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AN OVERVIEW OF EVACUATION SYSTEMS FOR STRUCTURES IN ICE-COVERED WATERS

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ABSTRACT

This paper presents an overview of the types of evacuation systems that have been used or proposed for use on offshore structures in ice-covered waters. Various ice considerations are highlighted in relation to the use of these systems, and some of the key issue areas that are associated with different in-ice evacuation approaches identified. Past experience from the Beaufort Sea is used for illustrative purposes. Brief recommendations about key initiatives that may lead to improvements in evacuation technologies for use in ice-covered waters are also provided.

INTRODUCTION

Safe emergency evacuation of personnel from offshore structures is of critical importance in the event of a major problem occurring onboard. In addition to the issue of specific evacuation systems and their capabilities, the consideration also involves the procedures and training that are required for personnel to systematically respond in different 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 ice-covered waters, and in other ice-infested areas of the world. Evacuation systems and procedures are normally put into place on a structure-specific basis as part of the design and implementation phase, then handed over to operating personnel for subsequent use on an as-required basis. Training of onboard staff, periodic escape drills, and routine safety audits are all part of this process.

Although safe evacuation from offshore structures has always been an issue of concern, it has become an increasingly important consideration over the past decade or two, particularly in light of major offshore accidents like the loss of the Ocean Ranger and Piper Alpha. A significant amount of effort has been directed towards improving evacuation methods for platforms in open water. However, there have been few recent initiatives involving improved evacuation methods for structures located in ice conditions. With the exception of the ARKTOS, which was purpose built as an ice-capable escape unit, open water evacuation systems have generally been adapted (or accepted) for use in ice-covered waters. 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. Development projects on the Grand Banks, in the Beaufort Sea, in the offshore Sakhalin area, and in the Caspian Sea are recent examples. In this regard, it is important that sound in-ice evacuation approaches are available within these projects, ones that are configured for in-ice applications and "well proven" in various ice situations.

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, evacuation approaches must be capable of accommodating a broad spectrum of different ice situations, which are often complicated by factors such as low temperatures, blowing snow, and icing. Several studies have addressed some of the issues surrounding evacuation in ice, including those by Zahn and Kotras (1987), Poplin et al. (1998a, 1998b), Polomoshov (1998), Bercha et al. (2001), Barker et al. (2001), Cremers et al (2001), Bercha (2002) and Wright et al. (2002).

KEY CONSIDERATIONS

Any evacuation system that is developed for use on an offshore structure 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 both a timely and orderly manner, without a high potential for injury to anyone. 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 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; and muster and temporary refuge areas on the structure.
- The range of 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.; and 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 (eg: crushing, flexure, large scale fractures, downdrift wakes, grounded or floating ice rubble, etc.); and various combinations of wind, sea, ice and other weather conditions (eg: broken ice floes in large swells).

- The logistics that are available to support any required evacuations from the structure, including the presence of a standby vessel and its capabilities (eg: to manoeuvre and station keep in ice); other structures or vessels operating in the general area; and distances to support bases, heliports and airfields, etc.

All of these factors should be recognized when developing evacuation methods for a specific structure, and assessing their probable effectiveness and reliably. In most cases, a variety of evacuation options are required to satisfy the spectrum of possible problem scenarios, particularly in ice-covered regions.

EVACUATION APPROACHES

In broad terms, there are three different approaches for evacuating people from an offshore structure. The first is commonly termed a direct or dry evacuation, wherein groups of people are moved off the platform directly, without having to move into the surrounding sea or ice conditions by various means. Evacuation options that involve helicopters or transfer of personnel directly to the deck of a support vessel are examples of this. Clearly, the presence of ice around a platform has little impact on the use of helicopters, and this evacuation method is generally preferred. However, helicopters are not reliable in all weather conditions (eg: high winds, low temperatures, icing) and in all emergency situations (eg: gas plumes, major fire). Vessel access to offload people can also be restricted by factors such as gas, fire, high waves, and so forth. When access is possible and ice is present, key 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 within fairly tight tolerances over the time frame required to move large numbers of people onto its deck. (Appropriate ice strengthening is a clear requirement for the vessel itself).
- the type of transfer system that is used to move large numbers of people from the platform to the vessel (eg: slides, chutes, stairways), the "reach" of this system, and its ability to accommodate the range of environmental and vessel movement situations that can be anticipated.
- in certain scenarios (eg: the presence of grounded ice rubble around a structure), a support vessel may also need specialized equipment like azimuth thrusters, to enable rapid clearance of grounded rubble to allow access (or egress of other types of escape craft onboard the platform).

