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ISO 19906 – IMPLICATIONS FOR ARCTIC OFFSHORE ESCAPE, EVACUATION AND RESCUE

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ABSTRACT

The International Standard ISO 19906 Arctic Offshore Structures was published in December 2010. One topic addressed in the Standard is arctic escape, evacuation and rescue (EER) in the design, construction, transportation, installation, operation and decommissioning phases of a structure. EER is critical to emergency response in arctic conditions (and elsewhere) and is not currently covered in any other ISO Standards. The EER provisions in the Standard are intended to promote the successful escape from the incident, subsequent evacuation from the installation and the ultimate rescue of installation personnel. The Standard specifies design requirements and provides background and guidance on its intended use. This paper describes the ISO 19906 Standard that will supersede most existing arctic EER guidelines and standards worldwide.

INTRODUCTION AND BACKGROUND

Escape, evacuation and rescue (EER) are defined as:

Escape	Act of personnel moving away from a hazardous event to a place on the installation where its effects are reduced or removed
Evacuation	Planned precautionary and emergency method of moving personnel from the installation (muster station or Temporary Refuge – TR) to a safe distance beyond the immediate or potential hazard zone usually off the installation
Rescue	Process by which persons entering the sea or reaching the ice surface, directly or in an evacuation craft, are subsequently retrieved to a place where medical assistance is typically available

Arctic EER is receiving more attention with the resurgence of interest in the Arctic offshore for hydrocarbon exploration and production. Extensive focus on improving EER in open water areas was largely in response to major loss of life/asset incidents (e.g. Ocean Ranger, Piper Alpha, Petrobras 36 and Deepwater Horizon). Comparatively little effort has gone into improving EER systems and procedures in sea ice areas (Bercha 2010). Arctic EER strategies have evolved as activities moved into more challenging ice environments. Emerging technologies and a better understanding of the offshore ice environment may lead to advances in the EER state-of-the-art. Additionally, consistent standards and guidelines were needed.

Performance-based standards (PBS) are verifiable attributes or benchmarks that provide qualitative levels or quantitative measures of performance, which must be achieved. The performance standard is set by the designer/operator and constitutes their safety goal. PBS set out the desired result while prescriptive standards set out details of a process or equipment, which may or may not achieve the desired result (Bercha and Gudmestad, 2008). The overall performance goals of the EER system are to provide: 1) adequate means for personnel to protect themselves while escaping credible incident scenario potential hazards; 2) adequate means for personnel (including injured personnel) to abandon the installation in a controlled manner; and 3) adequate means and support for the rescue of personnel.

As part of their findings, both the Royal Commission on the Ocean Ranger (1984) and the Cullen (1990) inquiry recommended development of performance based EER standards. Until recently, no open water or ice EER performance requirements existed. Transport Canada initiated a multi-year multi-faceted program directed at the development of performance based EER standards for installations in Canadian waters (both ice-free and where ice was present) which is described in Bercha (2008) and Transport Canada (2006) which was followed by ISO in 2010. This paper describes the ISO 19906 (2010) Arctic Offshore Structures Standard that will supersede most existing Arctic EER guidelines and standards worldwide.

ISO 19906 STANDARD

International Standard (ISO 19906, 2010) - "Petroleum and Natural Gas Industries - Arctic Offshore Structures" was developed to address design requirements and assessments for offshore structures used by Industry in arctic regions where ice is present. The Standard provides Industry a coherent and consistent definition of methodologies to design, analyze and assess arctic offshore structures worldwide and is expected to replace existing arctic offshore standards and guidelines. The Standard’s objective is to ensure that offshore structures deployed where arctic conditions prevail, provide an appropriate level of reliability (Bercha and Gudmestad, 2008) with respect to personnel safety, environmental protection and asset value to the owner, to the industry as well as to society. The Standard addresses EER design requirements that are largely performance-based and also provides background and guidance on the use of the document.

