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Escape, Evacuation, and Rescue Research Project

Phase II

Prepared for
Transportation Development Centre
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by

BERCHA GROUP
Bercha Engineering Limited

April 2003

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16. Abstract

This report describes Phase II of the research and development program leading to the implementation of Escape, Evacuation, and Rescue (EER) Performance-Based Standards (PBS) for Canadian East Coast offshore oil and gas installations. The principal tasks addressed under Phase II were as follows:

- Study of human performance under extreme conditions.
- Reliability analysis of a specific evacuation system.
- Expansion and improvement of computerized EER simulator, the Risk and Performance Tool (RPT).
- Application of RPT to generate information in support of the PBS development program.
- Facilitation, coordination, and technical and administrative support of the PBS development program.

The effects on human performance of psychological and physiological stressors, resulting from extreme conditions, were evaluated and methods of quantifying them for incorporation into the RPT were developed. The RPT was applied to the reliability analysis of the Preferred Orientation and Displacement (PROD) system, with results including the distribution of contributions of human and mechanical factors to evacuation performance. Version 4.0, the new version of the RPT, includes extended options for reliability and availability analysis, human factors, and output multiple generation. Finally, the development of the PBS was advanced, through numerous draft revisions, from an initial draft to a final draft ready for implementation through the facilitation of, and participation in, a multi-disciplinary process involving technical experts, administrators, and stakeholders.

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16. Résumé

Le présent rapport décrit la phase II du programme de recherche et développement devant mener à la mise en œuvre de normes axées sur la performance (NAP) relatives aux systèmes de secours, d'évacuation et de sauvetage (SES) destinés aux installations pétrolières et gazières exploitées au large de la côte est du Canada. Voici les principales tâches accomplies au cours de la phase II :

- Étude des performances humaines dans des conditions extrêmes.
- Analyse de fiabilité d'un système d'évacuation.
- Expansion et perfectionnement d'un logiciel de simulation de systèmes SES, appelé outil d'évaluation du risque et du rendement (OERR).
- Application de l'OERR à la collecte d'information à l'appui du programme d'élaboration de NAP.
- Facilitation, coordination, et soutien technique et administratif du programme d'élaboration de NAP.

Les chercheurs ont évalué les effets sur les performances humaines des agents de stress psychologique et physiologique associés aux conditions extrêmes, et ils ont mis au point des méthodes pour quantifier ces agents stressants en vue de leur incorporation à l'OERR. Cet outil a été appliqué à l'analyse de fiabilité du dispositif à déplacement et orientation privilégiés (PROD, pour *Preferred Orientation and Displacement*). Les résultats de cette analyse ont mis en relief les contributions relatives des facteurs humains et mécaniques au succès de l'évacuation. La dernière version (4.0) de l'OERR comprend des options supplémentaires pour les analyses de fiabilité et de disponibilité, la prise en compte des facteurs humains et la génération multiple de résultats. Finalement, l'élaboration des NAP s'est poursuivie : au terme d'un processus itératif qui a donné lieu à de multiples révisions, le projet de norme a abouti à une version finale, prête à être mise en œuvre, à la faveur d'une démarche multidisciplinaire qui a réuni des experts techniques, des administrateurs et diverses parties intéressées.

17. Mots clés
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▪ Ernst Radloff	• Senior Development Officer, Transport Canada, Scientific Authority, EER Research Project
▪ Paul Barnes	• Manager, East Coast, Canadian Association of Petroleum Producers (CAPP)
▪ Ian Denness	• Manager, Total Loss Management – Environment, Health, Safety & Security, Offshore Development Operations, Petro-Canada • CAPP Representative, EER Research Project Steering Committee
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▪ António J. Simões Ré	• Research Officer, Advanced Projects and Business, Development, Institute for Marine Dynamics, National Research Council of Canada

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EXECUTIVE SUMMARY

Summary of Work

The scope of work consisted of the provision of research support for, and the development of Escape, Evacuation, and Rescue (EER) Performance-Based Standards (PBS) for installations in Canadian waters.

The provision of research support can be best described under three areas as follows:

(1) Study of human performance under extreme conditions.

(2) Reliability analyses of specialized evacuation systems.

(3) Development of the Risk and Performance Tool (RPT).

In the study of human performance under extreme conditions, the effects of psychological and physiological stressors on error rate and time of performance by personnel was studied, quantified, and incorporated into the RPT. Psychological stressors within the context of EER are primarily the effects of life-threatening accident conditions that may occur in association with an emergency installation abandonment. Physiological stressors are the physical effects of the accident causing the emergency. Such physiological stressors include movements and deformations of the installation, toxic emissions, and thermal radiation and explosion overpressures. In this study, methods of quantifying the effects of these types of stressors were defined and incorporated into the RPT to expand its capability from that of simulating drill situations to that of simulating life-threatening situations.

In the second area of research, two specialized evacuation systems, the Seascape system and Preferred Orientation and Displacement (PROD) system were reviewed, and the latter system was subjected to a reliability analysis. Specifically, the PROD system, an enhanced lifeboat launch system, was analyzed utilizing the RPT with validation from available full-scale launch data. The results from the analysis indicated the relative importance of human and mechanical failures, and priorities for maintenance and training based on the relative contributions of different activities and mechanical failures that result in launch failures.

A new version of the computer simulation program, the Risk and Performance Tool (RPT), was generated incorporating three principal improvements and modifications. The first improvement was the subdivision of the task analysis into human error and mechanical failure components, so that the users are able to trace system faults not only to the task, but also to the type of failure causing the task to fail. Second, two sub-versions of the RPT were created: one giving all-inclusive success rates, which include considerations of both system availability and reliability, and the second giving success rate without considering availability. These two versions were required in support of the PBS program. Finally, the RPT was used to generate a wide spectrum of results for all practical combinations of evacuation and rescue modes, and weather and accident conditions in order to provide strategic and tactical information to be included in the Standards.

The second principal area of work covered under this project was the development of the Performance-Based Standards (PBS). This work included facilitation, coordination, standards drafting, meeting organization, information generation, and extensive communication and consultation to advance the draft standards to their final draft for implementation. Three main organizational functions were required under this work: direction and participation in a technical Task Force, facilitation of Steering Committee meetings, and consultation with stakeholders through an appropriate process. During the tenure of the present contract, the PBS were advanced from a rough first draft to a polished final draft ready for implementation in March 2003.

Conclusions

Conclusions from Study of Human Performance Under Extreme Conditions

Human performance, as represented by error rate and time to perform tasks, is significantly affected by physical and psychological stressors. The effects of these stressors can be quantified through appropriate factors, which have been incorporated into the RPT to reflect the conditions under which tasks, activities, and process are performed.

Specific conclusions for evacuation, which was analyzed in detail for both human error and mechanical failure, may be summarized as follows:

- For evacuation in calm conditions, human error and mechanical failure made the same contribution.
- Under moderate and severe conditions, human error contributed roughly twice as much to failure as mechanical failure.
- Under extreme conditions, both human error and mechanical failure were at the limit (90%), essentially meaning the probability of failure is very high.
- Evacuation success rate is high in calm and moderate conditions but decays rapidly from severe to extreme weather.
- The weighted average (WA) evacuation and total EER values represent average expectations for a specific site.
- For the example offshore location, human error, on the average (WA), contributes roughly twice as much to evacuation failure as mechanical failure.

Table 1 provides results for a twin-davit lifeboat launch, substantiating the above conclusions, while Figure 1 graphically illustrates them.

Table 1 Twin-davit TEMPSC evacuation and EER human and mechanical performance contributions and success rates (%)

		Evacuation					EER
		Calm	**Moderate**	**Severe**	**Extreme**	**Evac. WA**	**EER WA**
TEMPSC	Human Error	1	2	36	90	7	-
	Mechanical Failure	1	1	20	90	4	-
	Success Rate	99	96	43	10	89	70

Note: **Evac.WA** - Evacuation weather-weighted average
EER WA - Total EER weather-weighted average success rate

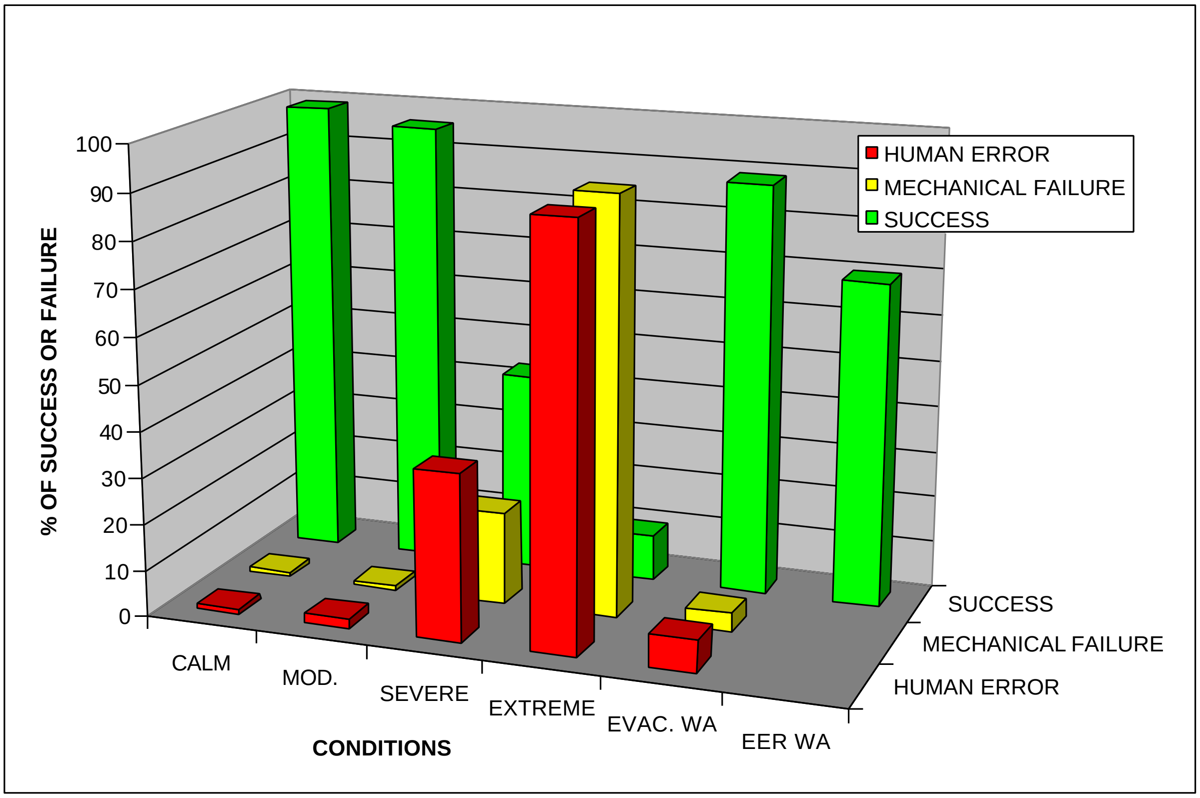

Figure 1 Twin-davit TEMPSC evacuation and EER human and mechanical performance contributions and success rates

Conclusions from PROD Reliability Analysis

The PROD reliability analysis demonstrated the contributions of human and mechanical performance to the success of a launch of the PROD system. The following conclusions may be drawn from the reliability analysis conducted:

- PROD evacuation success rate is highly dependent on environmental state, with a significant decay as environmental conditions move from severe to extreme.
- Mechanical failure is independent of the emergency stress level, as the equipment is expected to function in the same manner regardless of the psychological stress. However, mechanical failure probability increases rapidly with severity of weather, approaching unity (100%) for extreme conditions.
- Human error performance decays significantly with increase in emergency psychological stress level, with human error probability doubling from drill to precautionary emergency, and increasing by approximately an order of magnitude (factor of 10) from drill to life-threatening emergency.
- The principal activities that can result in critical human errors are roughly equally distributed in their order of importance; however, the correct manoeuvring of the craft to clear the installation provides an increasing proportion of the human error failure probability as the weather becomes more severe.
- Of the mechanical functions, the reliability of the craft release gear and lowering mechanism outweigh the importance or the expected contribution to failure of boom tether disconnect, engine starting, and craft manoeuvrability function.

Conclusions from Risk and Performance Tool (RPT) Development

The RPT Version 4.0 is the most advanced and comprehensive EER computer simulation model currently in existence.

In addition to the capabilities possessed by Version 3.5, the current work has successfully incorporated the following additional RPT capabilities:

- Tracking of human performance contributions to all tasks, activities, and processes in the EER process.
- A reliability version and an availability version so that system reliability can be modeled with or without the inclusion of availability.
- Generation of a full spectrum of reliability values for all practical combinations of nine evacuation modes, four recovery platforms, four weather conditions, and three psychological emergency stress levels.

Conclusions from the EER PBS Development Program

The conclusions summarized below encapsulate the lessons learned to date from the conduct of the PBS development program.

- Although extensive prescriptive regulations and guidelines on offshore EER exist, no comprehensive set of PBS appears to be available.
- Development of new PBS, as undertaken here, is likely to require significant amounts of applied research to rigorously formulate and quantify the PBS targets or goals.
- In conducting a PBS development program, the separation of the administrative and management functions and the research and technical functions is desirable. Accordingly, in the present program, a Steering Committee and a Task Force were established to address the administrative and technical functions, respectively.
- An effective PBS development program requires consultation with all stakeholders, including regulators, operators, suppliers, labour, experts, and other interested parties. Although stakeholder information sessions can be successfully conducted in informal verbal form, stakeholder comments and PBS replies should be carried out formally in writing.
- An adequate schedule to accommodate all aspects of the PBS development program should be established. For a national level program such as the present one, the schedule should allow for identification of data gaps and research priorities, conduct of the research itself, standards drafting, stakeholder consultation, and publication and final promulgation. Figure 2 shows a schematic of the PBS program and schedule to date.

Recommendations

Recommendations on Study of Human Performance Under Extreme Conditions

Further development of the understanding of parameters characterizing human performance under extreme conditions can be achieved through a combination of additional numerical simulation or Monte Carlo modeling, studies of the effects on human performance of training and equipment and procedure ergonomics, and expansion of stressors to include ice and cold weather effects. The following summarizes the recommendations:

- Derive distributions for human error and performance times and conduct Monte Carlo studies to assess the confidence intervals of the RPT predictions.
- Through a study similar to that used to date, including data assimilation and Delphi techniques, assess the effect of training on human performance under extreme conditions and integrate this into the RPT.
- Conduct a similar study on equipment and procedure ergonomics and incorporate these into the RPT.
- Assess the physical and psychological effects of ice and cold weather on human performance in EER and incorporate this into the RPT.