The second approach, termed an indirect or semi-dry evacuation, involves groups of people moving to survival craft onboard a platform, down into the ambient sea or ice conditions, and then away from the platform 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 include the use of lifeboats, rafts, or the ARKTOS craft to move people off and then away from a platform. Key in-ice issues for these types of escape craft include:

- the means by which the survival 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, a gas plume, etc.) in the ice conditions that are present, either actively (with propulsion) or passively (drifting with the ice), to a nearby location where the craft and its onboard personnel can be picked-up by a rescue vessel
- the ability of the craft to safely function and, in fact, survive when it is deployed in the ambient ice conditions, from a structural perspective.

The third approach is a "wet" evacuation, and is generally the least preferred. It involves individual methods of personnel abandoning a platform and reaching the ambient sea or 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, through individual personnel lowering devices, to people simply jumping from the platform. This last resort approach is typically wet and dangerous, and requires subsequent pick up of separated individuals with rescue craft. However, in specific ice situations (eg: when stable ice or a stable grounded ice rubble field is present 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 emergency scenarios.

EVACUATION SYSTEMS

A large number of specific evacuation systems are available to move personnel off structures, either directly or indirectly. Most have been developed, tested, certified, and put into place for operations in conventional open water areas. However, some have also been selected for use on offshore platforms and vessels working in ice-covered waters. With the exception of direct evacuation of personnel to helicopters or support vessels, or wet escape of individuals into the sea, there are several basic classes of systems for indirect or semi-dry evacuation. They include the survival craft (lifeboats (TEMPSC), liferafts and specialized vessels such as the ARKTOS and Seascape craft), the craft deployment system (standard davit launch and freefall systems, and methods to launch a craft in a specific direction and at some distance from a platform such as the PROD, TOES and Seascape launch systems) and personnel transfer systems (slides and chutes, stairways and bridges, GEMEVAC). Examples of these are shown in Figure 1.

These types of systems have been reviewed in Wright et al. (2002), and some of the issues regarding their use on structures in ice-covered areas discussed. When evacuation systems are being developed for particular offshore facilities in various ice conditions, the suitability and applicability of all these options is generally evaluated, along with their relative advantages and disadvantages. Key issues and themes that often arise include:

- the local and global strength of a craft when exposed to various ice situations and loads
- the ability of a craft to move in the ambient ice conditions, and at what speed

- the question of where a craft can be safely deployed in relation to ice action on the platform, and how many units are needed to accommodate different ice drift directions
- possible problems like punctures in rafts due to ice, lowered rafts being "ripped away" from slides due to ice drift, slush ice ingestion into water-cooled engines of lifeboats, ice damage to their propellers, rudders and so forth
- basic concerns around the use of various craft and deployment systems in conditions that include low temperature, high winds, icing, snow storms, darkness, poor visibility, etc.
- practical considerations like the size, weight, space requirements and cost of a system, its level of certification, and past experience with it
- ease of deploying the system, suitability for its use in both ice and open water conditions, and throughput in terms of quickly moving large numbers of personnel
- operating factors like the level of maintenance required, level of operator training, etc.

Figure 1: (1) - TEMPSC during recent JIP in-ice trials, (2) - ARKTOS in Caspian ice, (3) - Seascape during recent JIP in-ice trials, (4) - TEMPSC in davit on the Molikpaq, (5) - PROD assisted TEMPSC deployment, (6) - Seascape articulated launching arm, (7) – Escape chute and raft, (8) - typical raft and slide system, (9) – GEMEVAC test transfer to vessel

In general terms, escape systems like lifeboats, liferafts and chutes are the mainstay on high freeboard platforms like the Molikpaq and the Hibernia GBS, which are exposed to moving pack ice conditions at times. Larger, heavier craft that require more space, like the ARKTOS, are more common on low freeboard structures. For example, ARKTOS units are being used as a key element of the evacuation system on the North Star production island in the Beaufort, and on the Sunkar barge and artificial islands now being used for drilling operations in the Caspian Sea.

PAST EXPERIENCE

Most of the original experience that was developed with evacuation systems for structures operating in ice-covered waters came from the Beaufort Sea. In the 1970s and 1980s, various types of platforms were used for offshore drilling in this area. They ranged from artificial islands, to shallow caissons like the Tarsiut CRI and Esso CRI, through high freeboard GBS structures like the Molikpaq, SSDC and CIDS units, to floating vessels like ice-reinforced drillships and the Kulluk. These drilling systems worked in a wide spectrum of different ice and ice/interaction situations, which included landfast ice and moving pack ice of various concentrations, thicknesses, floe sizes, and roughnesses (Figure 2). All of these platforms had evacuation plans, systems and procedures in place to deal with emergencies, should the need arise. A summary of the evacuation approaches that were used on these Beaufort platforms, and on other structures working in different ice-infested parts of the world, is given in Wright et al. (2002).