The EER provisions in the Standard will be used as part of a continuous improvement process for managing risks and the safety of personnel working offshore in extreme environments. Some of the provisions are derived from open water environments where no such measures currently exist whereas most take into account cold region operations where the persistence of ice conditions place more onerous demands on the EER system. The Standard should be used by designers, Duty Holders and regulators. If utilized as the authors intended, the Standard will foster a system for continuous EER improvement incorporating advances in EER technology, training, procedures, and applications of risk assessment and management in the design, maintenance and operation of an offshore installation in ice-covered waters.

The wide range of environmental conditions including solid stationary ice, dynamic ice, grounded and ungrounded ice rubble, a partial cover and open water pose formidable challenges to developing the EER portion of the Standard. Unfortunately, there is ***no single*** evacuation method currently available that enables personnel to abandon an installation under the full range of environmental/ice conditions. Whereas design concepts, developments and research are ongoing to satisfy these challenges, multiple, diverse means of abandonment, including modifications of open water systems for use in ice are typically required in the interim.

The EER portion of the Standard was developed by the Industry, consulting and regulatory representatives shown in Table 1. The high level content of the EER section of the Standard is provided as Table 2. The normative section stipulates performance-based design requirements for the EER system whereas information Annex A provides background and user guidance.

Table 1. ISO 19906 EER Technical Panel Make Up

Representative	**Region**
Jim Poplin – Panel Chairman	USA
Frank Bercha	Canada
Cees Brummelkamp	Europe
Dave Dickins	USA
Steve Knight	Europe
Marat Mansurov	Russia
Morten Mørland	Europe (sub)
Dag Onshuus	Europe
Victor Santos-Pedro	Canada
Antonio Simões Re	Canada
Garry Timco	Canada

Table 2. EER Section Table of Contents

18	**Escape, Evacuation and Rescue (Normative)**	**A.18**	**Escape, Evacuation and Rescue (Informative)**
18.1	General	A.18.1	General
18.2	Escape, Evacuation and Rescue Philosophy	A.18.2	Escape, Evacuation and Rescue Philosophy
18.3	EER Strategy	A.18.3	EER Strategy
18.4	Environment	A.18.4	Environment
18.5	Hazard and Risk Analysis	A.18.5	Hazard and Risk Analysis
18.6	Continuous Assessment	A.18.6	Continuous Assessment
18.7	EER System Design	A.18.7	EER System Design
18.8	Emergency Response Organization	A.18.8	Emergency Response Organization
18.9	Competency Assurance	A.18.9	Competency Assurance
18.10	Communications and Alarms	A.18.10	Communications and Alarms
18.11	Personal Protective Equipment (PPE)	A.18.11	Personal Protective Equipment (PPE)
18.12	Man Overboard Recovery	A.18.12	Man Overboard Recovery
18.13	Escape Design	A.18.13	Escape Design
18.14	Evacuation Design	A.18.14	Evacuation Design
18.15	Rescue Design	A.18.15	Rescue Design

Figure 1 illustrates a hierarchy governing emergency response documents in which the ISO EER standard provisions can be reflected. This emergency response taxonomy is made up of global international standards, operator or corporate standards and facility-specific standards and procedures. The system for managing EER shall be designed and implemented systematically as diagramed in Figure 2. The three main components of EER, namely hardware design, personnel competence, and procedures and controls comprising the sides of the triangle are equally important in the design and operations phase of the EER system for cold regions hydrocarbon offshore facilities. Hardware integrity includes escape routes, the temporary refuge, evacuation systems, and other systems and needs to be designed to comply with EER system performance standards and maintained to meet environmental, operational and emergency conditions anticipated. Personnel competence requirements need to be defined early in the design process to allow for EER safety training and for the development and assessment of critical roles and responsibilities of the EER chain of command. Personnel need to be trained and organized to deal with the range of anticipated environmental, operational and emergency conditions that could occur. Finally, procedures and controls include aspects such as EER muster procedures, communications requirements, EER scenario developments and related emergency scenario drills, etc. All three components form an integral part of the EER statement of operational readiness that would normally be captured in the facility specific HSE case and should be applied to each part of the EER triangle well in advance of beginning each distinct project phase. Processes and procedures must be in place, checked and verified prior to personnel working offshore and during the various phases of the installation's life.

