Polar Waters (Polar Code)

4.2.2 Ships of Polar Classes 1 to 3 inclusive, icebreakers and ships intended to be used in the ramming mode should be designed with adequate provisions to ensure the safety of personnel using shower facilities. Such facilities should include non-slip decking, three rigid sides, hand holds and insulation from exposed hot water pipes.
4.2.3 Galley facilities should be provided with grab rails projecting from the front on cooking equipment for use by the crew during ice operations.
4.2.3.1 Equipment designed to heat oil for cooking purposes such as deep fat fryers should be located in a position suitably separated from hotplates or other hot surfaces. Such appliances should also be secured to the deck or other fixed structure and provided with an oiltight lid or closure to prevent splashing or spillage during ice operations.

4.3 Escape Measures

4.3.1 All means of escape from accommodation or interior working spaces should not be rendered inoperable by ice accretion or by malfunction due to low external ambient air temperatures.
4.3.2 All escape routes should be dimensioned so as not to hinder passage for persons wearing protective clothing suitable for the lowest ambient air temperatures specified for the ship's Polar Class in chapter 1.
4.3.3 Escape routes should be designed to minimize the distance between their exit to an open deck and the survival equipment to which they lead.

Chapter 11 - Life-Saving Appliances and Survival Arrangements

11.1 Compliance

11.1.1 Adequate supplies of protective clothing and thermal insulating materials should be provided in all ships operating in Polar Waters for all persons on board at any time.
11.1.2 Training in the use of all equipment should be included as an element of the operating procedures and drills described at Chapter 14. Where appropriate, dedicated training equipment should be carried to avoid compromising the performance of the emergency equipment itself.

11.2 Categories of Lifesaving Equipment

11.2.1 Ships operating in Polar Waters should carry life-saving appliances and survival equipment according to their environmental conditions of operation, as indicated in Chapter 1.1.6.
11.2.2 Personal Survival Kits (PSKs) as described in 11.3 should be carried whenever a voyage is expected to encounter mean daily temperatures below 0°C.
11.2.3 Group Survival Kits (GSKs) as described in 11.4 should be carried whenever a voyage is expected to encounter ice conditions which may prevent the lowering and operation of survival craft.
11.2.4 Sufficient PSKs and GSKs (as applicable) should be carried to cover at least 110% of the rated complement of the ship.

11.2.5 Personal Survival Kits should be stored so they may be easily retrieved in an emergency situation. Arrangements such as storage in cabins or in dedicated lockers near the muster stations may be considered.
11.2.6 Group Survival Kits should be stored so they may be easily retrieved in an emergency situation. The containers should be located adjacent to the survival craft and liferafts and be stowed on cradles. Containers should be designed so that they may be easily moved over the ice and be floatable.

11.3 Personal Survival Kit (PSK)

11.3.1 A Personal Survival Kit should consist of the items listed in table 11.1. Specifications for the equipment are given in Annex IV.

Table 11.1 - Contents of the Personal Survival Kits

Equipment	Quantity
Clothing	
Head Protection (VP)*	1
Neck and Face Protection (VP)	1
Hand Protection - Mitts (VP)	1 Pair
Hand Protection - Gloves (VP)	1 Pair
Foot Protection - Socks (VP)	1 Pair
Foot Protection B Boots	1 Pair
Insulated Suit (VP)	1
Approved Immersion Suit	1
Thermal Underwear (VP)	1 Set
Miscellaneous	
Handwarmers	240 hours
Sunglasses	1 Pair
Survival Candle	1
Matches	2 Boxes
Whistle	1
Drinking Mug	1
Pen Knife	1
Handbook (Polar Survival)	1
Carrying Bag	1

*VP means Vacuum Packed

11.3.2 The following notice should be displayed wherever personal survival kits are stored:

> NOTICE:
> CREW MEMBERS AND PASSENGERS ARE REMINDED THAT THEIR PERSONAL SURVIVAL KIT IS FOR EMERGENCY SURVIVAL USE ONLY. NEVER REMOVE ITEMS OF SURVIVAL CLOTHING OR TOOLS FROM THE PERSONAL SURVIVAL KIT CARRYING BAG - YOUR LIFE MAY DEPEND ON IT.

11.3.3 Personal Survival Kits should not be opened for training purposes. Equipment for training purposes should be provided for in accordance with 11.1.2.

11.4 Group Survival Kit (GSK)

11.4.1 The contents of the Group Survival Kit should include those items defined in Table 11.2. Specifications for this equipment are given in Annex III.

Table 11.2 - Contents of the Group Survival Kit

Equipment	Quantity
Group Equipment	
Tents	1 per 6 persons
Air Mattresses	1 per 2 persons
Sleeping Bags (VP)*	1 per 2 persons
Stove	1 per tent
Stove Fuel	0.5 litres per person
Fuel Paste	2 tubes per stove
Matches	2 boxes per tent
Pan (with sealing lid)	1 per stove
Fortified Health Drinks	5 packets per person
Flashlights	1 per tent
Candles and Holders	5 per tent
Snow Shovel	1 per tent
Snow Saw and Snow Knife	1 per tent
Tarpaulin	1 per tent
Foot Protection B Bootees	1 per person
GSK Container	1
Spare Personal Equipment	(1 set per GSK container)
Head Protection (VP)	1
Neck and Face Protection (VP)	1
Hand Protection - Mitts (VP)	1 pair
Hand Protection - Gloves (VP)	1 pair
Foot Protection - Socks (VP)	1 pair
Foot Protection - Boots (VP)	1 pair
Insulated Suit (VP)	1
Thermal Underwear	1 pair
Handwarmers	1 set
Sunglasses	1
Whistle	1
Drinking Mug	1

*VP means Vacuum Packed

11.4.2 Where a shot gun or hunting rifle is provided to protect survivors from wildlife, it should be stored in a secure location readily available in an emergency.

11.5 Lifeboats

11.5.1 All lifeboats carried by Polar Class ships should be of the fully enclosed type to provide adequate shelter from the environment. Other ships which are equipped with open or partially enclosed boats should carry tarpaulins of sufficient size to provide complete coverage of the lifeboats, and suitable structure to support them.

11.5.2 Ice accretion should be regularly removed from the lifeboats and launching equipment to ensure ease of launching when required. An icing removal mallet should be available in the vicinity of the lifeboats.

11.5.3 All lifeboat engines should be equipped with a means to ensure they will start readily when required at the minimum anticipated operating temperature.

11.5.4 The lifeboat engine fuel oil should be suitable for operation in the minimum anticipated operating temperature.

11.5.5 Drinking water should be stored in containers that allow for expansion due to freezing.

11.6 Liferafts

11.6.1 Ice accretion should be regularly removed from the liferafts, cradles and launching equipment to ensure ease of launching and inflation when required. An icing removal mallet should be available in the vicinity of the liferafts.

11.6.2 Ships should carry in a warm space in the vicinity of the liferafts, manual inflation pumps that are proven to be effective in the expected air temperatures.

11.6.3 Air or other proven cold temperature gas should be used for the inflation of lifesaving equipment at ambient air temperatures below -30°C.

Chapter 14 Operational Standards

14.4 Drills and Emergency Instructions

14.4.1 On board instruction and operation of the ship's evacuation, fire and damage control appliances and systems should include appropriate cross training of crew members with appropriate emphasis to changes to standard procedure made necessary by polar operations.

14.4.2 Emergency instructions including a general diagram of the ship showing the location of all exits, routes of evacuation, emergency equipment, life-saving equipment and appliances and illustration of immersion suit and lifejacket donning should be available to each passenger and crew member.

14.4.3 Evacuation

14.4.3.1 Evacuation drill scenarios should be varied so that different emergency conditions are simulated, including abandonment into the water, onto the ice, or a combination of the two.

14.4.3.2 Each evacuation craft drill should include:

.1 exercises in passenger control in cold temperatures as appropriate;

.2 checking that crew and passengers are suitably dressed;

.3 donning of immersion suits or thermal protective clothing by appropriate crew members;
.4 testing of emergency lighting for mustering and abandonment; and
.5 giving instructions in the use of the ship's life-saving appliances and in survival at sea, on the ice or a combination of both.

14.4.3.3 Rescue boat drills should be conducted as follows:

.1 As far as is reasonable and practicable, rescue boats should be launched each month as part of the evacuation drill with their assigned crew aboard and manoeuvred in the water, with due consideration of the dangers of launching into Polar Waters if applicable.
.2 If rescue boat launching drills are carried out with the ship making headway, such drills should be practised in sheltered waters only and under the supervision of an officer experienced in such drills.*

14.4.3.4 Individual instructions may cover different parts of the ship's life-saving system, but all the ship's life-saving equipment and appliances should be covered within any period of one month on passenger ships and two months on cargo ships. Each member of the crew should be given instructions which should include but not necessarily be limited to:

.1 problems of hypothermia, first-aid treatment of hypothermia and other appropriate first-aid procedures; and
.2 special instructions necessary for use of the ship's life-saving appliances in severe weather and severe sea conditions on the ice or in a combination of water and ice cover.

14.4.6 Survival Kits

14.4.6.1 The Master should ensure that before the ship leaves port and at all times during the voyage, all Personal Survival Kits and Group Survival Kits are complete, in working order, and ready for immediate use.
14.4.6.2 The ship should keep spare personal survival equipment on board for the purpose of providing replacements for missing or damaged items of equipment in those Personal Survival Kits issued to the complement. In addition, a number of sewing kits and replacement parts (buttons, boot laces etc.) should be kept on board for the purpose of minor repair to personal survival kit items of clothing.
14.4.6.3 Group Survival Kit inspections should be carried out annually.

Annex III - Life-saving Appliances and Survival Equipment

Summer Season Standards

The following items are considered to be life saving appliances and as such the quality of workmanship and construction should be to the highest standards Manufacturers may propose alternate designs provided they demonstrate equivalent capabilities.
Head protection - A touque or alternate should be supplied to provide protection for the head. Good insulating properties and speed of drying are important design criteria. The material used should be a natural fibre or suitable synthetic fibre material. It should be of sufficient length to be rolled down over the ears and face.

Neck and face protection - A scarf should be supplied to provide protection for the neck and face. The scarf should be approximately 1.8 metres in length and 15 cm in width. A neck warmer may be considered as an alternative. Good insulating properties and speed of drying are important design criteria. The material used should be a natural fibre or suitable synthetic fibre.

Hand protection - Gloves should be supplied in a range of sizes to provide protection for the hands when dexterity is required. The most important feature of the design is ease of manipulation of the fingers. The glove wrist should extend up at least one third of the forearm length. Although insulation and waterproofing are desired features, they are of secondary importance. The material used should be a natural fibre or suitable synthetic fibre material.

Foot protection - Heavyweight socks should be provided in a range of sizes. These socks should be made of natural fibres (such as wool or silk) or synthetic fibres or some blend of natural and synthetic fibres. The socks should extend at least up to the mid-calf.

Insulated suit – Pants - Pants should be supplied to provide adequate insulation in cold temperatures. An approximate insulation thickness of 1 cm is considered to be acceptable. These pants should incorporate the following features:

- Two large thigh pockets (about 17 cm wide and 22 cm deep) should be provided and should have large Velcro fastened flaps.
- Ankle cuffs should be provided and reinforced for heavy wear with leather trim. The ankles should be snug fitting to the footwear worn underneath using an adjustable elastic or drawstring arrangement.
- Reflective tape should be sewn onto the pant leg seam to ensure a high degree of visibility.
- A snug fitting waist band should be fitted with an adjustable elastic or drawstring arrangement and suspenders or be of the Farmer John style.

Insulated Suit – Parka - A Parka should be supplied to provide adequate insulation in cold temperatures. An approximate insulation thickness of 1 cm is considered to be acceptable. These parkas should incorporate the following features:

- A fur hood should be fitted and extend at least 15 cm in front of the face. The hood should be fastened by velcro along the underside of the tunnel.
- Breast and side pockets should be provided, with large covering flaps, velcro fastening and double stitched for increased wear resistance.
- Wrist cuffs should be fitted and snug fitting to the arm; the cuffs should be elasticized or include a drawstring.
- Reflective tape should be sewn onto the arms and back of the parka to ensure a high degree of visibility.
- The parka should have an adjustable drawstring in the waist band.

Alternate designs of insulated suits may be considered provided they incorporate the important features described above.

Eiderdown offers the greatest degree of thermal insulation per unit weight and is the most compressible of suitable insulating materials (easily vacuum packed). The outer shell should be both wind and water resistant and orange in colour.

Survival candle - A Beeswax candle should be provided which should feature minimum bulk, no toxic emissions when burning and maximum light and heat output. The candle should include a set of cooking brackets which clip onto the rim of the candle housing.

Matches - Boxes of waterproof matches containing a minimum of 50 matches should be provided. Each box should be sealed in a waterproof wrapping. The matches should be of the windproof type with large heads.
Pen knife - A two blade pen knife should be provided.
Survival handbook - A survival handbook should be provided, sealed in a waterproof wrapping.
Personal survival kit carrying bag - A Personal Survival Kit Carrying Bag should be provided, designed to contain all items of equipment for the designated Personal Survival Kit. The Carrying Bag design should incorporate grab handles, a shoulder strap and a zip closure. The material of construction should be water resistant/repellent, easily pliable and extremely durable (double stitching of seams). The bag should be orange in colour and have reflective tape sewn in to ensure a high degree of visibility from all angles. The Personal Survival Kit contents and their size should be clearly stencilled on the Carrying Bag; lettering to be a minimum of 12.5 mm in height.

Unlimited Season Standards

The following items are considered to be life saving appliances and as such the quality of workmanship and construction should be to the highest standards Manufacturers may propose alternate designs provided they demonstrate equivalent capabilities.
Head protection - A touque or alternate should be supplied to provide protection for the head. Good insulating properties and speed of drying are important design criteria. The material used should be a natural fibre or suitable synthetic fibre material. It should be of sufficient length to be rolled down over the ears and face.
Neck and face protection - A scarf should be supplied to provide protection for the neck and face. The scarf should be approximately 1.8 metres in length and 15 cm in width. A neck warmer may be considered as an alternative. Good insulating properties and speed of drying are important design criteria. The material used should be a natural fibre or suitable synthetic fibre.
Hand protection – mitts - Mitts should be supplied in a range of sizes to provide adequate hand insulation for extreme cold air temperatures. These mitts should be of the gauntlet style, the outer shell should be durable and water repellent (such as seal skin or nylon), the inner shell should be of a natural fibre or synthetic blend. The preferred design features are:

- The backhand of the mitt outer shell should incorporate a wool pad (lambs wool or synthetic equivalent).
- The palm of the mitt outer shell should be durable yet pliable; soft leather (horsehide or pigskin) is recommended but an equivalent synthetic material will be acceptable.
- The wrist cuff should be fitted with means to make a snug fit around the wrist; an adjustable elastic or drawstring arrangement is recommended.
- A nylon cord should be provided and used to connect the mitts together by their cuff-loops. The cord must be long enough to be threaded up one sleeve, across the shoulders and down the other sleeve to prevent loss of the mitts when they are removed to use the bare or gloved hands.

Hand protection – gloves - Gloves should be supplied in a range of sizes to provide protection for the hands when dexterity is required. The most important feature of the design is ease of manipulation of the fingers. The glove wrist should extend up at least one third of the forearm length. Although insulation and waterproofing are desired features, they are of secondary importance. The material used should be a natural fibre or suitable synthetic fibre material.

Foot protection – socks - Heavyweight socks should be provided in a range of sizes. These socks should be made of natural fibres (such as wool or silk) or synthetic fibres or some blend of natural and synthetic fibres. The socks should extend at least up to the mid-calf height.

Foot protection – boots - Insulated boots should be supplied to provide protection for the feet. The design should be suitable use in extreme cold air temperatures and should be comprised of: the boot, felt and plastic inserts (to raise the feet off the ground) and a felt sock or liner.

Insulated suit – pants - Pants should be supplied to provide adequate insulation in cold temperatures. An approximate insulation thickness of 3 cm is considered to be acceptable. The outer shell should be both wind and water resistant and orange in colour. These pants should incorporate the following features:

- Two large thigh pockets (about 17 cm wide and 22 cm deep) should be provided and should have large velcro fastened flaps.
- Ankle cuffs should be provided and the ankles should be snug fitting to the footwear worn underneath using an adjustable elastic or drawstring arrangement.
- Reflective tape should be sewn onto the pant leg seam to ensure a high degree of visibility.
- A snug fitting waist band should be fitted with an adjustable elastic or drawstring arrangement and suspenders or be of the Farmer John style.

Insulated Suit – Parka - A Parka should be supplied to provide adequate insulation in cold temperatures. An approximate insulation thickness of 3 cm is considered to be acceptable. These parkas should incorporate the following features:

- A hood should be fitted and extend at least 15 cm in front of the face. The hood should be fastened by velcro along the underside of the tunnel.
- Breast and side pockets should be provided, with large covering flaps, velcro fastening.
- Wrist cuffs should be fitted and should be elasticized or include a drawstring.
- Reflective tape should be sewn onto the arms and back of the parka to ensure a high degree of visibility.
- The parka should have an adjustable drawstring in the waist band.

Alternate designs of insulated suits may be considered provided they incorporate the important features described above.

Eiderdown offers the greatest degree of thermal insulation per unit weight and is the most compressible of suitable insulating materials (easily vacuum packed). The outer shell should be both wind and water resistant and, preferably, orange in colour.

Thermal underwear - Thermal underwear should be supplied to provide thermal protection for the body. The underwear should be of the two piece design consisting of pants (long johns) and shirt (long sleeved turtle neck). The underwear should be of natural fibre, a suitable synthetic fibre material or a blend.

Handwarmers - A 240 hour supply of chemically activated handwarmers should be supplied. The individual packets should be of a size suitable for placing inside a mitt or inside boots.

Sunglasses - A pair of polarized sunglasses should be provided to protect against snow-blindness. The glasses should be equipped with a neck cord to prevent loss or damage.

Survival candle - A Beeswax candle should be provided featuring minimum bulk, no toxic emissions when burning and maximum light and heat output. The candle should include a set of cooking brackets which clip onto the rim of the candle housing.

Matches - Boxes of waterproof matches containing a minimum of 50 matches should be provided. Each box should be sealed in a waterproof wrapping. The matches should be of the windproof type with large heads.

Whistle - A plastic, pea-less whistle should be provided. The whistle should have a string to facilitate attachment to the parka.

Drinking mug - A wide based drinking mug should be provided. The mug should be durable, made of aluminum or some other material suitable for the application of direct heat from a candle and be able to withstand the thermal shock of instantaneous temperature variance between boiling liquids (100^{o}C) and cold ambient temperatures down to -45^{o}C. The mug should be provided with a hinged lid to retain heat.

Pen knife - A two blade pen knife should be provided.

Survival handbook - A survival handbook should be provided, sealed in a waterproof wrapping.

Personal survival kit carrying bag - A Personal Survival Kit Carrying Bag should be provided, designed to contain all items of equipment for the designated Personal Survival Kit. The Carrying Bag design should incorporate grab handles, a shoulder strap and a zip closure. The material of construction should be water resistant/repellent, easily pliable and extremely durable (double stitching of seams). The bag should be orange in colour and have reflective tape sewn in to ensure a high degree of visibility from all angles. The Personal Survival Kit contents and their size should be clearly stencilled on the Carrying Bag; lettering to be a minimum of 12.5 mm (0.5") in height. The individual contents of the carrying bag should be placed in two separately tied plastic bags to seal them against any potential water damage.

Tents - Tents should be provided. Six person free standing tents are preferred. There should be a zippered entrance flap at one end. The zipper should be made of plastic or teflon; alternately, Velcro strips or ties may be used.

Air mattresses - Air mattresses should be supplied to maintain an air cushion between a person and the floor of the tent or liferaft. The mattresses should be self-inflating and be capable of being topped-up by mouth. The mattresses should have a minimum thickness of 3.5 cm. The construction material should be suitable for use in extreme cold air temperatures.

Sleeping bags - Sleeping bags should be supplied to provide adequate insulation to protect the body in extremely cold conditions. This corresponds to an insulation thickness of approximately 7.5 cm. Weight, volume, durability and the ability to cope with a range of air temperatures are the important design features. One style of sleeping bag that has proven to be effective is described below:

- A main bag which provides the insulation value, although this can be achieved with a single or multiple bags. Each bag should have a full length zipper of plastic or teflon. The zipper arrangement should be such that multiple bags may be joined together to form a double occupancy sleeping bag. Bags should be fitted with hanging loops at the foot to facilitate drying.

- An insulated hood should be provided to protect the head. If these hoods are separate components, they should be collared to make an airtight connection with the main bag at the neck. Hoods may also be incorporated as an integral part of the main bag.
- Other designs may be considered if they can be demonstrated to provide an equivalent level of protection.

Stove - Stoves capable of operation in extreme cold air temperatures should be supplied. The stove should be stable, compact and lightweight and should preferably include the following features:

- single burner;
- pre-heat loop;
- pan supports;
- wind screen (aluminium or equivalent);
- heat reflector (of durable aluminium or equivalent);
- fuel bottles (heavy duty aluminium or equivalent);
- maintenance kit with parts and tools for repair of the stove; and
- stove support pad.

Stove fuel - Fuel be sealed in fuel containers suitable for easy re-fuelling while wearing gloves. The fuel should be changed annually at the start of each Polar shipping season.
Fuel paste - Fuel paste should be provided for use in pre-heating the stove burner pan and fuel pre-heat loop before lighting the kerosene fuel. The shelf life of the paste should be checked annually.
Pan with sealing lid - A pan should be provided for use with the stove. The pan capacity should be 1 litre and it should have a sealing lid. The pan handle should be non-metallic, or metallic with a non-metallic sheath. The pan should be constructed of a material with excellent heat transfer properties (for example, copper and aluminum transfer heat more efficiently than cast iron).
Fortified health drinks - Powdered, fortified health drinks should be provided. The drink mixes should contain vitamin and energy additives.
Flashlights - Flashlights should be provided. The flashlights should be constructed of material suitable for operation at air temperatures down to -45^{o}C and should be provided with batteries suitable for long life at low temperatures. The batteries should be date marked along with the recommended maximum storage life.
Candles and holders - Candles should be provided. These candles should be of the long burning variety and should be as compact as possible. Important design features are minimum bulk, no toxic emissions when burning and maximum light and heat output; 100% beeswax is preferred. Holders should be provided for the candles.
Snow shovels - Four folding snow shovels should be provided.
Snow saw and snow knife - A snow saw and knife should be provided. The saw and knife blades should be at least 60 cm in length.
Tarpaulin - A tarpaulin may be provided. The tarpaulin should be at least 4 metres square and made from a waterproof material.

Rifle or shotgun - A rifle or shotgun may be provided for protection against polar bears. For the inexperienced user a short barrelled, 12 gauge pump shotgun is recommended. There should be 50 rounds of ammunition with the weapon. The ammunition should be in a waterproof case with a date of purchase marked on it. The weapon should have its own waterproof case and be properly stored. It should be coated with oil or other suitable preservative so as to be in good condition when needed. The weapon should not need cleaning before use.

Foot protection – bootees - Insulated bootees should be supplied in a range of sizes to provide protection for the feet in extreme cold air temperatures. The bootees should be light, compressible and of a one component design. Bootees are essentially heavily insulated socks with a durable sole which provide a lightweight alternative to insulated boots. Insulation may be either eiderdown or a synthetic material. The bootee sole should be waterproof and include some tread to improve traction on ice. The bootee upper material should be water resistant.

Container - The equipment should be assembled in containers which can be easily handled by two persons. The containers could be of the liferaft container type, coloured orange, and be designed in two halves with a watertight seal and snap closures. Other types of containers and sleds are acceptable if they have the same features.

- The number and size of containers should depend upon the number of crew and passengers and the resultant volume of equipment.
- The size of container, in general, should not exceed the size of a 20 person liferaft container so that it may be easily handled. Experience has shown that such a container may be pulled or otherwise moved over the ice to some safe distance from the ship.
- There should be at least one container on each side of the ship, each with the capacity for 55% of the persons on board. There should be an equal number of containers on each side of the ship.
- A list of the Group Survival Kit contents should be clearly stencilled on the container; the lettering a minimum of 12.5 mm in height.

Appendix B

Canadian Offshore Petroleum Installations Escape, Evacuation, And Rescue (EER) Performance-Based Standards

DRAFT FOR COMMENT

CANADIAN OFFSHORE PETROLEUM INSTALLATIONS ESCAPE, EVACUATION, AND RESCUE (EER) PERFORMANCE-BASED STANDARDS

For:
Transportation Development Centre
Montreal

By:
PBS Development Task Force
Calgary, Ottawa, Montreal, Halifax, St. John's

Facilitated By:
Bercha Engineering Limited
Calgary

July 24, 2002

Notes on "*Draft for Comment*"

- This is a preliminary draft for comment from stakeholders and entirely subject to change.
- Some of the Standards exceed current requirements either by increasing an exisiting requirement or by creating a new requirement (such as a reliability level).
- Standards that exceed current requirements should be interpreted as goals. A schedule for each goal to become a requirement will be developed as part of the Standards. Also, the next draft will identify Standards which are current requirements and those that are goals.
- The availability and reliability numbers are still under development. Hence, those given are preliminary.
- The tabular formats in the body of the Standards is for convenience in the development process. A consistent non-tabular format will be used in the final draft.

PBS Task Force
July 24, 2002

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GLOSSARY OF ACRONYMS

ALARP	=	**A**s **L**ow as **R**easonably **P**racticable
CAPP	=	**C**anadian **A**ssociation of **P**etroleum **P**roducers
CGSB	=	**C**anadian **G**eneral **S**tandards **B**oard
CNOPB	=	**C**anada-**N**ewfoundland **O**ffshore **P**etroleum **B**oard
CNSOPB	=	**C**anada-**N**ova **S**cotia **O**ffshore **P**etroleum **B**oard
CSA	=	**C**anadian **S**tandards **A**ssociation
EER	=	**E**scape, **E**vacuation, and **R**escue
ERRV	=	**E**mergency **R**esponse and **R**escue **V**essel
FRC	=	**F**ast **R**escue **C**raft
H_2S	=	**H**ydrogen **S**ulphide
HEP	=	**H**uman **E**rror **P**robability
IMO	=	**I**nternational **M**aritime **O**rganization
JRCC	=	**J**oint **R**escue **C**oordination **C**entre
MFP	=	**M**echanical **F**ailure **P**robability
MODU	=	**M**obile **O**ffshore **D**rilling **U**nit
MSS	=	**M**arine **S**urvival **S**ystem
OIM	=	**O**ffshore **I**nstallation **M**anager
RCC	=	**R**escue **C**oordination **C**entre
SBV	=	**S**tandby **V**essel
SOLAS	=	**S**afety **o**f **L**ife **a**t **S**ea
TEMPSC	=	**T**otally **E**nclosed **M**otor **P**ropelled **S**urvival **C**raft
TP	=	**T**ransport (Canada) **P**ublication
TSR	=	**T**emporary **S**afe **R**efuge
UKOOA	=	**U**nited **K**ingdom **O**ffshore **O**perators **A**ssociation

1. Introduction

1.1 Foreword

The Report of the Royal Commission on the Ocean Ranger marine disaster recommended in 1985 that Performance-Based Standards for evacuation systems be developed. This recommendation was one of a series that was intended to improve safety for workers in the Canadian offshore petroleum industry. While the recommendations were aimed specifically at the petroleum industry, the results of research and improvements in approaches to management for the offshore petroleum industry have resulted to improvements in worker safety in other offshore industries.