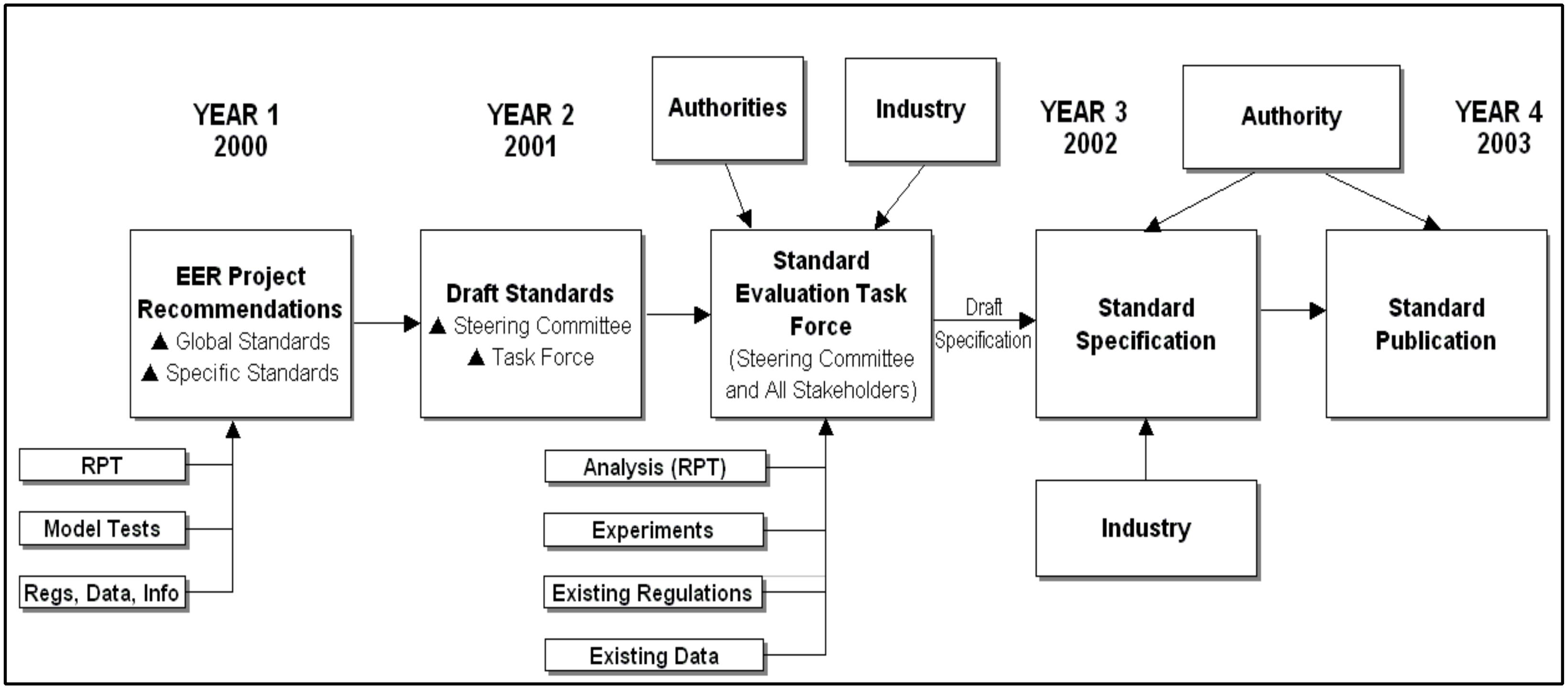

Figure 2 PBS development

Recommendations on PROD and Seascape Reliability Analysis

Results of the current PROD and reliability analysis should be used as inputs to the design of further PROD model and full-scale experiments, and PROD system implementation.

Although initially the scope of work included the analysis of the Seascape 2000 system, work with the system was restricted to two site visits involving inspections of the lifeboat comprising part of the system. In the future, a launch reliability analysis based on full-scale launches should be conducted utilizing reliability engineering techniques and the RPT.

Recommendations on the RPT Development

The RPT in its current version, Version 4.0, provides satisfactory function for support of the majority of the PBS requirements. From a practical application point of view, however, it lacks the ability to simulate post-accident scenarios, individual evacuation and rescue devices, and ice and cold weather performance. In addition, to be optimally useful to administrators having jurisdiction over the PBS, it should be further refined in its functionality in order to be more user-friendly. The following specific recommendations are intended to optimize the RPT:

- Develop an individual and mass evacuation systems module to include evacuation methods such as abseil devices, buoys, and ladders.
- Develop an accident inventory module and integrate it into the RPT to provide methods for assessing and incorporating the effects on EER of different emergency-initiating accidents such as fires, explosions, or loss of stability.
- Develop an ice and cold weather RPT (IRPT) that would involve the expansion of the RPT to include ice conditions and cold weather effects on EER.
- Generate ice and cold weather reliabilities for the scope of EER systems addressed in the PBS.
- Develop user-friendly RPT comprising the normal tasks in the transformation of the scientific Beta version of a software program to a technical user version.

Recommendations on EER Performance-Based Standards Development

Since the EER Standards are largely under the control of the Steering Committee, the petroleum boards, the National Energy Board, and Transport Canada, specific recommendations on their implementation will largely depend on inter-agency agreements and priorities. However, general recommendations on the continuation of the standards development program and implementation of the Standards can be made as follows:

- Conduct inter-agency meetings and discussions to determine the precise regulatory framework for the Standards. Options include Transport Canada federal regulations, board regulations, or industry guidelines.

- Adjust the final version of the Standards to be fit for purpose for the regulatory framework chosen. Maintain an open consultative process with stakeholders through appropriate forums such as the stakeholder information workshops.
- Maintain an expert technical body to answer stakeholder concerns, expand the Standards as required for their regulatory framework, and address new issues associated with the Standards. The most effective way to do this with continuity is to maintain the current Task Force for the Standards.
- Provide an adequate time schedule, in the order of two to three years for final implementation.
- Budget the necessary resources to accomplish the above tasks.

SOMMAIRE

Sommaire des travaux

Les travaux consistaient à faire les recherches préalables à l'élaboration de normes axées sur la performance (NAP) touchant les systèmes de secours, d'évacuation et de sauvetage (SES) destinés aux installations se trouvant dans les eaux canadiennes, et à élaborer lesdites normes.

Les recherches préalables visaient trois domaines :

(1) Étude des performances humaines dans des conditions extrêmes.

(2) Analyses de fiabilité de systèmes d'évacuation spécialisés.

(3) Développement de l'outil d'évaluation du risque et du rendement (OERR).

L'étude des performances humaines dans des conditions extrêmes a consisté plus précisément à cerner et quantifier les effets des agents de stress psychologique et physiologique sur le taux d'erreur et le délai d'évacuation, et à incorporer ces données dans l'OERR. Les agents de stress psychologique, tels que compris ici, résultent principalement de conditions qui mettent la vie en danger, conditions souvent associées à l'accident qui a déclenché l'abandon de l'installation. Quant aux agents de stress physiologique, ils sont assimilés aux effets physiques de l'accident à l'origine de la situation d'urgence. Ces agents comprennent notamment les mouvements et les déformations de l'installation, les émissions toxiques, le rayonnement thermique et les surpressions causées par des explosions. Au cours de l'étude, des méthodes pour quantifier les effets de ces types d'agents stressants ont été définies et incorporées à l'OERR. Cela a amélioré les capacités de cet outil, qui ne simule plus des situations d'exercice d'évacuation mais plutôt des situations constituant un danger pour la vie.

Le deuxième domaine de recherche a comporté l'étude de deux systèmes d'évacuation spécialisés, soit le système Seascape et le dispositif à déplacement et orientation privilégiés (PROD, pour *Preferred Orientation and Displacement*), puis l'analyse de fiabilité du PROD, dispositif qui facilite la mise à l'eau des canots de sauvetage. Cette analyse a été effectuée à l'aide de l'OERR, puis validée au moyen de données issues d'expériences de mise à l'eau en vraie grandeur. Les résultats de l'analyse ont révélé l'importance relative des défaillances humaines et mécaniques et, corollairement, ont souligné les priorités en matière d'entretien et de formation, cela à partir des contributions relatives de différentes activités et défaillances mécaniques à l'échec des mises à l'eau.

Une nouvelle version du logiciel de simulation appelé outil d'évaluation du risque et du rendement (OERR) a été mise au point, laquelle comporte trois grandes améliorations. Premièrement, l'analyse des tâches a été subdivisée en deux composantes : erreur humaine et défaillance mécanique. Les utilisateurs peuvent donc relier les défaillances du système d'évacuation non seulement à une tâche, mais aussi au type de défaillance qui a mené à

l’échec de la tâche. Deuxièmement, deux sous-versions de l’OERR ont été créées : une qui donne des taux de succès tout compris, c’est-à-dire qui tient compte à la fois de la disponibilité et de la fiabilité du système, et l’autre qui donne un taux de succès sans tenir compte de la disponibilité du système. Ces deux versions s’étaient avérées nécessaires pour appuyer le programme de NAP. Finalement, l’OERR a servi à produire un large éventail de résultats pour toutes les combinaisons possibles de modes d’évacuation et de sauvetage, de conditions météorologiques et de conditions d’accidents. De ces données a été extraite une information stratégique et tactique à inclure dans les normes.

Après les recherches préliminaires, l’autre grand volet du projet a été abordé, soit l’élaboration des NAP. Ces travaux ont comporté diverses tâches de planification, de coordination, de rédaction de projets de normes, d’organisation de réunions et de transmission d’information. En outre, des communications suivies et d’intenses consultations ont été nécessaires pour amener les projets de normes au statut de version définitive, prête à être mise en œuvre. À ces travaux de normalisation se sont greffées trois grandes fonctions administratives : diriger le Groupe de travail technique et y participer, animer les rencontres du Comité directeur et consulter les parties intéressées selon un processus approprié. Ainsi, pendant la durée du présent contrat, les NAP sont passées de l’état brut de la première version à l’état châtié de la version définitive, prête à être mise en œuvre en mars 2003.

Conclusions

Conclusions - Étude des performances humaines dans des conditions extrêmes

Les performances humaines, telles que représentées par le taux d’erreur et le délai d’exécution associés à une tâche, sont significativement altérées par les agents de stress physique et psychologique. Il est possible de quantifier les effets de ces agents en mesurant certains facteurs qui révèlent les conditions dans lesquelles se déroulent les tâches, activités et processus. Ce sont ces facteurs qui ont été incorporés à l’OERR.

Des conclusions précises ont été formulées concernant la tâche d’évacuation, laquelle a été analysée en détail tant du point de vue des performances humaines que des défaillances mécaniques. Les voici :

- Lors d’une évacuation dans des conditions calmes, le rôle de l’erreur humaine et celui de la défaillance mécanique s’équivalent.
- Dans des conditions allant de modérées à rigoureuses, le rôle de l’erreur humaine est environ deux fois plus important que celui de la défaillance mécanique dans l’échec de l’évacuation.
- Dans des conditions extrêmes, autant l’erreur humaine que la défaillance mécanique sont à leur limite (90 %), ce qui signifie essentiellement une probabilité d’échec très élevée.
- Le taux de succès de l’évacuation est élevé dans des conditions calmes et modérées, mais il décline rapidement dans des conditions météorologiques allant de rigoureuses à extrêmes.

- La moyenne pondérée (MP) des évacuations et les valeurs totales d'une simulation SES représentent les attentes moyennes pour un site donné.
- Pour l'installation en mer citée à titre d'exemple, l'erreur humaine joue un rôle deux fois plus important, grosso modo, que la défaillance mécanique dans l'échec de l'évacuation, comme le révèle la comparaison des MP associées à ces deux facteurs.

Le tableau 1 présente les résultats obtenus pour la mise à l'eau d'une embarcation de sauvetage à l'aide d'un bossoir à garants doubles, qui confirment les conclusions ci-dessus, et la figure 1 donne une illustration graphique de ces résultats.

Tableau 1 Évacuation d'une ESMEF à l'aide d'un bossoir à garants doubles et simulation SES – Contribution des performances humaines et mécaniques et taux de succès (en %)

		Évacuation					**SES**
		Calmes	**Modérées**	**Rigoureuses**	**Extrêmes**	**MP Évac.**	**MP SES**
ESMEF	Erreur humaine	1	2	36	90	7	-
	Défaillance mécanique	1	1	20	90	4	-
	Taux de succès	99	96	43	10	89	70

Nota : **MP Évac.** – Moyenne des évacuations pondérée selon les conditions météo
MP SES – Taux de succès moyen pondéré selon les conditions météo pour toutes les simulations SES

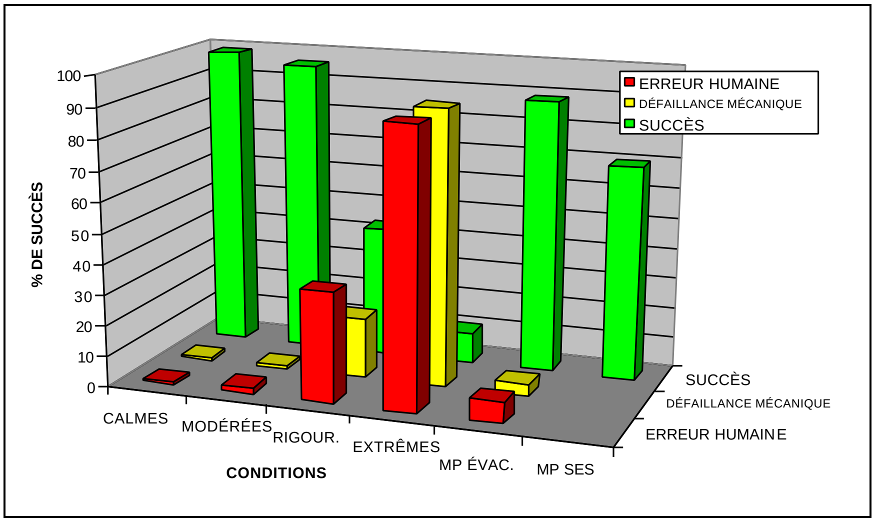

Figure 1 Évacuation d'une ESMEF à l'aide d'un bossoir à garants doubles et simulation SES – Contribution des performances humaines et mécaniques et taux de succès

Conclusions - Analyse de fiabilité du dispositif PROD

L'analyse de fiabilité du dispositif PROD a démontré les contributions relatives des performances humaines et mécaniques au succès d'une mise à l'eau à l'aide du dispositif PROD. Voici les conclusions auxquelles a mené l'analyse de fiabilité :

- Le taux de succès de l'évacuation à l'aide d'un dispositif PROD est largement tributaire des conditions environnementales, ce taux déclinant radicalement lorsque les conditions environnementales passent de rigoureuses à extrêmes.
- La défaillance mécanique est indépendante du niveau de stress occasionné par la situation d'urgence, car le matériel fonctionne en principe de la même manière, peu importe l'état de stress psychologique des utilisateurs. Mais la probabilité de défaillance mécanique augmente rapidement lorsque les conditions météorologiques s'aggravent, se rapprochant de l'unité (100 %) dans des conditions extrêmes.
- Les performances humaines décroissent de façon importante lorsque le niveau de stress psychologique attribuable à la situation d'urgence augmente, la probabilité d'erreur humaine étant deux fois plus grande dans une situation d'urgence préventive que dans une situation d'exercice, et d'environ un ordre de grandeur (facteur de 10) plus grande dans une situation d'urgence où la vie est en danger que dans une situation d'exercice.
- Les principales activités susceptibles de mener à des erreurs humaines graves sont assez également réparties par ordre d'importance; toutefois, la manœuvre correcte de l'embarcation, qui exige notamment de l'éloigner suffisamment de l'installation, donne lieu à une probabilité croissante d'erreur humaine, à mesure que les conditions météorologiques deviennent plus difficiles.
- Parmi les fonctions mécaniques, la fiabilité du mécanisme de mise à l'eau des embarcations de sauvetage joue un rôle plus grand dans le succès de l'évacuation que le sectionnement du filin qui rattache l'embarcation au tangon, le démarrage du moteur et la manœuvrabilité de l'embarcation.

Conclusions - Développement de l'outil d'évaluation du risque et du rendement (OERR)

La version 4.0 de l'OERR est le logiciel le plus évolué et le plus complet qui existe pour la simulation d'une opération SES.