Both continuous improvement and an assessment process need to be incorporated into the EER system both during the design and operations phases, including times when changes to the installation and/or operations are made. The three components are part of a continuous assessment process with respect to environmental condition preparedness and other risks that can be implemented as part of the overall HSE management system.

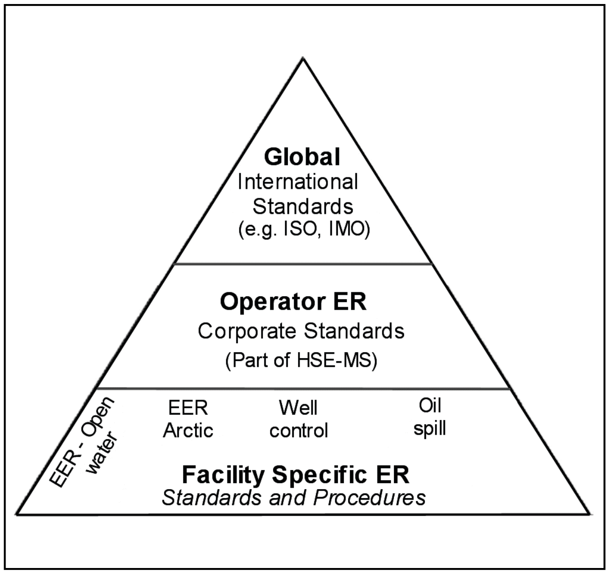

Figure 1. EER hierarchy

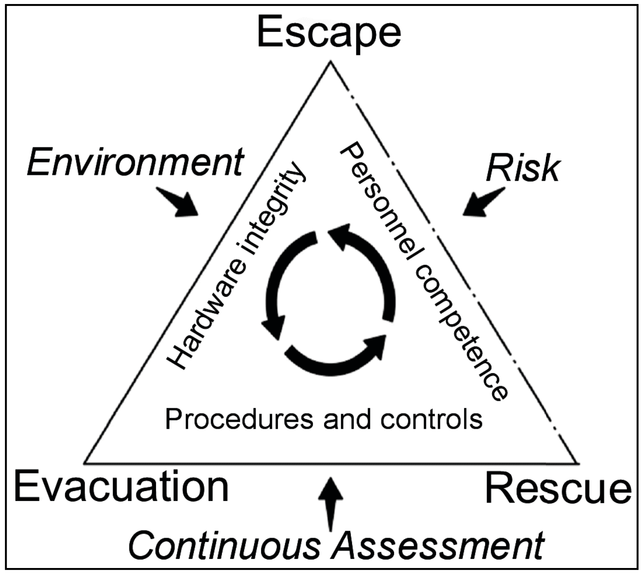

Figure 2. EER philosophy for hydrocarbon facilities

Environmental Factors

The Arctic environment can profoundly influence the design, operational and maintenance success of the EER system necessitating that the full range of physical environment conditions be accounted for when developing and implementing the EER plan (Poplin et al., 1998b; Timco and Dickins, 2005). These include both conditions existing at the platform and those impacting rescue efforts (e.g. between the shore base and the installation). Environmental conditions may include: ice with or without rubble, ice-wave combinations, sea spray and atmospheric icing, air temperature and wind chill, wind (direction and speed), visibility (including the effects of blowing snow, fog and ice mist), cold open water, currents, the amount of daylight and the presence of contaminated hydrocarbons (e.g. H_2S).

A winter EER strategy for a platform operating in the landfast ice regime may be quite different from that where dynamic ice conditions prevail much of the winter. In some instances, the EER strategy for the former scenario may be similar to that for land based drilling operations and could potentially include a provision to evacuate to the surrounding ice cover (Barker et al, 2009; Barker et al., 2007; Barker et al., 2006). The EER strategy developed will need to account for the site-specific environmental conditions that persist in the particular region of interest (Polomoshnov, 1998; Spencer et al., 2007).