The development of the Escape, Evacuation and Rescue (EER) Performance-Based Standards can be seen as the culmination of research and development activities that have taken place since the Ocean Ranger disaster. The development of survival suit standards, enhanced life craft launching mechanisms, and improved emphasis on safety and risk management are all accomplishments that have improved the safety of offshore petroleum operations. The developed EER Performance-Based Standards are intended to be used as part of a continuous improvement process for managing safety and risk in the offshore. Among the standards are ones that are within current requirements, and ones that exceed current requirements. Exceeding current requirements occurs either by increasing the current requirement or by posing a new requirement such as a specific reliability.

The EER Performance-Based Standards will define the expected performance of EER systems under specified environmental and damage conditions for offshore petroleum installations. The standards will foster a system of continuous improvement to incorporate changes in technology and improvements in risk assessment and hazards management.

1.2 Scope

This standard applies to the escape, evacuation and rescue process of personnel from offshore petroleum installations operating in Canadian jurisdiction.

1.3 Purpose

In the event of a problem posing threat to life or serious injury on board an offshore installation, there must be established facilities, equipment, procedures, and plans for the safe escape, evacuation, and rescue (EER) of personnel under all credible environmental, operational, and accident conditions. The overall objective of "Canadian Offshore Petroleum Installations Escape, Evacuation, and Rescue (EER) Performance-Based Standards" (the Standards) is to ensure that offshore installations be as safe as reasonably practicable for personnel in the event of a situation which requires abandonment of the installation. Standards are measurable and can be assessed with the use of analytical tools. These performance-based standards are to be used by operators and regulators to enhance offshore safety.

1.4 Standards Categories

The Standards are categorized into four principal categories, according to the EER process and its main components, as follows:

- The overall EER process
- Escape
- Evacuation
- Rescue

Each of the Standard categories (except for the first one) is subdivided into Global and Specific Standards. The first one has only Global Standards.

Evacuation systems are functionally classified as dry, semi-dry, and wet systems, as defined under Section 2.

2. Definitions

The following are definitions pertaining specifically to these Standards.

2.1 EER Systems and Components

2.1.1 Escape, Evacuation, and Rescue (EER)

Escape, evacuation, and rescue (EER) is the process of transferring personnel from an offshore installation from their location at the time of an evacuation alarm to a place of comparable safety in relation to the one evacuated, such as a standby vessel or search and rescue helicopter.

2.1.2 Escape

Escape is the first stage of the overall process whereby personnel move from their location at the time of the alarm on the offshore installation to the temporary refuge or muster point and ending when they reach a place of relative safety.

2.1.3 Evacuation

Evacuation is the second stage of the EER process, whereby personnel transfer from the temporary refuge or muster point to a location clear of the offshore installation.

2.1.4 Rescue

Rescue is the final stage of the EER process whereby personnel are transferred directly or indirectly to a safe haven.
The rescue process is subdivided into the survival and the recovery component because these two components have distinct characteristics.

2.1.5 Safe Haven

A *safe haven* is a location of safety comparable to that of the undamaged installation. This includes a standby vessel (SBV), passing vessel, land, or an installation.

2.1.6 Abandonment

Abandonment is the combined process of escape and evacuation.

2.1.7 Dry Evacuation

Dry evacuation systems are systems that involve the emergency evacuation of personnel directly from the offshore installation to a rescue craft or a safe haven.

2.1.8 Semi-dry Evacuation

Semi-dry evacuation systems are systems that involve the emergency transfer of personnel by evacuation equipment that is stored on the offshore installation and is boarded before launching to the sea. These may comprise active or passive systems.

2.1.8.1 Active Evacuation

An *active evacuation* system is a system which has an independent means of propulsion or maneuvering such as a Totally Enclosed Motor Propelled Survival Craft (TEMPSC).

2.1.8.2 Passive Evacuation

A *passive evacuation* system is a system that does not have an independent means of propulsion or maneuvering once launched.

2.1.9 Wet Evacuation

A *wet evacuation* process consists of evacuating personnel directly into the sea. This category includes such items as personnel protection and floatation devices, and systems to aid in the location and recovery of personnel.

2.2 Definitions Related to Safety and Performance

2.2.1 Safety

Safety, in the context of EER, means operation without any casualties. Casualties are fatalities or serious injuries. The maximum practicable level of safety must be achieved, and in no case will target safety levels be compromised.

2.2.2 Risk

Risk is a compound measure or description of the probability and number of casualties. Safety is the opposite of risk. Approach to risk will be within the As Low as Reasonably Practicable (ALARP) principle

2.2.3 Performance

Achievement of the intended function simply and efficiently in a timely manner through human, or mechanical means, or combination of both.

2.2.4 Success

The achievement of a process or operation without incurring one or more casualties.

2.2.5 Failure

(a) On a global level, *failure* of a process means that one or more casualties are incurred in carrying out or attempting to carry out that process.

(b) On an activity level, *failure* means a human error or mechanical malfunction which could (but does not necessarily) lead to one or more casualties.

2.2.6 Availability

The probability that a system is capable of commencing performance when required.

2.2.7 Reliability

The probability that a process, task, or activity will be successfully completed at any and all required stages (in a system operation) within a required time limit (if a time limit exists).

2.2.8 Critical

An adjective used to describe any activity, task, or process, which can lead to casualties if it fails.

2.2.9 Human Error

Any member of a set of human actions that exceeds some limit of acceptability. Here, the limit of acceptability is that the error can lead to the occurrence of one or more casualties.

2.2.10 Human Error Probability (HEP)

The probability that a human error will occur in a given activity, task, or process.

2.2.11 Mechanical Failure

Any member of a set of mechanical operations or functions that exceeds some limit of acceptability. Here, the limit of acceptability is that the malfunction can lead to the occurrence of one or more casualties. Mechanical failure covers any failure except one in human performance, and therefore, includes electrical, electronic, and software failures.

2.2.12 Mechanical Failure Probability (MFP)

The probability that a mechanical failure will occur in the machinery, apparatus, or other physical component in a given activity, task, or process.

2.3 Other Definitions

2.3.1 Design

Design means all considerations and communications, including but not restricted to plans, drawings, specifications, or written or verbal communications, intended to direct the manufacturers, builders, and installers of a system or component so that it will perform as intended.

2.3.2 Operational Conditions

Operational conditions include all the effects on personnel and equipment resulting from the functioning of the installation.

2.3.3 Environmental Conditions

Environmental conditions are the atmospheric and sea conditions in which the installation is located. Environmental conditions are characterized by four seastate classes (as described in Appendix A), ambient temperature fields, and visibility.

2.3.4 Accident Conditions

Accident conditions are the effects of an accident. They include but are not restricted to smoke, fire, explosions, toxic effects, and structural deformations.

3. Relevant Publications

The Standards are intended to supplement and enhance other applicable regulations having jurisdiction in the Canadian offshore areas. Other regulations and standards (as amended from time to time) relating to these Standards and having the same jurisdiction are cited herein.

In these Standards, references given in this Section 3 are cited by sub-section number and designation (e.g., [3.3(a)] = "Newfoundland Offshore Petroleum Installations Regulations." Section 2.(1), Updated to Dec. 31, 2000).

3.1 Canadian Federal Acts and Regulations

(a) Canada Oil and Gas Operations Act, R.S. 1985, c-07, Amended 1994, c.10 ss.3, 15.

(b) Canada Oil and Gas Installations Regulations, SOR/96-118

(c) Canada Oil and Gas Operations Regulations, SOR/83-149

(d) Canada Oil and Gas Drilling Regulations, SOR79-82

3.2 ACCORD Acts

(a) Canada-Newfoundland Atlantic Accord Implementation Act, 1987, c.3

(b) Canada - Nova Scotia Offshore Petroleum Resources Accord Implementation Act, July 21, 1988

3.3 Canada-Newfoundland Offshore Petroleum Board (CNOPB)

(a) Newfoundland Offshore Petroleum Installations Regulations. Section 2.(1), SOR/95-104

(b) Regulations Respecting the Issuance of Certificates of Fitness for Petroleum Production, Drilling, Accommodation and Diving Installations in Areas Offshore Nova Scotia, 21 February 1995, SOR/95-100.

(c) Newfoundland Offshore Petroleum Drilling Regulations, 28 January 1993, SOR/93-23.

(d) Petroleum Occupational Safety and Health Regulations - Newfoundland., Draft Federal Version, 1989 (Not Promulgated)

3.4 Canada-Nova Scotia Offshore Petroleum Board (CNSOPB)

(a) "Canada-Nova Scotia Offshore Petroleum Board Regulations." Sections 19 and 22. Copied from CNSOPB website Oct. 2, 2001.

(b) Regulations Respecting the Issuance of Certificates of Fitness for Petroleum Production, Drilling, Accommodation and Diving Installations in Areas Offshore Nova Scotia (11 April 1995), SOR/95–198.

(c) Nova Scotia Offshore Area Petroleum Installations Regulations, S.N.S. 1987, c. 3, as amended O.I.C. 97-756 (December 9, 1997), N.S. Reg. 166/97

(d) Nova Scotia Offshore Area Petroleum Drilling Regulations, S.N.S. 1987, c. 3, as amended O.I.C. 96-21 (January 9, 1996), N.S. Reg. 5/96.

(e) Nova Scotia Offshore Petroleum Occupational Health & Safety Requirements, December 18, 2000.

3.5 Canadian General Standards Board (CGSB)

(a) CGSB- CAN/CGSB-65.16-99 – Marine Abandonment Immersion Suit Systems.

(b) CAN/CGSB-65.17-99 – Helicopter Passenger Transportation Suit Systems.

3.6 Canadian Association of Petroleum Producers (CAPP)

(a) CAPP Training Qualifications Guideline (TQG).

3.7 International Organizations

(a) International Maritime Organization: Safety of Life At Sea (SOLAS) 1974, Including the Articles of the Protocol of 1988, including 2000 Amendments, effective January and July 2002.

(b) International Maritime Organization: Code for the Construction and Equipment of Mobile Offshore Drilling Units 1898 (MODU Code), amended Consolidated Edition 2001.

(c) Guidelines for the Safe Management and Operation of Vessels Standing by Offshore Installations, UK Offshore Operators Association, Issue 2, November 2001.

3.8 Transport Canada

(a) Life Saving Equipment Regulations, 1978, amended to SOR/2001-179, May 17, 2001.

(b) Boat and Fire Drill Regulations, 1978, amended to SOR/82-1054, November 26, 1982.

(c) Standards Respecting Mobile Offshore Drilling Units (Canadian MODU Code) , amended December 1985, TP 6472E*. (* The Nova Scotia Offshore Area Petroleum Drilling Regulations were amended in 1996, removing all references to the Canadian MODU Code).

(d) Standards for Pyrotechnic Distress Signals and Similar Devices, January 1987, TP 7319E.

(e) Standards for Lifeboats, August 1992, TP 7320E.

(f) Standards for Liferafts and Inflatable Rescue Platforms, February 1992, TP 7321E.

(g) Standards for Rescue Boats, December 1992, TP 7322E.

(h) Launching and Embarkation Appliances, January 1992, TP 7323E.

(i) Standards for Lifebuoys and Integral Equipment, June 1992, TP 7325E.

(j) Standards Respecting Standby Vessels, Amended October 1988, TP 7920E.

(k) Standards for the Construction and Testing of Emergency Boats, August 1992, TP 9247E.

4. General Requirements

4.1 Standards Organization

The structure of the standards is depicted in Figure 1. There are two main levels of Standards: Global Standards and Specific Standards. Global Standards pertain to the related process as a whole. Specific Standards pertain to each mode or sub-component of each of the EER components. The rescue “survival” and “recovery” components are specific only.

4.2 Standards Objectives

The purpose of these Standards is to establish objective and measurable criteria to optimize the following:

- Safety
- Performance
- Reliability
- Availability

In doing so it is hoped that the standards will help focus research and development efforts aimed at developing new escape, evacuation and rescue systems and methods and also help to measure the effectiveness and thus lead to improvements in existing systems and methods.

The legislation related to escape evacuation and rescue systems in most offshore petroleum jurisdictions is prescriptive. Even where goal setting legislation is provided the guidance given operators in meeting these performance-based requirements is usually set in prescriptive form. Most offshore petroleum legislation also requires, either explicitly or implicitly, that operators identify hazards, assess risks and reduce the risk associated with any activity to a level that is as low as is reasonably practicable (ALARP). Operators generally utilize some combination of quantitative and qualitative risk assessment techniques to demonstrate that they have indeed met the ALARP test. Escape, evacuation and rescue systems and methods figure prominently in the mitigation of risk and assumptions regarding the safety, performance, reliability and availability of these systems are very important in risk assessment. It is hoped that these Standards will help objectify these assumptions and result in more robust and realistic assessments. The Standards should also improve assessments of the risk associated with the evacuation process itself on any given installation under defined environmental conditions. Thus operators should be in a better position to demonstrate that the risk is indeed ALARP and regulators better equipped to assess demonstrations provided to them.

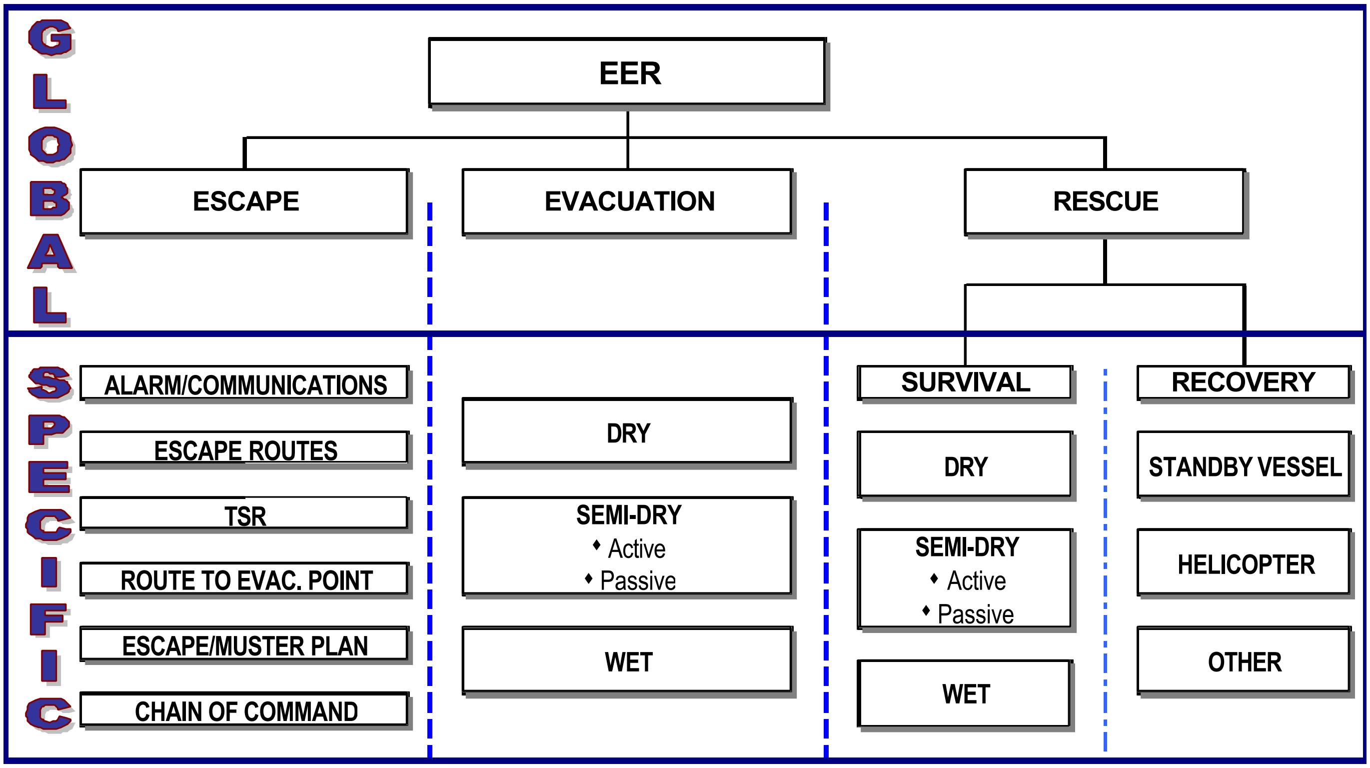

Figure 1
Structure of Performance-Based Standards

5. EER Global Standards

Global Standards address the safety, reliability, performance, and availability of the entire EER system in all design environmental conditions. The following are EER Global Standards:

(a) Achievement of optimum degree of safety, performance, reliability, and availability.

(b) All procedures shall be simple to follow, involving minimal manual operations, decision-making, number of operating crew, and special training.

(c) System hardware locations shall be provided and arranged to optimize the effectiveness of the EER process.

(d) Equipment shall be simple to operate and maintain, requiring minimum operational decisions

(e) To the extent practicable all critical systems hall have at least two modes of operation, a primary mode, and an independent secondary mode such that the in the case of common mode failure of the complete system is prevented.

(f) All components and procedures shall be of a type proven and tested using the latest technology available under anticipated operational and environmental conditions, and shall be designed with sufficient allowance for accident conditions.

(g) All load bearing components, whether plates, beams and struts, cables, or other solid elements shall be designed with adequate safety factors against ultimate loads, and in no case less than those set out in applicable design standards.

(h) Means of protecting personnel from all, operational, environmental, and accident conditions shall be incorporated into the EER system.

(i) The system shall be designed and constructed in accordance with cost-benefit principles without compromising the purpose of the Standards as set out in Section 1.3.

(j) An optimal inspection, maintenance, testing, and repairs program shall be incorporated for the EER system for each installation.

(k) Drills shall be conducted regularly, from personnel location at time of alarm, to TSR, muster, and to embarkation point so that all personnel participate in these drills pursuant to the applicable regulation.

(l) Quantitative evaluation of the EER system availability, reliability, and expected performance under all operational, environmental, and accident conditions shall be done using approved methodology.

(m) Successful evacuation shall be completed as rapidly as possible, compatible with safety considerations, once the order to abandon the installation has been given. Currently the International Maritime Organization (IMO) MODUCode [3.7(b)] stipulates that survival craft embarkation arrangements be so designed so that lifeboats can be boarded by their full complement of persons within 3 minutes of the time that the instruction to board is given (10.3.6.1). The MODU Code also requires: that all lifeboats required for the abandonment by the total number of persons permitted onboard, should be capable of being launched with their full complement of persons and equipment within 10 minutes from the time the signal to abandon the unit is given (10.6.8).

(n) For each installation, procedures on how to conduct a safe and effective EER process including designation of the person that has the authority to initiate it, shall be developed and formally communicated to all personnel. There shall be designated a primary and secondary person in charge of the emergency response activity. There also shall be an onboard organization chart showing who should be notified and actioned to assist the operation.

6. Escape Standards

6.1 Escape Global Standards

The escape process considers two main alternative escape procedures:

- All personnel assemble at the primary muster point appropriate for the type of alarm.
- All personnel assemble directly at a primary or secondary evacuation point.

Escape Global Standards are as follows:

(a) Each personnel location on an installation shall have more than one escape route to the TSR and evacuation point with the number and location of routes to be established to assure that there is always at least one usable route for each combination of operational, accident, and environmental conditions.

(b) Escape routes shall provide such means as will ensure, as far as reasonably practicable, the safe escape of all persons wearing all required safety protective equipment.

(c) All offshore installations shall have a TSR.

6.2 Escape Specific Standards

6.2.1 Escape Chain of Command

In the ***escape chain of command*** there must be a designated primary and secondary person in charge of the emergency response activity. There also must be an onboard organization chart showing who should be notified and actioned to assist the operation.

6.2.2 Alarm/Communications

Standards relating to alarms and communications for EER purposes are identified within the Installations Regulations for the authority having jurisdiction for the operating area. Notwithstanding the regulations, the following specific Standards apply:

(a) Emergency alarms will be audible and also visual where necessary in order to ensure that all persons are made aware of the emergency situation.

(b) All emergency alarms and communications shall be clearly perceptible in all parts of the Installation.

6.2.3 Escape Routes

On every permanently or temporarily* manned installation:

(a) Each personnel location on an installation shall have more than one escape route to the TSR and evacuation point with the number and location of routes to be established to assure that there is always at least one usable route for each combination of operational, accident, and environmental conditions.

(b) In addition to the escape routes required by Standard 6.2.3 (a), clear passage shall be provided, where practicable, to the helicopter deck and sea level and other embarkation locations.

(c) All corridors that are more than 5 m long, all accommodation areas and, where practicable, all work areas shall have at least two exits leading to escape routes, and located as far apart as is practicable.

(d) Every escape route and embarkation station shall be free of all obstructions, and each door along the route shall be manually operable and be a sliding door or designed to open outwards. Water tight doors, when remotely operated, must be equipped with an audible and visual alarm at the door that activates 10 seconds prior to the remote closing of that door.

(e) Every escape route leading to an upper or lower level shall, where practicable, be provided in the form of ramps, stairways or chutes of sufficient width to accommodate stretcher-bearers with stretchers.

(f) Suitable means shall be provided, where practicable, for persons to descend from the installation to the water.

(g) Materials used for escape routes shall have a level of fire durability equivalent to steel.

(h) Semi-dry primary evacuation stations, located adjacent to the accommodation areas shall be protected from fire for a period of at least two hours, and shall be shielded for explosion protection.

(i) All secondary evacuation stations and other escape routes shall be appropriately protected for the effects of fire and explosion.

* Note: Certain installations, which are temporarily (not permanently) manned, are called "unmanned"; but have visiting maintenance crews for which EER Standards also apply.

6.2.4 Temporary Safe Refuge (TSR)

A temporary safe refuge (TSR) is a location in an installation in which all personnel can remain without harm for a specified time under any accident scenario. A Marine Survival System (MSS) is a suit or system in which an individual is protected from marine environmental effects.

The following Standards apply to the TSR:

(a) TSR integrity (breathable air, fire resistance) for the maximum complement on the installation shall be maintainable for a minimum duration of 2 hours.

(b) Approved Marine Survival Systems (MSS) are suits or other systems that provide protection to individuals from cold shock, swimming failure, hypothermia and post-rescue collapse and include airway protection to prevent drowning. There shall be a sufficient number of MSS to provide for 100% of the complement, stowed in the TSR, and the remainder stored in strategic locations in proximity to the evacuation points.

(c) The MSS shall be inspected and maintained in accordance with the manufacturer's instructions.

6.2.5 Escape and Muster Plan

The following Standards apply to the Escape and Muster plan:

(a) There must be a method specific to each installation, accounting for all persons onboard the installation. This accounting shall include the current location, identity, condition and plan for escape for each person.

(b) A simplified Escape and Muster Plan must be available to all persons on the installation, and briefed to all new personnel as soon as practicable following their arrival.

6.2.6 Escape Drills

The following are Standards pertain to escape drills:

(a) Regular escape drills will be conducted for all escape scenarios, including escape to TSR, and to each of the main embarkation points.

(b) Escape drills may normally be conducted in standard work wear; however, they shall be conducted by all personnel wearing the MSS at least every six months.

(c) Escape drills should also be conducted on a regular basis to include the designated standby vessels and their Fast Rescue Craft (FRC). Refer to CAPP Training Qualifications Guideline (TQG) – Chapter 7 [3.6(a)]. The CAPP TQG recommends that Man Over Board Drills be conducted with Fast Rescue Craft on board the installation and/or designated standby vessel at least monthly (TQG: 7.3.1.5).

7. Evacuation Standards

7.1 Evacuation Global Standards

The following are Evacuation Global Standards applying to all evacuation systems:

(a) There shall be at least two marine evacuation systems. One system must be a dry system and the second must be either dry or semi-dry. These systems must be independent of each other.

(b) Helicopter services for evacuation purposes shall be available as much as practicable.

(c) The evacuation systems shall have their own uninterruptable power source independent of the installations power systems, or be powered by gravity

(d) The evacuation systems shall be inspected and maintained by trained personnel in accordance with manufacturers' requirements.

(e) The evacuation systems shall be designed in accordance with established human engineering principles.

(f) Clearing Capability

- Any semi-dry evacuation system will have the capability to clear the installation (once launched) by at least 50 meters in minimum time for all environmental design conditions, and in no case more than 5 minutes.
- The active semi-dry evacuation system will have the capability to clear the installation (once launched) by at least 50 meters in minimum time for all environmental design conditions, and in no case more than 5 minutes.
- The passive semi-dry evacuation system will have the capability to launch without impact with the structure of the offshore installation, and capability to be cleared from the structure for all environmental design condition within 5 minutes.

(g) The minimum combined availability of the evacuation systems on an installation shall be 99.9% of the time at sea.

(h) Reliability

- The minimum combined reliability of the evacuation systems of an installation shall be 95% for severe weather (Beaufort 8-10).
- The minimum weather-weighted average combined reliability of the evacuation systems on an installation shall be 98%.

7.2 Evacuation Specific Standards

These standards will be addressing systems divided into dry, semi-dry, and wet categories. Semi-dry systems are divided into active and passive systems.

7.2.1 Route from TSR or Muster Point to Evacuation Point

Once the personnel are in the TSR, or Muster Point, the Offshore Installation Manager (OIM) will announce the chosen method of evacuation. Standards for the route to any evacuation point are as follows:

(a) The route(s) between the TSR or Muster point and the chosen evacuation point(s) shall be as uncomplicated and as direct as possible. There shall be a minimum of hatches, stairs, and branchings. The passageway shall be designed to allow smooth uninterrupted progress with no obstructions. Evacuation routes shall be designed to allow free passage of a casualty on a stretcher.

