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ARCTIC OFFSHORE ESCAPE, EVACUATION, AND RESCUE

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ABSTRACT

Results of a survey of the state-of-art Arctic escape, evacuation, and rescue (EER) are presented. The review covers regulations and standards, current and emerging technologies, and analytical methods for the assessment of Arctic EER performance. The status of Arctic EER international (ISO) and Canadian national standards is described. Both sets of standards are performance based, but vary in their approach. Although many different open water technologies have been adapted to some degree for Arctic use, there does not appear to be a fully operational evacuation system adequate for both open water and ice conditions. Finally, methods for assessing the risk and reliability associated with emergency operations in Arctic ice laden waters are reviewed. These methods include algorithms for human and mechanical performance generating probabilities of likely EER outcomes under different environmental, operational, emergency, and personnel conditions. Conclusions from the work are summarized.

INTRODUCTION

The Ocean Ranger and Piper Alpha marine disasters initiated extensive inquiries into the adequacy of marine EER systems. These inquiries were the Public Inquiry into the Piper Alpha disaster (Cullen, 1990), and the Royal Commission on the Ocean Ranger marine disaster (1984). Common to the results of both inquiries was the recommendation to develop performance-based standards for EER systems for offshore installations, rather than a prescriptive regulatory framework. Development for such a framework, for both open and ice populated waters, requires supporting development work on EER performance evaluation and appropriate technologies. This paper reports on current developments in EER resulting from the disaster inquiries, with particular emphasis on developments of EER for polar offshore conditions, in the regulatory, technology, and performance assessment areas.

STANDARDS AND REGULATIONS

Summary of Current Status

The author is involved in the development of Arctic EER standards for Canadian waters, under Transport Canada (TC) sponsorship, as well as on the international level with the International Standards Organization (ISO). As the initial step on both sets of standard developments, a worldwide Arctic EER data and literature search was conducted online, through libraries,

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classification societies, offshore organizations, and through contacts with petitioners and operators in polar offshore regions. Although research and development is underway, it was found that no standards, guidelines, or regulations exist for polar or ice covered water EER. Accordingly, the draft Arctic EER performance-based standards described below appear to be unique and represent a pioneering regulatory excursion into this area.

Performance-Based Standards

Performance-Based Standards (PBS) are verifiable attributes that provide qualitative targets and quantitative measures of accepted performance. The key characteristic of PBS is their focus on what must be done, rather than on how it should be done. The difference between PBS and the more traditional prescriptive standards is that PBS concentrate on the result, while prescriptive standards set out details of the process, which may or may not achieve the desired results.

Confusion results because both PBS and the traditional prescriptive standards, in a generic sense, both prescribe certain values or quantities. However, PBS prescribes performance targets; traditional standards prescribe how to do something. This “how to” approach may or may not lead to desirable targets, although it is intended that it lead to a desirable target. To avoid confusion, these traditional prescriptive standards in the balance of this paper will be referred to as the “how to” standards (HTS) in contrast with PBS.

In recent years, there has been a strong interest worldwide in developing codes and standards that are more performance based. The building industry in Australia (Foliente, 2000), Israel (Gross, 1996), USA (NBS, 1977), and Canada (Legget and Hutcheon, 1979), is undergoing a transition from HTS to PBS. Military organizations worldwide have long been the user of performance-based standards and measurement systems. Therefore, not untypically, a good working definition to form the basis of performance-based measurement can be drawn from the Canadian Department of National Defense, Defence Planning Guide, Chapter 5: Performance Measurement, 1998 (CDND, 1998) as follows:

> “There are three broad elements in the performance measurement framework: Measures; Indicators; and Standards. They are defined as follows:
> (a) Measures are attributes that must be analyzed to determine whether the expected results are being achieved;
> (b) Indicators are aspects of the measures that are to be assessed; and
> (c) Standards are the quantitative targets or qualitative goals to be achieved.”