Potential scenarios based on varying environmental conditions that could exist when abandoning a platform in a region containing sea ice at least a portion of the year include:

- Open water abandonment with little or no sea ice present
- Abandonment to a newly formed ice cover
- Abandonment to a solid, non moving ice cover, and
- Abandonment to the sea having a partial ice cover.

Dynamic sea ice can pose significant challenges to EER because the ice concentration can vary widely. On the other hand, a dynamic sea ice environment may actually be beneficial for example, in a sour gas release scenario whereby marine evacuation craft (if used), would be carried away from the installation if deployed onto the ice. A partial sea ice cover condition could range from isolated floes to 9/10ths ice with the ice cover that is present potentially able to support personnel and equipment depending on the ice thickness.

Example Case

The full range of environmental conditions as well as hazardous areas on the installation and potential incident scenarios specific to the platform need to be assessed when selecting and positioning lifesaving appliances on the installation. Ice rubble (whether grounded or only temporarily in place) may have a major impact on the winter EER strategy. As ice floes impact the structure they are broken into smaller fragments referred to as ice rubble shown as blocks in the upper left diagram in Figure 3. The ice pieces constituting the rubble may vary in size from individual granules to room size floe fragments. Early in the ice loading event, ice rubble forms as a result of the ice sheet failing against the structure and drifts past the structure. The distance from the structure to the ice that was deformed as a result of its interaction with the structure (see Figures 4a and 4b) is referred to by Poplin and Timco (2003) as the *Ice Damage Zone*.

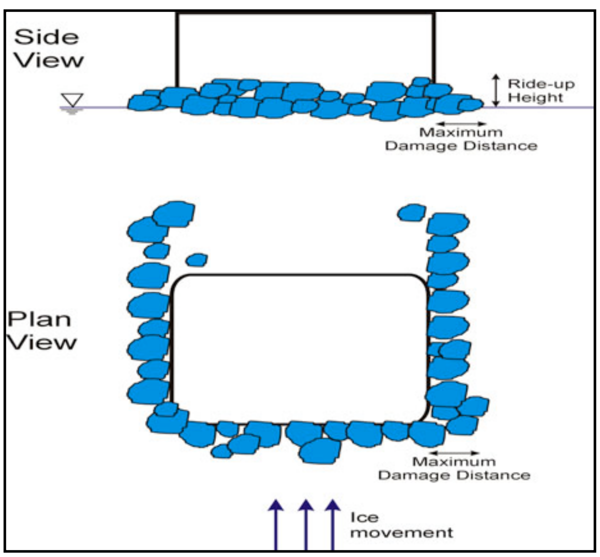

Figure 3. Schematic of ice rubble at a platform.

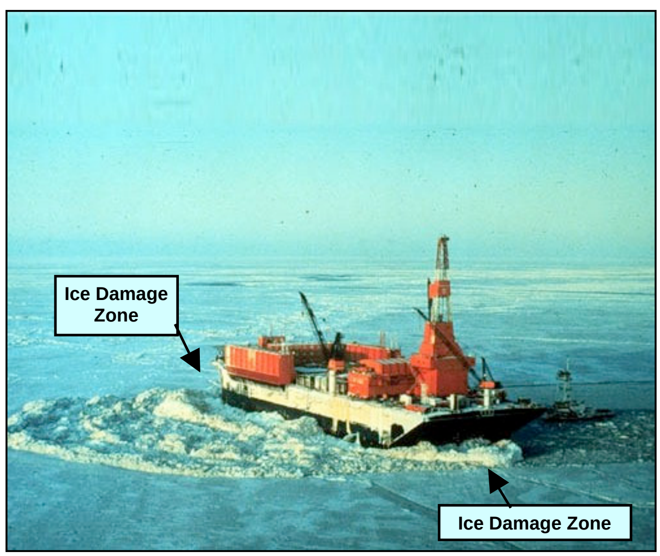

Figure 4a. Ice rubble around the SSDC.

Timco et al., (2006) and Poplin and Timco (2003) reported that the width of the ice damage zone varies in response to factors including the ice thickness, ice failure mode and ice drift velocity. They further noted that ice damage zone widths can vary depending on structure type as shown in Figures 5 and that widths of 10-20 m were not uncommon.