(b) The route(s) between the TSR or Muster Point and the chosen evacuation point(s) shall be designed to be protected against accidents and environmental effects so as not to impair safe evacuation.

(c) An evacuation route from the TSR or Muster Point to the evacuation point(s) must always be available 100% of the time.

7.2.2 Dry Evacuation Systems

Examples of this type of evacuation system includes aircraft, cable transfer systems, gang bridge, and personnel transfer basket. The dry evacuation system is the preferred method of evacuation. The following Standards apply:

(a) Design		(b) Performance	
i	A dry evacuation system shall be designed for all operational, accident, and environmental conditions of the installation.	**i**	The dry evacuation system shall be operable under all operational, accident, and environmental conditions.
ii	Access and egress ways shall be designed to accommodate evacuees in MSS and injured and stretchered persons.	**ii**	System boarding time shall be in accordance with the current specified 3-minute standard for individual survival systems (TP7320E, Section 3.4.2 [3.8(e)]).

(c) Availability	(d) Reliability
▪ Each dry evacuation system shall be available at least 94% of the time at sea (this means maximum 3 weeks downtime per year per system). ▪ For installation independent systems (such as helicopters) and partly dependent systems (such as transfers to SBV), the dry system availability shall be sufficient to provide combined availability of all evacuation systems in accordance with Section 7.1(g).	▪ The minimum reliability of each dry evacuation system under severe weather conditions (Beaufort 8-10) shall be 95%. ▪ Minimum weather-weighted average reliability for each dry evacuation system shall be 98%.

7.2.3 Semi-Dry Active Systems

Semi-dry systems are composed of active and passive systems. Examples of semi-dry active evacuation systems include TEMPSC. Semi-dry passive evacuation systems include inflatable life rafts. This includes the launching systems and the vehicle that is being launched. The semi-dry system shall be of a suitable safe design in accordance with human engineering principles, considering seaworthiness, controllability, and ease of rescue. The following Standards shall apply to semi-dry active systems.

7.2.3 Semi-Dry Active Systems

	(a) Design		(b) Performance
i	Designed for operation and occupancy in all accident, environmental and operational conditions of the installation design.	**i**	General performance: ▪ Operate under its design accident, environmental and operational conditions. ▪ The system structure or enclosure shall protect the occupants from the effects of fire on the sea for a period of 10 minutes. (TP7320E [3.8(e)]). ▪ Air-supply capacity of 10 minutes. The self-contained air support system shall be so arranged that when proceeding with all entrances and openings closed, the air within the lifeboat remains safe and breathable and the engine runs normally for a period of not less than 10 minutes. ▪ The vessel shall be seaworthy for 72 hours to ensure the safe occupancy of the

7.2.3 Semi-Dry Active Systems

(a) Design		(b) Performance	
			vessel (survival). ▪ If toxic atmosphere (e.g., H_2S, smoke) is potentially present the system must have the ability to function with occupants wearing adequate respiratory protection.
ii	The system shall be designed for a rapid, simple, and safe launching process.	**ii**	Launch performance: ▪ System will have the capability to clear the installation (once launched or airborne) by at least 50 meters in minimum time for all environmental design conditions, and in no case more than 5 minutes. ▪ System will have the capability to launch without impact with the structure of the offshore installation. ▪ Shall be maneuverable in a sea state up to Beaufort 8. ▪ *Speed* – The speed of launching should be conducive to safe and effective water arrival (TP7323E) [3.8(h)]. ▪ *Motion control* – Wherever possible there should be control to minimize the motion throughout descent of the craft. ▪ *Launch angle* – The launching system shall provide an appropriate inclination at the point of water entry of the craft to insure that there is immediate thrust from the propulsion system. ▪ *Protection* – appropriate fendering of the hull shall be provided to avoid operational impacts with other structures. ▪ *Floating installations* – For the semi-submersible and monohull installation it shall be possible to launch the craft safely and effectively in the event of a combination of list and trim as per Nova Scotia and Newfoundland installations regulations [3.3(a), 3.3(b), 3.4(b)].

7.2.3 Semi-Dry Active Systems

	(a) Design		(b) Performance
			▪ *Orientation* – The craft shall be capable of rapid acceleration and effective departure after splash down on a safe departure course and must be free from all launch encumbrances. ▪ *Clearance* – The clearance shall be such that the craft does not impact any of the rig structure, for guidelines refer to Appendix B, Section B.1. ▪ *Control* – The operator must have full control of the craft during the process of launch and release. ▪ *Equipment* – The craft as launched shall have appropriate equipment to sustain survivability of occupants. ▪ The time for preparation must be adequate. If more than one system is served by any launching appliance, effective successive launching of all systems shall be demonstrated to determine that the total complement may be loaded and launched within 30 minutes (TP7323E) [3.8(h)].
iii	The system shall be designed with static and dynamic stability to function right side up or if temporarily inverted, to float and self-right immediately in the event of an inversion. *Positive stability is considered as the measure of the ability of a floating body to remain upright, or return unaided to the upright position if inverted by an external force*	**iii**	Shall function in both orientations and must meet TP 7320E [3.8(e)] testing requirements.
iv	Hatches, passageways, and stairs or ladders shall be designed for rapid access for entry and egress of evacuees wearing marine systems including injured persons and stretchers.	**iv**	Embarkation time in accordance with the current specified 3-minute standard for marine survival systems (TP7320E, Section 3.4.2) [3.8(e)], stretchers to be boarded within 5 minutes.
v	Designed with heating of cabin while stowed.	**v**	The system must be stowed at a minimum interior cabin temperature of (10°C).

7.2.3 Semi-Dry Active Systems

(a) Design		(b) Performance	
vi	Designed with cabin lighting and stowage for provisions and water for the complement for 72 hours.	**vi**	Provide lighting at 4d/lux for 72 hours and adequate water provisions for occupant subsistence for 72 hours (per TP7320E, Section 3.9.4 [3.8(e)]).
vii	Craft to be designed to permit for rapid and safe recovery of survivors from the water without endangering the rescuers or the craft.	**vii**	Safe and rapid recovery of a survivor from the water shall be achievable by 2 persons from inside the craft.
viii	Safe individual restraint systems to be designed for each seating position.	**viii**	System shall restrain seated or stretchered occupant movement in accordance with human engineering tolerances. Seat restraints shall be clearly identifiable with seat position, have easy buckle function even with a gloved hand, and shall be easily adjustable.
ix	Guards or shields and any external protrusions on the craft shall be designed for so as to avoid injury of persons in the water or those being recovered to the craft.	**ix**	Contact with external features shall not cause injury to adjacent immersed persons or during the recovery of persons from the water.
x	Shall be designed for appropriate color and exterior lighting.	**x**	Exterior lighting shall meet the requirements of TP 7320E, Section 13.3 [3.8(e)]. Colour to be optimally visible for all conditions.
xi	Craft designed with operator positioned providing a full 360° horizontal field of view around the craft.	**xi**	Operator positioned with a full 360° horizontal field of view to allow safe operation of the craft.
xii	Seating shall be designed to be as low as practicable in the craft, which shall be capable of supporting the number of persons (each weighing 100 kg) for which spaces are provided. (Note current Transport Canada standard (TP7320E [3.8(e)]) is 75-kg person).	**xii**	Seating to not adversely affect the static or dynamic stability of the craft.
xiii	The number of stretcher berths shall be a 5% percentage of capacity of personnel on board.	**xiii**	Stretcher berths to safely accommodate the design allocation in a securely stowed position. Seating positions may double as stretcher berths if adequately designed. Regardless of the number of stretcher berths, the system must still permit the maximum assigned numbers of evacuees to each have a seat with a safety restraint harness.

7.2.3 Semi-Dry Active Systems

(a) Design		(b) Performance	
xiv	A system to communicate between the craft and rescue resources shall be designed so it is powered by means of the craft's engine.	**xiv**	At least one communication system shall be available 99.9% of the time and shall be 98% reliable.
xv	Design shall provide for recovery of craft from a launch abort (with exception of free fall systems).	**xv**	Craft to be recoverable from an abort at any stage of the launch (except for free fall systems).
xvi	Controls and displays should be designed for optimal and safe use.	**xvi**	The operator's controls and displays shall be in compliance with (CSA/CGSB).

(c) Availability	(d) Reliability
▪ Each semi-dry active system shall be available at least 98% of the time at sea (this means 1 week per year downtime). ▪ The semi-dry active system availability shall be sufficient to provide combined availability of all evacuation systems in accordance with Section 7.1(g).	▪ The minimum reliability of each semi-dry active evacuation system in severe weather (Beaufort 8-10) shall be at least 95%. ▪ The minimum weather-weighted average reliability of each semi-dry active evacuation system shall be 97%.

7.2.4 Semi-Dry Passive Systems

Semi-dry passive systems generally consist of chute or transfer mechanism and a craft to which evacuees are transferred, such as a life raft. The following Standards apply to semi-dry passive systems.

7.2.4 Semi-Dry Passive Systems

	(a) Design		(b) Performance
1. Chute or Transfer Mechanism:			
i	Designed for operation and occupancy in all accident, environmental and operational conditions of the installation design.	**i**	Operate under its design accident, environmental and operational conditions.
ii	Designed for smooth controlled descent and entry into craft (and daughter craft it needed).	**ii**	▪ Evacuees should be able to descend chute in a safe and controlled manner, without snagging. ▪ Evacuee transfer to daughter craft (if there is one) shall be simple and easy.
2. Craft:			
i	Designed for operation and occupancy in all accident, environmental and operational conditions of the installation design.	**i**	General performance: ▪ Operate under its design accident, environmental and operational conditions. ▪ The craft body and enclosure shall protect the occupants from the effects of fire on the sea if possible. ▪ The craft shall be seaworthy for a minimum of 72 hours in all design environmental conditions to ensure the safety of occupants of the vessel. ▪ If toxic atmosphere (e.g., H_2S, smoke) is potentially present the craft must have the ability to function with occupants wearing adequate respiratory protection.
ii	The system shall be designed for a rapid, simple, and safe deployment process.	**ii**	Launch performance: ▪ Craft will have the capability to be cleared (by FRC or other powered vessel) from the installation by at least 50 meters in minimum time for all environmental design conditions.

7.2.4 Semi-Dry Passive Systems

	(a) Design		(b) Performance
			▪ System will have the capability to launch without impact with the structure of the offshore installation. ▪ Shall be capable of being launched in a Beaufort force scale of 8-10 with a minimum reliability level of 85%. ▪ *Speed* – The speed of craft launching should be conducive to safe and effective water arrival. ▪ *Motion control* – Wherever possible there should be control to minimize the motion throughout descent of the system. ▪ *Floating installations* – For the semi-submersible and monohull installation it shall be possible to deploy the system safely and effectively in the event of a combination of list and trim as per Nova Scotia and Newfoundland installations regulations [3.3(a), 3.3(b), 3.4(b)]. ▪ *Clearance* – The clearance shall be such that the system does not impact any of the rig structure, for guidelines refer to Appendix B, Section B.1. ▪ *Equipment* – The craft as launched shall have appropriate equipment to sustain survivability of occupants. ▪ The time for preparation must be adequate. If more than one system is served by any launching appliance, effective successive launching of all systems shall be demonstrated to determine that the total complement may be loaded and launched within 30 minutes (TP7323E) [3.8(h)].
iii	The system shall be designed with static and dynamic stability to function right side up or inverted.	**iii**	Shall function in both orientations and must meet TP7320E [3.8(e)] testing requirements.
iv	Hatches, passageways, and stairs or ladders shall be designed for rapid access	**iv**	Embarkation time in accordance with the current specified 3-minute standard for marine

7.2.4 Semi-Dry Passive Systems

(a) Design		(b) Performance	
	for entry and egress of evacuees wearing MSS including injured persons and stretchers.		survival systems (TP7320E, Section 3.4.2) [3.8(e)], stretchers to be boarded within 5 minutes.
v	Designed with stowage for provisions and water for the complement for 72 hours.	**v**	Provide lighting at 4d/lux for 72 hours and adequate water provisions for occupant subsistence for 72 hours (per TP7320E, Section 3.9.4 [3.8(e)]).
vi	Craft to be designed to permit for rapid and safe recovery of survivors from the water without endangering the rescuers or the craft.	**vi**	Safe and rapid recovery of a survivor from the water shall be achievable by 2 persons from inside the craft.
vii	External surface shall be designed to prevent damage from sharp or abrasive objects.	**vii**	Puncture proof exterior.
viii	Shall be designed for appropriate color and exterior lighting.	**viii**	Exterior lighting shall meet the requirements of TP 7320E, Section 13.3 [3.8(e)]. Colour to be easily visible for all conditions.
ix	Occupant position shall be designed to be as low as practicable in the craft, which shall be capable of supporting the number of persons (each weighing 100 kg) for which spaces are provided. (Note current Transport Canada standard (TP7320E [3.8(e)]) is 75-kg person).	**ix**	Occupant position to not adversely affect the static or dynamic stability of the craft.
x	If the launch is aborted, the system should have the capability to recover the craft (with exception of free fall systems).	**x**	Craft to be recoverable from an abort at any stage of the launch (except for free fall systems).

(c) Availability	(d) Reliability
▪ Each semi-dry passive system (chute and craft combined) shall be available 96% of time at sea (this means two weeks per year downtime). ▪ The semi-dry passive system availability shall be sufficient to provide combined availability of all evacuation systems in accordance with Section 7.1(g).	▪ Each semi-dry passive evacuation system shall have a minimum reliability of 92% for severe weather conditions (Beaufort 8-10). ▪ The weather-weighted average reliability of each semi-dry passive evacuation system shall be a minimum of 96%.

7.2.5 Wet Systems

A wet system is one that is designed to take an individual safely from the installation directly to the sea and then provide a system of survival until rescue. Examples of wet systems include ladders, ropes, chutes, slides, abseiling devices, or if all else fails – jumping. Wet systems consist of a transfer mode from the installation to the sea and a marine survival system (MSS) for personal protection when immersed. This section deals with the transfer mode. Section 8, Rescue Standards, addresses the marine survival aspect.

(a) Design		(b) Performance	
i	Transfer systems shall be designed to facilitate easy and safe movement of each individual from the deck to the sea.	**i**	Transfer systems shall be simple to use and operate effectively in transferring evacuees from installation to sea.
ii	Transfer system storage locations shall be designated using risk-based guidelines.	**ii**	Appropriate numbers of wet transfer systems shall be available at locations to accommodate for malfunction of the dry or semi-dry systems and their lack of accessibility due to accident or environmental conditions.
iii	Transfer systems shall be designed to accommodate the marine survival system (MSS) that each individual uses.	**iii**	Shall operate with evacuees using MSS.
iv	MSS shall be designed for evacuee survival in all environmental conditions.	**iv**	The MSS shall protect from cold shock, swimming failure, hypothermia and post-rescue collapse and include airway protection to prevent drowning. There shall be a sufficient number of systems to provide for 100% of the complement, stowed in the TSR, and another 100% (NS Installations Regulations [ss 22(1)(c)] and similarly in the NF Installations Regulations [ss 22(1)(c)]) – stored in strategic locations in proximity to the evacuation points.

(c) Availability	(d) Reliability
▪ Wet systems for 100% of the complement shall be available 100% of time at sea.	▪ Each wet system shall have a minimum reliability for severe weather (Beaufort 8-10) operation of 85%. ▪ Each wet system shall have a weather-weighted average reliability of no less than 95%.

8. Rescue Standards

8.1 Rescue Global Standards

The following are rescue Global Standards:

(a) Design

i. The Rescue process shall be designed to recover all evacuees from an offshore installation 72 hours after the abandonment in any environmental conditions expected for the area of operation.

ii. Evacuation systems shall be designed (in terms of recovery potential) to deal with the expected available rescue modes (standby vessel, FRCs, support via JRCC).

iii. The equipment shall be designed to minimize the requirement for specialized training and shall be intuitive in its use.

(b) Performance

i. Functionality of components and systems in the equipment used for rescue shall be assured for all installations.

ii. The system shall have simple to read operating instructions, in both official languages, which shall be available with or attached to each piece of equipment.

iii. System shall have markings and lights to allow for maximum visibility from recovery platforms under all relevant environmental conditions.

8.2 Rescue Specific Standards

Rescue Specific Standards are divided into two categories; namely, those pertaining to survival and those, to recovery.

8.2.1 Survival Specific Standards

8.2.1.1 Dry-Systems Survival Standards

There is no survival component for dry systems since these systems provide personnel transfers directly to a safe haven.

8.2.1.2 Semi-Dry Active System Craft Survival Standards

The following are Standards pertaining to survival in semi-dry active system crafts:

(a) Design		(b) Performance	
i	The craft shall be designed to sustain operation for 72 hours for a full or partial load in all design environmental conditions of the installation.	**i**	▪ The craft must be capable of maintaining a heading in prevailing weather conditions up to a Beaufort 8. ▪ The systems shall be proven in representative environmental conditions, must be reliable and easily maintained, and compliant with safety codes and practices of the installation.
ii	The craft shall be designed to accommodate the full evacuee capacity, and provisions for 72 hours.	**ii**	Demonstrated to be equipped and provisioned to sustain life of a full complement of evacuees for a minimum of 72 hours.
iii	The craft shall be designed to be habitable for up to 72 hours.	**iii**	72-hour habitability of the craft shall be proven.
iv	The design shall be such that it minimizes the occurrence of motion sickness.	**iv**	Craft characteristics to minimize motion sickness shall be demonstrated.
v	The craft shall be designed to be towed.	**v**	Towing (as towed vessel) ▪ Capable of being towed at 10 knots in calm water tow cable must be able to be attached without intervention from inside the craft. ▪ Tow system arranged to ensure craft rises on a plane under tow. ▪ Towed to make safe headway in Beaufort 8. ▪ Any system that is used for stabilizing the craft into the wind must be deployable from within the craft without the opening of hatches
vi	The craft shall be designed to be a towing vessel.	**vi**	Towing (as towing vessel) ▪ Maintain a connection for 24 hours to a wet evacuation system in Beaufort 7. ▪ Maintain a tow for 24 hours at 3 knots
vii	The craft shall be designed to facilitate recovery of personnel from the water.	**vii**	Capability to recover personnel from the water shall be demonstrated for conditions up to Beaufort 4.

(c) Availability		(d) Reliability	
i	Not applicable as personnel are already in the craft for the rescue process.	**i**	The craft shall have a minimum weather weighted average reliability of 99%.

8.2.1.3 Semi-Dry Passive System Craft Survival Standards

The following Standards apply to semi-dry passive system crafts:

(a) Design		(b) Performance	
i	Designed to maintain upright stability in all environmental conditions.	**i**	▪ Will maintain functional integrity in states up to Beaufort 7 for a minimum of 72 hours. ▪ In the even of inversion, be able to be righted by one person.
ii	The craft shall be designed to accommodate the full evacuee complement, and provisions for 72 hours.	**ii**	Demonstrated to be equipped and provisioned to sustain life of a full complement of evacuees for a minimum of 72 hours.
iii	Designed to be habitable for up to 72 hours.	**iii**	72-hour habitability of the craft shall be proven.
iv	The design shall be such that it minimizes the occurrence of motion sickness.	**iv**	Craft characteristics to minimize motion sickness shall be demonstrated.
v	Craft shall be designed to maintain a heading in conditions up to Beaufort 7.	**v**	The craft shall be able to maintain a heading in conditions up to Beaufort 7.
Vi	The craft shall be designed to be towed, with appropriate patch towline attachments.	**vi**	Towing (as towed vessel) ▪ Capable of being towed at 3 knots in calm water for 24 hours. ▪ Maintain a connection under tow in weather conditions up to Beaufort 7.
vii	The craft shall be designed to facilitate recovery of personnel from the water.	**vii**	Capability to recover personnel from the water shall be demonstrated for conditions up to Beaufort 4.

(c) Availability		(d) Reliability	
i	Not applicable as personnel are already within the craft.	**i**	The craft shall have a minimum weather weighted average reliability 97%.

8.2.1.4 Wet Systems Survival Standards

Provision is needed to protect personnel from environmental effects during rescue operations. Marine Survival Systems (MSS) are suits or other systems designed to protect personnel from these effects. The following Standards apply to survival in Wet Systems:

	(a) Design		(b) Performance
i	The MSS shall be designed to accommodate the full anthropometric range of workers, and to maintain life support for all design environmental conditions for 72 hours.	**i**	▪ Shall maintain life support for a minimum of 72 hours. ▪ Should not inhibit the critical survival functions of the evacuees.
ii	Shall be designed to provide protection from cold shock, swimming failure, hypothermia, and post-rescue collapse and include airway protection to prevent drowning.	**ii**	Shall be demonstrated to provide protection from cold shock, swimming failure, hypothermia, and post-rescue collapse and include airway protection to prevent drowning.
iii	The design shall include provision for the appropriate lifting harnesses.	**iii**	The lifting harness should, whenever possible, lift the survivor out of the water horizontally or semi-horizontally (i.e. a two sling arrangement, one for under the arms one for under the knees).
iv	Lifebuoys	**iv**	Refer to TP 7325E Standards for Lifebuoys [3.8(i)]. Every lifebuoy, lifebuoy self-igniting light, and self-activating smoke signal that is manufactured on or after July 1, 1986, for use on board a Canadian ship, shall comply with the requirements of TP 7325E [3.8(i)].

	(c) Availability		(d) Reliability
i	Not applicable as personnel are already in a MSS.	**i**	The MSS shall maintain structural and functional integrity (when used by evacuees) for a minimum of 72 hours with a minimum weather weighted average reliability of 98%.

8.2.2 Recovery Specific Standards

8.2.2.1 Dry Systems Recovery Standards

Since evacuation using a dry system results directly in recovery, no additional recovery standards for dry systems are required.

8.2.2.2 Semi-Dry Active Systems Recovery Standards

The following Standards pertain to personnel transfer to rescue platforms, or recovery from semi-dry active systems:

(a) Design		(b) Performance	
i	The craft shall be designed for optimal and safe transfer of personnel to the expected available rescue platforms.	i	▪ Be able to maintain station along side the recovery vessel or below the recovery helicopter. ▪ The system shall be capable of the maneuvers, stability, procedures, and be designed to adequately effect transfers of personnel to the expected rescue platforms including SBV, helicopters, installations, and vessels of opportunity in design environmental conditions. See Appendix A for weather categories. ▪ Able to facilitate the safe transfer of all personnel from the craft to the recovery vessel or helicopter.
ii	A communication link between the craft and recovery platform(s) shall be designed.	ii	The system shall be capable of communication during all recovery operations.
iii	Appropriate marking, colour, and lights to optimize visibility shall be included in the design.	iii	System shall have markings and lights to allow for maximum visibility from recovery platforms under all environmental conditions to Beaufort 9.

(c) Availability		(d) Reliability	
i	Not applicable as the system is already in the recovery process.	i	Recovery systems shall have a minimum weather weighed reliability of 99.9% for up to Beaufort 8 conditions.

8.2.2.3 Semi-Dry Passive Systems Recovery Standards

The following Standards apply to recovery of personnel from semi-dry passive systems:

(a) Design		**(b) Performance**	
i	The craft shall be designed for the safe transfer of all personnel from the craft to the recovery vessel.	**i**	The system shall be stable and adequately effect transfers of personnel to the expected rescue systems including SBV, helicopters, installations, and vessels of opportunity in design environmental conditions.
ii	The craft shall be designed for communication during all recovery operations.	**ii**	The craft shall be capable of communication during all recovery operations.
iii	The craft shall be designed with markings and lights to be visible from recovery platform under all relevant environmental conditions to Beaufort 8.	**iii**	The craft shall have markings and lights to be visible from recovery platform under all relevant environmental conditions to Beaufort 8.

(c) Availability		**(d) Reliability**	
i	Not applicable as the system is already in the recovery process.	**i**	Recovery systems shall have a minimum weather weighted reliability of 99.9% for up to Beaufort 6 environmental conditions.

8.2.2.4 Wet Systems Recovery Standards

The following Standards pertain to recovery of personnel in wet systems:

(a) Design		**(b) Performance**	
i	Designed to maintain life support for a minimum of 72 hours for all environmental conditions.	**i**	Able to maintain life support for a minimum of 72 hours for all environmental conditions.
ii	Designed to be safely recovered from the sea to the recovery vessel or helicopter.	**ii**	Capable of being safely recovered from the sea to the recovery vessel or helicopter.
iii	Designed to be easily detected in all environmental conditions by recovery platform.	**iii**	Capable of being easily detected in all environmental conditions by recovery platform.
iv	Designed to facilitate the recovery procedure including the use of slings, lifting beckets etc.	**iv**	Facilitate the recovery procedure including the use of slings, lifting beckets etc.

(c) Availability		(d) Reliability	
i	Not applicable as system is already in the recovery process.	i	Wet system weather weighted average recovery reliability shall be a minimum of 99.9% up to Beaufort 5 conditions.

8.2.3 Transfer Specific Standards

8.2.3.1 Transfer from Wet or Semi-Dry Systems to Recovery Platforms

Recovery platforms include helicopters, standby vessels, vessels of opportunity, land and other installations. Standards relating to transfer are all under the category of Performance; that is, no Design, Availability, or Reliability Standards apply. Rescue operations limitations dependence on weather, as recommended by the UKOOA [3.7(b)], are given in Section B.3 of Appendix B.

8.2.3.2 Helicopter

If a decision has been made to recover by helicopter the limitations regarding environmental conditions will be evaluated by the military or commercial helicopter crew in coordination with the rescue coordination centre (RCC). From this decision a rescue plan will be formulated.

Basic conditions under which helicopters can be launched and operated are described in Appendix B, Section B.2.

This section to be completed.

8.2.3.3 Standby Vessel (SBV) System

8.2.3.3.1 Standby Vessel Platform

The following Standards apply to standby vessel (SBV) requirements for recovery of personnel:

(a) Manoeuverability

(i) Shall be able to maneuver close to the damaged installation. Master to determine safe proximity considering vessel, installation, and weather.

(ii) Shall be able to manoeuver to pick up survivors from the water or clinging to wreckage.

(iii) Shall be able to maintain its positions.

(iv) The transfer zone shall be as far forward (away from propellers) as practicable.

(b) Visibility

(i) In order for the Master to be able to continuously monitor rescue operations and at the same time safely approach and rescue people from the water, the bridge should be so designed that allows him/her to view the rescue area at all times.

(c) Lighting and Markings

(i) There should be adequate lighting to cover the full 360 degrees to see survivors in the water, to aid rescue.

(ii) Adequate local lighting in the survivor pick up and FRC launching areas.

(iii) The transfer zone shall be as far forward (away from propellers) as practicable.