Les présents travaux ont enrichi les capacités de la version 3.5 du logiciel en y ajoutant celles-ci :

- Suivi de l'importance du facteur «performances humaines» dans toutes les tâches, activités et processus en jeu dans une opération SES.
- Choix entre une version «fiabilité» et une version «disponibilité», qui permet de modéliser la fiabilité d'un système sans nécessairement tenir compte de sa disponibilité.
- Production de toute la gamme des valeurs de fiabilité pour toutes les combinaisons possibles de neuf modes d'évacuation, quatre plates-formes de récupération, quatre

conditions météorologiques, et trois niveaux de stress psychologique associés à une situation d'urgence.

Conclusions – Programme d'élaboration de NAP visant les systèmes SES

Les conclusions résumées ci-après représentent les leçons tirées à ce jour du programme d'élaboration de NAP.

- Malgré toutes les règles et lignes directrices normatives en vigueur concernant les systèmes SES, il ne semble pas exister d'ensemble complet de NAP.
- L'élaboration de nouvelles NAP, telle qu'entreprise en marge du présent projet, nécessitera probablement d'importants travaux de recherche appliquée axés sur une formulation et une quantification rigoureuses des valeurs cibles et des objectifs associés aux normes.
- Pour mener à bien un programme d'élaboration de NAP, il est souhaitable de séparer les fonctions administratives des fonctions techniques, y compris la recherche. C'est pourquoi, aux fins du présent programme, un Comité directeur et un Groupe de travail ont été établis, qui assument respectivement les fonctions administratives et techniques.
- Un bon programme d'élaboration de NAP nécessite des consultations avec toutes les parties intéressées : organismes de réglementation, exploitants, fournisseurs, travailleurs, experts et autres intervenants concernés. Pour transmettre l'information aux intervenants, des séances d'échanges verbaux informels conviennent tout à fait. Mais les commentaires des intervenants, notamment en réponse aux projets de normes, doivent être consignés dans des procès-verbaux formels.
- Un calendrier doit être établi pour l'élaboration des NAP. Celui-ci doit tenir compte de tous les aspects d'une telle entreprise. Dans le cas d'un programme d'envergure nationale, comme le présent programme, le calendrier doit prévoir les étapes suivantes : inventaire des données manquantes et établissement des priorités en matière de recherche, exécution des travaux de recherche, rédaction d'un projet de norme, consultation des parties intéressées et publication et promulgation finale de la norme. La figure 2 donne un aperçu du programme d'élaboration de normes et du calendrier établi à ce jour.

Recommandations

Recommandations – Étude des performances humaines dans des conditions extrêmes

Pour mieux comprendre les paramètres qui caractérisent les performances humaines dans des conditions extrêmes, il y a lieu de combiner diverses stratégies, soit réaliser d'autres simulations numériques ou d'autres modélisations à l'aide de la méthode Monte-Carlo, mener des études sur les effets de la formation et de l'ergonomie du matériel et des procédures sur les performances humaines, et se pencher sur d'autres agents stressants, comme les effets des conditions de glace et du temps froid. Voici un résumé de ces recommandations :

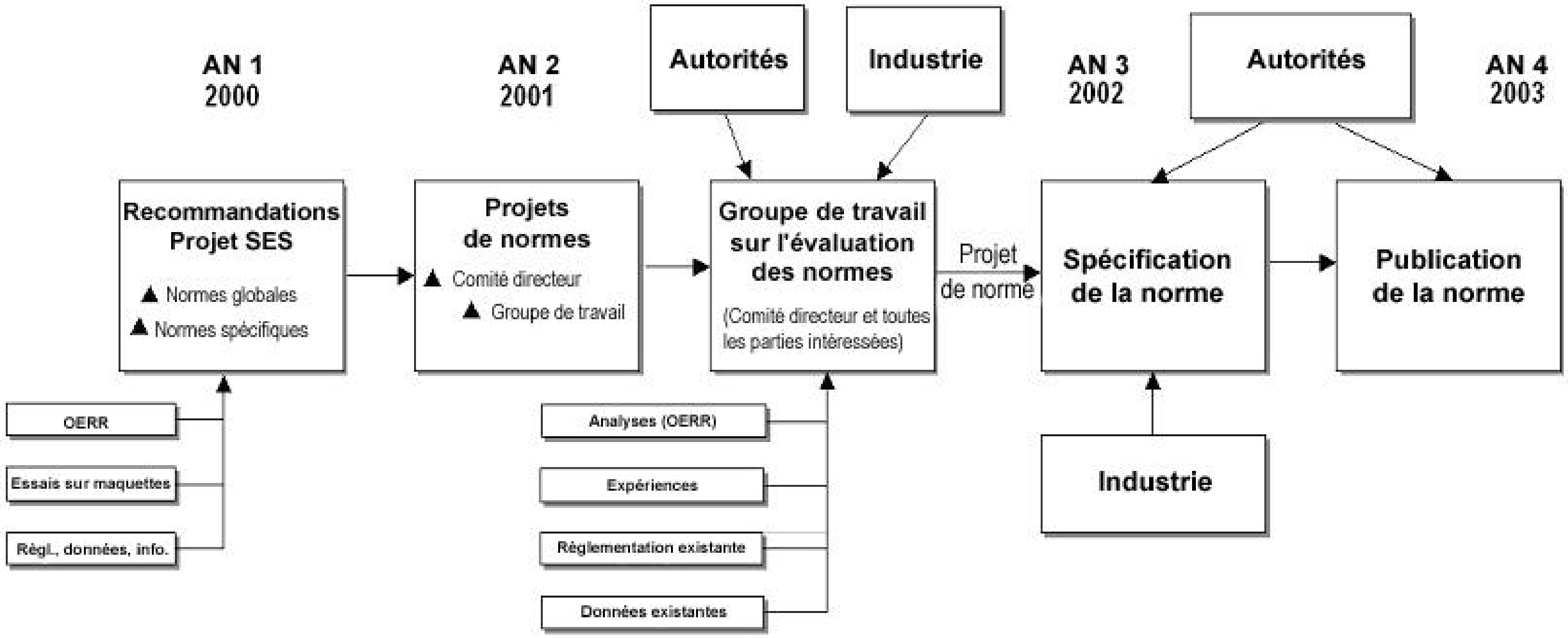

Figure 2 Élaboration des NAP

- Établir des distributions pour l’erreur humaine et les délais d’évacuation et mener des études Monte-Carlo afin de déterminer les intervalles de confiance applicables aux prédictions faites par l’OERR.
- En utilisant des méthodes semblables à celles utilisées jusqu’à maintenant, dont l’assimilation des données et la technique Delphi, évaluer l’effet de la formation sur les performances humaines dans des conditions extrêmes et intégrer les résultats à l’OERR.
- Mener une étude semblable sur l’ergonomie du matériel et des procédures et intégrer les résultats à l’OERR.
- Évaluer les effets physiques et psychologiques des conditions de glace et du froid sur les performances humaines lors d’une opération SES et intégrer les résultats à l’OERR.

Recommandations – Analyse de fiabilité du dispositif PROD et du système Seascape

Les résultats de l’analyse de fiabilité du dispositif PROD devraient servir de données d’entrée pour la conception d’une autre maquette de PROD, suivie d’autres expériences en vraie grandeur et de la mise en œuvre du dispositif.

Même si, à l’origine, une analyse de fiabilité du système Seascape 2000 était prévue, ce système n’a été utilisé qu’à l’occasion de deux visites de sites, qui comportaient des inspections d’embarcations de sauvetage dotées d’une partie du système. À l’avenir, il est recommandé de mener une analyse de fiabilité de la mise à l’eau fondée sur des mises à l’eau en vraie grandeur, à l’aide de techniques d’ingénierie de la fiabilité et de l’OERR.

Recommandations – Développement de l’OERR

La version actuelle, soit la version 4.0, de l’OERR offre une fonctionnalité qui concorde de façon satisfaisante avec la majorité des exigences posées par les NAP. Mais dans une perspective d’application pratique, cette version comporte des lacunes. En effet, elle ne peut simuler ni des scénarios postérieurs à un accident, ni des dispositifs individuels d’évacuation et de sauvetage, ni des évacuations dans des conditions de glace et par temps froid. De plus, pour maximiser l’utilisation de l’OERR par les administrateurs responsables des NAP, il conviendrait de rendre cet outil plus convivial. Voici quelques recommandations précises destinées à optimiser l’OERR :

- Développer un module d’évacuation individuelle et d’évacuation collective auquel seront associées diverses méthodes d’évacuation, comme des dispositifs de descente en rappel, des bouées et des échelles.
- Développer un module «répertoire des accidents» et l’intégrer à l’OERR, de façon à disposer de moyens pour évaluer et catégoriser les effets, sur un système SES, de différents types d’accidents à l’origine d’une situation d’urgence (incendies, explosions, perte de stabilité).
- Développer un OERR pour la glace et le froid, c.-à-d. en accroître les capacités pour qu’il englobe les effets de la présence de glace et du temps froid sur un système SES.

- Produire des indices de fiabilité dans des conditions de glace et par temps froid pour les divers systèmes SES prévus dans les normes.
- Rendre l'OERR davantage convivial en transformant la version bêta du logiciel, conçue à l'usage des chercheurs, en une version destinée à être utilisée par des techniciens.

Recommandations – Élaboration de normes axées sur la performance visant les systèmes SES

En raison du rôle prédominant du Comité directeur, des Offices des hydrocarbures extracôtiers, de l'Office national de l'énergie et de Transports Canada dans l'élaboration des normes relatives aux systèmes SES, toute recommandation précise concernant la mise en application de ces normes dépendra largement des ententes interinstitutions et des priorités établies. Toutefois, des recommandations générales peuvent être formulées concernant la poursuite du programme d'élaboration de normes et la mise en application de celles-ci :

- Organiser des rencontres et des discussions interinstitutions pour déterminer le cadre réglementaire précis dans lequel s'inscriront les normes. Diverses options sont possibles : règlement fédéral appliqué par Transports Canada, règlement appliqué par un office, ou directives destinées à l'industrie.
- Revoir la version définitive de la norme en fonction du cadre réglementaire choisi. Faciliter les consultations avec les parties intéressées, en les invitant à diverses activités, comme des séances d'information.
- Établir un comité technique chargé de répondre aux préoccupations des parties intéressées, de modifier les normes en fonction du cadre réglementaire prévu et de régler toute question associée aux normes. La meilleure façon de donner suite à cette recommandation est de garder en place le Groupe de travail actuel.
- Établir un calendrier réaliste, d'une durée de deux à trois ans, pour la mise en application des normes.
- Prévoir les budgets nécessaires pour réaliser les tâches ci-dessus.

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GLOSSARY

Abandonment	Escape and evacuation
ALARP	**A**s **L**ow **A**s **R**easonably **P**racticable
API	**A**merican **P**etroleum **I**nstitute
Casualty	Fatality or severe injury
Casualty Rate	Probability of casualty in a given potentially casualty-causing incident or event
CDF	**C**umulative **D**istribution **F**unction
Consequence	The direct effect of an accidental event
EER	**E**scape, **E**vacuation, and **R**escue. The process of personnel at an offshore installation transferring from their location at the time of an evacuation alarm to a safe haven such as a standby vessel or search and rescue helicopter.
EEGL	**E**mergency **E**xposure **G**uideline **L**evel
ERCB	Alberta **E**nergy **R**esource **C**onservation **B**oard
ERPG	**E**mergency **R**esponse **P**lanning **G**uidelines for Air Contaminants
Escape	The process of personnel at an offshore installation transferring from their location to the temporary refuge or muster point, starting from the time an evacuation alarm sounds
Evacuation	The process of personnel at an offshore installation transferring from the temporary refuge or muster point to a location clear of the platform where they can be rescued
Failure	In the context of EER, a specific procedure (such as evacuation) that directly results in one or more casualties. Such casualties do not include occupational accidents or natural causes (such as a heart attack), which may occur during the procedure.
Failure Rate	Probability of carrying out an action incorrectly in a given situation or activity
FPSO	**F**loating **P**roduction **S**torage and **O**ffloading
FRC	**F**ast **R**escue **C**raft
GBS	**G**ravity-**B**ased **S**tructure
Gemevac	**G**eneral **E**lectric **M**otorized **Evac**uation System
GRP	**G**lass Fibre-**R**einforced **P**olyester
Hazard	A condition with a potential to create risks such as accidental leakage of natural gas from a pressurized vessel

HAZID	**Haz**ard **Id**entification
HAZOP	**Haz**ard and **Op**erability analysis
HE	**H**uman **E**rror
HEP	**H**uman **E**rror **P**robability. The probability of making a wrong decision or taking a wrong action in a given situation or per demand.
HF	**H**uman **F**actors, including human performance in different situations
HP	**H**uman **P**erformance
HRA	**H**uman **R**eliability **A**nalysis
HSE	**H**ealth and **S**afety **E**xecutive of the United Kingdom
HTS	**H**ow **t**o **S**tandards. Prescriptive standards that delineate how to achieve something.
IDLH	**I**mmediately **D**angerous to **L**ife or **H**ealth
IMD	**I**nstitute for **M**arine **D**ynamics
IRT	**I**ce **R**esistant **T**EMPSC
MCRPT	**M**onte **C**arlo **R**isk and **P**erformance **T**ool
MEG	**M**ono**e**thylene **G**lycol
MF	**M**echanical **F**ailure
MMS	**M**inerals **M**anagement **S**ervice
MOB	**M**an **O**ver**b**oard
Monte Carlo	A numerical method for evaluating combinations of statistical distributions
MSS	**M**arine **S**urvival **S**ystem
NGL	**N**atural **G**as **L**iquids
NPD	**N**orwegian **P**etroleum **D**irectorate
NRC	**N**ational **R**esearch **C**ouncil Canada
ODELE	**O**ffshore **D**ry **E**vacuation **L**ifesaving **E**quipment
OIM	**O**ffshore **I**nstallation **M**anager
PBS	**P**erformance-**B**ased **S**tandards. Set what to achieve.
PDF	**P**robability **D**istribution **F**unction
PEL	**P**ermissible **E**xposure **L**imit
PLL	**P**robable **L**oss of **L**ife
POB	**P**ersons on **B**oard

PPM	**P**arts **P**er **M**illion
PROD	**Pr**eferred **O**rientation and **D**isplacement
PSF	**P**erformance-**S**haping **F**actors
QRA	**Q**uantitative **R**isk **A**ssessment
Rescue	For evacuated offshore personnel, rescue consists of survival until a rescue platform (such as a standby vessel or SAR helicopter) is available and transfer to the rescue platform or safe haven.
Risk	A compound measure of the probability and magnitude of adverse effect
RPT	**R**isk and **P**erformance **T**ool
SAR	**S**earch **a**nd **R**escue
SBV	**S**tand**by** **V**essel
Skyscape	An evacuation system based on an enclosed series of slides to evacuate from deck level to a raft at sea level
SOEP	**S**able **O**ffshore **E**nergy **P**roject
SOLAS	**S**afety **o**f **L**ife **a**t **S**ea
SPEGL	**S**hort-Term **P**ublic **E**mergency **G**uidance **L**evel
SR	**S**uccess **R**ate
STEL	**S**hort-**T**erm **E**xposure **L**imit
Success	In the context of EER, the conduct of a specific procedure (such as evacuation) without incursion of any casualties as a direct result of that procedure. Such casualties do not include occupational accidents or natural causes (such as heart attacks), which may occur during the procedure.
TDC	**T**ransportation **D**evelopment **C**entre of Transport Canada
TEMPSC	**T**otally **E**nclosed **M**otor **P**ropelled **S**urvival **C**raft
THERP	**T**echnique for **H**uman **E**rror **R**ate **P**rediction
TLV	**T**hreshold **L**imit **V**alue
TOES	**T**EMPSC **O**rientation and **E**vacuation **S**ystem
TR	**T**emporary **R**efuge, sometimes called Temporary Safe Refuge (TSR)
TSR	**T**emporary **S**afe **R**efuge, sometimes called Temporary Refuge (TR)
UKOOA	**U**nited **K**ingdom **O**ffshore **O**perators **A**ssociation
WA	**W**eighted **A**verage

1. INTRODUCTION AND BACKGROUND

1.1 General Introduction

This final report describes the work and associated results from the Escape, Evacuation, and Rescue (EER) Research Project commenced on April 1, 2001, and substantially completed on March 31, 2003.