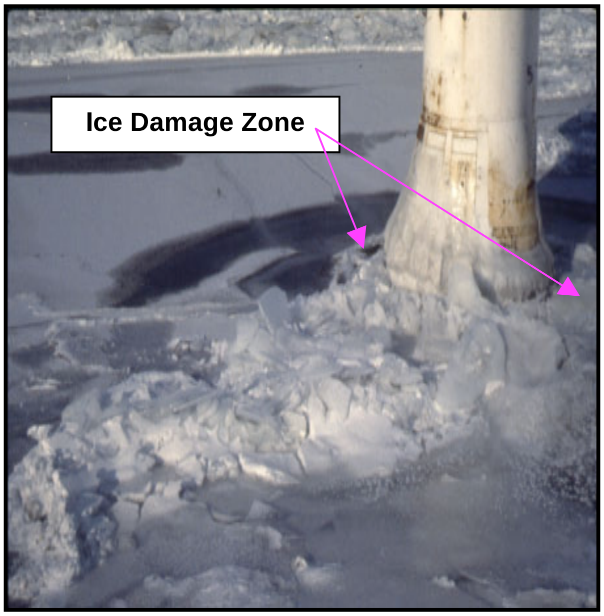

Figure 4b. Conical structure ice damage zone

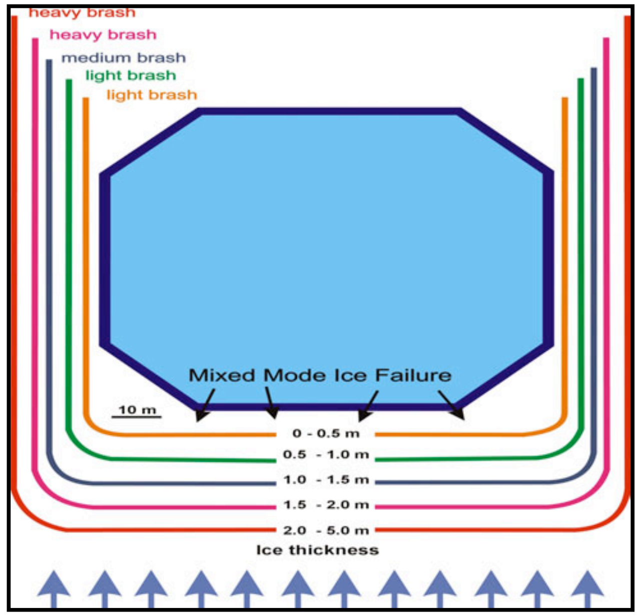

Figure 5. Ice rubble around *Molikpaq* structure (after Timco et al, 2006)

Example rubble fields are shown in Figures 6 and 7. Even though the ice eventually slows or reverses direction, the grounded rubble field may remain. With tidal reversals, it may even be possible, to get grounded rubble around the entire platform. Even if the drifting pack ice moves away from the platform, the grounded rubble field could remain such as that shown in Figure 6.

Figure 6. Ice rubble around gravel island structure.

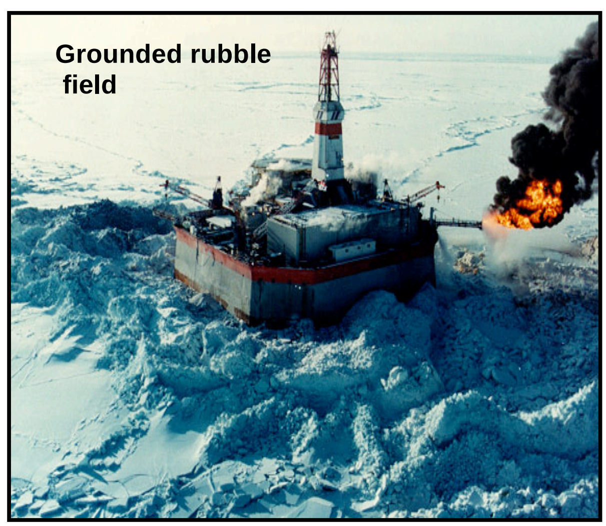

Figure 7. Example rubble field around *Molikpaq*.