(d) Communications

(i) There should be adequate communication among the master and crew and the standby vessel and its FRCs, the installation and standby vessels and aircraft.

(e) Recovery

(i) The FRC is the primary, with two of the other methods being any two of:

- Scramble nets and ladders
- Dacon Scoop
- Rescue basket
- 300-kg SWL powered davits located in the rescue zone

8.2.3.3.2 Recovery Methods

(a) Fast Rescue Craft (FRC)

(i) A rapid and safe launching facility for FRCs must be installed.

(ii) FRC recovery systems must be capable of recovering a fully laden FRC within 60 seconds from connection.

(iii) Crewing and training should be in accordance with TP7920E [3.8(j)], Standards Respecting Standby Vessels.

(iv) Fully reliable mechanically.

(v) Must be constructed to perform in accordance with TP 7322E [3.8(g)], Standards for Rescue Boats.

(vi) The FRC should be capable of launching within 10 seconds from coxswain giving the ready to launch signal.

(vii) FRC must be capable of being launched and recovered in sea conditions up to Beaufort 6 (4 meter sea / 30 knots).

(viii) Coxswain must have effective hands free reliable communication with his standby vessel.

(ix) Should have effective search lighting (TP7920E, Appendix V [3.8(j)]), a searchlight capable of effectively illuminating a light-colored object at night having a width of 18 m at a distance of 180 m for a total period of 6 h and of working for at least 3 h continuously.

(x) An FRC shall be capable of:

- when proceeding ahead and loaded with its full complement and equipment and with all engine powered auxiliary equipment in operation at a speed of at least 6 knots;
- manoeuvring at any speed up to 6 knots; and
- of operating at its maximum speed for a period of at least 4 hours (TP7322E) [3.8(g)].

(xi) Every FRC shall be of sufficient strength to enable it to be safely lowered into the water when loaded with its full complement of persons and equipment and to be capable of being launched and towed when the ship is making headway at a speed of 5 knots in calm water (TP7322E) [3.8(g)].

(b) Dacon Scoop (or equivalent method of lifting survivors or small vessels from sea)

(i) Standby vessel – Shall have an articulated personnel recovery system capable of recovering a survivor in a horizontal position and be able to be deployed on both sides of the vessel.

(ii) FRC – Shall have an articulated personal recovery system capable of recovering a survivor in a horizontal position.

(iii) Lifeboat – Shall have a personal recovery system capable of recovering a survivor in a horizontal position.

(c) Rescue Basket

(i) Standby vessel

- The rescue and recovery by the basket will be under the discretion of the master of the vessel.
- A minimum 6 person recovery basket capable of being trolled at minimum steerage speed and capable of floating in the water with the upper floatation collar at the surface so that a survivor can swim into the recovery basket with minimum effort.

(d) Scrambling Nets

(i) Shall meet current standards TP7920E [3.8(j)], Standards Respecting Standby Vessels.

8.2.3.4 Return to Installation

In the case of a precautionary abandonment of non-essential personnel, returning to the original installation is a likely option. Alternatively, when there are several installations in the same area, transfer to the nearest other installation may be a likely option also.

The following Standards pertain to recovery from a semi-dry or wet evacuation system to an installation:

(a) The evacuation system shall be capable of the performance in, and have equipment necessary to effect a safe transfer of personnel from the system to an installation in calm and moderate environmental conditions.

(b) Installations shall have means of recovering personnel from or with semi-dry active and passive systems and wet systems in calm and moderate environmental conditions.

(c) In severe and extreme environmental conditions, personnel transfers to installations shall not, in general, be attempted.

Appendix A – Environmental Conditions

Table A.1
Beaufort Wind Strength Scale

BEAUFORT FORCE	**WIND SPEED** Knots (Mile/hour) [km/hour]	**DESCRIPTION**
0	0-1 (< 1) [< 2]	**Calm**: Still. Smoke will rise vertically. The sea is mirror smooth.
1	1-3 (1-3) [2-6]	**Light Air**: Rising smoke drifts, weather vane is inactive. Scale-like ripples on sea, no foam on wave crests.
2	4-6 (5-7) [7-11]	**Light Breeze**: Leaves rustles, can feel wind on your face, weather vane is active. Short wavelets, glassy wave crests.
3	7-10 (8-12) [13-19]	**Gentle Breeze**: Leaves and twigs move around. Lightweight flags extend. Long wavelets, glassy wave crests.
4	11-16 (13-18) [20-30]	**Moderate Breeze**: Moves thin branches, raises dust and paper. Fairly frequent whitecaps occur.
5	17-21 (20-24) [31-39]	**Fresh Breeze**: Small trees sway. Moderate waves, many white foam crests.
6	22-27 (25-31) [41-50]	**Strong Breeze**: Large tree branches move, open wires begin to "whistle," umbrellas are difficult to control. Some spray on sea surface.
7	28-33 (32-38) [52-61]	**Moderate Gale**: Large trees begin to sway, noticeably difficult to walk. Foam from waves blown in streaks.
8	34-40 (39-46) [63-74]	**Fresh Gale**: Small branches broken from trees, walking in wind is very difficult. Long streaks of foam appear on waves.
9	41-47 (47-54) [76-87]	**Strong Gale**: Slight damage occurs to buildings, shingles are blown off roofs. High waves, crests start to roll over.
10	42-55 (55-63) [89-102]	**Whole Gale**: Large trees are uprooted, building damage is considerable. Sea takes on white appearance.
11	56-63 (64-72) [104-117]	**Storm**: Extensive widespread damage occurs. Exceptionally high waves, visibility affected.
12	64+ (>74) [>119]	**Hurricane**: Extreme destruction. Storm waves at sea. Air is filled with spray and foam.

Table A.2
Weather Condition Categories Used in Standards

Category	Beaufort Force	Avg. Max Wind Velocity knots (km/hr)
Calm	0-4	16 (28)
Moderate	5-7	33 (61)
Severe	8-10	55 (102)
Extreme	11&12	64+ (118+)

Appendix B – Supporting Technical Information

B.1 Zone Definitions for TEMPSC

(a) A <u>danger zone</u> should be an exclusion zone. That is, the lifeboat should never enter it at or after splash-down. The distance from the installation to the danger zone boundary is the *exclusion distance*.

(b) *Exclusion distance* the minimum distance needed to accommodate launching in damaged conditions, Figure 1 (different damage conditions will have to be set-up for the different types of installations).

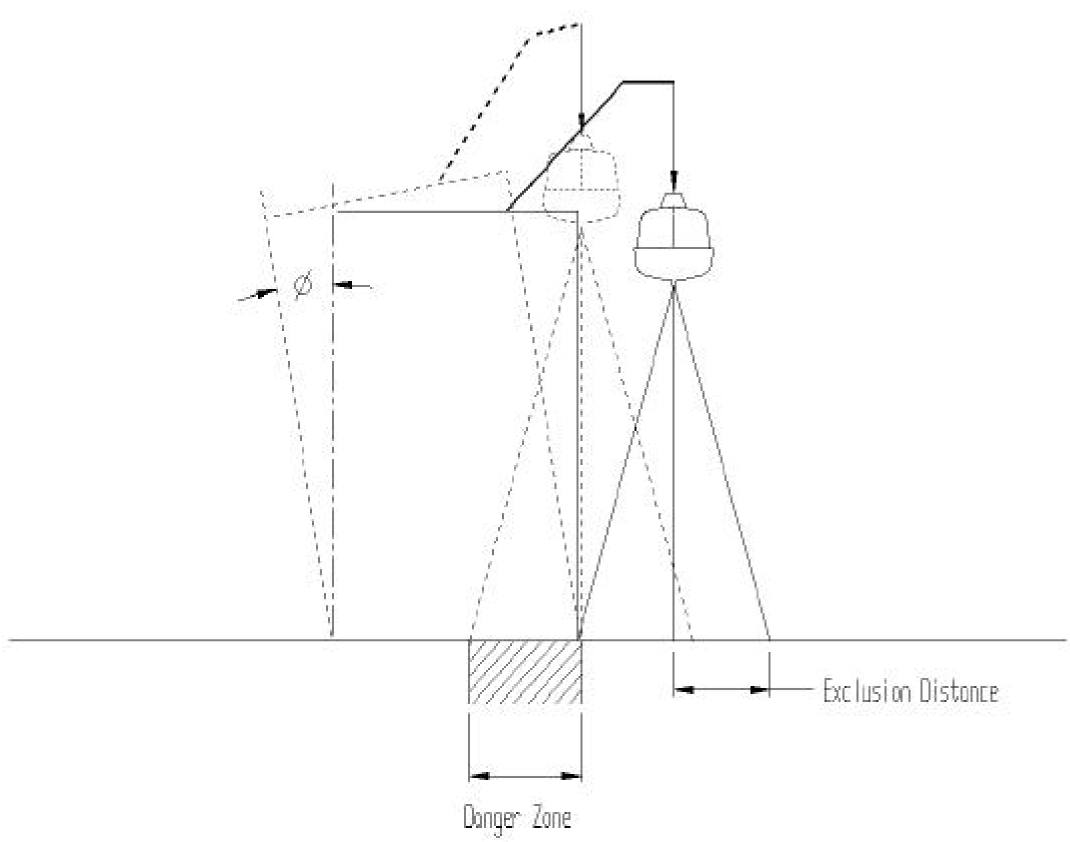

Figure B.1
Exclusion Distance

(c) The *splash-down zone* centers on the target launch point and is circumscribed by a boundary defined by the larger of the missed target and the combination of the missed target and set back, as depicted in Figure 2 by points *A* and *B* respectively.

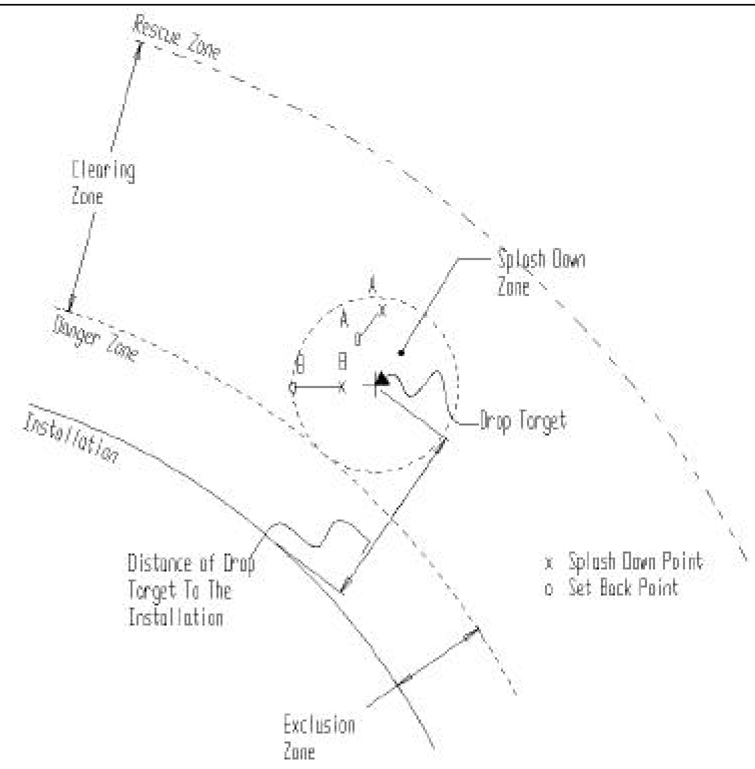

Figure B.2
Splash-Down Zone

(d) The *drop target* is the position of the planned launch relative to the installation. It is located by putting the splash zone boundary tangent to the danger zone boundary. Together, the danger zone and splash-down zone are arranged to prevent collisions between the TEMPSC and the platform.

(e) Some distance away from the installation may be considered "safe" for rescue operations. The region beyond this is the *rescue zone*. This may be defined as the closest distance to the installation that a stand by vessel can come in an emergency situation, for example. The region between the danger and rescue zone boundaries is the *clearing zone*.

B.2 Operation Limitations of Helicopters

(a) **Icing** – In freezing conditions ice builds up on the helicopter in flight and increases the risk of ditching. Ditching is extremely dangerous especially in cold weather. Some helicopters are cleared for flight in light icing conditions up to 1500 m and temperatures of -10°C.

(b) **High Wind** – High wind in flight may delay arrival of helicopters but in prevailing wind conditions it may speed up the process. Helicopters are allowed to land and take off in winds of up to 60 knots if they keep their rotors going. The main limitation in high winds is the ability to start the rotors

(c) **Low Visibility** – Visibility limits apply to the final approach to the platform, which is normally made visually. Typical limits:

- Day: cloud ceiling 75-100m and ~ 900 m horizontal visibility.
- Night: cloud ceiling ~ 300 m, horizontal visibility ~ 6000 m, or
  cloud ceiling 150 m, horizontal visibility ~ 9100 m.

Instrument flight:

- Day: cloud ceiling 75 m and 600 m horizontal visibility.

(d) **Endurance/Seats/Transit Speed**

Helicopter Type	Seats Available*	Transit Speed (knots)	Endurance (hours)
Bell 212	18	125	3
Super Puma	24	150	3
S61	44		3.75
Chinook	80		6.5

*Seats: Represent the maximum emergencies capacity.

(e) **Limitations for Floating Installations** – Helicopters are somewhat limited by the deck movement at which they can land, (e.g. 7-8º pitch and roll in emergencies, 3-4º in normal operations) by conventional simple main rotor helicopters or 20º pitch, 6º roll in emergency (15º pitch, 3º roll in normal conditions) for the Chinook.

(f) **Salt on Turbine and Windows –** This has influence on engine thrust and visibility. This can be a problem at low heights when the sea is rough.

In emergencies, pilots may be expected to disregard operational limits and fly to the limits of air-worthiness. Better operability would be achieved. Operability of helicopters in precautionary evacuation has been estimated at 98.7% (Cullen 1990).

(g) **Impairment of Helideck** – The helideck may become unavailable due to thermal radiation, smoke, potential explosive gas concentrations or explosion overpressure. Evacuation by helicopter in major emergencies involving fire, smoke, gas release or structural failure may only be possible on 5% of the time (Cullen 1990).

B.3 UKOOA Limits for Rescue Operations

Table B.1 gives the UKOOA [3.7(b)] recommended limits for various rescue related operations as a function of weather conditions at sea.

Table B.1
UKOOA Adverse Weather Standards for Emergency Response and Rescue Vessel, Flying Operations, and Overside Working

Offshore Conditions Assessment						Indicative Working Criteria		
Beaufort Scale	Wind Speed (kts) 10m Level	Wind Speed (kts) 100 m Level	Significant Wave Height (m)	Maximum Wave Height (m)	Significant Wave Height Limits (m)	ERRV Operations (Ref. Notes 1, 2, 3, & 6)	Flying Operations (Ref. Notes 2, 4, 5, & 6)	Overside Operations (Ref. Notes. 1, 3, & 6)
5 (Fresh Breeze)	17 – 21	22 – 27	2.0	2.5	-	No limitations.	No limitations.	No limitations.
6 (Strong Breeze)	22 – 27	28 – 35	3.0	4.0	3.5	Limit for normal operation of FRC.	No limitations.	Overside work limit.
7 (Near Gale)	28 – 33	36 – 43	4.0	5.5	-	Emergency Operation of FRC only.	No limitations.	-
8 (Gale)	34 – 40	44 – 52	5.5	7.5	5.5	Limit for emergency operation of FRC.	Aircraft not to engage rotors (45 kts).	-
9 (Strong Gale)	41 – 47	53 – 61	7.0	10.0	7.0	Limit for use of mechanical recovery aids.	60 kts on helideck, 7 m significant wave height. Routine flying suspended.	-
10 (Storm)	48 – 55	62 – 71	9.0	12.5	-	No longer good prospect of rescue from sea.	-	-
11 (Violent Storm)	56 – 63	72 – 82	11.0	16.0	-	Safety of emergency response and rescue vessel takes precedence over all other operations.	-	-
12 (Hurricane)	64+	83+	14.0	-	-	-	-	-

Notes

1. For overside working, consideration should be given to the ability of the ERRV to observe and monitor personnel engaged in overside work, e.g., consider effect of fog, heavy rain, etc.
2. The decision to suspend flying operations rests with the OIM in consultation with the ERRV Master, HLO and Aircraft Commander.
3. The decision to suspend overside working rests with the OIM in consultation with the ERRV Master.
4. The assessment of conditions should include the use of hand-held anemometers and consideration of present and forecast conditions.
5. Other limitations pertaining to heave, roll and pitch of mobile installations/emergency response and rescue vessels are covered by specific procedures of the helicopter operator concerned.
6. During periods of adverse weather which may affect operations, e.g., reduced visibility due to fog or heavy rain, icing, etc., the decision to continue operations rests with the OIM in consultation with the Aircraft Commander and/or ERRV Master.

Appendix C – Lifesaving Appliances and Equipment

C.1 Evacuation Systems

CTF – A list of typical evacuation systems in each of the two main categories, lifeboat, and mass evacuation, is given for reference in this appendix.

C.2 Lifeboat-Based Systems

- Davit-launched lifeboats
  - Preferred Orientation and Displacement (PROD) system
  - TEMPSC Orientation and Evacuation system (TOES)
  - The Power Dolphin system
  - Survival Craft Anchored Tow (SCAT)
- Freefall lifeboat systems
  - Vertical Drop
  - Skidfall
- Arctic evacuation systems
  - ARKTOS
  - IRT
- Seascape

C.3 Mass Evacuation Systems

- Liferafts
  - Davit-launched liferafts
  - Quick release liferafts
  - Offshore Dry Evacuation Lifesaving Equipment (ODELE)
- Gemevac
- Escape chutes
  - Skyscape (Selantic-Escape Chute)
  - Inflatable chutes
- Collapsible stairs
  - Selantic Offshore Access system
  - SDSC safety systems
  - Gotech escape stair system
- Bridges
  - Flexitrans
  - Safelink gangbridge
  - Safeway

- Ladders and stairs
- Scrambling nets and knotted ropes
- Rope decent devices
  - Donut rapid evacuation system
  - Surescue
- Chain evacuation system

Appendix D – Personnel and Organizations Involved in PBS Development and Implementation

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D.2 PBS Steering Committee

(CTF – Final participation to be defined).

Appendix C

Legislation Related to Emergency Evacuation

The importance of the evacuation topic area should not be underestimated. Quite clearly, the availability of evacuation systems and procedures that work is critical to all involved, when a major problem is encountered on an offshore structure or vessel. This has been recognized in various codes, regulations and guidelines that have been developed over the past number of years. Some key clauses and points that have been excerpted from a variety of sources are summarized below, with particular reference to EER requirements for systems operating in ice-infested waters.

Although there does not appear to be any direct legislative requirements for the provision of evacuation equipment that will *guarantee* safe evacuation of personnel from offshore structures in all weather and ice conditions, there is legislation that requires detailed plans to be developed to ensure the safe evacuation of onboard personnel. For example, from a federal regulatory perspective in Canada:

SOR/87-612 Oil and Gas Occupational Safety and Health Regulations - Regulations have been made under Part II of the Canada Labour Code Respecting Occupational Safety and Health of Employees employed on or in connection with Exploration or Drilling for, or the Production, Conservation, Processing or Transportation of, Oil and Gas in Canada Lands, as defined in the Canada Oil and Gas Act. Part XVIII - Safe Occupancy of the Workplace. It contains the following sections and requirements of relevance.

Section 18.9 and 18.10 – Emergency Procedures
Section 18.11 and 18.12 – Emergency Evacuation Plan
Section 18.13 – Instructions and Training
Section 18.14 – Emergency Drills
Section 18.15 – Standby Craft – “For every drilling operation and production operation, the employer shall provide a standby craft capable of safetly evacuating all employees from the workplace.”

SOR/90-791 Canada Oil and Gas Production and Conservation Regulations. Part VIII of these regulations - Physical Environmental Reporting contains the following sections of relevance.

Section 53(6) “- including forecasts of meteorological conditions and ice movements-.”
Section 55 - Hazards - “The operator of the production site shall take all reasonable precautions to protect the personnel at the site, the production installation and all the associated equipment at the site from naturally occurring hazards and hazards associated with the operations carried out at the production site.”

Part IX of these regulations – Operations Safety, Environmental Protection and Ice Management Plans includes:

Section 60 (1) “Every operator shall submit --- a safety plan relating to the safety of the personnel and the integrity of the production installation ---.”
Section 60 (4) (c) “--- in the case of an ice management plan, permit an appropriate response to ice conditions to ensure the safety of personnel and the installation.”

Section 63 - Support Craft
Section 64 - Standby Vessels (1). The operator of a manned offshore production installation shall have a standby vessel (a) within 5 km of the installation at all times -- "

For the East Coast of Canada, where offshore petroleum activity is focused off the coasts of Nova Scotia and Newfoundland, guidelines have been developed that are somewhat more specific, albeit limited to the conditions and operations in these two areas. From a regulatory perspective, each area comes under the jurisdiction of their respective joint Federal-Provincial Offshore Accord Acts and Accord Implementation Acts. The Canada Nova Scotia Offshore Petroleum Board and Canada-Newfoundland Offshore Petroleum Board administer joint Federal-Provincial legislation within their respective jurisdictions. Without the power to develop and promulgate statutes or regulation, each of the Boards have published *Guidelines*, *Safety Notices* and *Directions to [Petroleum] Operators* in order to affect change.

A review of the regulatory and industrial reference documents for the Nova Scotia and Newfoundland offshore suggests there are no specific requirements for marine evacuation systems or life saving technologies with respect to their operations in ice-infested waters. However, some general statements have been extracted from the following documents.

Nova Scotia

- Offshore Petroleum Drilling Regulations, May 1996
- Offshore Petroleum Drilling Regulations Guidelines, Rev 1.1, April 2001
- Offshore Petroleum Installations Regulations
- Offshore Petroleum Diving Regulations
- Offshore Area Certificate of Fitness Regulations
- CNSOPB Occupational Health & Safety Requirements
- Petroleum Occupational Safety & Health Regulations (as Element II of the CNSOPB *OHS Requirements*)
- CNSOPB Guideline 3150.002 - Operator's Safety Plan
- Offshore Petroleum Geophysical Operations Regulations
- Offshore Area Petroleum Production & Conservation Regulations

Newfoundland

- Offshore Petroleum Drilling Regulations, May 1996
- Offshore Area Guidelines for Drilling Equipment, March, 1993
- Offshore Petroleum Installations Regulations
- Offshore Petroleum Diving Regulations
- Offshore Area Certificate of Fitness Regulations
- (Draft) Petroleum Occupational Safety and Health Regulations

- Offshore Petroleum Geophysical Operations Regulations
- Offshore Area Petroleum Production and Conservation Regulations

Transport Canada

- Canada Shipping Act - *Life Saving Equipment Regulations*
- Canada Shipping Act - *Boat and Fire Drill Regulations*
- TP Document 7320e - Standards for Lifeboats
- TP Document 7323e - Launching and Embarkation Appliances
- TP Document 7920e - Standards Respecting Standby Vessels

Nova Scotia References

Offshore Petroleum Drilling Regulations:

No references to ice in respect of evacuation or life saving equipment.

Section 105 Operator to ensure that ongoing operations will cease when the following condition (among others) exists: a serious and imminent threat of ice or icebergs.

S.117(c)(v) The Standby Vessel shall stand ready to assist in when the drilling unit is threatened by ice.

Drilling Regulations Guideline Draft – Rev 1.1, April 2001

No references to ice in respect of evacuation or life saving equipment.

Section 6.2 Report of ice conditions to be provided to the Board daily and also in the event of an alert or an emergency situation.

Section 6.4 Canadian Coast Guard Vessel Traffic Services and the Halifax Joint Rescue Coordination Centre to be informed if a rig move is caused by pack-ice or ice bergs.

Appendix B Drilling Program Approval Checklist:

- Petroleum Operator to provide a copy of the Ice Management Plan.

Appendix C Contingency Plans:

- Petroleum Operator may include an ice management program including ice detection, monitoring and avoidance procedures
- Oil spill response plan to include cleanup strategy for any ice-covered areas.
- As necessary, environmental reference materials to include physical sensitivity charts which identify ice forms and movements.

Appendix D Final Well Report:

- Difficulties and Delays: any downtime due to pack-ice or icebergs are to be reported.

Petroleum Installations Regulations

No references to ice in respect of evacuation or life saving equipment.

S.14(3)(c) Where steam generation equipment is carried, it shall include outlets, hoses and hose clamps capable of being used at the helicopter deck and the lifeboat embarkation stations.

S.54(1) Every floating platform that is intended to be used in areas in which sea ice is present shall be able to withstand, without major damage, the ice loads to which it may be subjected when it is operating in accordance with the operations manual

S.59(6) Where there is an annual probability of 10^{-2} of ice or icebergs being present at the site of a floating platform, the mooring system of the platform shall incorporate a primary quick release system with a remote triggering device and at least one back-up system

Offshore Area Petroleum Production & Conservation Regulations

No references to ice in respect of evacuation or life saving equipment.

Section 2 Interpretation includes a definition of "physical environmental conditions" that includes ice conditions that could affect an ongoing operation

S.46(1)(a) The operator of a production installation shall maintain a comprehensive record of observations of the physical environment made by the operator during the life of the production project, including the location and movement of any ice floes or icebergs in the vicinity of the installation

S.51(3)(d) The Safety Plans shall address abnormal conditions and emergencies that can reasonably be anticipated, including forecast or actual physical environmental conditions that may result in loads or load effects on the production installation in excess of those for which it was designed

S.59(4)(a) Under the direction of the installation manager, the standby vessel is to attend close to the production installation when any of the following situations occurs, including weather, sea or ice conditions limit the safe deployment of a powered rescue boat from the production installation

<u>Newfoundland References</u>

Offshore Petroleum Drilling Regulations:

No references to ice in respect of evacuation or life saving equipment.

S.105(4)(k) Every operator shall ensure that any drilling operation in progress at a drill site is suspended where there exists a serious and imminent threat of ice or icebergs

S.117(c)(v) The standby vessel shall stand ready to conduct rescue operations at any time when the drilling unit is threatened by ice.

Offshore Petroleum Installations Regulations:

No references to ice in respect of evacuation or life saving equipment.