1.2 Objectives

The objectives of the work carried out in the above mentioned project were as follows:

- Provision of research support for the development of Escape, Evacuation, and Rescue (EER) Performance-Based Standards (PBS) for installations in Canadian waters.
- Development of EER PBS.

Specifically, the research support necessary for the PBS (also called Standards herein) development included studies of human performance under extreme conditions, reliability analysis of a specific system, and incorporation of the results of the research into the computer simulation program known as the Risk and Performance Tool (RPT). In addition, the necessary application of the RPT to the generation of information in support of the PBS was required.

The development program for the PBS consisted of the following:

- Continuous facilitation and organization of meetings, and generation of agendas and minutes from the meetings.
- Coordination of a Task Force and Steering Committee.
- Production of 17 drafts of the PBS, including the necessary revisions and updating.
- New work in the area of ice and cold weather PBS.
- Organization of stakeholder workshops, assimilation of feedback, responses to feedback, and general organization, coordination, and facilitation throughout.

1.3 Scope of Work

The scope of work, contractually, was subdivided into three sub-projects as follows:

- Sub-Project #1 – Facilitation and drafting of EER Performance-Based Standards.
- Sub-Project #2 – Human performance under extreme conditions.
- Sub-Project #3 – Assimilation and analysis of PROD and Seascape data.

Each of the sub-projects was subdivided for both contractual and functional purposes into several sub-tasks. Table 1.1 gives a description of the sub-tasks under each sub-project, together with their estimated completion dates. At the time of writing of this report, all sub-tasks have been substantially completed.

1.4 Outline of Report

The report has been organized according to the logical interaction of the tasks, with the research and computer modeling tasks first, followed by the Standards development sub-project. Following this introductory chapter, sequential chapters are dedicated as follows:

- Chapter 2 – Human performance under extreme conditions (Sub-Project #2).
- Chapter 3 – PROD reliability analysis (Sub-Project #3).
- Chapter 4 – Risk and Performance Tool (RPT) development (Sub-Projects #1, #2, and #3).
- Chapter 5 – EER Performance-Based Standards development (Sub-Project #1).
- Chapter 6 – Conclusions and recommendations.

Appendices A and B are dedicated to presenting results of the Standards development program, with Appendix A giving a full version of the final draft and Appendix B showing the stakeholder comment form extensively used throughout the stakeholder consultation processes.

Table 1.1 Description of sub-project components

TASK	DESCRIPTION	ESTIMATED DATE
	Sub-Project #1 – Facilitation and Drafting of EER Performance-Based Standards	
1.1	Team organization meeting, designation of standard category types, and allocation of work among team members.	August 25, 2001
1.2	Presentation of sample global and specific performance-based standards (PBS) and consultation with stakeholders, Progress Report #1, Progress Meeting #1.	October 15, 2001
1.3	Preliminary development of global standards for each of the major components (EER), and specific standards for two escape modes, two evacuation systems, and two rescue modes.	February 15, 2002
1.4	Stakeholder consultation and feedback.	March 31, 2002
1.5	Detailed stakeholder consultations.	May 15, 2002
1.6	Internal organizational team meeting, final allocation of work for each of the Standards to be developed, and agreement.	July 15, 2002
1.6.1	Review and implementation of PBS stakeholder comments from June 17 and subsequently. Resolution of target/goal VS requirement philosophy.	September 30, 2002
1.6.2	Assimilation of stakeholder comments and formulation of responses through Task Force meeting in Halifax.	September 30, 2002
1.6.3	Draft response to stakeholders issues, review of draft response by Steering Committee and final response to stakeholders. Meeting of Steering Committee and Task Force in Halifax. Development of Ice and Cold Weather Standard.	October 30, 2002
1.6.4	Formal responses to stakeholders, distribution of same, and further dealing with stakeholder issues.	November 30, 2002
1.7	Incorporation of stakeholder comments in final draft. Generation of reliability matrices.	December 15, 2002
1.8	Final Draft of Performance Standards.	February 15, 2003
1.9	Preparation of Stakeholder Information Workshop #2 (SIW2).	March 15, 2003
1.10	Organization, funding, participation, and follow-up for SIW2. RPT utilization in support of the PBS development program.	March 31, 2003
	Sub-Project #2 – Human Performance Under Extreme Conditions	
2.1	Study all available historical descriptions (e.g., Ocean Ranger, Piper Alpha).	December 15, 2002
2.2	Discuss and refine the findings with experts using the Delphi Technique in Canada and UK.	February 15, 2002
2.3	Quantify the findings, incorporate into simulator (RPT), simulate.	March 15, 2002
2.4	Apply Delphi methods with the experts in Canada and UK.	July 15, 2002
2.5	Finalize the HF parameters and factors (e.g., extreme psychological stress effect on error rate and performance) and incorporate into RPT.	November 15, 2002
2.6	Deliver final report on Sub-Projects #1, #2, and #3.	February 15, 2003
	Sub-Project #3 – Assimilation and Analysis of PROD and Seascape Data	
3.1	Acquisition and initial review of both the PROD and Seascape data. Two Seascape site visits.	March 15, 2002
3.2	Conduct of high-level reliability analysis of PROD system and incorporation into the RPT.	February 15, 2003

2. HUMAN PERFORMANCE UNDER EXTREME CONDITIONS

2.1 Introduction

The principal difficulty with simulating EER under extreme accident conditions has been lack of reliable data on human performance (HP) under such conditions. Typical offshore installation life-threatening conditions include extreme accidents such as an uncontrolled fire (say, from an ignited gas blowout) rapidly impairing an installation's integrity, and the need to evacuate under severe or extreme weather conditions and associated rescue attempts. In all cases there is significant threat of loss of life, and circumstances are extremely unpredictable and abnormal. Although much has been said about the subject (Bercha Engineering, 2001; Swain, 1963; Edita Ltd., 1999; Galea, 2000; Spouge, 1996), quantitative data on human performance (e.g., speeds on stairs and ladders, operations, error rates, group behaviour) under such extreme conditions directly applicable to EER simulation have not been available. We have seen significant variations already between individual and group performance from the simple experiments performed under this project earlier (Bercha Engineering, 2001).

How can we approach this? Definitely not through full-scale human experiments – and mice are not good enough models (of humans) for EER either! When there are no data for a specific condition and experiments cannot be carried out, but real occurrences have taken place and are documented, there are three main approaches to the problem: (1) assimilate all pertinent historical data, (2) conduct discussions with experts using the Delphi Technique, and (3) modify known (non-extreme) EER simulations with factors to simulate extreme conditions. A combination of all three approaches was used here.

The balance of this chapter discusses the process used for developing extreme condition HP parameters, and presents representative results from incorporating these parameters into the Risk and Performance Tool (RPT). Details of the modifications and redesign of the RPT for integration of HP simulation capability are presented in Chapter 4. This chapter is restricted to representative results illustrating the effect of HP on EER reliability under representative conditions.

2.2 Human Performance Fundamentals

2.2.1 HP in the Context of EER

Successful marine emergency escape, evacuation, and rescue (EER) is achieved through an effective and efficient interaction of the evacuees' human performance and the mechanical performance of the physical EER system. Whether the emergency site is in freezing or temperate regions, moderate or extreme environment, in the form of a vessel or a gravity-based structure (GBS), whether the accident threat is a fire or explosion, or a structural or buoyancy failure, the EER success is always predicated on these two elements – the human and mechanical performances. Without a fit-for-function EER technology, human performance becomes an act of brute survival – running, jumping, swimming, and fighting hypothermia. So, the focus here is not on human performance alone, but rather on the modeling of the interaction between humans and EER physical systems under extreme conditions.

EER success depends on the adequacy of the interaction between machines and humans. The terms “machines” and “mechanical” are used in this report in their broad context to include all non-human components, including machinery, structures, electrical and electronic systems, communications, and software.

2.2.2 Definitions Relating to HP Analysis

Human reliability analysis was extensively developed in the late 1950s, 1960s, and 1970s, under the auspices of the U.S. Nuclear Regulatory Commission, by a variety of investigators including Swain (1963), Swain & Guttman (1983), and others (Rasmussen, 1982; Rasmussen & Pedersen, 1984; Rasmussen et al., 1988, 1994).

In these works, human reliability is defined as the probability that a person correctly performs some system-required activity in a required time period (if time is a limiting factor), and performs no extraneous activity that can degrade the system or the process.

Human performance is defined as the way in which a human being carries out or attempts to carry out a given task. This definition applies for the type of macro modeling of processes, tasks, and activities applicable to the RPT. Human performance, then, for the purposes of reliability analysis, has two primary components: reliability or lack of mistakes with which the task is carried out, and the time over which the task is carried out.

A *task* can be an individual action, an activity consisting of several actions, or a process consisting of a series of activities, such as launching a lifeboat.

Human error (HE) is defined as any member of a set of human actions that exceeds some limit of acceptability. *Human error probability* (HEP) is the probability that an error will occur when a given task is performed. Human error probability should be considered synonymous with human failure probability or human task failure probability.

A *stressor* is any external or internal force that has an impact on human performance.

2.2.3 Approaches to HP Analysis

Human reliability analysis (HRA) is a method by which human reliability is estimated in quantitative terms. In carrying out an HRA, it is necessary to identify those human actions that have an effect on process reliability or availability. The most common application of HRA is the evaluation of human performance required within a system or process concept. Methods developed by Swain and Guttman (1983), and other investigators (Rasmussen, 1985; Rasmussen et al., 1988) for solving practical human reliability problems is known as the Technique for Human Error Rate Prediction (THERP). It is this technique that has been substantially adopted as a basis for the current model for the more explicit inclusion of human factors effects.

The EER model (Bercha & Cerovšek, 1997; Bercha et al., 1999; Bercha Engineering, 2001) is essentially a probabilistic risk assessment and time simulation model. A model of a system, generally speaking, is a mathematical abstraction that symbolically reproduces or simulates the way in which the system functions operationally. In modeling human performance as part of a model, it is necessary to consider those factors that have the most effect on performance. Many factors affect human performance in a complex human-mechanism system such as the EER process. Some of these Performance-Shaping Factors (PSF) are external to the person and some are internal. The external PSF include the entire work environment, including weather, noise, and geometry of installation, as well as the equipment design and the written procedures or oral instructions. The internal PSF represent the individual characteristics of the person, his or her skills, motivations, and expectations that influence performance. Psychological and physiological stresses result from a work environment in which the demands placed on the operator by the system or process do not conform to his or her capabilities and limitations.

2.3 Effect of Psychological Stress on HP

One of the most influential factors is stress. Montagne, a French essayist in the late 1500s noted “men under stress are fools, and fool themselves”. This quotation reflects a commonly held view that stress is undesirable. In fact, it has been shown (Swain & Guttman, 1983; Rasmussen et al., 1988, 1994) that the relationship between human performance and stress is non-linear – too little stress and too much stress both lead to less than optimum or deficient performance. Some in-between level of stress is necessary to provide sufficient arousal to perform reliably. It is the relationship between stress of both or either psychological or physiological nature and human performance, as described below, that is the primary focus of the current sub-project.

The classical stress curve in Figure 2.1 (NUREG-75/014 WASH-1400, 1975) indicates that performance follows a curvilinear relationship with stress, from very low to extremely high. For HRA, it is adequate to represent the entire continuum of stress by only four levels, as follows:

- Very Low - Insufficient arousal to keep alert.
- Optimum - The facilitative level.
- Moderately High - Slightly to moderately disruptive.
- Extremely High - Very disruptive.

For HRA purposes, we consider the moderately high level of stress to be moderately (rather than slightly) disruptive. We use the term *high stress* to include both moderately high and extremely high levels of stress.

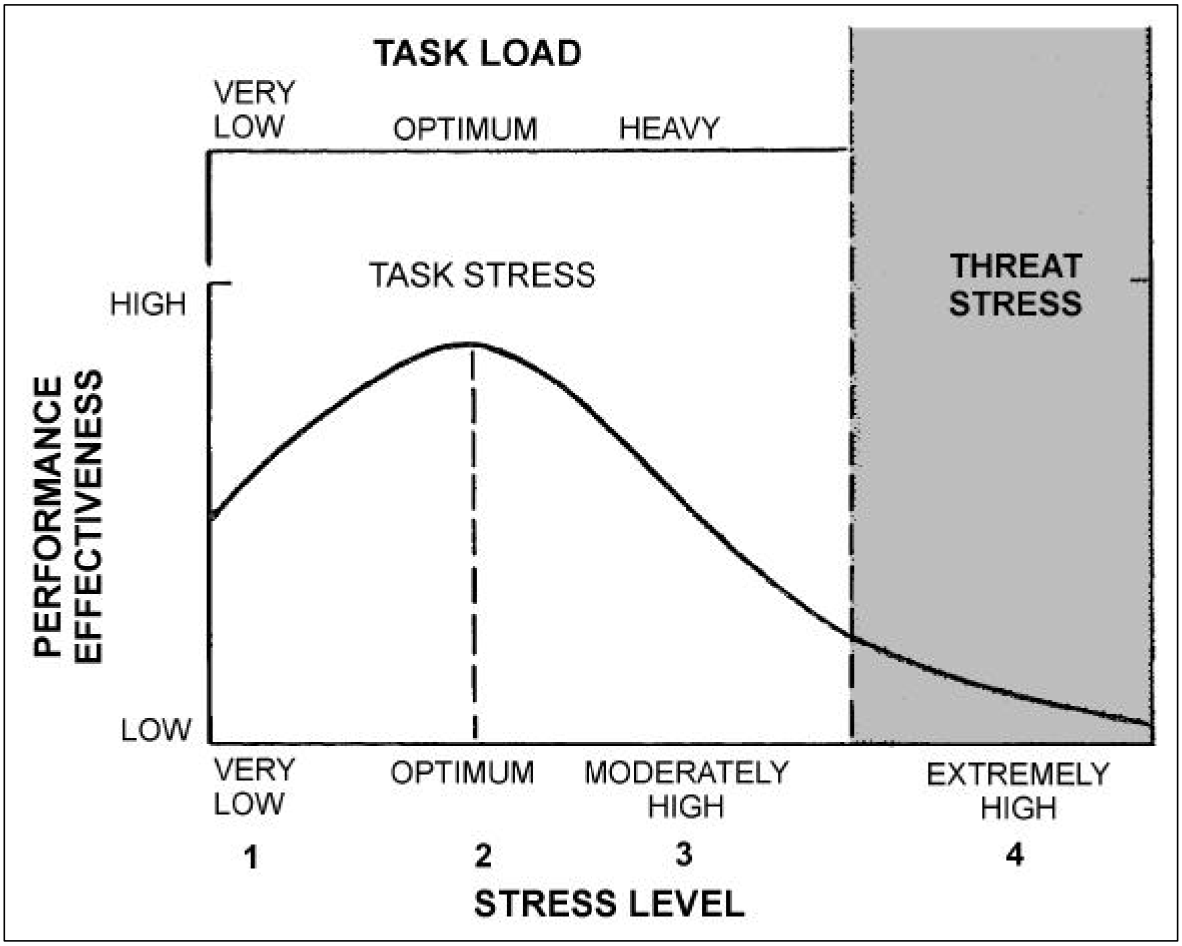


Figure 2.1 Hypothetical relationship between performance and stress with task stress and threat stress division

In this work, we have used four levels of stress, but we designate them differently for explanatory purposes. The first three levels are attributed to the *task load*, and the fourth level is attributed to feelings of threat. The four levels are as follows:

1. Very Low Task Load - Insufficient *arousal* to keep alert.
2. Optimum Task Load - The facilitative level.
3. Heavy Task Load - Approaches or exceeds the human’s normal capacity, moderately disruptive.
4. Threat Stress - Implies emotional reactions, very disruptive.