The side(s) of the platform being loaded by the drifting pack ice will not be accessible (Figure 8). For a gravity based structure deployed where the predominant ice drift is in the north and south directions, these sides may be unsuitable for evacuation. The lee of the platform could remain an open water wake or could be clogged with ice rubble clearing the platform. However, even if an open water wake exists, it may not enable evacuation due for example to smoke or unignited gas. Therefore, in this example, the preferred sides for platform abandonment from an ice perspective are the east and west.

The EER strategy needs to provide multiple means for platform abandonment under the full range of ice and open water (or any combination thereof) of environmental conditions anticipated. In many cases, this could necessitate that a greater number of lifesaving appliances are available both on and potentially off the installation for orderly and emergency evacuation.

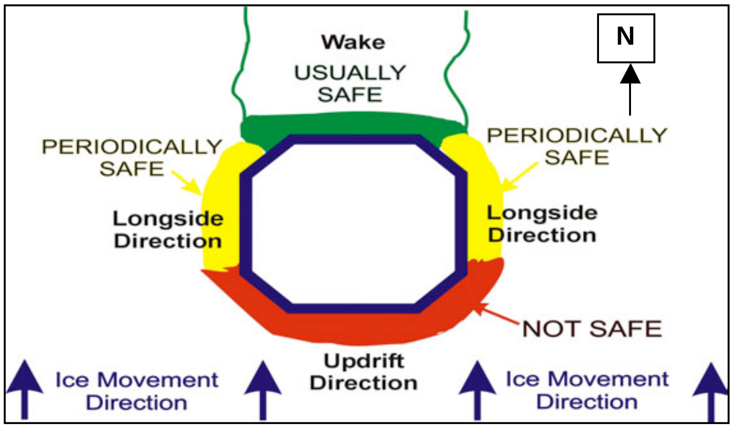

Figure 8. Potential evacuation directions.

Hazard Analysis and Risk Assessment

The EER system must serve to mitigate the effects of major accident hazards to personnel beginning with the earliest indication of a potential hazard and ending when the hazard has been removed or when the rescue of all platform personnel has been completed. The risk analysis process identifies hazards, assesses the frequencies and consequences and identifies adequate preventative, detection, control and mitigation measures. The purpose of such analyses is to assess the design and operations at key stages and to demonstrate that risks to personnel are as low as reasonably practicable (ALARP). However, each Operator is expected to deploy it's own Risk management and Asset Integrity-Process Safety Management system, to support the EER analysis.

To the extent possible, uniformity in the life-saving appliance arrangements is typically strived for across a region by the same operator. Life-saving appliance alternatives are evaluated to demonstrate that the most appropriate system components, procedures and support services have been selected to meet the required EER system performance standards and ALARP principles. Hazards that may potentially cause harm to people, the environment or property are determined. A variety of different methods may be used to estimate the risk. Once the risk level is determined, it is evaluated to identify high risk events, high risk areas or activities on the installation, develop recommendations, and to identify areas that may require future study. The designer may mitigate risks in different ways including preventing the incident from occurring and/or providing mitigations to lesson the severity of the incident's impact should it occur. The alternatives are ranked to identify the preferred approach in terms of project cost and project risk. The formal risk assessment is one input to risk management.

A number of risk studies will typically be undertaken to establish the proposed EER strategy, to refine and test the EER basis and to provide key input data needed to verify the approach. The ISO Standard leaves it up to the designer/operator to select and appropriately use the risk assessment methodologies. The risk studies listed in Table 3 may or may not be applicable and only constitute a subset of the risk assessment options available. Note that continuous assessments need to be performed at strategic periods throughout the design (starting early in the design) and throughout the installation lifecycle including in response to changes.

Table 3. Example risk assessment methodologies.