S.14(1)(f) Every installation shall be designed, constructed, equipped and insulated to ensure that, at the minimum air temperature that may occur at the drill site or production site during operations, based on an annual probability of exceedance of 10^{-2}, that the fluids in the lifesaving appliances and associated devices will remain operational

S.14(3)(c) Where steam generation equipment is carried, it shall include outlets, hoses and hose clamps capable of being used at the helicopter deck and the lifeboat embarkation stations

S.54(1)(a) Every floating platform that is intended to be used in areas in which sea ice is present shall be able to withstand, without major damage, the ice loads to which it may be subjected when it is operating in accordance with the operations manual

S.59(6) Where there is an annual probability of 10^{-2} of ice or icebergs being present at the site of a floating platform, the mooring system of the platform shall incorporate a primary quick release system with a remote triggering device and at least one back-up system

Petroleum Occupational Safety and Health Regulations (Draft)

No references to ice in respect of evacuation or life saving equipment.

Section 1 Interpretation includes a definition of "environmental conditions" that includes ice conditions that could affect an ongoing operation.

Safety Plan Guidelines

No references to ice in respect of evacuation or life saving equipment.

S.7.3(vi) Include or reference comprehensive ice management and collision avoidance plans.

Section 7.5 Ice and vessel traffic management. In Newfoundland, an ice management plan should include:

(i) a description of arrangements for aerial, vessel and installation-based surveillance

(ii) a description of the system for ice data reporting, collation, quality control and presentation

(iii) a description of the local tactical ice forecasting component where appropriate

(iv) procedures for iceberg deflection

(v) a list of iceberg deflection equipment available on each support vessel

(vi) ice avoidance and/or installation shutdown procedures, and

(vii) multi-operator ice management agreements, where appropriate

Appendix D

Impact Forces on a Lifeboat

Impact Forces on a Lifeboat

There have been no full-scale measurements of the impact forces or accelerations on a lifeboat that has been dropped onto an ice floe. The whole process is very complex. Loads at impact velocities are very poorly understood in the ice mechanics community. Over the years, there have been a few methods developed to analyze the loads due to impact events, and these mainly relate to iceberg impacts on fixed structures (Nevel, 1987) or vessels (Brown and Daley, 1999). There have also been a few laboratory measurements of impact forces from both drop-ball tests (e.g. Timco and Frederking, 1993), and impact of floating ice sheets (Frederking and Timco, 2000). Although these approaches and data are useful, it is still not possible to use this information to calculate the impact loads on the lifeboat due to a vertical impact with an ice sheet.

Consider the situation shown in Figure 1a. In the initial situation, the lifeboat is fixed to the structure at a height of "*d*" above the ice surface. The shape of the hull bottom of the lifeboat can take a number of forms, including a round shape, a somewhat pointed shape, or a relatively flat shape. In this example, the lifeboat is assumed to have a circular-shaped bottom hull with a radius "*R*".

During evacuation, the lifeboat is released from it stationary position and impacts the ice with a vertical velocity "*v*". The velocity at impact will depend upon the method used for release. The most severe case is a quick-release approach. A davit or twin-davit release would result in a lower velocity, and a release using the Seascape system would also have a lower velocity than a free-fall situation.[1] Once the lifeboat is released, it would drop from its initial (stationary) position and impact the ice floe. The lifeboat, with the crew, would have a mass "*M*", and impact the ice floe with a force "*F*". The initial potential energy of the lifeboat is Mgd where g is the gravitational acceleration. This potential energy would be converted into kinetic energy ($\frac{1}{2} Mv^2$). If a free-fall situation is assumed, the velocity at impact would be $(2gd)^{1/2}$. At impact, there are many mechanisms that would take place to absorb this energy (see Figure 1b). Part of the energy would go into the crushing of the ice. Also, but hopefully not, some of it could go into denting or puncturing the lifeboat. Other energy would be absorbed in a rebound of the vessel off of the ice floe, and in pushing and submerging the ice floe. The relative importance of each of these energy sinks would be a function of the mass and velocity of the lifeboat (i.e. the kinetic energy), the thickness and overall mass of the ice floe, the shape and size of the lifeboat, etc. These factors, along with the poor understanding of the strength and behaviour of ice at high loading rates does not allow a means for directly calculating the loads.

It is possible, however, to estimate, in a very simple manner, the maximum force that could be expected. This will be done by modifying the approach outlined by Brown and Daley (1999).

[1] The approach outlined here is not applicable to the Seascape system since that system also has a horizontal component to the velocity.

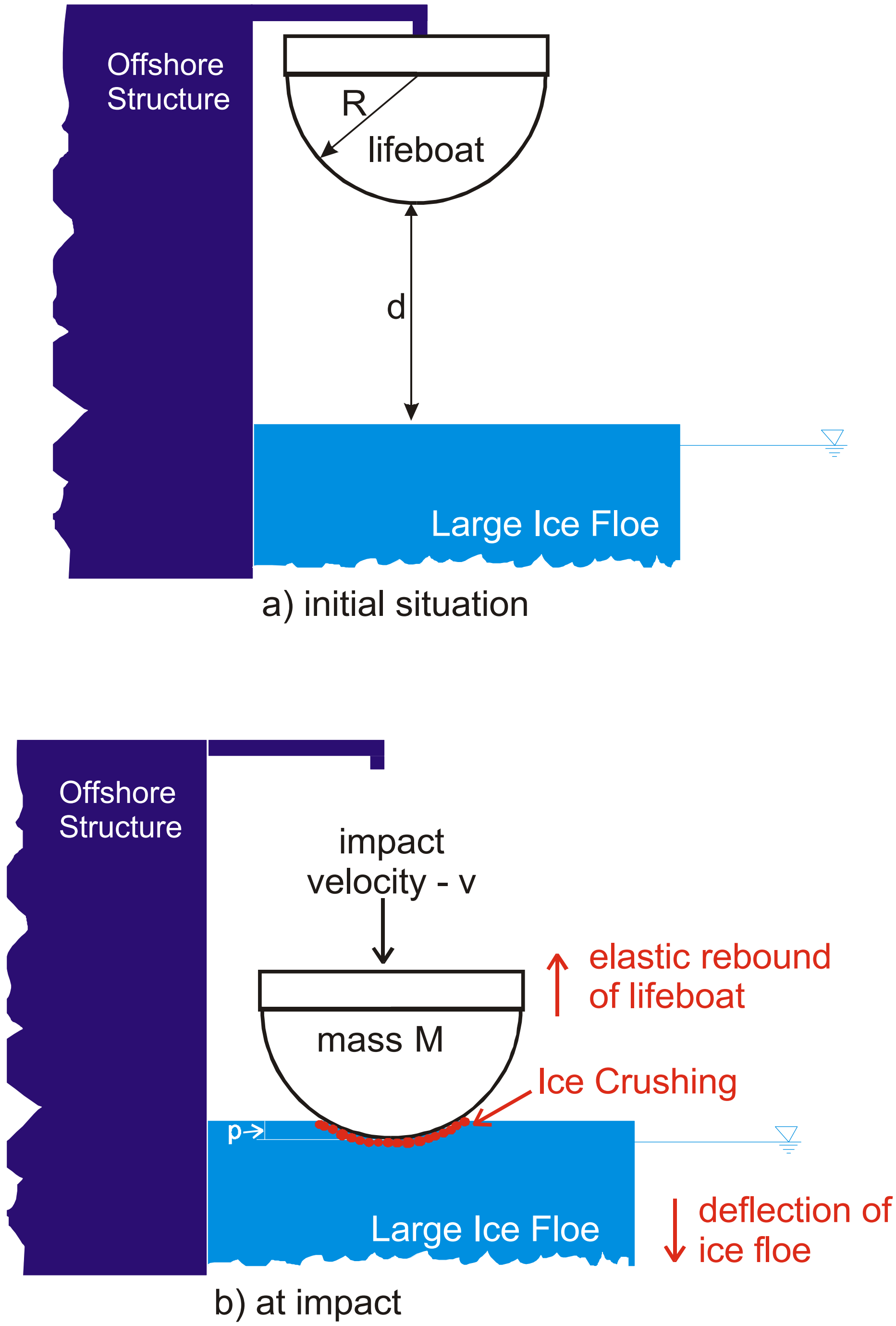

Figure 1: Simplified view of launching a lifeboat into a large pack ice floe.

In this analysis, the most conservative estimate of the force will be made. In this case, it is assumed that all of the energy is absorbed into crushing the ice floe.

For this analysis, it is assumed that the force is related to an area that is a function of the actual area with a relationship of the form:

$$P(A) = P_o\ A^x \qquad [1]$$

where x is the assumed are exponent, $P(A)$ is the average pressure over a contact area A, and P_o is the average pressure over an area of 1m^2. The Force F is given by

$$F = P\ A = P_o\ A^x\ A = P_o A^{(x+1)} \qquad [2]$$

To solve this equation, assumptions must be made on the shape of the ice floe and lifeboat. In this case, the ice floe is assumed to be flat and the lifeboat is assumed to be spherical with a bottom hull radius of "R". In this case, the contact area would be πR^2. By basic geometry the penetration depth "p" (see Figure 1b) can be determined. For small penetrations, the area is related to the depth of penetration by $A \sim \pi(2Rp)$. Then, the force at impact would be

$$F = P_o(\pi\ (2\ R\ p))^{(1+x)} \qquad [3]$$

The crushing energy (E_{cr}) can be determined from

$$E_{cr} = \int F\ dp = \{P_0\ /\ (2+x)\}\ (2\pi\ R)^{(1+x)}\ p^{(2+x)} \qquad [4]$$

If this is equated to the kinetic energy at impact, the depth of penetration can be solved to get:

$$p^{(2+x)} = [(x+2)/(2\ \ P_o\ (2\pi\ R)^{(1+x)}]\ M\ v^2 \qquad [5]$$

Substituting this expression into the equation for force (Equation 3) gives:

$$F = P_o^{\frac{1}{2+x}}\ [(x+2)\,\pi\ R]^m\ M^m\ v^{2m} \qquad [6]$$

where m = (1+x)/(2+x). As previously stated, this equation is a gross oversimplification of the lifeboat launching situation. It is intended to provide some general information on the maximum loads that could be exerted on a lifeboat directly launched onto a thick ice floe. To get an estimate of the forces, equation [6] was solved for two different cases. In both cases, it was assumed that the mass (M) of the lifeboat was 7500 kg (4500 kg for the empty lifeboat and a 30-person load of 3000 kg), and the drop height (d) was 20 m. Using a P_o value of 2 MPa, Equation [6] was solved for for different values of the area exponent (x) for four different impact velocities - 2, 5, 10 and 20 m/s. Two cases were considered: a rounded bottom lifeboat with R = 5 m (Figure 2), and a more flat-bottomed boat with R = 10 m (Figure 3).

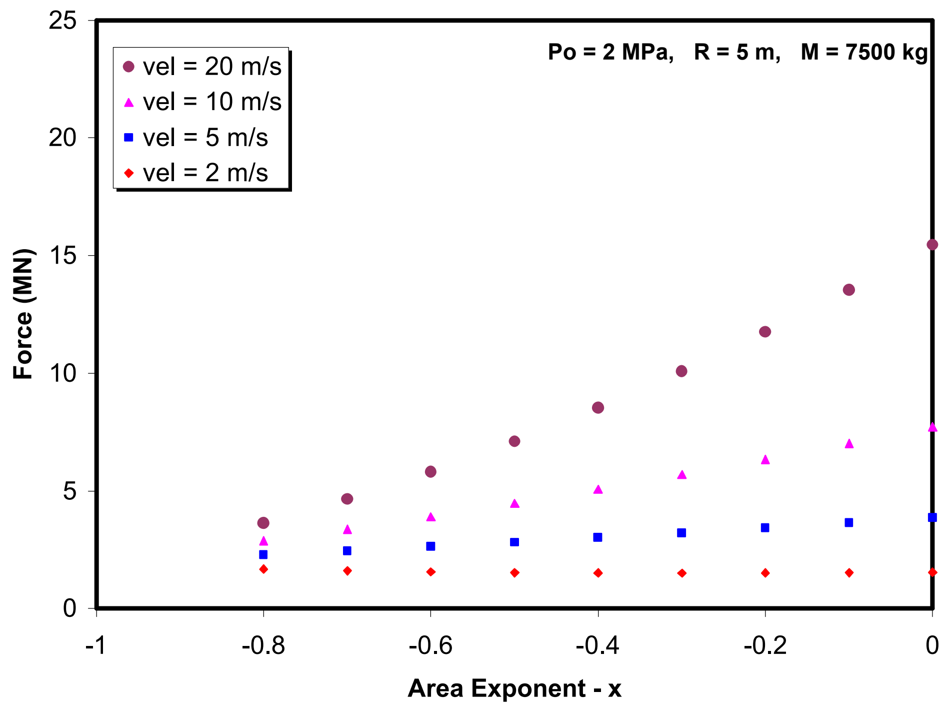

Figure 2: Force on the lifeboat for a relatively rounded bottom vessel.

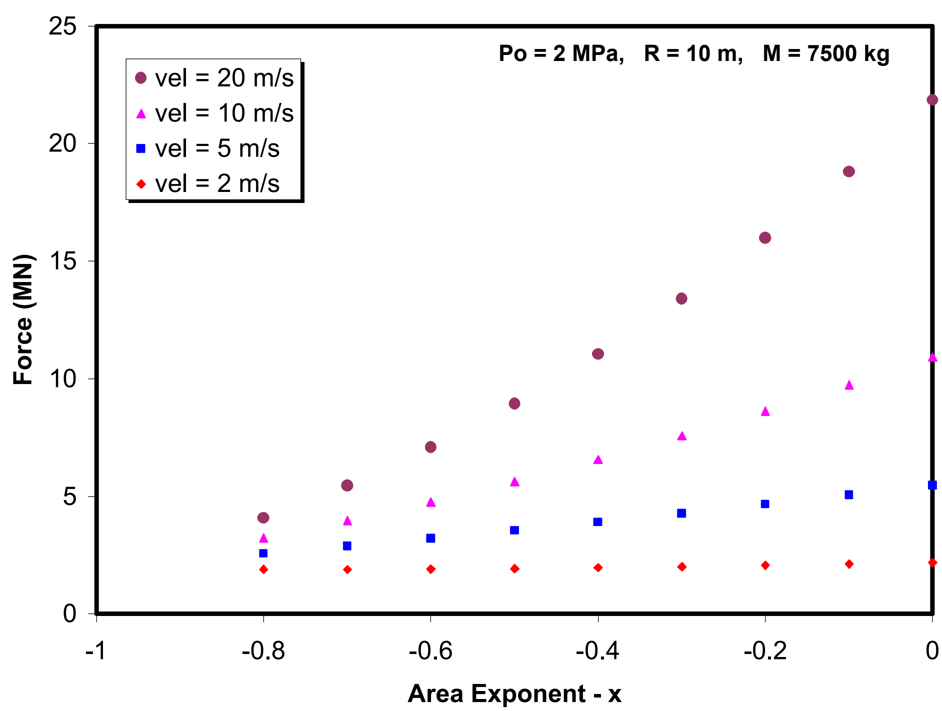

Figure 3: Force on the lifeboat for a more flat-bottomed vessel.

The results show that the loads are a very strong function of the impact velocity and the shape of the bottom of the lifeboat. It should be emphasized that these values are very conservative and are meant to illustrate the general trends and factors that affect the load. The results show that:

- Very high forces can be transmitted to the lifeboat if it is dropped onto a thick floe if sea ice;
- The velocity of the impact is critical in determining the load. The forces are considerably reduced with a low impact velocity;
- The shape of the lifeboat can influence the load. Flat-bottomed boats can lead to very high impact loads.

This simple analysis has shown that open-water free-fall lifeboats should not be used in an ice environment. The loads associated with a free fall impact could be very large. Any system that is used in ice-covered waters should try to minimize the velocity at impact. Also, some of the open-water lifeboats have a relatively flat bottom shape. This should be avoided in an ice environment.

References

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Appendix E

Details of Evacuation Systems for Structures in Canadian Waters

Canadian Beaufort Sea

Artificial Islands

Structure

Artificial islands were the first structures to be used for exploratory drilling in the shallow waters of the Beaufort Sea. They were constructed from either gravel or sand that was locally available, generally in the offshore, by dredging in summer or by "through ice dumping" in winter. Artificial islands were designed and built for drilling operations in water depths from several metres to 19m, in the latter case, at the Issungnak location. Most of these islands were constructed during one summer open water season, although the islands in deeper water depths sometimes took two years to complete.

Artificial islands formed the substructure onto which drilling facilities were placed. The drilling rig and other topsides facilities that were required were either mobilized by barge in the open water season or over ice roads in winter, depending upon the particular island construction scenario. These artificial islands had typical surface dimensions of about 100m in diameter and generally low freeboards, in the order of a few metres, sloping down to their beaches.

Function & Manning

The artificial islands that were used for exploratory drilling activities in the Beaufort Sea were designed for winter operations only. Their topsides facilities were rudimentary and generally consisted of a series of linked trailers (sometimes stacked) that formed living and working quarters on their surface. These facilities were configured to house 60 to 80 people, a typical complement required for drilling and various support operations.

Environmental Scenarios

Most artificial islands were constructed by dredging during the open water season, with equipment being mobilized onto their working surface in the fall, just prior to the onset of freeze-up. Similarly, this equipment was demobilized onto barges shortly after break-up in the early summer or in some cases, by ice road in late winter. The islands were not manned until the drill rig and topsides facilities were put in place, and everything deemed safe, in terms of potential exposure to late season storm waves, heavy ice intrusions and so forth. Operating personnel were then moved to and from the islands by helicopter (or by ice road), and usually worked in two to three week shifts. Because of this construction, equipment mobilization, drilling and demobilization sequence, drilling operations from artificial islands were only conducted once landfast ice had formed around them.

A low freeboard structure, surrounded by stable landfast ice, is the basic scenario that is appropriate to consider for artificial islands. Another factor to recognize, however, is the presence of grounded ice rubble formations around them. In this regard, it is well known that ice rubble fields are invariably seen around artificial islands. They form as the result of ice failing against island beaches during the freeze-up period, when the newly growing thin ice cover is still mobile. In shallow water locations, where the landfast ice stabilizes shortly after freeze-up, these rubble formations are generally only a few tens of metres in extent and are not particularly formidable in terms of the ridge sail heights they contain. In deeper water areas, where the ice is more mobile for longer, the rubble fields that surround artificial islands can be a few hundred metres in extent, with very sizable ridges and hummocks within them. Once formed, these ice rubble formations remain stable until the ice cover breaks up the following spring. Although they often contain rugged ice terrain, it is not difficult to walk through them to the surrounding landfast ice or in fact, build a level road through them.

This is actually the easiest type of ice scenario that any offshore structure can be exposed to, at least from an evacuation perspective. Clearly, other environmental factors to recognize in combination with this ice situation include low temperatures, high winds, snow storms and occasional blizzards. However, these other factors and the stable winter ice conditions around artificial islands suggest an overall winter scenario that is not dissimilar to one for a conventional drilling camp in Alberta, Saskatchewan or the NWT. The main difference is the remoteness of the Beaufort Sea.

Logistics Setting

In the early to mid 1970s, when artificial islands were first used in the Beaufort Sea, there was little infrastructure in place to support their operations. Some key points to note are given as follows.

- Most artificial islands were located between 100 km and 200 km from Tuktoyaktuk where Esso, the operator, had its main logistics support base. On a few occasions, two islands would be operated in one winter season, although they were tens of kilometres apart.

- Ice roads were built to many of the artificial islands that drilled at shallower water locations, giving access to and from Tuk by truck, over time frames of a few hours. Generally, there were a number of vehicles as well as heavy equipment (cats, loaders, etc.) present at these island sites.

- Helicopters were the only means of access to some of the deeper water islands, with flight times typically in the range of an hour or two. No icebreakers were present in the area that could be sent to an island in winter, in the event of a problem.

Evacuation Systems

In the early years, there were no specific evacuation systems or well defined evacuation procedures used on artificial islands. Escape routes from the living and working quarters were identified and muster points made known to all operating personnel. Common sense guidelines were also given to onboard staff at routine safety meetings, such as wearing Arctic gear if a fire or blowout forced people outside. It was reasonably assumed that the island's surface or the surrounding rubble field and landfast ice offered "safe location" options for people to get to by foot. It was also assumed the subsequent rescue of people, after leaving the problem area, would be accomplished by helicopter or vehicles or both. By the early 1980s, certain evacuation aspects were "tightened up" for artificial islands. For example, shelters were erected in a stable ice area off the islands that were stocked with blankets, food, heaters rifles and so forth, to act as a temporary refuge in the event an evacuation was required. In our experience, working on artificial islands was never uncomfortable in terms of having concerns about evacuation and rescue options.

Tarsiut Caisson Retained Island

Structure

The next type of bottom founded structure that was designed for drilling operations in the Beaufort Sea was the Tarsiut Caisson Retained Island (CRI). This concept was a logical extension of artificial island technology that reduced costs and shortened construction time frames, as exploratory drilling activities moved into deeper water areas. The Tarsiut CRI was a hybrid structure, consisting of four shallow concrete caissons that were set down on a large subsea berm. The caissons were roughly 70m in length, 15m in width and 11m in height, placed to form a square enclosure on a pre-constructed sand berm that was built to a height of 6m below sea level. The hollow caissons and the central core area between them were then filled with sand, to provide adequate sliding resistance against horizontal loads.

This structure was constructed at a location in about 20m of water. As deployed, it had a surface area of 70m x 70m and an above water freeboard of 5m. The drilling rig and stacked trailer modules that formed its topsides were mobilized to the CRI by barge in the fall then erected on it. The Tarsiut CRI was designed to withstand the forces from both first-year and multi-year ice and, in concept, storm wave events during the Beaufort Sea's open water season.

Function & Manning

The Tarsiut CRI was designed as an exploration and delineation drilling platform, for use on a year round basis in the Beaufort Sea. The topsides that were placed on this structure were capable of housing up to 120 people, which is the maximum complement generally required for drilling and associated support operations.

Environmental Scenarios

The Tarsiut CRI was located near the outer edge of the landfast ice zone in the Beaufort Sea. As a result, this structure was exposed to moving pack ice conditions much later into the fall and early winter periods than artificial islands. It was also designed for use on a year round basis. Consequently, environmental scenarios that involved thick moving ice during break-up, storm waves in open water, and old ice intrusions in summer were all of concern. The generic "high level" conditions in which drilling activities were carried out from the CRI are summarized below, along with the more difficult "second order" factors sometimes seen within them, considered as problematic from an evacuation perspective.

Generic Condition	More Difficult Factors
• winter landfast ice	- straightforward, as per artificial islands
• open water	- storm waves (maximum waves heights from 6m to 12m)
• summer ice intrusions	- small floes, variable concentrations & weak puddled ice
• moving pack ice in fall	- high concentrations of thin ice in small broken floes - ice pressure occurrences
• concurrent influences	- high winds - low air and sea temperatures - snow, blizzards & occasional icing events - poor visibility (fog, blowing snow, polar darkness, etc.)

As in the case of artificial islands, extensive areas of grounded ice rubble were expected to form around the Tarsiut CRI, and did. In this regard, a large rubble annulus had formed around the CRI by mid November. During its formation, thin moving ice was actively failing on the updrift side of the structure and along its sides, with an open water wake behind it. These ice interaction conditions would challenge many evacuation approaches. For example, twice during the late October to early November period, when equipment was being transferred to the CRI by vessel, newly grounded rubble that had formed on its downdrift side broke away because of ice action. These break-offs and the subsequent motion of unstable parts of the rubble was quite sudden, with large rubble sections rolling to find equilibrium once afloat. On two occasions, support vessels that were offloading cargo onto the CRI were trapped by thin moving ice pushing them against the structure (or its surrounding rubble). In fact, Canmar's Supplier 1 vessel was evacuated on one occasion, with the crew climbing onto grounded rubble and then onto the CRI, on the active updrift side. However, later into freeze-up and during winter, the grounded rubble around the caisson stabilized and provided a safe ice area to walk onto or through, should the need arise. Another challenging scenario was also identified over a several week period during break-up in early July, when the rubble field and surrounding ice cover was in the process of deteriorating and breaking up.

Logistics Setting

Drilling operations from the Tarsiut CRI were conducted in remote region that was far from any major centres, in a range of hostile conditions. At the time (in 1981), Dome / Canmar who designed and operated the CRI had a major exploration program underway in the Beaufort Sea. To support their offshore operations, they had a large base camp in Tuktoyaktuk and a marine fleet located further to the east, in McKinley Bay. The Tarsiut

CRI was located about 150 km northwest of Tuk. A few points about the logistics that was available to support this structure are highlighted as follows.

- During the summer and early freeze-up periods, ice capable support vessels were often available in the general vicinity of the CRI, with typical transit response times of roughly 3 to 24 hours. However, there was no requirement for a standby vessel, either year round or seasonally.

- In winter, no icebreakers operated in the area and helicopters were the only means of "immediate" access to the structure, with typical flight response times in the range of 1 to 2 hours.

- Other offshore platforms operating in the area at the time were remote, located from tens to hundreds of kilometres away.

- To forewarn operations of potential problems related to extreme ice or wave events, an environmental alert system was used on the Tarsiut CRI. This allowed helicopters and support vessels (in summer and fall) to be put on notice and made available in a timely manner, should ice or wave related concerns arise. However, in the event of a blowout, explosion or fire, this warning time would clearly not be there.

Evacuation Systems

The evacuation systems that were available for use on the Molikpaq during its Beaufort Sea operations are highlighted as follows.

- helideck for a large helicopter, with an emergency refuelling capability
- twenty-five man inflatable liferafts (portable canister type with basic survival supplies included), located on the north, east, south, and west walls of the caisson
- adjacent scramble nets to allow people to climb down the caisson walls
- 2 temporary one hundred man shelters placed on the stable rubble field in winter, complete with provisions for 2 weeks
- support vessels as an option during the summer and fall seasons, directly accessed by scramble net from a caisson side, or indirectly by pick-up (in liferafts or other) at sea.

A few comments about the evacuation systems on the Tarsiut CRI are outlined below.

Helicopters were seen as the primary means of escape and were able to operate in most conditions. However, icing, severe fog, extreme winds or low winter temperatures could prevent the use of helicopters in an evacuation scenario. In the case of the Tarsiut CRI, excessive wave run-up and spray during storm wave events (to heights of more than 50m) was a unique problem that could also prevent their use.

Liferafts were intended for use in open water and mixed ice and open water conditions. The canister type that was used onboard was very basic, with no modifications made for cold weather. At times, freezing of parts of the canister, marine icing or other effects could have created problems in trying to open and deployed them. In mixed ice and water conditions, any ice action also had the potential to damage (and sink) the rafts, which were made from durable nylon.

Scramble nets allowed access to the ice but were quite slow and cumbersome to safely get down, particularly when dressed in heavy Arctic gear. The nets were planned for use to move people onto "acceptable ice floes" during break-up, summer intrusions and fall, and onto more stable rubble around the structure in late freeze-up and winter.