Focusing on the current subject of the safety of offshore installations, both the Lord Cullen Inquiry (Cullen, 1990) and the Royal Commission on the Ocean Ranger Disaster (1984) recommend a greater emphasis on performance-based standards and regulations (Sefton, 1994) in offshore safety. The Canadian Maritime Law Association (1998) also points out the need for a unified performance-based set of standards. Current worldwide SOLAS (IMO, 1974) as well as Canadian East Coast (NOPIR, 2001; CNSOPBR, 2001) regulations are substantially HTS, as are associated offshore recovery (UKOOA, 2001) standards.

Canadian PBS

The “Canadian Offshore Petroleum Installations Escape, Evacuation, and Rescue (EER) Performance-Based Standards” (PBS Development Task Force, 2002) are a set of standards intended for offshore installations in both Arctic and temperate Canadian waters to assure adequate safety for all personnel in the event of a situation which requires emergency abandonment of an installation. Primary users of the PBS are intended to be the operators and the regulators.

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

- The overall EER process
- Escape
- Evacuation
- Rescue

Each of these Standard categories, except for the first one, is subdivided into global and specific standards (Bercha et al., 2003). Global standards apply to the overall process, while specific standards apply to different approaches to each of the components. The structure of the Standards is illustrated in Figure 1.

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

- Design
- Performance
- Reliability
- Availability

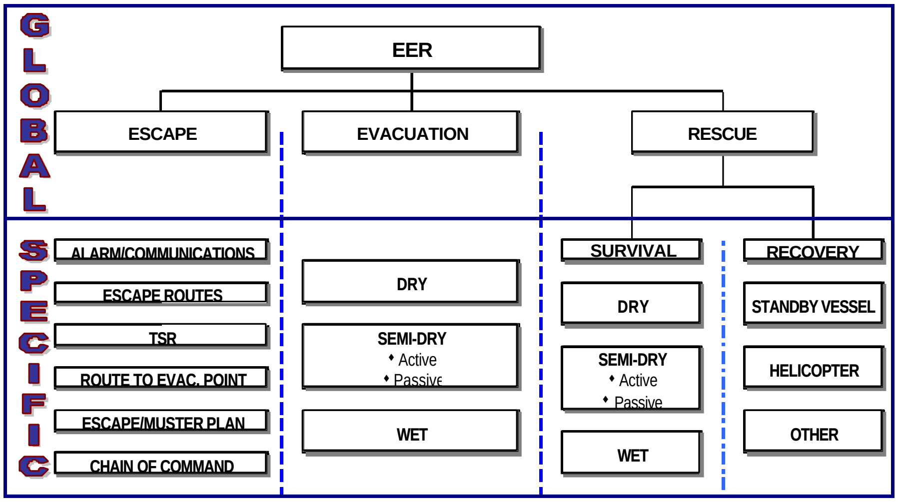

Figure 1: Structure of Performance-Based Standards

As shown in Figure 1, each of the principal components of the EER is further subdivided into a series of sub-components. Typical Standards in the above categories applying to semi-dry (or lifeboat type) systems are reproduced in Table 1. Only typical Standards in each of the main categories are given in this table. The reader is referred to view the entire set of Standards under (PBS Development Task Force, 2002), which can be viewed on either of the following websites: www.berchagroup.com or www.nrc.ca/imd/eer.

From this table, we can see typical examples of a qualitative PBS and quantitative PBS. Clearly a qualitative statement has been made in the area of design (a) and its associated performance (b). However, in the area of reliability (d), the statement made is quantitative. Essentially, it states that a certain reliability or success rate shall be achieved during an evacuation operation under a given set of weather conditions. The weather conditions for which specific reliabilities are required have been set up as described in Table 2, with a similar categorization for ice and Arctic conditions.