Risk Study	**Purpose/Description**
EER Analysis	Qualitative and quantitative evaluation to establish and subsequently assess adequacy of EER provisions
Escape Way Study	Assessment of the suitability of escape routes in the event of an emergency incident
Fire Risk Analysis	Fire and explosion hazard assessment to ascertain the extent which these are or could be controlled/mitigated to prevent escalation
Explosion Analysis	Assessment of explosion risk and to identify potential risk mitigation measures for consideration in the design
Temporary Refuge (TR) Impairment Study	Assessment to identify potential impairment mechanisms to the TR and their frequency
Rescue Vessel Probabilistic Event Tree Comparison	Determination of the probabilities for successful EER when utilizing vessel support
Evacuation Craft Arrangements Probabilistic Event Trees	Develop probabilistic event trees for various evacuation craft arrangement configurations and their probability of success
Timeline Study	Estimate of the time available to escape the incident, muster and abandon the facility for credible emergency scenarios

EER DESIGN

EER is an integral part of offshore installation design and therefore needs to be considered early and throughout the design and life cycle (Poplin et al., 1998b). EER system design must be fully integrated within the overall emergency response system. The selected components and procedures of the EER system must be determined by formal, documented risk assessment. The EER system must ensure that in the event of an emergency, installation personnel are protected while they move to a place of safety. The range of credible environmental conditions expected at the installation need to be accounted for. Once selected, the specific EER system needs to be installed, tested and operated according to established performance standards. The system design must take into account the need for regular inspection, maintenance, and testing. The design of rescue systems shall be compatible with the design of evacuation systems in the context of the arctic physical environment. Lifesaving appliances exposed to freezing environments need to be protected and regularly inspected. Finally, power supplies must be available to allow safety critical equipment to perform their emergency functions for the required duration.

The installation emergency response organization shall be documented and summarized (e.g. in a station bill), and posted at strategic locations throughout the installation. Human performance is an integral part of the EER system. The operator shall ensure that all installation personnel are adequately familiar with the safety management system, EER plans and hardware systems.

Additional design and operations considerations are effective communications and alarms. The communication system needs to operate under all emergency scenarios from all relevant locations taking into account geography, distance and environment. Personal protective equipment (PPE) is another critical component of the EER system design. The need for and numbers, types and storage locations of personal protective devices should be determined in the EER analysis and provided for personnel in sufficient numbers. In some cases, evacuee PPE may include devices to facilitate evacuee movement from the sea to ice floes, such as adequate clothing including footwear with traction devices to provide protection and mobility until rescued.

Escape Design

The goal of escape is to ensure that in an emergency, personnel move to a place of relative safety on the installation, consistent with the specified performance standards. Escape system design needs to take into account communications and alarms, escape routes, the temporary refuge, muster stations and PPE locations as well as their integrated function in the escape process.

Escape routes shall be designed to ensure that personnel can safely move from any part of the installation to the TR or muster station under credible incident, physical environmental and operational conditions. Escape routes, stairways and ladders need to be sized appropriately to take account of bulky cold weather PPE and the maximum flow of personnel in an emergency, as well as being illuminated and signed adequately. Exit doors, stairways and ladders must also be appropriately designed and maintained accessible taking account the potential for sea spray and atmospheric icing and/or snow accumulations. Escape ways should lead to a temporary refuge or to the muster areas. When provided, the TR shall be demonstrated to protect personnel from any credible incident and physical environmental effects for a time sufficient to allow control of the emergency or until a decision is made to abandon the installation.

Evacuation Design

The primary goal of evacuation is to ensure that personnel are able to leave the installation to a place of relative safety outside the hazard zone consistent with the developed performance standards. Personnel moving from the TR or muster station to the primary embarkation areas will need to be afforded protection from the installation hazards as well as the environment. There shall be as many independent evacuation systems and configurations as needed in accordance with the EER analysis.

Evacuation methods (whether installation or non-installation based) need to be assessed in the EER analysis according to number, location, orientation and means used. The design and selection of evacuation methods will typically include a risk assessment of the highest probability of incurring casualties, taking into account the range of credible physical environmental conditions during emergency, precautionary and scenario drill evacuations. Evacuation methods (e.g. boarding, securing, deployment, clearing the hazard zone, etc.) shall be designed to perform reliably for the credible environmental, operational, and incident condition combinations. Further, they need to be visible, identifiable, and provide location information to search and recovery platforms under design installation hazard and environmental conditions. Systems and/or methods for both precautionary and emergency evacuation need to be considered.