The *temporary shelters* that were placed on the stable ice rubble field in winter were a reasonably comfortable place to be. A small but important part of the survival supplies they contained were rifles, in case of polar bear encounters.

In terms of training, personnel on the Tarsiut CRI were given instructions about escape routes, muster locations, and evacuation options. Periodic safety drills were also carried out on the structure, to the point of having people mustered at various egress locations. However, none of the onboard evacuation systems were actually used or deployed to fully complete these drills.

Although rudimentary, the evacuation systems on the CRI were configured to ensure a safe evacuation in most conditions. The alert procedures had the intent of providing an adequate forewarning of potential environmental hazards and in turn, a timely response. In this regard, helicopters could be dispatched to the CRI to begin a phased evacuation, and non-essential personnel removed well in advance of the situation becoming critical. However, it was recognized that a combination of unfavourable environmental situations could prevent a safe evacuation. For example, in thin broken moving ice with active ice failures occurring around the caisson, combined with a no-fly condition, safely placing and maintaining liferafts on the ice cover would be very precarious. Furthermore, should a major blowout or fire be underway, the liferafts could not propel themselves away from the on-site hazard, and would be at the whim of ice movements at the time.

As noted earlier, there was also a concern about how to move people off the CRI at the time of break-up, when the rubble field was in the process of deteriorating. A cable and pulley arrangement that would run from the structure's surface to a stable area in the rubble (the relief well pad in this case) was conceptualised but never actually put into place.

There was one case where an evacuation of the Tarsiut CRI was actually required, due to storm waves early in the summer of 1982. This requirement was identified by the alert system and a phased evacuation that moved all personnel off the structure successfully completed by helicopter, before the storm waves occurred on site.

The following winter, after all drilling facilities had been demobilized from the Tarsiut CRI, a research camp was established on the structure to monitor ice forces and ice action on it. This camp housed between 8 and 12 people at any point in time. There was once incident during break-up, when a very large section of the landfast ice (> 10 kilometres in extent) moved against the caisson as the ice drifted offshore. Substantial sections of the grounded rubble field around the CRI were carried away during the ice interaction, and very high ridges began to form in close proximity to it, grounding on its berm. The people stationed at the research camp were threatened by the potential of significant ice overtopping onto the caisson's working surface, and radioed Tuktoyaktuk for a helicopter to evacuate them. The helicopter arrived in about an hour and a half. It is fortunate that the ice event had stopped by then, without overtopping the island.

Esso Caisson Retained Island

Structure

Esso designed and constructed a second type of caisson retained island for exploratory drilling operations in the Beaufort Sea, shortly after the Tarsiut CRI was used. Again, this caisson was intended for use in the intermediate water depth range (12m to 25m), where artificial islands were costly and time consuming to construct. It was a steel structure that consisted of eight sides, held together by a cable system, to form an octagonal ring. When deployed, the steel ring was placed on a pre-built subsea berm and filled with dredge sand to achieve the necessary sliding resistance. The surface diameter of this CRI was about 90m. Its draft was 8m to the top of the berm on which it sat, and it had an above water freeboard of 5m. There was a small outward sloping ice and wave deflector at the top of its outer walls. As with artificial islands and the Tarsiut CRI, the drilling rig and trailer modules that formed its topsides were mobilized to the structure by barge in the fall, then erected on it. The Esso CRI was designed to withstand the forces from first-year and some multi-year ice interactions. In shallow water deployments, it was also intended to withstand storm wave effects during open water operations.

Function & Manning

The Esso CRI was primarily developed for use an exploratory drilling platform in winter, and was used to drill three wells at three different locations in the early to mid 1980s. The topsides modules that were placed on this structure were capable of accommodating up to 100 people.

Environmental Scenarios

The locations where the Esso CRI was deployed were in the middle to outer reaches of the landfast ice zone in winter, in areas not dissimilar to the Tarsiut CRI site. Relevant environmental scenarios for the Esso CRI are highlighted as follows.

Generic Condition	More Difficult Factors
• winter landfast ice	- straightforward, as per artificial islands
• moving pack ice in fall	- high concentrations of thin ice in small broken floes - ice pressure occurrences

- concurrent influences
  - high winds, low air and sea temperatures
  - snow, blizzards & occasional icing events
  - poor visibility (fog, blowing snow, polar darkness, etc.)

Because the Esso CRI was exposed to thin moving pack ice well into the fall and early winter periods, extensive grounded rubble fields always formed around this structure. These rubble formations, which were several hundreds metres in extent, were generally quite deformed with high ridges and hummocks in many areas. Grounded rubble areas were stable shortly after their formation, and remained stable until break-up.

The manner in which ice interacted with the CRI and its surrounding rubble field is also a consideration. In this regard, the range of factors to recognize in terms of the details of evacuation approaches included:

- in moving pack ice
  - ice failing adjacent to it prior to rubble formation
  - active ice failures updrift
  - open or brash ice wakes downdrift
  - ice fracture and clearance processes along its sides
  - the time frames over which these factors vary

- in landfast ice
  - the size, geometry & stability of its rubble fields

Logistics Setting

The logistics that were available to support the Esso CRI were quite limited during the fall and winter periods. The structure was generally deployed at distances between 150 km and 200 km from Tuktoyaktuk, where Esso and other Beaufort operators had their main base camps. There were no ice roads built to the CRI drilling locations, and the only practical means of winter access was by helicopter.

Evacuation Systems

The evacuation systems that were available for use on the Esso CRI during its Beaufort operations are highlighted as follows.

- helideck for a large helicopter, with an emergency refuelling capability
- basic inflatable liferafts (portable canister type) located on the north, east, south, and west sides of the caisson
- scramble nets to allow people to climb down the caisson walls
- a temporary shelter placed on the stable rubble field in winter

Comments about the strengths and limitations of the evacuation systems on the Esso CRI are similar to those outlined for the Tarsiut CRI, since the two caissons were much the same. In short, it was felt that safe evacuations could be achieved in most conditions. Helicopters were viewed as the primary means of moving people off the structure. The stable rubble field that formed around it was also seen as comfortable place to move to, should an evacuation of the CRI be necessary due to an event such as a blowout or fire.

No actual evacuations have been required from the Esso CRI. The only situation of note occurred in early January of 1984, when an unexpected ice movement against the caisson (in unusual landfast ice and rubble field conditions) caused some ice overtopping on its south side. In this case, some ice blocks fell onto the CRI's working surface and people were evacuated from the immediate area to a safer part of the structure. Helicopters were dispatched in case the ice overtopping event continued and became worse, but it stopped. The ice blocks were subsequently cleared off the structure.

Molikpaq

Structure

The "Molikpaq" is a mobile arctic caisson that was designed and constructed for year round drilling operations in the Beaufort Sea. It is a deep steel caisson with a hull depth of 29m, base dimensions of 111m x 111m, and deck dimensions of 73m x 73m. As built, the lightship displacement of the caisson was 31,000 tonnes, with a lightship draft of 5.2m. When operating in the Beaufort Sea, the Molikpaq was generally deployed on a subsea berm. Its internal core was filled with sand to provide a high level of sliding resistance against horizontal loads. The structure was designed to withstand the forces from both first-year and multi-year ice interactions, as well as the extreme storm waves that can occur in the Beaufort Sea open water season.

The water depths in which the Molikpaq could operate ranged from 10m to 40m. For shallow water deployments, the caisson was set directly on the sea floor, for example, at the Isserk location in 12m of water. At deeper locations, the subsea berm was built to the necessary height to provide an acceptable caisson freeboard above waterline, once it was deployed. At the Tarsuit and Amauligak locations, in water depths from about 30m to 35m, berms heights were in the 15m to 20m range and caisson set down drafts from 15m to 20m. This resulted in an above water freeboard of roughly 10m to the Molikpaq's main deck, and 15m to the top of its "upper wall ice deflector".

Function & Manning

The Molikpaq was designed as a mobile offshore platform for exploration and delineation drilling operations. Its topsides facilities are an integral part of the caisson structure and were designed to accommodate up to 110 people, the maximum complement generally required for this type of operation. It should be noted that the evacuation systems onboard the caisson were configured to handle double this number of people, in case a problem arose during a "worst case" crew change.

Environmental Scenarios

During drilling operations in the Beaufort Sea, the Molikpaq was exposed to a wide range of different ice and open water situations, depending on its specific deployment location and configuration, and the season(s) of operations. The generic "high level" conditions in which drilling activities were carried out on the caisson are summarized as follows, along with some of the more difficult "second level" factors that were sometimes seen within them, in terms of evacuation methods.

<u>Generic Condition</u>	<u>More Difficult Factors</u>
• open water	- storm waves (maximum waves heights from 6m to 12m
• summer ice intrusions	- small floes, variable concentrations & weak puddled ice
• moving pack ice in winter	- high concentrations of thin ice in small broken floes - ice pressure occurrences
• landfast ice in winter	- thin moving ice prior to landfast ice stabilization
• concurrent influences	- high winds - low air and sea temperatures - snow, blizzards & occasional icing events - poor visibility (fog, blowing snow, polar darkness, etc.)

The manner in which the ice failed against and cleared around the Molikpaq was also a key consideration. In this regard, the range of ice interaction factors that were necessary to recognize in terms of the details of evacuation approaches included:

• in moving pack ice	- active ice failures & high pressures its updrift face - open or brash ice wakes on its downdrift face - ice fracture and clearance processes along its sides - the time frames over which these factors vary
• in quasi landfast ice	- the presence of grounded ice rubble fields - the size, geometry & stability of these rubble fields

Logistics Setting

- Molikpaq operations in the Beaufort Sea were conducted in a remote and hostile region, far from major centres, with relatively little infrastructure in place. Some key points to note are given as follows.

- While operating, the Molikpaq was generally located between 150 km and 250 km from its key logistics support base in Tuktoyaktuk.

- In winter, helicopters were the only means of “immediate” access to the structure, with flight response times typically in the range of 1 to 2 hours.

- During summer and the freeze-up to early winter periods, icebreaking support vessels were generally available in the area, with typical transit response times in the range of 3 to 12 hours. Because there was no requirement for a standby vessel, the Molikpaq was basically isolated in winter and spring, with the exception of helicopter flights.

- Other offshore platforms operating in the area were either “not there” in winter, or generally remote, located from tens to hundreds of kilometres away.

- To forewarn operations of potential problems related to extreme ice or wave events, an environmental alert system was used on the Molikpaq. This allowed helicopters and support vessels to be put on notice and made available in a timely manner, should any concerns about the structure’s overall stability arise.

- In the event of a blowout, major explosion, fire or ship collision, this warning time would clearly not be there, and helicopter or support vessels would take some time to arrive.

Evacuation Systems

The evacuation systems that were available for use on the Molikpaq during its Beaufort Sea operations are highlighted as follows.

- helideck for a large helicopter, with a year-round refuelling capability onboard
- 4 fifty man Watercraft lifeboats on 4 sides of the Molikpaq, lowered on davits
- 3 RFD inflatable escape slides
- 3 RFD liferafts
- 1 rescue boat – Hurricane Model 700-D
- various scramble nets
- 3 cranes and personnel baskets
- cold water survival suits
- support vessels as option, although not year round, directly via escape slides, cranes and baskets, or scramble nets or indirectly by liferafts (or other)

A few comments about the evacuation systems on the Molikpaq are outlined below.

Helicopters were established as the primary means of escape, and were able to operate in most conditions. However, icing, severe fog, extreme winds or low winter temperatures could prevent the use of helicopters in an evacuation scenario.

Lifeboats (four Watercraft 50 person covered lifeboats) that were modified to deal with cold weather condition were onboard. One lifeboat was placed on each of the four sides of the caisson, and a davit system installed to lower them over the Molikpaq’s upper ice wall. These totally enclosed self propelled lifeboats were fire tested and equipped with auxiliary breathing air. Modifications for cold weather included the following heating systems:

- release hook, heating system
- trace heating around the doors
- block heater in the diesel engine
- thermostatically controlled interior space heater
- oil pan and keel cooler heating.

These lifeboats were quite good for open water and for low to moderate ice concentration situations. However, in most winter pack ice conditions, they would have to be set down onto moving ice and could not propel themselves. Once away from the Molikpaq and "out into the moving pack", there was also the ice-related threat of damage (or sinking).

Escape slides and liferafts were also located on the Molikpaq. The escape slides were inflatable dual track units that would unfurl over the caisson's 15m high sides. They could be deployed in conjunction with the inflatable rafts into open water, mixed ice and open water, onto the deck of standby vessels, or onto relatively stable thick ice around the structure. Three separate systems were mounted around the caisson and could be used to move large numbers of people to the enclosed liferafts or onto the ice quickly. However, once placed on the ice or into high ice concentrations, these rafts were susceptible to the potential for damage, due to various types of ice action.

Scramble nets were fixed at several locations on the Molikpaq to allow for an auxiliary means of emergency escape onto the ice or into waiting life rafts, lifeboats, etc. Again, these would be not be easy to move down in heavy Arctic gear and would involve a drop of about 15m, given the caisson's typical freeboard.

Cranes and personnel baskets were also available as a means of escape from the caisson. The Molikpaq was fitted with three 65 tonne cranes and the associated personnel baskets for general use. The cranes and baskets could also be used to move personnel to vessels or onto "safe ice" in the event of an emergency, albeit at relatively low personnel transfer rates. Factors such as swinging of the baskets in high winds were a consideration here.

Personnel working onboard the Molikpaq were given instructions about escape routes, muster points, evacuation options and associated procedures, and evacuation drills were routinely carried out. These drills were taken to the stage of having people mustered at various locations, but the onboard evacuation systems were not actually deployed to fully complete the drills.

Given the evacuation equipment that was available when the Molikpaq was constructed in the early 1980s, and the fact there were a number of back-up systems in place, its evacuation system was intended to ensure safe evacuation in most conditions. There was confidence in the alert procedures used, in terms of providing an adequate forewarning of potential environmental hazards and in turn, timely helicopter and/or vessel responses. Associated procedures called for these resources to be dispatched to the Molikpaq to initiate a phased evacuation, with non-essential personnel being removed well in advance of a situation becoming critical. However, it was also recognized that a combination of unfavourable environmental and logistics support cases could prevent the safe evacuation of people, for example, in thin broken rapidly moving ice, during ice pressure events, and so forth. Some of these limitations eventually led to the development of the Arktos escape vehicle, which is discussed later in the report.

With respect to actual experience with evacuations from the Molikpaq, there are two instances that should be noted. Both occurred during the winter of 1986 and were caused by the presence of extreme multi-year ice floes, with the potential to threaten the stability of the structure. In the first case, a phased evacuation was successfully accomplished by helicopter as a large multi-year floe approached the caisson. This evacuation sequence was triggered by the environmental alert system and resulted in a full evacuation of all personnel from the Molikpaq. The second case was similar and occurred about a month later, with all but eight essential people being removed from the caisson by helicopter, prior to the subsidence of a very high multi-year ice loading event.

SSDC

Structure

The SSDC (or single steel drilling caisson) is another structure that was used to conduct drilling operations in the Beaufort Sea in the 1980s. It was constructed from an existing tanker by cutting off the vessel's bow and stern sections, and strengthening the remaining "vessel mid-body" along its sides and bottom, to withstand ice and other types of forces. In terms of its dimensions, the SSDC is about 160m in length, 40m in width, and 25m in overall height. It is actually a shallow caisson that, when first used, was deployed on a large submerged berm at a draft of 8m. This resulted in a structure with an above water freeboard of about 17m.

The SSDC was designed for use as a year round drilling platform at locations in the 20m to 40m water depth range. It was capable of withstanding the forces from first and multi-year ice in both moving pack ice and in the landfast ice zone, as well as the effects of extreme storm waves.

After two years of use for drilling operations in the Canadian Beaufort, over the winters of 1982/83 and 1983/84, a large steel mat was constructed for the SSDC. This mat took the place of the dredged subsea berm that the unit was set on in its first two deployments, and allowed the structure to be used for drilling operations in the Alaskan Beaufort Sea, where dredging is not permitted.

Function & Manning

The SSDC was designed as a mobile offshore drilling unit (MODU) for exploration and delineation drilling operations in the Arctic. Its topsides facilities were constructed as an integral part of the structure, and were designed to accommodate up to 110 people.

Environmental Scenarios

During drilling operations in the Beaufort Sea, the SSDC was encountered a wide range of different ice and open water situations, depending on its specific deployment location and configuration, and the season(s) of operations. In winter, the structure was always surrounded by a grounded rubble field because of its relatively shallow set down draft. The extent of the rubble was dependent on whether or not the SSDC was located in the moving pack ice zone or in the landfast ice. The generic conditions in which drilling activities were carried from the SSDC are summarized as follows, along with some of the more difficult factors that were sometimes seen within them, in terms of evacuation methods.

Generic Condition	More Difficult Factors
• open water	- storm waves (maximum waves heights from 6m to 12m
• summer ice intrusions	- small floes, variable concentrations & weak puddled ice
• moving pack ice in winter	- high concentrations of thin ice in small broken floes - ice pressure occurrences
• landfast ice in winter	- thin moving ice prior to landfast ice stabilization
• concurrent influences	- high winds - low air and sea temperatures - snow, blizzards & occasional icing events - poor visibility (fog, blowing snow, polar darkness, etc.)

Again, the manner in which the ice failed against and cleared around the SSDC is a key consideration. In this regard, the range of ice interaction factors that were necessary to recognize in terms of the details of evacuation approaches included:

• in moving pack ice	- active ice failures & high pressures its updrift face - open or brash ice wakes on its downdrift face - ice fracture and clearance processes along its sides - the presence of grounded rubble around the structure and the size, geometry & stability of the rubble - the time frames over which these factors vary
• in landfast ice	- the presence of grounded ice rubble fields - the size, geometry & stability of these rubble fields

Logistics Setting

Although operating in a remote region, the logistics that was available to support the SSDC was reasonable, particularly during the summer and fall months. Some key points to note are given as follows.

- In winter, helicopters were the only means of "immediate" access to the structure, with flight response times typically in the range of 1 to 3 hours.

- During summer and the freeze-up to early winter periods, icebreaking support vessels were generally available in the area, with typical transit response times in the range of 3 to 12 hours. Because there was no requirement for a standby vessel, the SSDC was basically isolated in winter and spring, with the exception of helicopter flights.

- To forewarn operations of potential problems related to extreme ice or wave events, an environmental alert system was used on the SSDC. This allowed helicopters and support vessels to be put on notice and made available in a timely manner, should any concerns about the structure's overall stability arise.

Evacuation Systems

The evacuation systems that were available for use onboard the SSDC during its Beaufort Sea operations are highlighted as follows.

- helideck for a large helicopter, with a year-round refuelling capability onboard
- support vessels in summer and freeze-up periods
- crane and personnel baskets
- conventional ship type davits for lifeboats
- conventional single point davit launched liferafts
- ladders (on each side) for egress to level ice or rubble field around the structure

Related comments are given as follows.

The various choices of evacuation system were intended to provide escape in open water, water and ice and solid ice conditions.

Bottom founded vessel unable to vane to provide a lee for boat or raft launching into open water/ice in swell conditions.

Crane reach and direction limited for evacuation use, also, support vessel may not be able to approach due to available water depth and/or rubble.

Kulluk

Vessel

The Kulluk is a conical drilling unit that was purpose built for extended season drilling operations in the Beaufort Sea. It was designed as a floating barge with integral drilling (and other) facilities on its deck, a very capable mooring system, and a strong hull that was strengthened to Arctic Class IV (CAC 2) standards. This vessel was used to conduct exploratory drilling operations in the Beaufort Sea in its deeper water areas (20m to 60m) from 1983 until the early 1990s. During this period, it worked in a wide range of pack ice and open water conditions, from late May until late December.

The Kulluk was designed with a unique circular shape and an inverted conical hull form, to accommodate ice action from any direction equally, and to fail the oncoming ice in downwards flexure at low force levels. It was also designed with an outwards flare near the bottom of its hull, to ensure that broken ice pieces would clear around it and not enter its moonpool or get entangled in its mooring lines. It has a radially symmetric mooring system comprised of twelve 3 1/2 inch wire lines that were designed to withstand fairly high ice loads as well as storm wave events. These mooring lines have a "through hull path" to underwater fairleads near the bottom of the Kulluk's hull. The mooring system was designed to prevent problems with ice entaglement, and to allow icebreakers and other vessels to work in close proximity to it. When operating in the Beaufort Sea, these mooring lines were connected to large anchors (typically 15 tonne Bruce anchors). To accommodate emergency release, each anchor line had a remote acoustic release (RAR) unit on it. It is important to note that icebreaker support was always available for the Kulluk when it was operating in ice. In fact, ice management was a key contributor to its overall success.

In terms of its dimensions, the diameter of the Kulluk is 81m at its main deck level and about 70m at the waterline. It has a height of 31.5m from the bottom of the hull to its elevated drill floor, and a freeboard of about 5m to its gunnels. The Kulluk's minimum and maximum operating drafts are 10m and 12.5m, respectively. The vessel's lightship displacement is 17,510 tonnes and it has a variable load capacity of about 7,000 tonnes. The vessel has been in "cold storage" in a sheltered coastal location in the Beaufort Sea since it last worked in the summer and fall of 1993.

Function & Manning

The Kulluk was designed as floating drilling barge, for exploratory drilling operations in the Beaufort Sea. As noted above, its topsides facilities are an integral part of the vessel and were designed to accommodate up to 110 people. The evacuation systems onboard the vessel were configured to handle double this number of people.

Environmental Scenarios

During drilling operations in the Beaufort Sea, the Kulluk was exposed to a wide range of different ice and open water conditions. Many of the ice situations in which operations were carried out were considerably more severe than the original ice design targets set for the unit (1.2m of level unbroken first year ice). The generic conditions in which drilling activities were carried out are summarized as follows, together with some of the more difficult factors sometimes seen within them, from an evacuation perspective. Here, it is important to note that ice management activities around the Kulluk invariably resulted in small broken ice fragments (typically several metres to several tens of metres) around it, rather than large unbroken ice areas onto which people or escape craft could be set. It is also important to note that the Kulluk was always operated in moving pack ice situations, and never in landfast ice.

Generic Condition	More Difficult Factors
• open water	- storm waves (maximum waves heights from 6m to 12m)
• summer ice intrusions	- moderate to high concentrations of managed ice floes, from deteriorating first year ice, to competent first year, second year & multi-year ice, much of which was rough and quite heavily ridged
• moving pack ice during freeze-up & early winter	- moderate to high concentrations of either thin or thicker managed pack ice, rough and ridged, or otherwise - high ice drift speed events - ice pressure occurrences
• concurrent influences	- poor visibility (polar darkness, fog, etc.) - low air and sea temperatures - snow, blizzards & occasional icing events - high winds, swell, etc.

The manner in which managed ice cleared around and sometimes failed against the Kulluk is also a key consideration. In this regard, the range of ice interaction factors that should be recognized in terms of the details of evacuation approaches include:

• in moving pack ice	- active ice action & pressures on the updrift side - ice "popping up" along the vessel's sides and in the lee - brash & managed ice pieces clearing around its sides - brash in its downdrift wake - the short time frames over which these factors vary

Logistics Setting

Kulluk operations in the Beaufort Sea were conducted in a remote and hostile region. However, the logistic infrastructure that was available to support it was quite reasonable during its spring, summer, fall and early winter operating season. A few key points to note are as follows.

- While operating, the Kulluk was generally located between 150 km and 300 km from its key logistics support base in Tuktoyaktuk.
- At least one vessel was always located in close proximity to the Kulluk when it was conducting drilling operations and, while operating in ice, two or three ice capable vessels were generally present within a 10 kilometre radius of the unit
- Helicopters were also available for the Kulluk, with flight response times typically in the range of 1 to 3 hours. In heavy ice conditions, a small helicopter was sometimes kept onboard for as-required ice reconnaissance duties.
- To forewarn operations of potential problems related to extreme ice or wave events, an alert system was used on the Kulluk. This allowed additional support vessels (and if necessary, helicopters) to be put on notice and made available in a timely manner, should any concerns about the environmental effects on the vessel, or any drilling or stability problems arise.
- In the event of a blowout, major explosion, fire or ship collision, this warning time would not be there, but support vessels would generally be close at hand.

Evacuation Systems

The evacuation systems that were available for use on the Kulluk during its Beaufort Sea operations are highlighted as follows.

- one or more icebreakers and/or a standby vessel, directly via escape slides, cranes and baskets, or scramble nets or indirectly by liferafts (or other)
- helideck for a large helicopter and re-fuelling station
- 4 fifty-four man Whittaker lifeboats (survival craft) on 4 sides of the Kulluk, lowered on davits
- 2 stations with RFD inflatable evacuation slides on 2 sides of the Kulluk
- 4 RFD liferafts (2 at each evacuation slide location)
- 1 rescue boat – Hurricane Model 700 D
- 3 cranes with personnel baskets (EMPRA baskets)
- cold water survival suits
- scramble nets

A few comments about the evacuation systems on the Kulluk are outlined as follows.

Helicopters were considered to be the primary means of evacuation from the Kulluk, similar to all of the other Beaufort Sea structures and vessels being used at the time. The helideck on the Kulluk was designed to accommodate the large Sikorsky S-61 or similar sized helicopters. The helideck facility included a re-fuelling station and all rotary wing aircraft in the area utilized Jet B fuel (wide-cut gasoline) to enable them to operate in cold weather and winter conditions. The helicopters were able to operate in all environmental conditions, except in heavy fog, icing conditions, high winds or very low temperatures.

Icebreaking support vessels that supported the Kulluk's stationkeeping operations were always present for immediate assistance. They were the clear "first call" for assistance in the event of an unforeseen problem. The number and type of vessels around the Kulluk was dictated by the ice, weather and drilling conditions. However, the four vessels that were generally used to support the Kulluk were all constructed to Arctic Class IV (CAC 2) standards and were highly capable and manoeuvrable icebreakers (24,000 HP & 15,000 HP). They were all equipped with Rescue craft, such as those described (below) for the Kulluk.

Lifeboats (four 54 man Whittaker Capsules) were on the Kulluk to accommodate its full complement of people (and more). Since this drilling unit operated in the warmer half of the year, no modifications were made to the lifeboats for operations in ice and very cold weather conditions. These lifeboats were CCG approved, were fire retardant with a sprinkler system, and were equipped with internal breathing air and engine air for transit through burning oil. They were quite good for open water and for low to moderate ice concentration situations. However, in most higher concentration pack ice conditions, they would have to be set down onto moving ice and could not propel themselves. They could be picked up by support icebreakers quite quickly, but were always under the threat of ice-related damage (eg: from jagged ice edges in cold managed, moving ice fragments), due to their rather flimsy fibreglass construction.