Table 1: Semi-Dry Active Systems PBS

(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.
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 metres in minimum time for all environmental design conditions within 5 minutes.
(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 minimum reliability of each semi-dry active evacuation system in severe weather (Beaufort 8-10) shall be at least 95%).
▪	The semi-dry active system availability shall be sufficient to provide combined availability during installation service of all evacuation systems in accordance with Section 7.1(g) (99.9%).	▪	The minimum weather weighted average reliability of each semi-dry active evacuation system shall be 97%.

Table 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+)

Normally, the weather weighted average reliability set out in the Standards is intended to be invariant regardless of the weather conditions. Thus, in order to achieve the stated reliabilities of the total system, components will have to optimize not only the types of systems, but also their configurations and redundancies in order to achieve the overall reliability required. For example, since reliabilities are relatively low for extreme conditions, operators will have to enhance or fortify their safety systems to achieve the performance goals in areas where extreme conditions are more prevalent, in order to maintain the same weather weighted average reliability.

Table 3 sets out the general contents of the ice and cold weather Standards. Because very limited quantitative information on cold weather performance exists, the current draft of the ice and cold weather Standards (Ice Standards) is largely qualitative in its description of performance targets. The structure of the Ice Standards, however, does conform to the body of the EER Standards described above, with the proviso for a set of ice severity categories, similar to the weather categories established in Table 1. All Ice Standards can also be viewed at the above-cited websites.

Table 3: Ice and Cold Regions EER PBS Summary Contents

Section	Title	Section	Title
1.	Introduction	7	Evacuation Standards
2.	Definitions	*7.1*	*Cold Temperature*
3.	Relevant Publications	*7.2*	*Ice Fog*
4.	General Requirements	*7.3*	*Icing*
5.	Global Standards	*7.4*	*Marine Ice*
6.	Escape Standards	8	Rescue Standards
6.1	*Cold Temperature*	*8.1*	*Survival*
6.2	*Ice Fog*	*8.2*	*Recovery*
6.3	*Icing*		
6.4	*Marine Ice*		

Jurisdiction of the Canadian EER PBS will be vested in the East Coast Petroleum Boards and the National Energy Board (NEB). The Canada Nova Scotia Offshore Petroleum Board (CNSOPB) and the Canada Newfoundland Offshore Petroleum Board (CNOPB) have jurisdiction over East Coast installations in Canadian waters. The NEB has jurisdiction over the Gulf of St. Lawrence, Arctic waters, and Pacific waters within Canadian limits. These boards are currently reviewing the draft EER PBS, and expect to promulgate them in the near future following their review and editorial process.

ISO PBS

The International Standards Organization (ISO) is currently addressing performance requirements of polar offshore installations through Working Group 8 – Arctic Structures. Work by technical panels (TP's) have been ongoing for over one year under the following technical panel categories:

- TP1: Environmental
- TP2: Action / Loading / Reliability
- TP2a: Reliability
- TP2b: Ice
- TP2c: MetOcean
- TP2d: Seismic
- TP3: Foundations
- TP4: Artificial Islands
- TP5: Steel
- TP6: Concrete
- TP7: Floating
- TP8a: Facilities – Topsides
- TP 8b: Facilities – EER
- TP9: Ice Engineering

All standards under development by these panels are to be performance-based standards (PBS), generally with the characteristics described in the first subsection of this section.

As the Canadian PBS development program had preceded the ISO EER TP8b work, many of the detailed provisions from the Canadian PBS were adopted with some modifications. However, the overall philosophy of the ISO EER PBS approach is to provide qualitative rather than quantitative performance targets through focus on the use of probabilistic and risk analytic procedures in the optimization of installation EER systems. TP2a, the reliability panel, however, is mandated to develop quantitative safety targets for not only each category of installation to guard against catastrophic and serviceability failures, but also for the associated installation EER systems and procedures.

To illustrate the content of the draft ISO EER PBS, the high level Table of Contents is given in Table 4. At this time, the ISO EER PBS are only in the form of a preliminary working draft. A committee draft is expected prior to the end of 2004, with promulgation likely by the end of 2005 or early 2006.