Existing and emerging evacuation systems (Poplin et al., 1998b) may include, but are not limited to: helicopters, extended life temporary refuge, ice management standby vessel, Seascape system of evacuation (O'Brien, 2003), ARKTOS evacuation craft (Seligman and Hall, 2010) modified TEMPSCs (lifeboats) or launch arrangements (Power, et al., 2010; Kennedy et al., 2010) telescoping gangways to the sea, ice or vessel, escape chutes and slides to the sea, ice or vessel, hovercraft, evacuation shelters on the ice (Barker et al., 2009) and combinations of systems used together. Each independent method (type) of evacuation shall typically accommodate the full complement of personnel on-board (POB) the installation, including visitors, under any emergency scenario requiring evacuation. The evacuation methods need to be designed and located to minimize the effect of the surrounding ice cover in their deployment and movement beyond the incident hazard zone.

An ideal evacuation system for ice covered waters allows personnel to abandon the facility in response to an emergency under any ice or open water sea condition and proceed a safe distance from the disabled facility to await rescue. Several promising EER concepts are emerging that may offer significant performance enhancements compared to systems currently available. When evaluating evacuation systems, one needs to address occupant space and restraint design given that evacuees may be donning bulky cold regions PPE and/or respiration protection. The design of the boarding area layout, and launching equipment and method needs to account for the safety of personnel during emergency use as well as during drills and maintenance. To facilitate rescue, the evacuation system should have a provision onboard for retrieval of personnel, including injured personnel from the sea or ice. Thus PPE may need to include specialized arctic clothing.

Rescue Design

The goal of rescue is to retrieve evacuees to a place of safety or safe haven. The design integrity of the rescue system shall ensure that evacuees are recovered in the prevailing physical environmental conditions. Therefore, a means must be available to recover evacuees from the sea, the ice, or from evacuation systems onto a rescue platform. As such, rescue platforms must have equipment and capabilities suitable for locating and recovering evacuees. Rescue system design needs to take into account: 1) survival in the anticipated environmental conditions, 2) shelter strategies deployed on a stable ice cover where warranted, 3) design integrity of hardware and personnel components, 4) communications systems including with the rescue platform, 5) lifting appliances for evacuee recovery, 6) tertiary evacuation system interfaces where deemed necessary, 7) medical treatment for rescued personnel, 8) materials suited for cold temperatures and ice, 9) the propulsion system taking into account the range of natural and incident impacted environmental conditions, and 10) the rescue vessel including bridge and deck layouts.

DISCUSSION

The EER component of ISO 19906 incorporates industry and country standards and provisions, human factors guidelines and best practices. It will supersede existing standards and guidelines. The Standard does not preclude the use of emerging technologies provided that the reliability of these systems can be demonstrated in the environments/applications proposed. The Standard does not specify EER requirements or methodologies that must be used to verify the EER strategies, but rather leaves it up to the designer/operator to do so by applying sound engineering practices.

The Standard contains a provision for a deviation process that includes a formal review and approval for the deviation. Users of the Standard need to be aware that to date, the effectiveness of EER systems in ice-covered waters has not been fully assessed under emergency conditions.

CONCLUSIONS

An overview of the EER section of the ISO 19906 Arctic Offshore Structures Standard was given. The Standard provides Industry a coherent and consistent definition of methodologies to design, analyze and assess arctic offshore structures worldwide and is expected to replace existing arctic offshore standards and guidelines. The Standard will assist designers and operators toward the development of a viable EER strategy. Formal assessments should be carried for each offshore installation based on performance standards taking into account the full range of considerations. The EER strategy needs to provide for platform abandonment under the full range of incident and environmental conditions anticipated in the arctic environment which with current technology relies on multiple systems. The EER strategy for the open water season in cold regions may rely heavily on the sound use of current technology. The Standard does not preclude the use of promising EER concepts that are emerging that may offer significant performance enhancements compared to systems currently available.

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