The effects of the first three levels of stress can be approximated by applying modifying factors to the HEPs in the RPT. The fourth level of stress is qualitatively different from the other three levels – the effects of this level of stress will outweigh other PSF. For this reason, a different set of HEPs is assigned to the threat stress situation. A summary set of guidelines for estimating HEPs for various types of tasks as a function of stress level is presented in Table 2.1. Figure 2.2 shows estimates of HEP as a function of time after the onset of the accident.

The rationale for the curve is explained as follows (NUREG-75/014 WASH-1400, 1975):

> “Following an accident, human reliability would be low, not only because of the stress involved, but also because of a probable incredulity response. Among the operating personnel the probability of occurrence of a large accident is believed to be so low that, for some moments, a potential response would likely be to disbelieve indications. Under such conditions it is estimated that no action at all might be taken for at least one minute and that if any action is taken it would likely be inappropriate.
>
> With regard to the performance curve, in the study the general error (probability) was assessed to be .9 five minutes after a large accident, to .1 after thirty minutes, and to .01 after several hours. It is estimated that by seven days after a large accident there would be a complete recovery to a normal, steady-state condition and that normal error (probabilities) for individual behaviour would apply.”

The solid 1ine in Figure 2.2 indicates the estimated HEPs that apply if the personnel are trained to mitigate the effects of the accident. Otherwise, threat stress is assumed, as shown by the dashed line, and the error probability will not decrease below the value of .25 as long as the threat stress conditions persist. The wide uncertainty bounds around the .25 estimate (.05 to 1.0) allow for some individuals to perform well and for others “to be a part of the problem.”

Table 2.1 Modifications of estimated HEPs for the effects of stress on skilled personnel[1]

Item	Stress Level	Factors for Modifying HEPs		
		Low	Expected	High
1	- Very Low (Very Low Task Load) - Optimum (Optimum Task Load)	1	2	4
2	- Step-by-Step[2]	1	1	2
3	- Dynamic[3] - Moderately High (Heavy Task Load)	1	1	2
4	- Step-by-Step	1	2	3
5	- Dynamic - Extremely High (Threat Stress)	3	5-10	100
6	- Step-by-Step	2	5	20

---

[1] A skilled person is one with 6 months' or more experience in the tasks being assessed. The "HIGH" values can be used for novices as a first approximation.

[2] Step-by-step tasks are routine, procedurally guided tasks, such as carrying out written calibration procedures.

[3] Dynamic tasks require a higher degree of man-machine interaction, such as decision-making, keeping track of several functions, controlling several functions, or any combination of these. These requirements are the basis of the distinction between step-by-step tasks and dynamic tasks, which are often involved in responding to an abnormal event.

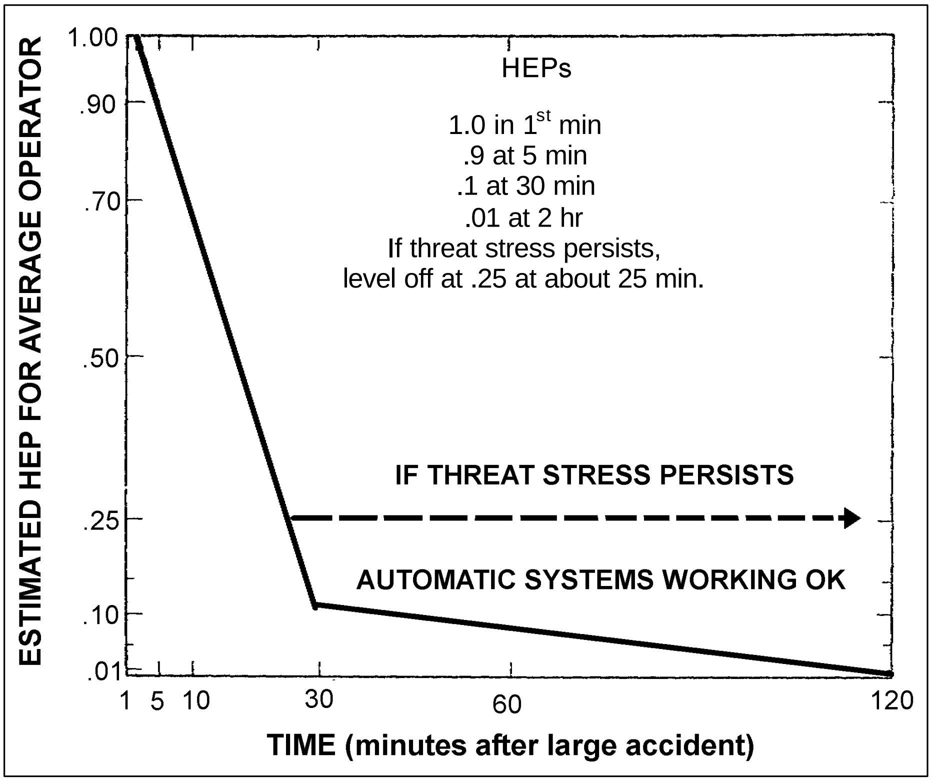


Figure 2.2 Estimated human performance after a large accident

2.4 Effect of Physiological Stress on HP

2.4.1 General

True physiological stressors are physical effects that impact on human performance. In the context of an installation, these include fire and explosion effects, toxic effects, smoke and visibility, and the installation motions and deformations. Unlike the effects of psychological stressors, effects of extreme physiological stressors are generally empirically documented from accident records.

2.4.2 Fire and Explosion Effects

Fires and explosions can result if an accidental natural gas or other flammable substance release is ignited. Fire effects were considered for either direct contact with the flame or exposure to injurious levels of thermal radiation. Direct contact with a fire, for example inside a vapour cloud, will often result in fatality. A probability of fatality of 50% is generally used for locations within a flash fire (CCPS, 1994).

Thermal radiation hazards vary with distance near a jet fire. A summary of selected effects of thermal radiation is given in Table 2.2 from (CCPS, 1989). Experimental data on thermal radiation hazards show that a thermal radiation level of 37.5 kW/m^2 is sufficient to cause 100% fatality within 60 seconds. For the jet fire 25.0 kW/m^2 was used, with a probability of fatality of 50% within 60 seconds.

Explosion effects on people involve either direct exposure to overpressures or impact by missiles or collapsing objects resulting from the explosion. Empirical data on blast overpressure damage is used to estimate human effect criteria for vapour cloud explosions. A summary of effects for explosion overpressures from (CCPS, 1989) is given in Table 2.3. Ninety-nine percent fatality may be expected from direct human exposure to 100 kPa (15 psi) blast overpressures. Buildings, however, will be damaged if exposed to 20 kPa (2.8 psi) overpressures and therefore people inside such buildings could die as a result of structural collapse. An overpressure criterion of 35 kPa (5 psi) causing a 10% likelihood of fatality for exposed people is often used (CCPS, 1994).

It should be noted that the damage criteria used, together with the fatality probabilities assigned, represent worst-case conditions of exposure and effect concentration. Lesser average fatality probabilities can be expected for randomly distributed individuals in an urban landscape, due to the mitigating effects of building shields, wake effects, funneling and lateral channel flows, and evasive action. Thus, when collective risks are assessed, lower averaged probabilities of fatality can be used to reflect the effect of the above mitigating factors.

Table 2.2 Effects of thermal radiation

RADIATION INTENSITY		**OBSERVED EFFECT**	**% CASUALTIES**	
(kW/m^2)	**(BTU/ft^{2}hr)**		**Fatalities**	**Injuries**
1.9	600	Will cause no discomfort for long exposure.	0	0
6.3	2000	Sufficient to cause pain to personnel if unable to reach cover within 20 s; blistering of the skin (second degree burns) is likely; 0% lethality.	0	0
9.5	3000	Pain threshold reached after 8 s; second degree burns after 20 s; 1% lethality after 60 seconds	1	10
12.5	3960	Melting of plastic tubing. 10% fatality after 60 seconds.	10	100
25	7925	Minimum energy required to ignite wood. 50% fatality after 60 seconds	50	100
37.5	11887	Sufficient to cause damage to process equipment. 100% fatality after 60 seconds.	100	100

Table 2.3 Effects from explosion overpressures

OVERPRESSURE			**OBSERVED EFFECT**	**% CASUALTIES**	
(Bars)	**(kPa)**	**(psi)**		**Fatalities**	**Injuries**
.02	2	.3	Typical pressure for 10% glass failure. Safe distance.	0	0
.07	7	1.0	Damage to houses; 100% glass breakage.	0	0
.2	20	2.8	Non-reinforced concrete or cinder block walls destroyed (1% fatality); wood frame partial collapse.	1	10
.25	25	3.5	Steel buildings collapse (90% eardrum rupture) (5% fatality).	5	50
.35	35	5.0	Wooden utility poles snapped; buildings destroyed (10% fatality).	10	100
1.0	100	15.0	100% fatalities among exposed populations due to direct blast effects.	100	100

2.4.3 Toxic Effects

Although there are many toxic substances that can be released in offshore accidents, a common toxic threat is sour gas, which is essentially methane with hydrogen sulphide (H_2S). Hydrogen sulfide gas is known to be physiologically damaging to humans when ingested by breathing. Quantitative assessments of the damage (ERCB, 1990a, 1990b, 1994; CCPS, 1989) are restricted to acute or immediate lethality effects; long-term or chronic effects are not unambiguously understood and continue to be a subject of controversy worldwide. The current investigation is restricted to the analysis of acute effects of H_2S. The nature of the damage due to exposure to a toxic gas depends on the concentration and exposure time and condition of the receptor.

Many useful measures are available to use as benchmarks for predicting the likelihood that a release event would result in serious injury or death. Some of the established (CCPS, 1989) toxicologic criteria and methods to assess the magnitude of damage to humans from exposure to toxic gases such as H_2S include the following:

- Emergency Response Planning Guidelines for Air Contaminants (ERPGs) issued by the American Industrial Hygiene Association.
- Immediately Dangerous to Life or Health (IDLH) Levels established by the National Institute for Occupational Safety and Health.
- Emergency Exposure Guidance Levels (EEGLs) and Short-Term Public Emergency Guidance Levels (SPEGLs) issued by the National Academy of Sciences/National Research Council.
- Threshold Limit Values (TLVs) established by the American Conference of Governmental Industrial Hygienists, including Short-Term Exposure Limits (STELs) and ceiling concentrations.
- Permissible Exposure Limits (PELs) promulgated by the Occupational Safety and Health Administration.
- Alberta Energy Resource Conservation Board (ERCB) L50 Toxic Load.
- Probit functions.

In the present study, a combination of some of the above guidelines together with probit functions to assess the likelihood of lethality are presented.

For a number of commonly known toxic substances, there exists information on dose-response relationships that can be applied to quantify the number of fatalities that are likely occur with a given exposure. Probit relationships for specific substances are based on experimental animal data, resulting in some uncertainty around risk estimates in applications to human populations. Once an adequate dispersion model has been applied to give time-concentration zones, it is possible to apply a probit function to obtain additional information on the lethality of the release for substances that have been documented in the form for application to the probit method. The probit method uses a logarithmic expression of the form:

$$P_r = a + b \log_e (C^n t)$$

where, a, b, and n are constants, C is the gas concentration in ppm, and t is the exposure time in minutes.

With this expression, the toxic dose fatality percentage can be determined using standard probit tables. Specifically, the necessary inputs for the probit analysis for H_2S are shown in Table 2.4, showing the probit constants (P_r) for a number of substances including H_2S. The transformation of the probit value to a percentage of lethality can be obtained from Table 2.5. For the purposes of the present risk analysis, certain established toxicological criteria from among those cited above were chosen, and the probit function was used to assess associated probabilities of lethality for input into the risk model. Specifically, the following dosage criteria were investigated:

▪ ERPG-1	10 ppm, 60 minutes
▪ ERPG-2	30 ppm, 60 minutes
▪ IDLH (new)	100 ppm, 30 minutes
▪ ERPG-3	100 ppm, 60 minutes
▪ IDLH (old)	300 ppm, 30 minutes
▪ ERCB L50	700-1000 ppm (ERCB, 1994), 5 minutes
▪ MAX	1000-2000 ppm, 6 seconds

Application of the probit equation with appropriate constants for H_2S gave probabilities of lethality of 1%, 5%, and 75%, respectively, for the ERPG-3, IDLH(old), and ERCB L50; the others gave a zero probability of lethality criteria. Table 2.6 summarizes these criteria together with the above-cited results. Although several dosages result in 0% probability of death, they are included for screening of hazard scenarios.

Unfortunately, no solid data on injury probabilities or probit functions for H_2S injury are available. CCPS (1989) suggests a ratio of one fatality to 10 injuries; various disasters, such as the recent grim event in Moscow,[1] where approximately 150 dead and 1500 injured were reported, also confirm this ratio. Accordingly, a probability of injury 10 times that of lethality is shown in Table 2.6.

---

[1] In October 2002, Russian Special Forces brought a swift and dramatic end to a three-day siege in a Moscow theatre, where hundreds of people were held hostage by Chechen rebels. The Special Forces' assault and use of an incapacitating "sleeping" gas (based on Fentanyl derivatives) terminated the hostage situation.