The suitability of any evacuation approach is dependent on the particulars of a platform, the nature of hazard, the escape systems available, and the ambient ice and other environmental conditions at play. Although details vary from structure to structure, some of the main messages from past Beaufort Sea experiences are highlighted as follows, on a scenario basis. These messages remain relevant for the evacuation considerations that many practitioners are confronting in association with some of the current offshore projects in ice-covered water.

Figure 2: Photographs showing Beaufort Sea structures operating in various conditions.

Platforms surrounded by stable landfast ice and/or stable grounded ice rubble in winter

- this is generally the most straightforward evacuation scenario to deal with
- moving personnel from a platform to the surrounding stable ice cover is the most reasonable approach to adopt in various situations, 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 moving onto the ice, personnel must have appropriate cold weather survival gear and should also be educated to recognize that the surrounding ice cover can be "quite friendly" in emergency circumstances
- once on the ice, there should be one or more temporary shelters available nearby (as options to be clear of gas plumes, heat and smoke from fire, etc.), in which people can stay until rescue by helicopter, nearby vehicles on ice roads, or other pick-up methods can be implemented

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

a) Direct Personnel Evacuation to a Support Vessel

- 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 very close proximity to it is normally acceptable in this scenario (depending upon the vessel's capabilities and any draft restrictions), but can be limited by high swell, strong winds, poor visibility and certain types of 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, low temperatures and wind chill, icing and excessive support vessel movements are all factors that can challenge the safe use of many personnel transfer systems

b) Indirect Personnel Evacuation to the Ice

- this evacuation approach is often the least preferred, except for the last resort option of having people make their way off a platform and into the surrounding ice conditions individually
- lifeboats and liferafts must be deployed at locations around a platform where they will not be subjected to high ice forces (even in thin ice conditions) and the potential for damage, any potential to be overturned and/or overtopped by ice rubbling (or other types of active ice failures), or any ice movement or ice interaction situations with the potential to push them back against the platform
- survival craft lowered on davits typically have landing zones that are in close proximity to the side of most platforms, where the ice can often be actively failing and clearing, which can be problematic
- in this regard, deployment systems that have enough reach to place a survival craft "out and away from a platform", beyond the broken and active ice zone around it, are preferred but this type of system is not well developed nor proven for use in moving ice conditions
- the practicality of lowering lifeboats or deploying liferafts in low 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, lifeboats should (ideally) have the ability to move away to a nearby area in a self propelled mode
- 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 no more capable of moving in high ice concentrations than a liferaft, 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 of a loaded lifeboat or liferaft (carrying 50 man) will generally cause it to break through in ice thicknesses to about 30 cm
- concerns about the potential for significant ice damage to conventional lifeboats and liferafts when they are afloat in high concentrations of moving ice are obvious
- in short, the technology for indirect evacuations into high concentrations of thin ice using lifeboats or liferafts is not well developed, and remains far from proven

Platforms in high concentrations of thick moving pack ice during winter

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

Platforms in mixed ice and open water conditions during break-up involving low to moderate concentrations of mobile thin or thick ice

- this evacuation scenario is considerably more straightforward than in higher ice concentration situations
- for example, support vessel access to and stationkeeping near a platform is much easier in low to moderate ice concentrations, for direct transfer of personnel
- similarly, standard lifeboats and liferafts can be deployed in transient open water areas around a platform, with lifeboats moving away by navigating around ice floes
- also, the use of liferafts is not uncomfortable in this low to moderate ice coverage situation, at least to ice concentrations of about 5/10ths

It is noteworthy that deficiencies in Beaufort Sea evacuation approaches in high concentrations of both thin and thick moving pack ice led to the development of the ice capable ARKTOS system in the late 1980s. However, some of the deficiencies and uncertainties in the "in-ice" evacuation technologies that were available during Beaufort Sea operations still persist.

RECOMMENDED INITIATIVES

Here, a general conclusion is that reliable methods for evacuating personnel from offshore structures in various pack ice conditions and emergency situations are not yet "comfortably available", nor proven. The purpose-built ARKTOS craft is one exception, but this type of unit does have limitations in certain applications (Metge, personal communication & others).

To bring this paper to a closure, a number of the initiatives that appear to be warranted to make strong advances in this technology area are highlighted as follows:

- systematic evaluation of the safety and performance limits of both traditional and new survival craft once they are placed into various ice conditions, with **full scale tests and trials**
- systematic evaluation of different deployment methods for 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 in very close proximity 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 the deck of a standby vessel, 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 and to transfer information about in-ice evacuation technologies, including interactive discussions with operating personnel.

In this regard, recent JIPs studies involving in-ice field trials with a standard TEMPSC, and the Seascape life rescue craft, are refreshing and meaningful full-scale technology assessment initiatives.

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