Escape slides and liferafts were also located on the Kulluk. The RFD inflatable dual track escape slides were designed for rapid and immediate evacuation of all on-board personnel, and could be deployed into open water, on the deck of a stand-by vessel, or onto large ice floes immediately adjacent to the vessel (a rare occurrence in managed ice). The RFD Escape System included two covered rafts with each dual track slide. The liferafts could be deployed independently of the slides or in conjunction with the slide system. The liferafts could accommodate the full complement of the vessel and besides their open water capability, could be used in an emergency on an ice flows for protection of personnel from the arctic weather, while waiting for rescue. However, this system, again, was susceptible to ice-related damage.

The rescue boat on the Kulluk (and on the standby icebreakers) was a Lucas Hurricane Model 700 D Rigid Hull Inflatable Rescue Boat, designed with a solid aluminium hull and inflatable outer ring to provide increased stability and lower draft for rescue at sea. The rescue craft was powered by a Volvo Aqad–155 HP 6 cyl Turbo Diesel Engine. The overall length of the vessel was 6.86m and breadth 2.79m, with a cruising range of 300 miles. It could carry up to 20 persons and was CSI approved.

The three cranes onboard the Kulluk could be used for evacuating personnel to standby vessels with the personnel basket or EMPRA basket, or a work platform. This type of evacuation would be “dry”, but could take a fair amount of time, depending on the emergency. The EMPRA is a collapsible, open-top ring net with a rigid base, designed to be slung from beneath a helicopter or slung from the Kulluk’s crane. This was tested in open-water and broken ice for the purpose of recovering personnel from open water, mixed ice and open water, and from an ice flow. This system was expected to perform a fast rescue without the exhaustive training required for helicopter winch rescue.

Cold water survival suits, for accidental immersion in cold water, were developed and put into service onboard the Kulluk and also for transit to and from the drilling unit. Helicopter immersion suits were designed to be dry suits with minimal floatation. This would allow for the exit from an inverted or underwater helicopter. Floatation was activated following the safe exit from the helicopter. The drilling unit Immersion suits, on the other hand, included full floatation and were designed more as a “one size fits all", where-as the aviation suits were fitted to the size of the individual. Both immersion suits were designed to be used in cold water and ice infested water and included thermal protection.

Two rope scramble nets were provided on opposite sides of the Kulluk to be used as a “last-ditch” evacuation over the side of the drilling unit. This would allow workers to climb down the net to sea level, onto the deck of a standby vessel, or an ice floe or a previously launched lifeboat or life raft.

Personnel working onboard the Kulluk were given instructions about escape routes, muster points, evacuation options and associated procedures, and evacuation drills were routinely carried out. These drills were taken to the stage of having people mustered at various locations, and involved some people actually being deployed to sea by lifeboats or onto icebreakers via scramble nets, to complete the drills. However, they were never carried out in anything but open water or light ice conditions, and usually in fair weather.

Given the evacuation equipment that was available when the Kulluk was constructed, its evacuation system was intended to ensure safe evacuation in most conditions. Although the most effective and up-to-date equipment was selected for use at the time, it was (quietly) recognized that various combinations of events and circumstances could arise which would make a sudden evacuation risky or impossible, although probability levels were very low.

In terms of actual evacuation experiences, there was only one instance when a full scale evacuation of personnel was required on the Kulluk. This situation occurred in early June of 1989, as the result of an unexpected shallow gas blowout that occurred while drilling operations were underway. The Kulluk was operating in mixed ice and open water conditions at the time, with typical ice concentrations in the order of 3/10^{ths}, managed ice in the area, and fair weather. There was no time to summons helicopters (landing on the rig would have been a problem with the gas), and the support icebreakers could not come along side (again, for fear of their engines shutting down or gas ignition). All personnel were evacuated to the lifeboats and the rescue craft, and quickly moved away from the drilling unit to the nearby icebreakers, without incident. This is an impressive evacuation example, but was undertaken in very light ice and good weather conditions.

Although not an evacuation, another noteworthy experience occurred on the Kulluk in the fall of 1993, after Canmar had purchased the unit. It was drilling off the Alaskan coast at the time, in high waves and low temperatures, with considerable icing due to sea spray. Two of the lifeboats were damaged in high seas due to a combination of the vessel's low freeboard and heavy icing. One of the lifeboat capsules was actually swept overboard and later recovered, damaged and partially flooded.

Drillships

Vessel

Relatively conventional drillships were used for exploratory drilling operations in the mid to deeper water areas of the Beaufort Sea from 1976 until the late 1980s. Although these vessels were ice strengthened (to Baltic Class 1A Super levels), their operating season was limited to the open water and early freeze-up periods. Four drillships were used in the Beaufort, all having displacements of about 15,000 tonnes and overall dimensions of roughly 100m x 20m x 9m. Each vessel was deployed with an eight point mooring system comprised of 2 3/4 A wire lines (four bow and four aft) that came off the deck and through the waterline (except for the Explorer 4 which had underwater fairleads). These lines were equipped with remote anchor releases (RARs) that allowed the drillships to quickly disconnect from their anchors and move off location, should difficult ice or storm wave conditions occur. Once moored, the drillships were aligned in a fixed direction and could not reorient themselves in response to changing drift directions without moving off location. From an ice management perspective, typical support for drillship operations consisted of one or two CAC 4 supply vessels and at times, the Robert Lemeur (CAC 3) and/or the more highly powered Kigoriak (CAC 2) icebreakers.

These drillships conducted drilling operations at more than 40 locations in the Beaufort and Chukchi Seas. The majority of these wells were scheduled for the summer and fall periods, when open water and relative light ice conditions are common. However, with ice management support, the drillships sometimes worked in moderate to relatively high ice concentration conditions during summer ice intrusions, provided the ice was managed into small pieces and could flow around them.

Function & Manning

The drillships were used for exploratory drilling operations in the Arctic offshore. Their drill rig and other topsides facilities were an integral part of the vessel and were designed to accommodate roughly 100 people.

Environmental Scenarios

During drilling operations in the Beaufort and Chukchi Seas, drillships were exposed to a considerable range of ice and open water conditions. The generic conditions in which drilling activities were carried out are summarized as follows, together with some of the more difficult factors sometimes seen within them, from an evacuation perspective. Here, it is important to note that ice management activities invariably resulted in small broken ice fragments (typically several metres to several tens of metres) around drillships, rather than large unbroken ice areas onto which people or escape craft could be set.

Generic Condition	More Difficult Factors
• open water	- storm waves (maximum waves heights from 6m to 12m)
• summer ice intrusions	- low to moderate concentrations of managed ice floes, from deteriorating first year ice, to competent first year, second year & multi-year ice, some of which was rough and quite heavily ridged
• moving pack ice during freeze-up	- moderate to high concentrations of thin managed pack ice (to about 15 cm thick) & typically quite level - high ice drift speed events - ice pressure occurrences
• concurrent influences	- poor visibility (polar darkness, fog, etc.) - low air and sea temperatures - snow, blizzards & occasional icing events - high winds, swell, etc.

The manner in which managed ice fragments cleared around the drillships is also a key consideration. In this regard, the type of ice interaction factors that should be recognized include:

• in thin moving pack ice	- some floating ice rubble accumulations along the side of the vessel during lateral ice movement events - brash & managed ice pieces clearing around its sides - brash in its downdrift wake - ice pieces sometime getting caught on mooring lines - the short time frames over which these factors vary

Logistics Setting

Although drillship operations in the Beaufort and Chukchi were conducted in a remote region, the logistic infrastructure that was available to support them was quite reasonable. A few points to note are as follows.

- At least one support vessel was always located in close proximity to a drillship when it was conducting drilling operations, and more than one support vessel when the drillships were operating in ice.

- Helicopters were also available, with flight response times typically in the range of 2 to 3 hours.

- To forewarn operations of potential problems related to extreme ice or wave events, an alert system was used on the drillships. This allowed additional support vessels (and if necessary, helicopters) to be put on notice and made available in a timely manner, should any concerns about the environmental effects on the vessel, or drilling or stability problems arise.

Evacuation Systems

The evacuation systems that were available for use on drillships during their operations in the Arctic offshore are highlighted as follows, along with a few related comments.

- a standby vessel, with direct transfer of personnel by cranes and baskets, or scramble nets, or indirectly by lifeboats or liferafts
- helideck for a large helicopter
- 4 lifeboats (survival craft), 2 on each side forward and aft, lowered on davits
- cranes with personnel baskets

None of these evacuation systems were specifically designed for use in either ice or cold weather conditions.

Crane transfers require good stationkeeping by support vessels (especially for anchored rather than DP drillships, and particularly between above water anchor systems). Crane basket transfers are also slow (4 to 6 people at a time) and are limited by winds, waves and so forth.

Conventional davit launch of lifeboats and liferafts is particularly difficult in high seas, especially where ice is a factor. Exposure to collision between the drillship and the boat or raft is also increased if the drillship is anchored.

Grand Banks

Environmental Setting

The Grand Banks of Newfoundland lies at the eastern-most edge of the North American continental shelf and extends into the North Atlantic. Water temperatures are cold due to the Labrador Current flowing south from the Arctic. This current transports icebergs from Greenland and the Baffin Island area onto the Grand Banks and, with prevailing northerly winds during February and March, can also bring pack ice onto the southernmost banks. When this occurs, pack ice concentrations in the southern banks operational area can be as high as 8 to 9/10^{ths} in wide bands, consisting mostly of small floes and ice cake. Level ice thicknesses are typically medium (0.3m to 0.7m) and thin (0.15 to 0.3m), but most of the ice has some level of deformity caused by ridging or rafting. Traces of old and glacial ice are also present in the pack.

Frontal storms are particularly frequent during the winter months, especially between November and March when maximum winds of hurricane force (>80 knots) and waves up to 30 meters have been experienced. A storm of similar intensity that sank the "Ocean Ranger" was experienced on the Grand Banks on January 22 of this year (2002). At least one tropical storm (hurricanes) also tracks over the southern Grand Banks annually, most often during September and October.

In winter, air temperatures can vary between +10°C when winds are from the south, to –17°C in northerly winds, and sea surface temperatures can be as low as –1.7°C. High winds and low temperatures cause extreme "wind chills", and can produce a significant structural icing. Precipitation in winter may be in the form of snow, fog, freezing rain, freezing fog or rain. These conditions can result in reduced visibility conditions about 40% of the time in winter.

In summer air temperatures can rise to 27°C and the sea surface temperature to 15.4 °C. Southerly winds in summer bring warm moist air in contact with the cold ocean currents, creating advection fog. The southern Grand Banks of Newfoundland is well known as one of the "foggiest" places on earth with reduced visibility occurring up to 80% of the time in June and July.

From the brief description given above, it should be clear that various combinations of environmental conditions can make personnel evacuation from offshore structures and vessels procedures challenging. These conditions also suggest the necessity for more than one method of evacuation.

Logistics Setting

The present operational area on the Grand Banks of Newfoundland is located in a region where two production systems and a semi-submersible exploration rig are now operating year round. One of the production systems is the gravity base structure (GBS) at Hibernia and the second is the Terra Nova FPSO. The other vessel that is now drilling exploration and delineation wells in the area the semi-submersible "Henry Goodrich". All of these systems are being operated in fairly close proximity to one another, within a radius of about 50 kilometres.

Each unit has a standby vessel, so that within a 50 km radius, there are at least three support vessels. The standby vessels are generally "ice type" and as such, they are able to transit limited pack ice regimes. They are also equipped with iceberg towing hawsers for iceberg management. All exploration and production systems are required to have an ice alert strategy and contingency plan in place. The support vessels are outfitted with the required rescue equipment (including FRC) for Canadian standby ships, along with their own davit launched, fully enclosed lifeboats, and/or manually launched liferafts for evacuation. They also have survival suits for all onboard.

The Hibernia and Terra Nova sites are approximately 350km ESE of St John's, Nfld. where commercial helicopters are located, or about 2 hours flying time. These sites are about 3 hours flight time from Gander, Nfld. where Coast Guard SAR helicopter support is based. All of the exploration and production systems in the area have helidecks. In this regard, one of the benefits is that helicopters have alternate locations that can be used for shuttling personnel, and as re-fuelling stations, during an emergency. Each floating system (the FPSO and semi-submersible) has different motion characteristics in heavy sea states, while the GBS offers a landing area that is stable and unaffected by sea state. On the downside, with all of the systems being in close proximity, weather conditions that can restrict flying will usually be similar. In recent years, a number of advancements have been made toward the use and safety of helicopter travel in this harsh environment, including better communications, flight tracking, increased flight range, de-icing systems and a helicopter flight simulator for practice landings on various vessels with different motion characteristics.

Semi-Submersible Drilling Rigs - Henry Goodrich

The Mobile Offshore Drilling Unit (MODU) "Henry Goodrich" is an example of the type of anchored semi-submersible exploration rigs that are designed to operate in harsh environments, like the Grand Banks. This rig has been consistently operating in the southeastern region of the Grand Banks since 1999. Other semi-submersible rigs that use chain and anchor moorings for stationkeeping, such as the "Glomar Grand Banks" and the "Bill Shoemaker", have also operated in the same area where the Hibernia and Terra Nova production installations are located over the past few years.

It is anticipated that sometime in 2002/2003, deeper water exploration will commence further to the north on the Grand Banks and in the Flemish Pass region. This work can be carried out by dynamically positioned (DP) drillships or a DP semi-submersible, such as the 'Erik Raude' that is currently under construction in Halifax. These more northerly regions are more susceptible to pack ice intrusions than the current operating locations, where pack ice is only seen once every several years.

The launching systems for lifeboats on various vessels and rigs basically fall into two categories, free fall and davit launched. To avoid duplication, the evacuation systems and procedures used on the "Henry Goodrich" will be used as representative for all harsh environment semi-submersibles and drillships.

Vessel

The Henry Goodrich is a Mitsui SES 5000 fourth generation design, twin hull semi-submersible MODU. This semi was built in 1985 to national authority requirements for operations in Norway, Canada, US and UK, is approved as DNV +1A1, and complies with IMO, SOLAS and UKCS regulatory requirements (1998). The mooring system is a 12 point, all chain spread with thruster assist (2 x 7000 hp thrusters).

The rig has an overall length of 98m and a beam of 76m, four equally spaced columns and two full length, 14m wide pontoons. When the rig is in transit under tow, its draft is about 12.5m. In the drilling condition, the vessel's draft is 28m with a displacement of 49,400 tonnes. Its survival draft is 21m with a displacement of 43,600 tonnes.

The Henry Goodrich is designed for exploration and delineation drilling operations. The anchored unit is equipped to operate in water depths ranging from 65m to 610m, and is configured to support a crew of 146 persons.

Evacuation Systems

The Henry Goodrich is equipped with the following evacuation equipment.

- a heliport with a re-fueling station capable of supporting a large (20 person) Sikorsky S-61N or Chinook 234 type helicopter
- 4 x 75 person fully enclosed lifeboats, optional 'free fall' or davit launched
- 6 x 25 person liferafts, davit launched
- 1 x 9 person rescue boat
- 2 cranes each with a 4 person 'Billy Pugh' transfer basket
- sufficient cold water Marine Abandonment Immersion Suits (survival suits) and lifejackets for all on board
- a standby vessel (generally an AHTS vessel) equipped according to the requirements of the regulatory authorities - Transport Canada (TC)/Canadian Coast Guard (CCG) and the Canada Newfoundland Offshore Petroleum Board (CNOPB).

Terra Nova FPSO

Vessel

The Terra Nova FPSO is the first floating production, storage and offloading tanker of its kind in North America. Construction and commissioning was completed in the summer of 2001 and the vessel is now on location approximately 35km SE of the Hibernia GBS on the southern Grand Banks, moored in a 90m water depth.

The Terra Nova FPSO is a purpose built vessel that is 292 meters long and 45.5 meters wide, with storage capacity for 960,000 barrels of oil. The ship is double hulled and ice reinforced, with an overall displacement of 196,000 tonnes. The FPSO contains the world largest disconnectable turret mooring system, which allows a rapid disconnection from the vessels mooring and risers, if required. This turret structure is used to secure the vessel with a 9 anchor line system, and is positioned forward of midships to allow the ship to weathervane into the direction of oncoming wind, wave or ice influences, to reduce environmental forces. The FPSO also has azimuthing thrusters can be used for self-propulsion, to reduce mooring loads. These thrusters can also create a lee in ice, for example, in the case of evacuation by survival craft. Stability calculations indicate that the vessel can accommodate up to 2000 tonnes of superstructure icing. The FPSOs living accommodations will support up to 80 persons. Its freeboard is about 20m.

Design parameters indicate that, in exceptional circumstances, the vessel could remain moored on location in pack ice concentrations up to 9/10^{ths} broken ice coverage, and slowly transit through 10 tenths of thin, broken ice.

The FPSO vessel has a network of escape routes in totally enclosed shielded passageways that are mounted 4m above main deck level. These passageways allow for the transit of personnel fore and aft and across to each side of the ship. There are 6 ladders that can be accessed to leave the enclosed passageways and proceed to main deck level. A muster area has been established on the starboard side aft, with direct communications to the forward control centre. All in all, this is a very well thought out system to move people.

Evacuation Systems

The Terra Nova FPSO is equipped with the following evacuation equipment.

- a heliport with re-fueling station capable of supporting a large Sikorski S61, Chinook or SAR helicopter
- 3 x 80 person fully enclosed lifeboats, two forward and one starboard aft. They are aligned fore and aft for traditional davit launch, but are also equipped with specially designed ProD fittings. The aft boat is also fitted with a small bow thruster to assist with manouvring.
- 10 x 25 person davit launched liferafts in two forward locations (accommodation), 5 rafts each.
- 3 x 25 person davit launched liferafts aft (2 Port and 1 Starboard)
- 2 x 10 person (hand launched) liferafts located each side amidships
- 20 "Decender units" for the controlled lowering of people (one at a time) into the water from the ship's side. Evenly spaced, with 10 each side port and starboard.
- 2 cranes that can be used with "Billy Pugh" type transfer baskets
- Survival Suits, Liferings and Lifejackets for all persons on board.
- a standby support vessel (generally an AHTS vessel) equipped as required by the regulatory authorities - Transport Canada (TC)/Canadian Coast Guard (CCG) and the Canada Newfoundland Offshore Petroleum Board (CNOPB).

Hibernia GBS

Structure

The Hibernia GBS is massive steel reinforced concrete caisson and production platform with a specially designed 15m thick ice wall to protect its inner storage cells, which can contain almost 1,000,000 barrels of oil. The GBS was designed to operate at a location in 80m of water on the Grand Banks and built to withstand the impact of a medium size iceberg, the forces from extreme storm waves, and to continue operations in any pack ice conditions found on the Grand Banks. Its topsides deck overhangs supporting columns to its concrete substructure, with a freeboard to the main deck of about 30m.

The loading system that is used to transfer stored oil is located about 2 kilometres from the platform, where oil is pumped into 127,000 DWT shuttle tankers (the same ones that are used for offloading the Terra Nova FPSO). These 275m long, double hull tankers are custom built for operations on the Grand Banks and have been designed with additional waterline reinforcement to transit through bergy waters and limited pack ice regimes.

Evacuation Systems

The Hibernia GBS is equipped with the following evacuation equipment.

- 8 x 72 person TEMPSC Lifeboats (sufficient for 200% of total complement) all equipped with ProD launch assistance. 6 are attached to the accommodation module (South) and 2 to the process module (North).
- a heliport with re-fueling station capable of supporting a large (20 person) Sikorsky S-61N, Chinook 234 or SAR type helicopter;
- 3 x Selantic Skyscape escape chutes with 4 tethered liferafts attached to the bottom of each chute. (Total of 12 x 25 person liferafts). Two chutes on the south side and one on the north (auxiliary lifeboat station).
- 1 x 9 person rescue boat;
- 2 cranes each with ‘Billy Pugh’ transfer basket;
- sufficient cold water Marine Abandonment Immersion Suits (survival suits) and lifejackets for all on board;
- a standby vessel (generally an AHTS vessel) equipped as required by the regulatory authorities - Transport Canada (TC)/Canadian Coast Guard (CCG) and the Canada Newfoundland Offshore Petroleum Board (CNOPB).

An experimental evacuation system, known as “Gemevac”, is in development for the GBS. It is a transfer system that uses a gondola travelling along steel cables rigged between the platform and a suitably outfitted support vessel. Similar to a cable car, it is designed to transport 16 people at a time. The system is a prototype, but has experienced problems during trials and is not certified for use.

Appendix F

Numerical Simulation of the Broken Ice Zone around the Molikpaq: Implications for Safe Evacuation

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Numerical Simulation of the Broken Ice Zone around the Molikpaq: Implications for Safe Evacuation

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Abstract

This paper presents an investigation of the zone of broken ice around the Molikpaq during interaction with moving ice. The width of this zone may have direct implications with respect to safe evacuation of personnel. A two-dimensional numerical model was used to study the size and behaviour of the broken ice zones with level ice interacting with both the long and short sides of the Molikpaq. Several scenarios of ice interaction with the Molikpaq were investigated. The results show the influence of ice thickness, ice velocity and approach angle of the ice upon sail height and rubble extent. A review of field observations obtained during operation of the Molikpaq shows that the model well predicts the zone of broken ice. The model can be used to evaluate emergency evacuation systems for different structure shapes and ice conditions.

Introduction

Safe evacuation of personnel from offshore structures is of paramount importance in the event of a problem on the structure. There has been considerable work done on evacuation from offshore rigs and platforms in open water sea states (see e.g. http://www.nrc.ca/imd/eer/), but very little has been done for evacuation from structures in ice-covered waters, and many challenging problems remain. Evacuation in ice raises a number of different issues compared to evacuation onto water (Poplin et al. 1998a, 1998b; Polomoshnov, 1998). For an offshore caisson-type structure, the ice regime can be quite variable and safe approaches for evacuation must cover a wide range of ice conditions. When launching a lifeboat or other type of marine craft from an offshore structure, it is important to ensure that it does not get "caught" in the zone of ice broken by the structure during interaction with moving ice.

To investigate the size of these damage zones, an implicit Particle-in-Cell (iPIC) numerical model has been applied to a realistic situation of an offshore structure in a moving ice cover. In order to verify the qualitative and quantitative nature of the results, the model was applied to the offshore structure Molikpaq. This is a steel caisson structure that was used in the Beaufort Sea in the 1980s. Detailed information on the loads and ice conditions for this structure for each of the 4 years of its deployment in the Beaufort Sea is available (Timco, 1996). The iPIC numerical model was set-up using the Molikpaq geometry. A number of runs were carried out and compared to full-scale data. This paper presents a short description of the iPIC model, and presents the results of the numerical simulation. The results are compared to some representative results from the Molikpaq in the Beaufort Sea. The implications of the results are discussed in terms of emergency evacuation from structures in ice-covered waters.

Overview of the Model

The numerical approach is briefly outlined in this section with the intent to briefly convey the essential aspects of model formulation. A comprehensive treatment of the subject is outside the scope of this paper, and would be too lengthy to include here. Details of the present numerical formulation, however, were covered by Sayed and Carrieres (1999), who developed a version aimed at operational ice forecasting. The model was later adapted and validated for solving ice-structure interaction problems related to offshore structures, with the Kulluk and bridge piers (Sayed et al. (2000), Barker et al. (2000a), and Barker et al. (2000b)).

The present model uses a continuum rheology that follows a Mohr-Coulomb plastic yield criterion. The governing equations consist of the continuum equations for the balance of linear momentum and the plastic yield criterion. Those equations are solved using a fixed grid. Advection and continuity, on the other hand, are handled in a Lagrangian manner. An implicit Particle-In-Cell (iPIC) approach is employed. In that approach, an assembly of discrete particles represents the ice cover. Each particle has a fixed volume, and is assigned an area and a thickness. At each time step the velocities are interpolated from the grid to the particles. Thus, particles can be individually advected. From the new positions, values of particle area and mass are mapped to the grid. The resulting ice mass and area for each grid cell are then used to update ice thickness and concentration. Solution of the governing equations can then be carried out using the fixed grid. An implicit finite difference method is used. That method is based on uncoupling the velocity components and a relaxation iterative scheme. Updated velocities and stressses on the fixed grid are obtained from the solution.

A depth-averaged implementation of the model is used in this paper, which averages the values of stresses and velocities over the thickness. Thickness variations, however, are accounted for. As stresses exceed a threshold, representing a *ridging stress*, each particle undergoes ridging; i.e. the thickness increases and area decreases, while conserving ice volume.

Test Runs and Comparison to Full-scale Data

The Molikpaq is a caisson structure that was used for exploration drilling for 4 seasons in the Canadian Beaufort Sea. It is a gravity-based structure that consists of an octagonal steel caisson annulus, with dredged sand placed in its central core. The caisson has outside dimensions of 111m at its base and 86m at its deck, and an overall height of 33.5m (including its 4.5m ice deflector). At two of the drilling locations (the Tarsiut P-

45 and Amauligak I-65 wellsites, drilled in 1984/85 and 1985/86 respectively), the Molikpaq was placed on a deep submerged berm with a set down depth of about 20m. With this deployment draft, the caisson's walls were near vertical (8°) through the waterline. Because of this deployment configuration, there was no permanent accumulation of grounded ice rubble around the Molikpaq at either location. The caisson was directly exposed to moving pack ice throughout the winter. Since the pack ice was in near-continuous motion, a significant range of ice conditions moved past the Molikpaq over the course of these two winter seasons. The information from these sites was used in the present work for comparison with the output of the numerical model.

A total of ten runs were performed with the numerical model. The test runs were chosen such that ice properties and other parameters would represent conditions that are commonly encountered in the Beaufort Sea. The variables that could change between runs were the ice thickness (0.5 to 2m), ice velocity (0.05 to 0.2m/s) and the approach angle (225°, 248°, and 270°) of the oncoming ice (Table 1). The ice was initially "placed" upstream of the Molikpaq, with the initial ice concentration (or aerial coverage) set at 0.95. Each test was run for 5000s (2500 time steps). The grid node spacing in both the X- and Y-directions was 1m and the time step was set at 2s. The grid size was 500 nodes in the X-direction by 200 nodes in the Y-direction for runs 1 through 4 and 300 nodes by 400 nodes for runs 5 through 10. This change in grid size was necessary to accommodate the amount of ice required for the 248° and 225° approach angles. Node spacing and time step remained the same. The top edge of the grid (Y = 200m) is considered to be the north edge in later references.