Table 2.4 Constants for lethal toxicity probit equation

SUBSTANCE	a (ppm)	b (ppm)	n (min)
Ammonia	-35.9	1.85	2.00
Benzene	-109.78	5.3	2.00
Carbon monoxide	-37.98	3.7	1.00
Chlorine	-8.29	0.92	2.00
Hydrogen cyanide	-29.42	3.008	1.43
Hydrogen sulfide	-31.42	3.008	1.43
Methyl isocyanate	-5.642	1.637	0.653
Sulphur dioxide	-15.67	2.10	1.00

Table 2.5 Transformation of probits to lethality percentages

FATALITY PERCENTAGE (%)	PROBIT CONSTANTS (P_r)				
	0	2	4	6	8
0	--	2.95	3.25	3.45	3.59
10	3.72	3.82	3.92	4.01	4.08
20	4.16	4.23	4.29	4.36	4.42
30	4.48	4.53	4.59	4.64	4.69
40	4.75	4.80	4.85	4.90	4.95
50	5.00	5.05	5.10	5.15	5.20
60	5.25	5.31	5.36	5.41	5.47
70	5.52	5.58	5.64	5.71	5.77
80	5.84	5.92	5.99	6.08	6.18
90	6.28	6.41	6.55	6.75	7.05
99	7.33	7.41	7.46	7.65	7.88

Table 2.6 H_2S lethality criteria

DESCRIPTION	C (ppm)	DURATION (min)	PROBABILITY OF LETHALITY (%)	PROBABILITY OF INJURY (%)
ERPG-1	10	60	0	0
ERPG-2	30	60	0	0
IDLH (new)	100	30	0	0
ERPG-3	100	60	1	10
IDLH (old)	300	30	5	50
ERCB L50	700-1000	5	75	100
MAX	1000-2000	1.0	100	100

2.4.4 Smoke and Visibility

The effect of smoke is threefold. First, loss of visibility causes a reduction in travel speed and time for evacuation. The second problem is acute disorientation; this causes an inability to make an escape, resulting in death. This can have a cumulative effect; others may follow the disoriented person to their demise. The third problem is acute irritation of the eyes, the oronasal cavity and the lungs, causing choking, coughing, an inability to concentrate on the escape path, and ultimately death. Jin (1978) has examined the effect of smoke on speed of evacuation. With a visibility of approximately 10 m, evacuation speed of 1.2 m/sec is unaffected. However, when visibility is reduced to 4 m, travel speed is reduced to 0.4 m/sec. In non-irritant smoke when visibility is reduced to 2 m, travel speed is reduced to 0.5 m/sec, and in irritant smoke, walking speed is reduced to 0.3 m/sec at an extinction coefficient of 0.5.

A recent experiment conducted by Galea and Gwynne (2000) on an overturned railway carriage showed that the flow rate of 9.2 persons per minute to escape was reduced to 5 persons per minute in smoke. In other words, smoke halves the exit flow rate and doubles evacuation time. These findings are consistent with witness testimonies in the Ladbrooke Grove train accident in October 1999 (Galea, 2000). The E&P Forum (1996) gives further data on average speeds varying with smoke concentrations.

These figures measured experimentally and borne out practically were factored into the model for the escape, evacuation and rescue phase. Table 2.7 summarizes the effects of smoke (and other impairments) to escape routes.

2.4.5 Global Structural Deformations and Motions

An offshore installation can tilt or list in an accident. Floating installations will list due to differential loss of buoyancy. Fixed platforms can list due to structural failure. The degree of list has a profound effect on personnel ability to climb stairwells, travel along companionways, and board and launch lifeboats and liferafts. The following review of performance under list conditions provides a basis for data for the model.

Spouge (1996) concluded from detailed investigations of major Ro-Ro ferry accidents that at an angle of approximately 45º, escape from inside the ship presents much less difficulty than the subsequent evacuation off the ship. By contrast, at 90º or more, escape from inside is the dominant concern. On further review of the *Wahine* accident (Spouge, 1996), the list certainly caused the passengers to become disorientated and migrate to the incorrect side of the ferry for abandonment. In 1994, the *Estonia* capsized and sank. By the time the ship had a list of 45º, everyone had great difficulty (Edita Ltd., 1999).

To supplement this anecdotal accident data with experimental data, Koss et al. (1997) evaluated the mobility of humans under various conditions of list. The Koss subjects were young, healthy and under no stressful conditions or physiological difficulty, but not entirely unlike trained offshore installation personnel.

Table 2.7 Effects of smoke and other impairments

METHOD/IMPAIRMENT	AVERAGE SPEED (m/s)	FACTOR	
		Symbol	Value
External or internal walkway	1.2	-	1.0
Congested internal walkway (15-20 people)	0.6	CFW	1.7
Stairway	0.6	-	1.7
Debris-impaired walkway	0.1	DF	10.0
Ladder	0.2	-	5.0
In smoke (0 to 2.3%)	1.0	SF	1.2
In smoke (2.3 to 15%)	0.5	SF	2.5
In smoke > 15%	0.3	SF	5.0
List (<10°)	1.2	LF	1.0
List (10° to 30°)	0.6	LF	2.0
List (> 45°)	0.1	LF	12.0
Congestion (front)	1.3	CF	1.1
Congestion (centre)	1.0	CF	0.8
Congestion (rear)	0.8	CF	0.7

To summarize the results, rolls of up to 15º of list cause little change to a walking speed of 1.2 m/s, whether walking singly or in pairs, except for when there is an obstacle in the way. This appears to be validated by the anecdotal evidence in accidents presented in the previous paragraphs. Escape from the machinery spaces where climbing vertical ladders is necessary is slowed with increasing angles of static roll from 10º to 18º, and impossible when the angle increases to 25º. For increasing angles of negative pitch, the rungs climbed per second reduces from 1.5 per second to 1.2 per second when the angle reaches -20°. Mass evacuation with a crowd of four people per square metre showed that the crowd speed at the front (1.32 m/s) was more rapid than at the rear (0.80 m/s) and the centre (1.0 m/s).

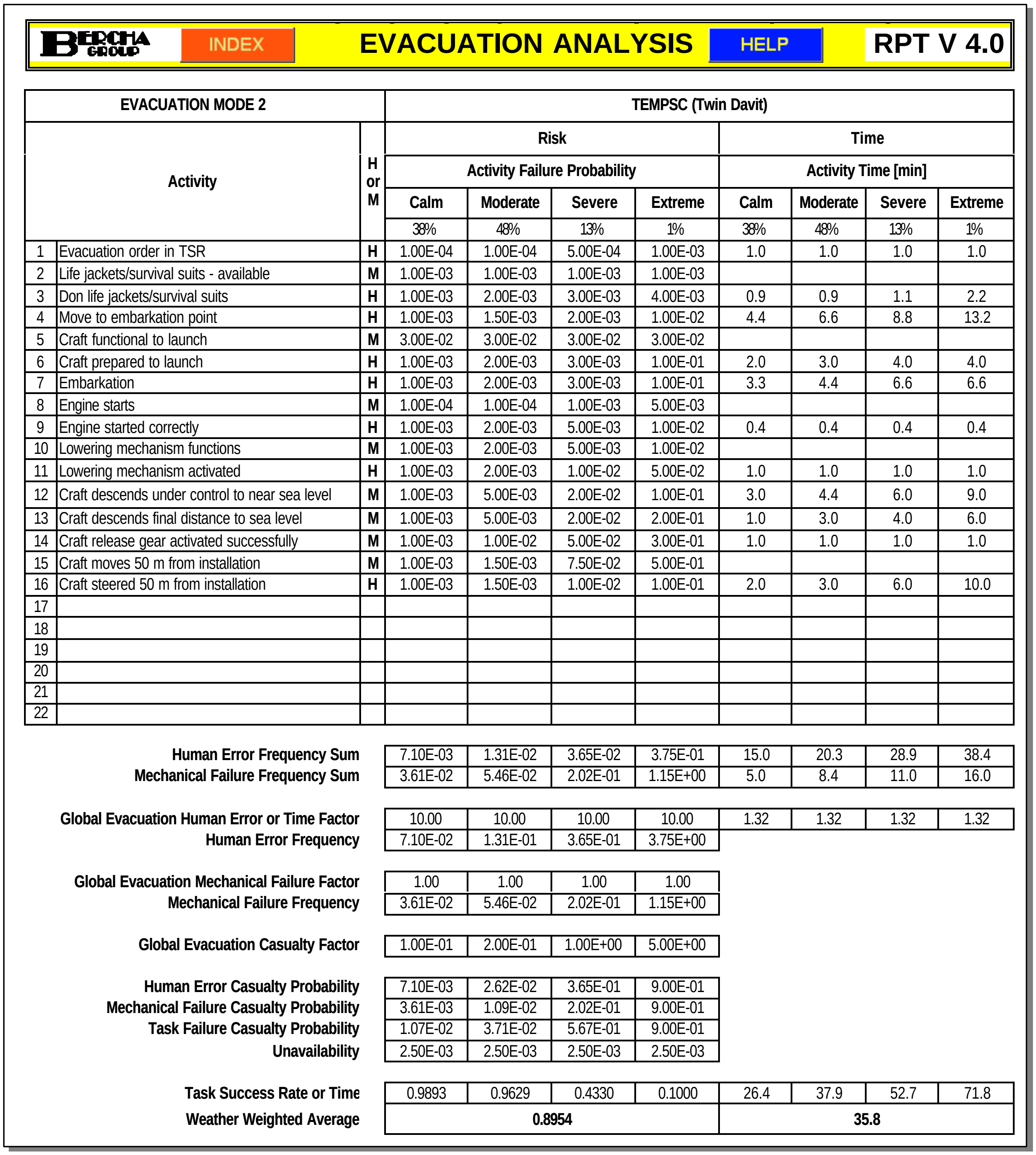
The above results, in a format suitable for the RPT, are also summarized in Table 2.7.

2.5 Results of Incorporation of HP Parameters into RPT

Since details of the RPT modifications to simulate HP are given in Chapter 4, only sample and bottom-line results are shown herein, including life-threatening (high stress) emergency. Figure 2.3 shows the evacuation analysis details for the twin-davit TEMPSC evacuation. As can be seen, on the left-hand side of the results screen is a section on risk, while the right-hand side gives the time simulation. Further, all of the activities are divided into those relating to human (H) performance and mechanical (M) performance. The figures given in each element of the matrix under risk are frequencies and probabilities. They are given for a series of characteristic environmental conditions that are based on weather severity. Time is given simply as the activity time in minutes: when it does not exceed a preset limit it remains independent of the risk; when it exceeds a preset limit it begins to excacerbate the failure probability. In the lower portion of the table are a series of results pertaining to various human and mechanical performance measures. The bottom line is the Task Failure Casualty Probability. The casualty probability is the probability of having one or more casualties. Casualties are serious injuries or fatalities. Success is its inverse, the probability of having no casualties. Task Success Rate gives the success probability for each weather condition and the weather weighted average.

The weather weighted average is essentially the sum of the probabilities of each weather or ice condition multiplied by the associated success rate or time. The weather weighted average is site-specific as it is a function of the proportions of each weather class at a given location. In this example, the following weather class distribution was used:

- Calm (C) - 38%
- Moderate (M) - 48%
- Severe (S) - 13%
- Extreme (E) - 1%



EVACUATION ANALYSIS

RPT V 4.0

	EVACUATION MODE 2		TEMPSC (Twin Davit)							
	Activity	H or M	Risk				Time			
			Activity Failure Probability				Activity Time [min]			
			Calm	Moderate	Severe	Extreme	Calm	Moderate	Severe	Extreme
			38%	48%	13%	1%	38%	48%	13%	1%
1	Evacuation order in TSR	H	1.00E-04	1.00E-04	5.00E-04	1.00E-03	1.0	1.0	1.0	1.0
2	Life jackets/survival suits - available	M	1.00E-03	1.00E-03	1.00E-03	1.00E-03				
3	Don life jackets/survival suits	H	1.00E-03	2.00E-03	3.00E-03	4.00E-03	0.9	0.9	1.1	2.2
4	Move to embarkation point	H	1.00E-03	1.50E-03	2.00E-03	1.00E-02	4.4	6.6	8.8	13.2
5	Craft functional to launch	M	3.00E-02	3.00E-02	3.00E-02	3.00E-02				
6	Craft prepared to launch	H	1.00E-03	2.00E-03	3.00E-03	1.00E-01	2.0	3.0	4.0	4.0
7	Embarkation	H	1.00E-03	2.00E-03	3.00E-03	1.00E-01	3.3	4.4	6.6	6.6
8	Engine starts	M	1.00E-04	1.00E-04	1.00E-03	5.00E-03				
9	Engine started correctly	H	1.00E-03	2.00E-03	5.00E-03	1.00E-02	0.4	0.4	0.4	0.4
10	Lowering mechanism functions	M	1.00E-03	2.00E-03	5.00E-03	1.00E-02				
11	Lowering mechanism activated	H	1.00E-03	2.00E-03	1.00E-02	5.00E-02	1.0	1.0	1.0	1.0
12	Craft descends under control to near sea level	M	1.00E-03	5.00E-03	2.00E-02	1.00E-01	3.0	4.4	6.0	9.0
13	Craft descends final distance to sea level	M	1.00E-03	5.00E-03	2.00E-02	2.00E-01	1.0	3.0	4.0	6.0
14	Craft release gear activated successfully	M	1.00E-03	1.00E-02	5.00E-02	3.00E-01	1.0	1.0	1.0	1.0
15	Craft moves 50 m from installation	M	1.00E-03	1.50E-03	7.50E-02	5.00E-01				
16	Craft steered 50 m from installation	H	1.00E-03	1.50E-03	1.00E-02	1.00E-01	2.0	3.0	6.0	10.0
17										
18										
19										
20										
21										
22										
	Human Error Frequency Sum		7.10E-03	1.31E-02	3.65E-02	3.75E-01	15.0	20.3	28.9	38.4
	Mechanical Failure Frequency Sum		3.61E-02	5.46E-02	2.02E-01	1.15E+00	5.0	8.4	11.0	16.0
	Global Evacuation Human Error or Time Factor		10.00	10.00	10.00	10.00	1.32	1.32	1.32	1.32
	Human Error Frequency		7.10E-02	1.31E-01	3.65E-01	3.75E+00				
	Global Evacuation Mechanical Failure Factor		1.00	1.00	1.00	1.00				
	Mechanical Failure Frequency		3.61E-02	5.46E-02	2.02E-01	1.15E+00				
	Global Evacuation Casualty Factor		1.00E-01	2.00E-01	1.00E+00	5.00E+00				
	Human Error Casualty Probability		7.10E-03	2.62E-02	3.65E-01	9.00E-01				
	Mechanical Failure Casualty Probability		3.61E-03	1.09E-02	2.02E-01	9.00E-01				
	Task Failure Casualty Probability		1.07E-02	3.71E-02	5.67E-01	9.00E-01				
	Unavailability		2.50E-03	2.50E-03	2.50E-03	2.50E-03				
	Task Success Rate or Time		0.9893	0.9629	0.4330	0.1000	26.4	37.9	52.7	71.8
	Weather Weighted Average		**0.8954**				**35.8**			

Figure 2.3 Arctic enhanced evacuation analysis results – twin-davit TEMPSC

Table 2.8 gives a summary of the results of application of the RPT to the twin-davit TEMPSC evacuation and EER under a range of weather conditions, showing contributions of human error (HE), mechanical failure (MF), and the total success rate (SR). Figure 2.4 shows a histogram of the key resultant quantities. These resultant quantities are the human error casualty probability (HE), the mechanical failure casualty probability (MF), and the success rate (SR). For evacuation they are shown for each of the four weather classes and their weighted average (WA). For the total EER process consisting of the three components, only the WA EER is given.

2.6 Conclusions from RPT HP Results

Based on Table 2.3 and Figure 2.4, the following conclusions on the impacts of HP and extreme conditions may be drawn:

- For Calm evacuation conditions, HE and MF made the same contribution.
- For Moderate and Severe conditions, HE contributed roughly twice as much to failure as MF.
- For Extreme conditions, both HE and MF were at the limit (90%), essentially meaning the probability of failure is very high.
- Evacuation success rate is high in calm and moderate conditions but decays rapidly from severe to extreme weather.
- The weighted average (WA) evacuation and total EER values represent average expectations for a specific site.
- For the example site (a typical one), HE, on the average (WA), contributes roughly twice as much to evacuation failure as MF.