Table 4: ISO EER PBS Table of Contents

Section	Title		Section	Title
1.	Introduction		7.	Environment
2.	Scope		8.	EER General
3.	Normative References		9.	Escape
4.	Nomenclature		10.	Evacuation
5.	EER Philosophy		11.	Rescue
6.	Hazards and Risk Analysis		Annex A	Environment

ARCTIC EER TECHNOLOGIES

Current EER systems function in open water with varying reliability depending on the severity of weather conditions. Factors, which would need to be incorporated in Arctic Arctic evacuation systems, are summarized in Table 5. Because of feasibility considerations, Arctic systems should also suffice for open water operation (IMO, 1974).

Table 5: Arctic Evacuation Problems

▪ Very cold. Adfreezing snow/ice obstructing mechanisms and causing slippage.
▪ No free fall or fast descent system due to ice.
▪ Ice conditions variable – dynamics and ice fraction can change quickly.
▪ Ice pressure, ride-up, adfreeze, pileup.
▪ Ice movement direction unpredictable.
▪ Visibility bad often – fog/Arctic winter.
▪ Damage to capsule greatly decreases survival.
▪ Arctic system must also work for open water.

Escape on Polar Installations

The process of escape on installations under polar winter conditions, is not significantly different from that on installations in temperate frontier regions. The escape process, by definition, is restricted to activities on the installation. Escape along outdoor walkways, stairways, and ladders may be hampered by accumulating snow, adfreezing ice, and low visibility and strong winds, but require no new technologies, rather only cold weather provisions such as non-slip surfaces, heat traced walkways or ladders, or wind and snow barriers. Full-scale trials in cold conditions have shown no significant impact of their effects on the escape process (Bercha et al., 2001).

Evacuation from Polar Installations

The conventional evacuation process needs to be significantly altered to ensure safe evacuation of ships or installations in ice. For lifeboats, alterations are needed both in the launch method and in the craft configuration while still maintaining the requisite IMO open water capability. Other methods of evacuation such as chutes, gondolas, inflatable carpets, also need significant modifications to adapt to polar conditions. The launch must safely transfer the loaded lifeboat from the installation to the ice surface or into the ice lead, in all expected conditions, including pile-ups. An indoor, heated stowage location is preferable to ensure that all mechanisms are not impaired by ice or snow buildup. The orientation and location with respect to prevailing wind and ice motion must also be considered. Bercha et al. (2004, 2003) describes different conceptual designs intended to effect safe and reliable evacuation utilizing a TEMPSC for a typical GBS with a sloped ice wall, requiring the launch mechanism to deposit the craft well beyond the toe of the ice wall or pile-up at the ice or water surface.

Rescue After Evacuation from Polar Installations

The rescue component of EER consists of the survival of the evacuees and their transfer to a safe haven. First, consider the craft in pressured broken ice. The Norwegian explorer, Fridtjof Nansen, with the help of his British Naval Architect, Colin Archer, solved this problem in 1890 with the hull design of his vessel, the *Fram*. The efficacy of the design was borne out by the fact that the *Fram* survived pressured Arctic ice in the winters of 1893-95, as well as several subsequent expeditions in later years. Nansen's principle was that "the ship should be pushed upwards by the expanding ice as it froze (or pressured) by giving the hull very rounded lines… flaring out over the ice in the main ice contact belt" (Fram, 2003). Shakelton's vessel, the *Endurance*, was not so designed (Lancing, 1999), resulting in "… pressure reached new heights…decks buckled and the beams broke…ice climbed up her sides foreward, inundating her under the shear weight of it." An adaptation of the basic lifeboat using the Fram principle, together with provisions to allow movement on solid ice, is described by Bercha (2003). For the on-ice case, the main problem is to maintain upright stability of the vessel, and to permit it to propel itself on the ice surface to a location clear of the installation hazard zone. Clearly, there is no limit to the possible on-ice locomotion designs, ranging from the amphibious *ARKTOS*, to the confirmed on- and off-ice reliable but high-energy consumptive air cushion vehicle lifeboats.