Table 1 Test matrix

Run	Ice Thickness (m)	Ice Velocity (m/s)	Approach angle of oncoming ice (°) (direction toward)
01	1.0	0.1	270
02	0.5	0.1	270
03	2.0	0.1	270
04	1.0	0.2	270
05	1.0	0.1	248
06	2.0	0.1	248
07	1.0	0.1	225
08	2.0	0.1	225
09	1.0	0.05	225
10	1.0	0.05	248

A schematic of the grid layout is shown in Figure 1. Lines "a", "b", "c" and "d" mark the locations of the cross-sections that are used to compare rubble heights over time. Line "c" is immediately in front of the Molikpaq and line "d" is perpendicular to the Molikpaq, parallel to the X-axis. Rubble extent is measured north and south from the edge of the structure where the cross-section is located, or in the case of line "c", from the centreline of the structure. The rubble extent is taken as a minimum threshold value, calculated as a change in sail height greater than 0.2m from level ice, and only where the concentration of ice is greater than 0.5.

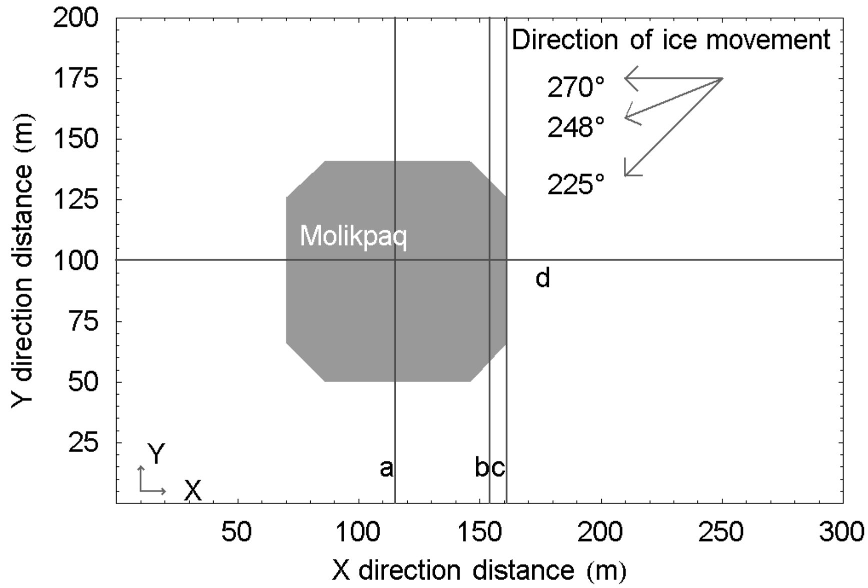

Figure 1 Schematic of the test area. Lines "a", "b", "c" and "d" mark the locations of the cross-sections that are used to compare rubble heights over time.

A plan view of the thickness contours after 5000s for Run_01 is shown in Figure 2. The contour levels are in 0.5m intervals, with minimum and maximum values of zero (white, representing the open water wake downstream of the Molikpaq), and 5m (black) respectively. A narrow wake forms at the west side (downstream) of the Molikpaq and the ice rubble surrounds the remaining three sides of the structure. It should be noted that the contours include both the sail region (which is observable from the structure) and the keel (which is under the ice sheet and not observable from the structure). This is an important point in comparing the results to full-scale conditions.

Information on level ice interaction with the Molikpaq was examined to quantitatively determine the regions of broken ice around the structure for different conditions. It was noted that the level ice interaction was characterised by 3 different failure modes – ice crushing, mixed mode failure and large-scale fracture. Representative values for the crushing and mixed mode failure were determined for an ice thickness of 1m. It was found that the width of the damage zone was different for the regions "updrift" of the structure and "alongside" the structure (see Figure 3). Moreover these widths were a function of the failure mode, with larger zones for mixed mode failures. In the "downdrift" region, there was generally open water, often mixed with broken ice pieces. Typical sizes and shapes for the 3 regions are shown in Figure 3.

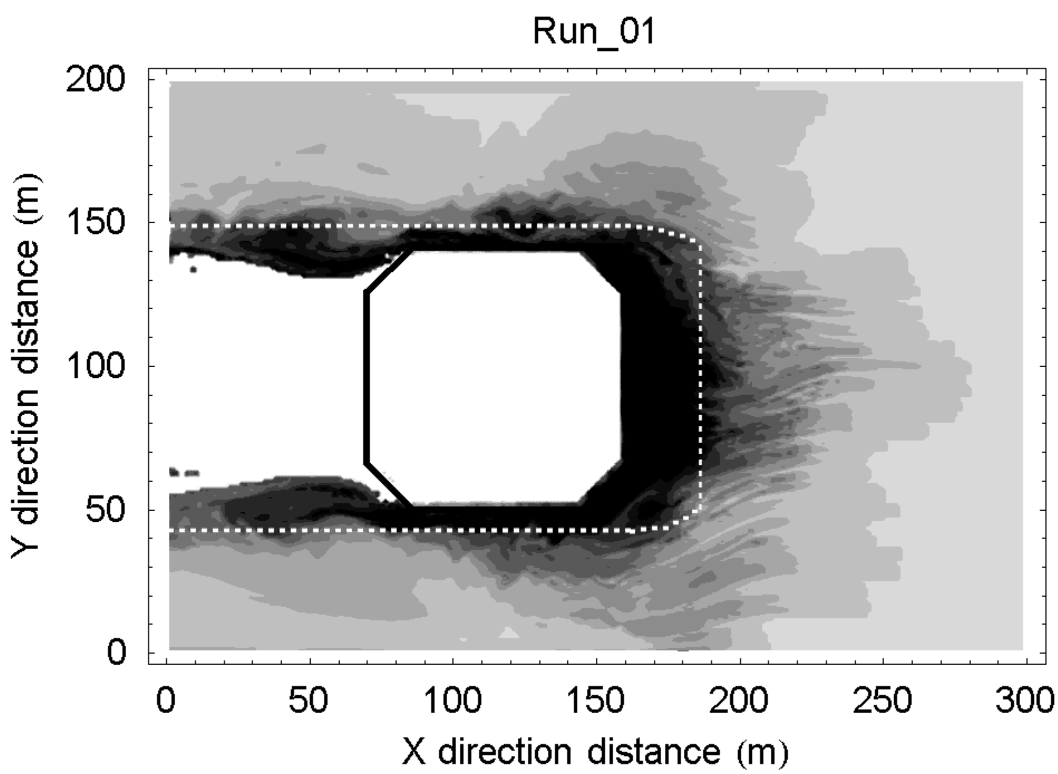

Figure 2 Plan view of total thickness contours for Run_01 after 5000s. Contour levels are in 0.5m increments, with minimum and maximum values of zero (white), representing open water, and 5m (black), respectively. The dashed line indicates the extent of the sail of the ice rubble, with a sail height threshold of 0.2m.

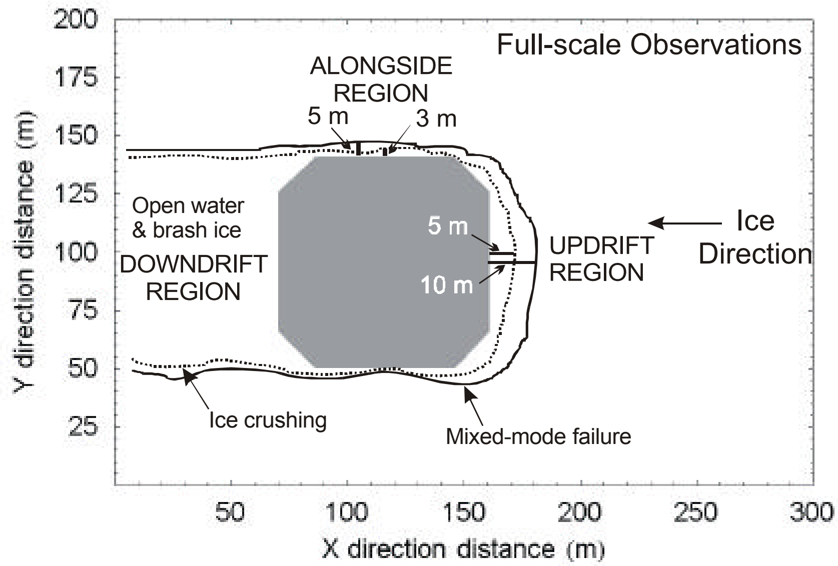

Figure 3 Observations of ice damage zones around the Molikpaq for 1m thick level ice. Note that data are presented for 2 different failure modes.

Comparing the model results with the full-scale behaviour was not a trivial task. The full-scale data consist of visual observations taken from the top of the structure looking down towards the rubble field. As such, the observer is able to note the failure zone around the structure, but is unable to fully observe the whole rubble field and keel, which may be covered with snow or submerged. It would be difficult for an observer to note subtle differences in sail height, such as those less than 0.5m. The numerical model, on the other hand, provides different information. It cannot differentiate between the failure zone and the zone of accumulated ice. Therefore the output of the simulations depicts the entire rubble field.

In comparing Figure 2 to Figure 3, there is good qualitative correlation. The overall behaviour of the ice is the same. With the numerical model, the rubble extent of the sail extended about 25m in the updrift direction, which is larger than the observed values of 5m and 10m for ice crushing and mixed mode failures respectively. In the alongside direction, the extent of the rubble sail was calculated as 8m. The field observations were less than this, with values of 3m and 5m for crushing and mixed mode failures. In the downdrift section, the size and shape are the same in the model and the field; however, in the field, there are often broken ice pieces in the wake. Again, these differences are partly a result of the differences between what could be observed visually and partly due to the chosen threshold value.

Figure 4 shows the evolution of sail and keel geometry at the north side of the Molikpaq, at cross-section “a” (see Figure 1 for location of the cross-section). Only this side of the test grid is shown in the figure, in order to compare the numerical results with representative values of the observed sail height and width of broken rubble, also presented on the figure, for both crushing and mixed mode failure. The cross-sections are plotted in terms of sail height and keel depth, instead of total thickness, to make it convenient for comparison with field observation. The figure shows sail heights and keel depths every 1000s. Since the ice rubble is neutrally buoyant, the ratio of sail height to keel depth is assumed to be 1:4, and is used to present the resulting cross sections. It can be seen that there is reasonable agreement between the observed sail heights and rubble extent and those from the numerical model. Note, however, the additional information on the extent of the keel portion of the ice is included in the results for the numerical model. This information is not observable in the full-scale situation.

As an example of the effect of changing the angle of the oncoming ice, Figure 5 shows the ice thickness contours surrounding the Molikpaq for Run_07, and Figure 6 shows the sail and keel evolution. Both figures show that the open water wake shifts with the changing angle of the approaching ice. This results in open water along both the south and the west sides of the Molikpaq. When the ice approaches at 270°, as shown previously in Figure 2, only the west side of the Molikpaq had open water alongside.

Figure 7 shows a “rubble map” around the Molikpaq on 9 December 1984. This figure shows the situation with loading along a short side of the structure. Note the excellent agreement between the results from the numerical model and the full-scale situation.

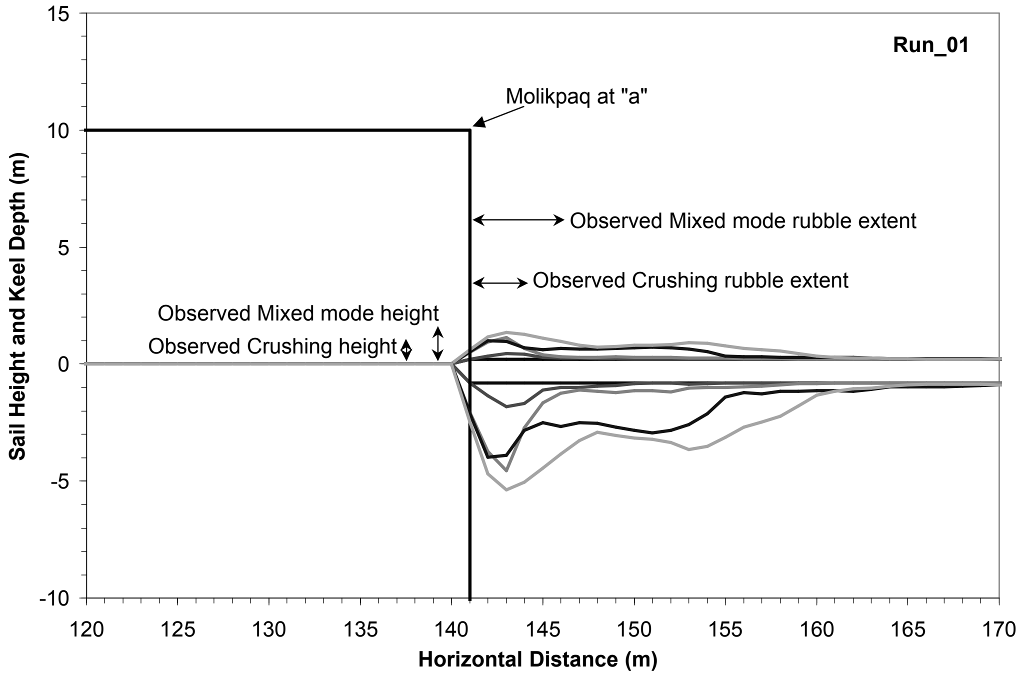

Figure 4 Cross-section, for north side only, at "a" for Run_01 (x=115m) showing the time evolution of the ice rubble zone. Typical sizes for observed ice crushing and mixed mode failure regions for the Molikpaq are also indicated.

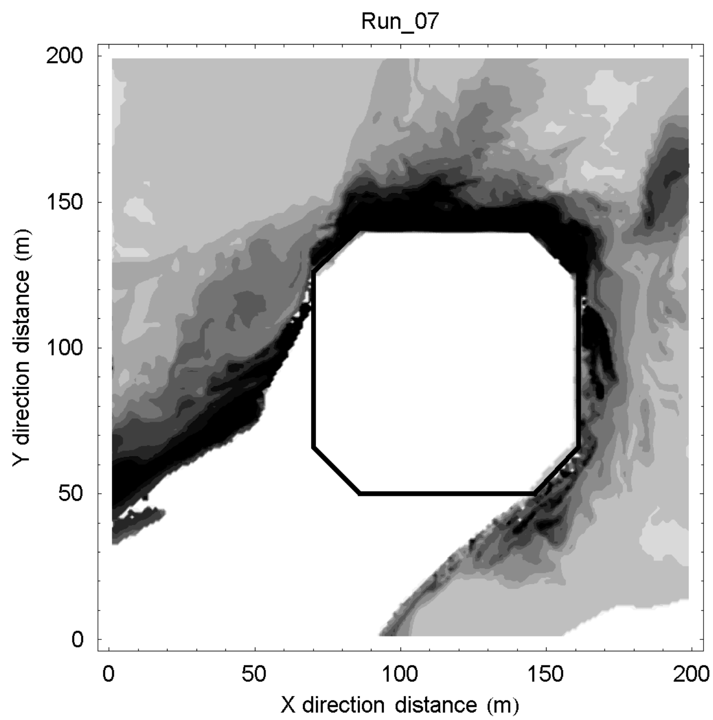

Figure 5 Plan view of total ice thickness contours for Run_07 after 5000s. Contour levels are in 0.5m increments, with minimum and maximum values of zero (white), representing open water, and 5m (black), respectively. The maximum sail height was 4.6m.

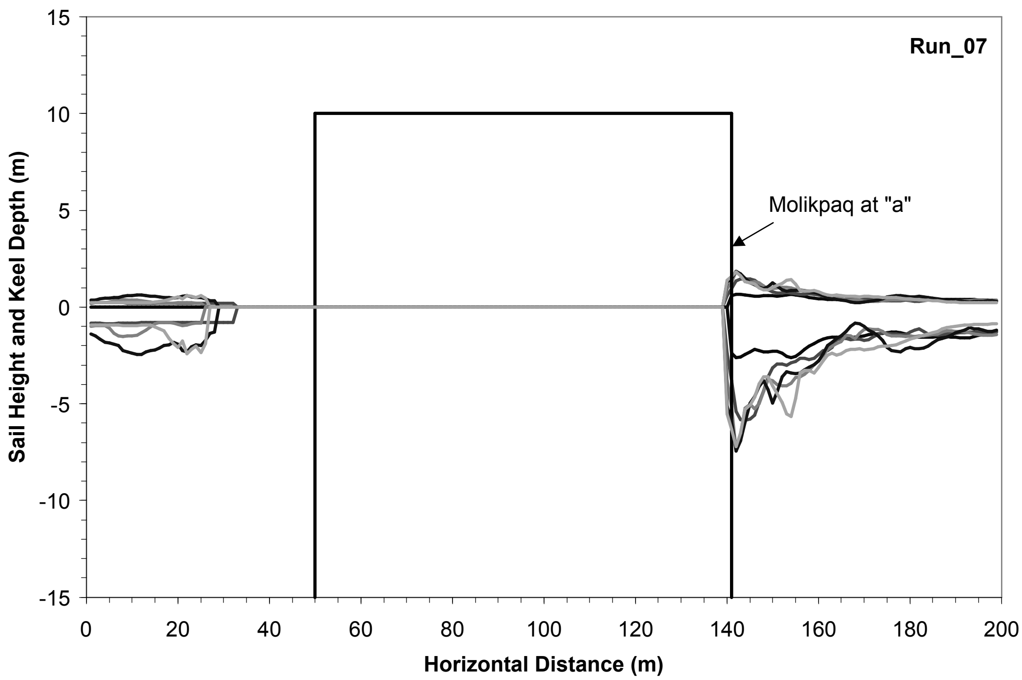

Figure 6 Cross-section at "a" for Run_07 (x=115m)

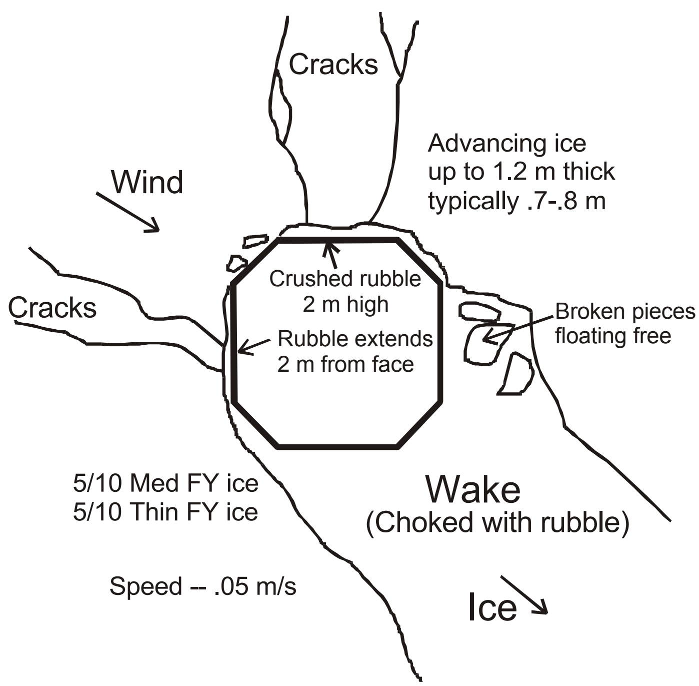

Figure 7 Sketch from the Molikpaq logbooks showing the ice conditions around the Molikpaq on December 9, 1984. Note that the zone of broken ice is close to the structure and there is a large open area along the side and in the downdrift direction, in agreement the results from the numerical model.

A comparison of results for the 10 test runs is shown in Table 2. For each run, and each cross-section, the table shows the maximum rubble extent from the face, the maximum ice thickness and the maximum sail height. These maximum values are taken after approximately 350m of ice have moved past the Molikpaq. As mentioned earlier, the maximum rubble extent is measured along a direction perpendicular to the north and south sides of the Molikpaq, and takes into account a change in sail height greater than 0.2m and only where the concentration of ice is greater than 0.5; where the results are zero, one or both of these criteria were not met.

Table 2 Comparison of run results for each cross-section

		Run_01	Run_02	Run_03	Run_04	Run_05	Run_06	Run_07	Run_08	Run_09	Run_10
"a"	Rubble extent (m)	8.0	0.0	16.5	14.5	4.0	12.0	19.5	14.0	21.5	6.0
	Ice Thickness (m)	4.5	2.4	7.5	6.2	5.1	11.6	9.0	18.6	7.6	5.7
	Sail Height (m)	0.9	0.5	1.5	1.2	1.0	2.3	1.8	3.7	1.5	1.1
"b"	Rubble extent (m)	12.0	10.5	20.0	15.0	11.5	18.5	17.0	25.0	17.0	6.5
	Ice Thickness (m)	9.7	4.9	12.2	8.8	12.2	14.4	13.6	19.0	15.7	16.1
	Sail Height (m)	1.9	1.0	2.4	1.8	2.4	2.9	2.7	3.8	3.1	3.2
"c"	Rubble extent (m)	15.0	13.5	25.0	18.5	9.5	19.0	13.5	27.5	25.5	13.0
	Ice Thickness (m)	8.5	5.4	14.3	16.7	8.6	18.1	10.2	12.1	8.2	7.4
	Sail Height (m)	1.7	1.1	2.9	3.3	1.7	3.6	2.0	2.4	1.6	1.5
"d"	Rubble extent (m)	25.0	14.0	42.0	35.5	0.0	11.5	15.0	0.0	24.5	0.0
	Ice Thickness (m)	15.8	6.4	25.6	41.0	0.0	3.0	2.2	0.0	3.3	0.0
	Sail Height (m)	3.2	1.3	5.1	8.2	0.0	0.6	0.4	0.0	0.7	0.0

Decreasing the angle of the oncoming ice had a varying effect on the rubble extent for both the 1.0m and 2.0m thick ice. Generally, the rubble extent increased with increasing ice thickness. The maximum rubble extent along a cross-section parallel to the Y-axis was 21.5m, observed during the case where the approaching ice was 1.0m thick, moving 225° towards the structure at 0.05m/s in Run_09. When examining the effects of increasing or decreasing the ice velocity, it was observed that the rubble extent results were inconclusive. Additional test runs are needed to provide more reliable results.

Along cross-section lines "a" and "c", when the ice velocity decreased, the sail height also decreased, and vice-versa. This was not the case along cross-section "b", located at the corner of the Molikpaq, where the sail height increased with decreasing ice velocity. Increasing the ice thickness increased the sail height, and decreasing the ice thickness decreased the sail height, along all cross-sections. The sail height along the "a", "b" and "c" cross-section lines generally increased with a decrease in the angle of the oncoming ice. The maximum sail height observed along the cross-sections parallel to the Y-axis was 3.8m, observed in Run_08, where the ice velocity was 0.1m/s, with 2.0m thick ice approaching at 225° towards the Molikpaq.

Implications for Safe Evacuation

Emergency evacuation from an offshore structure is complicated by the presence of moving ice. The present analysis of the field information and numerical model offer some guidance for a number of the key issues. For example, if the evacuation procedure involves launching a lifeboat from the structure, and since the ice can approach from any direction, the emergency evacuation system must have the flexibility to be quickly launched from any side. Additionally, unlike structures in ice-free conditions, lifeboats cannot be simply deposited a short distance from the structure. Evacuation procedures need to account for the generation of ice rubble around the structure. The failure zone of ice around the structure must be avoided, so that the lifeboats do not collide with the structure or get "caught" in the dynamic broken ice zone. However, lifeboats need only be launched a distance sufficient to clear this zone, as the keel of rubbled ice can provide additional buoyancy for a lifeboat.

Regarding the launch direction, as seen in Figures 2 and 3, launching in the updrift direction could be catastrophic since the ice would move the lifeboat back into the structure. Thus, launching in this direction must be avoided. If launching is done in the alongside direction, the launch distance must be larger than the width of the moving broken ice zone (the failure zone). Launching in the downdrift direction would put the lifeboat in ice-filled water and might be the best approach; however this is often the downwind direction, which could be problematic if there are toxic fumes from the structure. The information from Figures 5 to 7 show that there can be large open areas along two sides of the structure if the ice is moving in from an oblique direction. In terms of the distance the launch needs to be from the structure, using a threshold value of 0.2m to determine the extent of the rubble sail height, as mentioned previously, results in a conservative value for the rubble field. With a larger threshold value, the rubble extent would become smaller, or closer towards the structure, in keeping with the quantitative data from the full-scale observations. In practice, this would shorten the launch distance from the structure.

The results from the numerical model provide additional details not observed from the field. For example, the extent of the accumulation of broken ice under the ice sheet can be seen from Figures 2, 4, 5 and 6. This broken ice would provide more buoyant support for loads put on top of the ice sheet and could add to the "effective" thickness of the ice for bearing capacity purposes. Note, however, that the majority of the ice accumulates in the updrift direction, with very little extent in the alongside direction. Therefore, this added buoyancy should not be considered in determining the bearing capacity of the ice.

The good agreement between the numerical model and the full-scale observations is encouraging. It illustrates that useful information can be obtained from the model. This type of analysis can be extended to structures with different shapes, and structures that are placed in different ice conditions. Also, the influence of grounded rubble could be considered with good confidence (see e.g. Barker et al. (2001) for a study on ice pile-up along shorelines and vertical structures). The present work has shown that a detailed numerical analysis of ice interacting with offshore structures can provide additional insight into the parameters that should be considered for emergency evacuation in ice-covered waters.

Conclusions

This paper examined the geometry of floating ice rubble formation around an offshore structure, the Molikpaq. Identifying the extent and height of ice rubble, as well as open water leads, due to ice movement against the structure is a necessary step for developing emergency evacuation systems. The present investigation employed a numerical model to simulate various scenarios of ice interaction with the Molikpaq. The model is based on an implicit Particle-In-Cell (iPIC) formulation and includes an efficient implicit numerical solution method. Rheology of the ice cover follows cohesionless Mohr-Coulomb yield criterion.

The numerical runs simulated several scenarios of ice interaction with the Molikpaq, which correspond to field observations. The numerical results were in good qualitative agreement with field observations. For example, the resulting extent and height of ice rubble, and the formation of open water were in accord with observations. A parametric study was carried out in order to examine the role of several parameters. The role of ice thickness, direction of ice movement, and velocity were examined. The numerical results indicated that the sail height generally increased with decreasing approach angle and increasing thickness and velocity. The rubble extent increased with increasing ice thickness, but its relationship to ice velocity and approach angle was not as straightforward.

The present numerical simulations proved capable of predicting ice rubble accumulation and open water formation in the vicinity of offshore structures. The output could be used in evaluating emergency evacuation systems for different structure shapes and ice conditions.

Acknowledgements

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