Table 2.8 Twin-davit TEMPSC evacuation and EER human and mechanical performance contributions and success rates (%)

		Evacuation					**EER**
		Calm	**Moderate**	**Severe**	**Extreme**	**Evac. WA**	**EER WA**
TEMPSC	Human Error	1	2	36	90	7	-
	Mechanical Failure	1	1	20	90	4	-
	Success Rate	99	96	43	10	89	70

Note: **Evac.WA** - Evacuation weather-weighted average
EER WA - Total EER weather-weighted average success rate

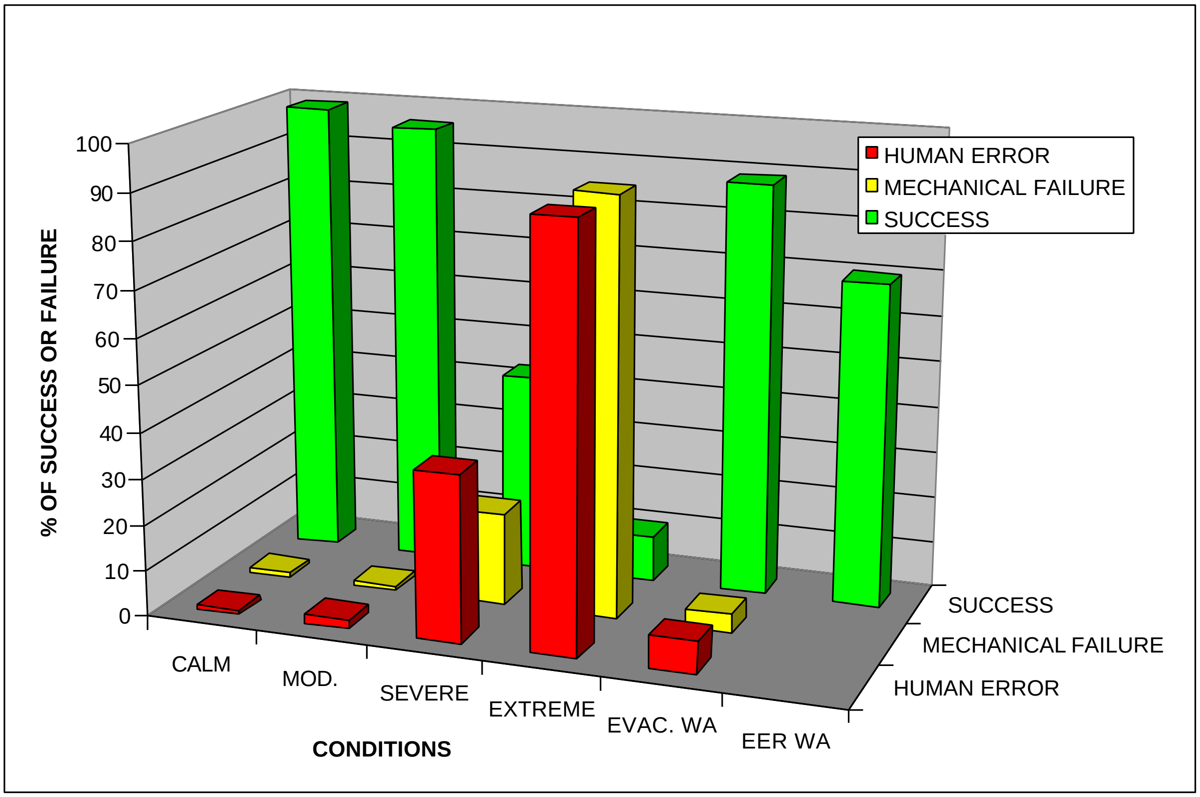


Figure 2.4 Twin-davit TEMPSC evacuation and EER human and mechanical performance contributions and success rates

3. PROD RELIABILITY

3.1 Introduction on Preferred Orientation and Displacement (PROD) System Reliability Investigation

The Preferred Orientation and Displacement (PROD) system is essentially a conventional lifeboat davit-launch together with an enhancement to facilitate clearing from the installation.

In this chapter, following a description of the PROD system, available unmanned launch data sets are summarized and the unmanned performance of the PROD is determined from these data sets. Next, use is made of an extended risk and performance tool (RPT) to assess human performance and its role in a PROD evacuation. To achieve this, the full-scale test mechanical and RPT-derived human performance characteristics are combined for benign (calm and moderate) weather conditions and low-stress situations, and extrapolated to estimate the likely performance of the PROD under more severe conditions and life-threatening emergencies.

3.2 General Description of PROD System

The PROD system, as illustrated in Figures 3.1 and 3.2, is an adaptation of the davit-launch system intended to give the lifeboats an impetus away from the platform. The PROD system comprises a long, tapered, flexible Glass Fibre-Reinforced Polyester (GRP) boom attached at right angles to the offshore structure by a hydraulic hinge (pictured in Figure 3.3). The boom may be a single-length, one-piece construction or hydraulically articulated to reduce storage space. The boom's outboard end is connected to the bow of the lifeboat by a fixed-length wire tagline incorporating an automatic release coupling.

When launching of the lifeboat commences (by conventional twin-fall davit), the weight of the lifeboat creates tension in the line, resulting in the pole being drawn down. The tension is stored in the hydraulic hinge connecting the boom to the structure, and in the flexible boom itself. The tension in the tagline has the effect of progressively swinging the boat's head away from the installation until it is about 45° to the structure. During lowering, the fall wires and tagline combine to stabilize the craft in high winds.

Once the craft is in the water, the engine throttle is opened to full ahead and the lift hooks are released. At this point the propulsion unit has attained maximum thrust and will be producing steerage way so that the boat can be manoeuvred safely, with a reduced chance of being swept back into the structure.

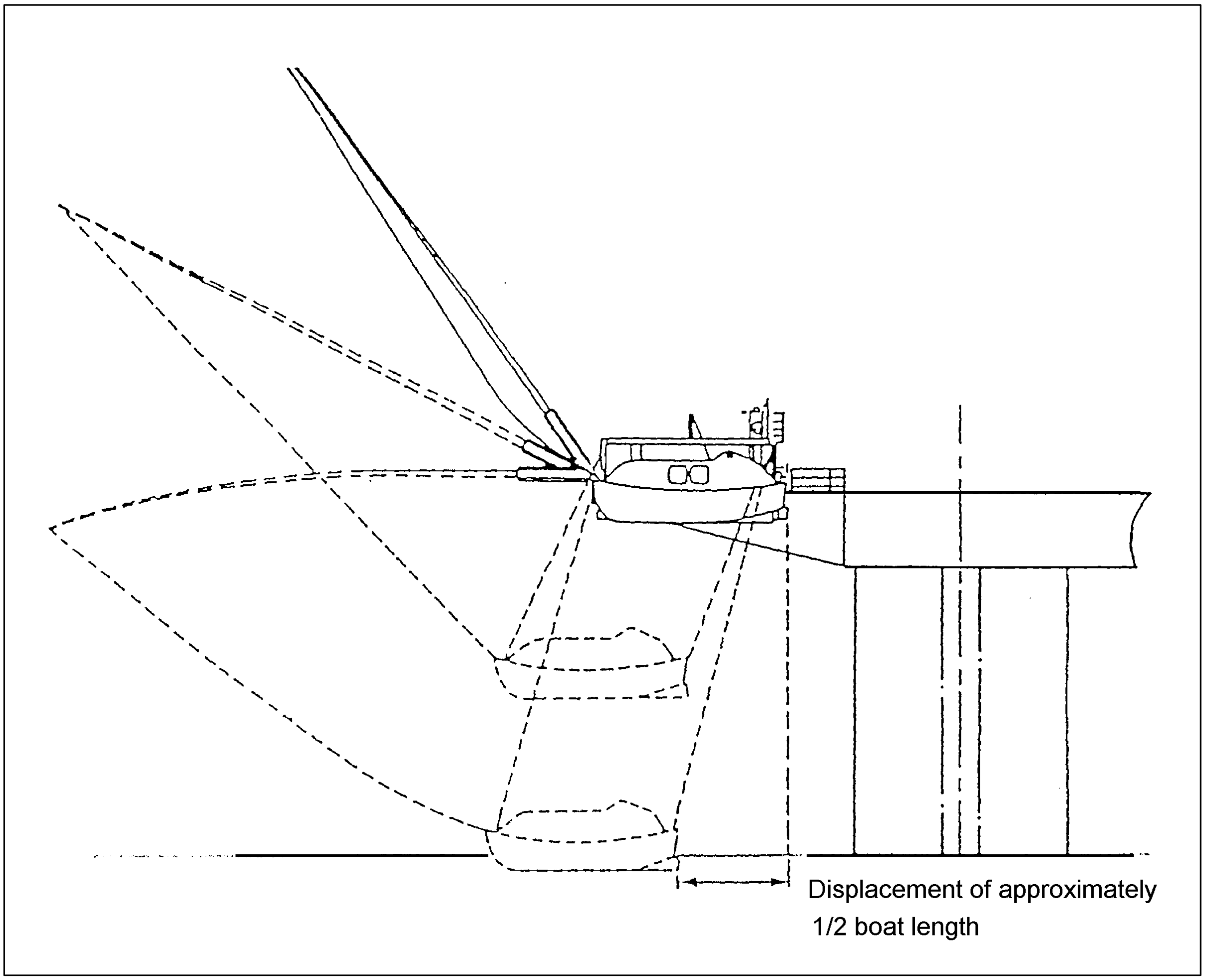


Figure 3.1 PROD system

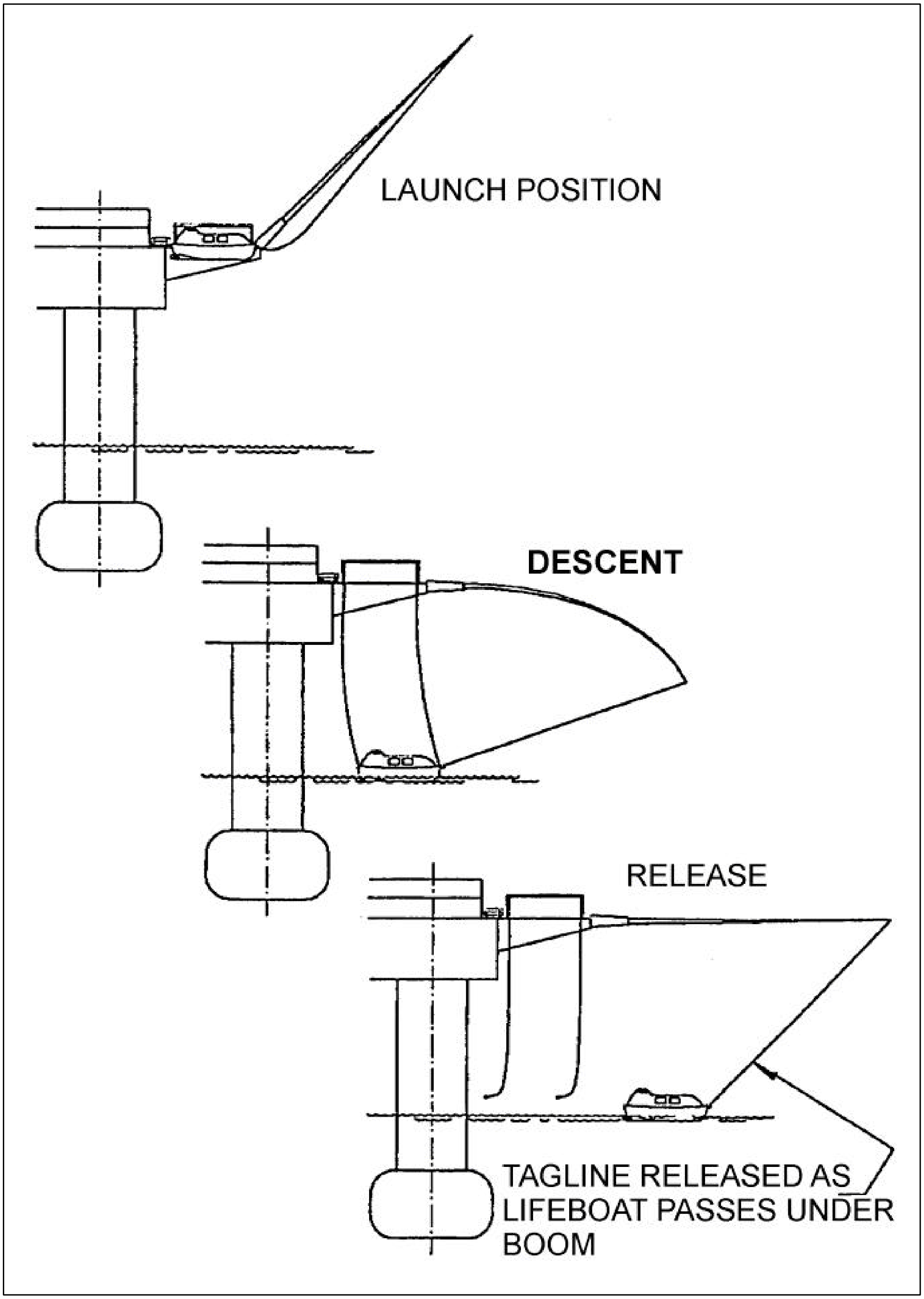


Figure 3.2 PROD launch sequence

30 9 '00

Figure 3.3 Photograph of PROD boom

The PROD construction allows the lifeboat to be positioned perpendicular to the platform rather than parallel to it, avoiding the twisting of the fall wires produced in the parallel system. In 1986 Husky/Bow Valley, in conjunction with Canadian authorities and industry, undertook full-scale trials from a semi-submersible deployed off the coast of Newfoundland. The trials evaluated different configurations to ensure the system was working within its design limitations. Although the weather was not particularly severe at the time, significant improvements using the PROD system were demonstrated. Therefore, for davit-launched systems, the use of a PROD system significantly enhances launch reliability. Data for 69 full-scale PROD launches conducted by Husky/Bow Valley were compiled and analyzed as part of this project. Both simulation time parameters and some reliability data were extracted for the RPT. The PROD system was developed by the Sussex company Watercraft UK and is certified by the Canadian Coast Guard.

3.3 Canadian Full-Scale PROD Data

From 1985 to 1986, Husky conducted 64 PROD launches intended to simulate fully the operational launch of unmanned systems in calm and moderate weather conditions. Specifically, the following launch sets were carried out:

- Phase 1 (22-person Watercraft lifeboat) – Parallel stow, 19 launches.
- Phase 2 (22-person Watercraft lifeboat) – Parallel stow, 20 launches.
- Phase 3 (66-person lifeboat) – Perpendicular stow, 25 launches.

Table 3.1 summarizes the typical activities necessary for the PROD launch.

In addition, reliability data for the launches was obtained and is reproduced in Appendix A. Of the 64 operational launches, error occurred in 17 launches, giving a minor (non-critical) error rate of 0.27 on demand. Only one of the launches, where the engine failed to start can be regarded as a critical failure, thus giving a critical error rate of 0.015, or approximately 1.5% on demand.

It should be recalled that the launches were unmanned. Hence, the error rates cited above are exclusive of human error; inclusion of HF in the error sequences will result in higher error rates.

3.4 UK Full-Scale PROD Data

In 1987, subsequent to the Canadian PROD tests, a series of 47 launches was carried out in the United Kingdom. These data did not, however, record the reliability information. Nonetheless, they did provide useful time information, giving a range of variations in ballast, boom length, lowering rate, and final TEMPSC speed as well as a detailed subdivision of times from launch to splash, and times from splash to 30-m clearance.