RISK AND RELIABILITY STUDIES

The setting of EER performance targets requires ways of assessing practical quantitative measures of reliability, availability, and safety. Such assessments can be based on the following:

- Full-scale and model test data
- Expert opinion based on experience
- Analytical and simulation modeling

Unfortunately, other than the anecdotal data referred to the anals from polar exploration (Fram, 2003; Lancing, 1999), full-scale data do not exist. Some model tests are underway with preliminary results giving performance in restricted concentrations of broken ice floes. However, these tests exclude the effects of human performance and do not model conditions resulting in craft failure. Expert opinion is valuable, but little or no experience exists. Thus, at this time, the main resource for quantifying performance parameters of polar EER systems remains analytical and computer simulation. To the best of the author's knowledge, the only comprehensive Arctic EER simulators which are operational and validated to the maximum extent currently possible are those described by Bercha et al. (2004, 2000). Naturally, EER analytical studies must have been carried out by operators such as Agip, ExxonMobil, and Shell associated with their operations in the Caspian Sea and Sea of Okhosk; but, results of these are not publicly available.

Results of a set of evacuation and integrated EER reliability sensitivity studies generated by the Bercha Probabilistic EER Simulator (PEERS) for both open water (base case) and ice conditions are summarized in Table 6.

Table 6: EER Reliability in Open and Ice Covered Water

Sensitivity	**Case**	**Description**	**Type**	**Weather**				**Weighted Average**	**Base Increment**	
				Calm .38	**Moderate 048**	**Severe .13**	**Extreme .01**		**Value**	**%**
Base	1.1	OPEN WATER	Evac.	0.9999	0.9949	0.9266	0.1600	0.9796	0.0000	0.00
			EER	0.9924	0.8678	0.3862	0.0049	0.8439	0.0000	0.00
Ice	1.10	ICE PACK 6/10 CONCENTRATION	Evac.	0.9216	0.8931	0.8210	-	0.8974	0.0822	-8.3
			EER	0.6001	0.3211	0.2501	-	0.4171	-0.4268	-50.6
	1.11	SOLID ICE SHEET – NO RUBBLE	Evac.	0.9950	-	-	-	0.9950	0.0154	1.5
			EER	0.9821	-	-	-	0.9821	0.1383	13.82

Selected EER systems based on current twin-davit TEMPSC and secondary chute systems were analyzed for a range of conditions for open and ice covered water locations (Bercha, 2004). The weather weighted average reliabilities are given in the right hand columns, together with their variation from that of the base case. As can be noted, relative to the base case, there is a marginal increase in reliability for both the evacuation (Evac) and integrated EER (EER) in solid ice, giving a percentage increase of 1.5% and 13.82%, respectively. However, there is a significant decrease in reliability for both evacuation and EER for the $^{6}/_{10}$-concentration case, primarily resulting from the dramatic decrease in EER reliability as weather conditions become more severe, resulting in the augmentation of ice pressure.

CONCLUSIONS

Significant activity in the areas of regulation, technology development, and performance analysis of polar EER is currently underway. The following conclusions may be reached from the activities described in this paper:

- Development of performance-based standards is well underway in Canada and internationally (under ISO auspices) with likely promulgation of performance-based standards worldwide within two years.
- Technology development, at least from published records, is very limited. Current polar operational evacuation systems appear to be restricted in reliability to operations under only a part of the environmental conditions likely to be encountered in ice covered and open waters.
- Performance and reliability assessment using analytical methods and computer simulation in comprehensive and well-developed, but its credibility is hampered by the lack of full-scale operational data for validation purposes.
- The imminent promulgation of performance-based reliability regulations and standards for ice covered water EER is likely to result in the acceleration of research and development of optimal EER technologies for ice conditions.

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