From these data, launch times – excluding boarding and preparation (the launches were unmanned again) – were found to be in the order of 60 seconds, with a variation of roughly 20%.

Table 3.1 Summary of activities in PROD launch

STEP*	SUMMARY
▪ Confirm PROD boom taglines are attached to lifeboat	▪ 5 seconds
▪ Open cover of Hydraulic Control Panel and Assess Primary and Backup Accumulator Pressures	▪ 5 seconds
▪ Change Control Levers from Park to Launch Position	▪ 5 seconds
▪ Raise PROD Boom to operating pressure (or angle) with Accumulator Regulator controls	▪ 20 seconds
▪ Assess Primary and Backup Accumulator Pressures	▪ 5 seconds
▪ Board and launch lifecraft	▪ Personnel and lifecraft design dependent ▪ Commence launch sequence at 0 seconds.
▪ Lifecraft touchdown on sea surface and automatic falls release	▪ Installation dependent factors: height of lifecraft and speed of fall winch. ▪ Lifecraft was stowed at 15.7 m above operating draft. ▪ Fall extension variances were averaged at 14.9 m from stowage plane. ▪ Fall winch speed averaged 0.67 m/s. ▪ Time from brake release to water surface averaged 22.2 seconds.
▪ PROD-assisted manoeuvring (Average time on tagline)	▪ 11.8 seconds
▪ Automatic release of PROD tagline when lifecraft clears the boom-tip plane	▪ At the 35-second mark of the launch sequence.
Summary:	
▪ PROD preparation for launch by a trained person:	40 seconds
▪ (Personnel muster and lifecraft boarding):	Unmanned
▪ PROD launch sequence to water touchdown:	22 seconds
▪ PROD-assisted manoeuvring to release point:	12 seconds
▪ **Total (PROD) Evacuation time:**	**74 seconds**

* Steps in PROD launch sequence, from arrival of first party at station. These steps assume that adequate hydraulic pressure has been maintained in the PROD accumulator and that the system is ready for deployment.

3.5 Reliability Analysis of PROD Evacuation Process

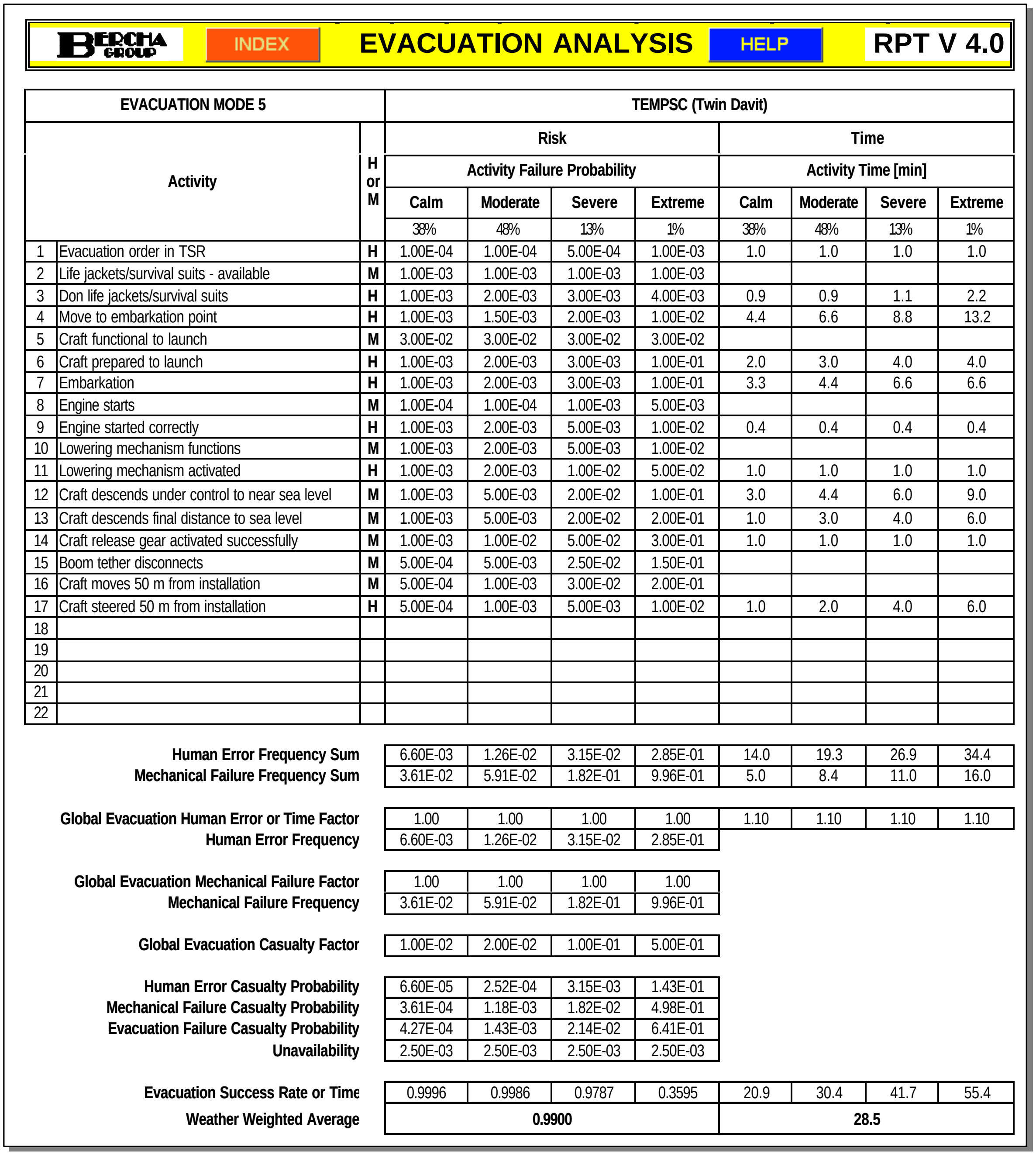
The PROD evacuation process, by definition, commences when the order to evacuate is given in the Temporary Safe Refuge (TSR) or at the muster point, and concludes when the craft is 50 m clear of the installation. In the RPT, an analysis of the tasks necessary to accomplish the evacuation is conducted in the RPT evacuation module, giving task failure rates and performance times, as well as their resultant effects in the evacuation process. Table 3.2 shows an evacuation analysis print-out for the reliability version (excluding consideration of availability) for a drill global scenario. As was mentioned in Chapter 2, Version 4.0 of the RPT analyzes both the human and mechanical components of each task, as applicable. It then totals these and computes the resultant success rate for each weather condition and the weather-weighted average for all weather conditions.

The reliability analysis is best carried out in conjunction with the full-scale PROD data described in Section 3.3. As is evident from Table 3.1, the time and reliability data do not cover all 17 activities included in the RPT simulation of evacuation. In fact, it can be seen that the activities included commence at embarkation, activity #7, and terminate at activity #17, as the craft moves clear of the installation. To provide a comparable analysis, accordingly, the RPT parameters were modified to exclude activities #1 to #6, and the evacuation simulation was run for the drill global scenario. The results of this RPT analysis are shown in Table 3.3. The results of the RPT that are comparable to full-scale PROD data are the Mechanical Failure Frequencies for calm and moderate weather. As can be seen, in percentages, these values are 0.51% for calm weather and 2.81% for moderate weather. The average of these two values is 1.66%. These values compare well with the reliability values based on the above referenced full-scale PROD data, which give an average value of 1.59% for the two weather conditions.

In full-scale manned evacuations, of course, the reliability is also affected by human performance. The RPT gives the human error frequency sum for the drill situation as well. This can be seen to be 0.35% and 0.70% for calm and moderate drill conditions, respectively.

The success of the RPT to generate information for real situations, including probabilities of casualty, is also illustrated in Table 3.3. As can be seen, following the transformation of the human errors and mechanical failure frequencies to casualty probabilities, the model provides casualties attributable to mechanical failure, Mechanical Failure Casualty Probability, and those attributable to human error, Human Error Casualty Probability. These constitute the salient results of the model, which are not available from unmanned full-scale or model tests. Naturally, as can be seen from Table 3.3, the probabilities of casualty (fatality or serious injury) are much lower than the probabilities of errors with the potential to cause casualties. For the PROD system, the evacuation success probability or rate per demand (the inverse of the casualty probability) is very close to unity for calm, moderate, and severe weather, but breaks down significantly for extreme weather (43.25%) – even in the drill condition – as exemplified in Table 3.3.

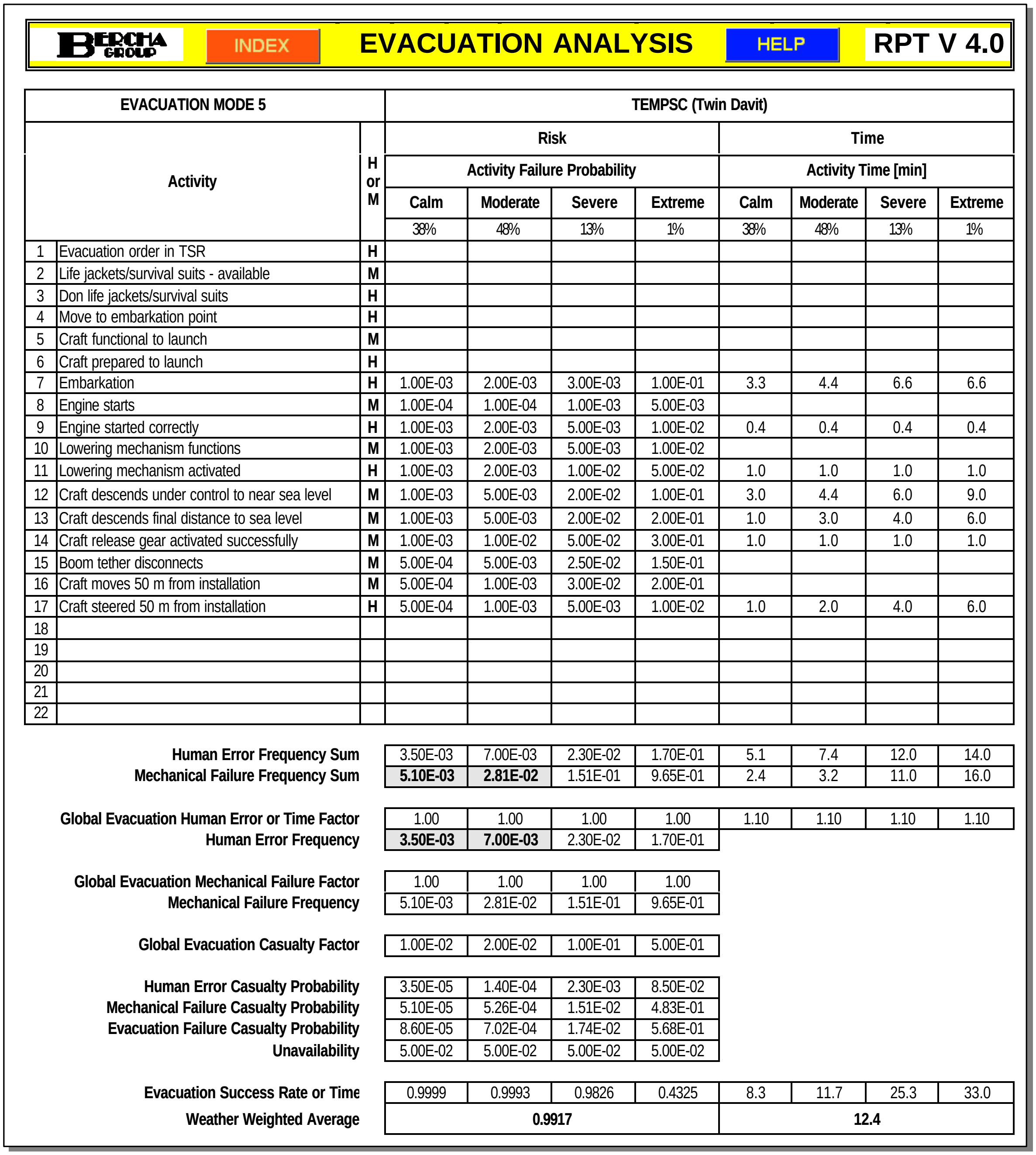
Table 3.2 PROD full evacuation RPT analysis for drill scenario



EVACUATION ANALYSIS **RPT V 4.0**

	EVACUATION MODE 5		TEMPSC (Twin Davit)							
			Risk				Time			
	Activity	H or M	Activity Failure Probability				Activity Time [min]			
			Calm	Moderate	Severe	Extreme	Calm	Moderate	Severe	Extreme
			38%	48%	13%	1%	38%	48%	13%	1%
1	Evacuation order in TSR	H	1.00E-04	1.00E-04	5.00E-04	1.00E-03	1.0	1.0	1.0	1.0
2	Life jackets/survival suits - available	M	1.00E-03	1.00E-03	1.00E-03	1.00E-03				
3	Don life jackets/survival suits	H	1.00E-03	2.00E-03	3.00E-03	4.00E-03	0.9	0.9	1.1	2.2
4	Move to embarkation point	H	1.00E-03	1.50E-03	2.00E-03	1.00E-02	4.4	6.6	8.8	13.2
5	Craft functional to launch	M	3.00E-02	3.00E-02	3.00E-02	3.00E-02				
6	Craft prepared to launch	H	1.00E-03	2.00E-03	3.00E-03	1.00E-01	2.0	3.0	4.0	4.0
7	Embarkation	H	1.00E-03	2.00E-03	3.00E-03	1.00E-01	3.3	4.4	6.6	6.6
8	Engine starts	M	1.00E-04	1.00E-04	1.00E-03	5.00E-03				
9	Engine started correctly	H	1.00E-03	2.00E-03	5.00E-03	1.00E-02	0.4	0.4	0.4	0.4
10	Lowering mechanism functions	M	1.00E-03	2.00E-03	5.00E-03	1.00E-02				
11	Lowering mechanism activated	H	1.00E-03	2.00E-03	1.00E-02	5.00E-02	1.0	1.0	1.0	1.0
12	Craft descends under control to near sea level	M	1.00E-03	5.00E-03	2.00E-02	1.00E-01	3.0	4.4	6.0	9.0
13	Craft descends final distance to sea level	M	1.00E-03	5.00E-03	2.00E-02	2.00E-01	1.0	3.0	4.0	6.0
14	Craft release gear activated successfully	M	1.00E-03	1.00E-02	5.00E-02	3.00E-01	1.0	1.0	1.0	1.0
15	Boom tether disconnects	M	5.00E-04	5.00E-03	2.50E-02	1.50E-01				
16	Craft moves 50 m from installation	M	5.00E-04	1.00E-03	3.00E-02	2.00E-01				
17	Craft steered 50 m from installation	H	5.00E-04	1.00E-03	5.00E-03	1.00E-02	1.0	2.0	4.0	6.0
18										
19										
20										
21										
22										
	Human Error Frequency Sum		6.60E-03	1.26E-02	3.15E-02	2.85E-01	14.0	19.3	26.9	34.4
	Mechanical Failure Frequency Sum		3.61E-02	5.91E-02	1.82E-01	9.96E-01	5.0	8.4	11.0	16.0
	Global Evacuation Human Error or Time Factor		1.00	1.00	1.00	1.00	1.10	1.10	1.10	1.10
	Human Error Frequency		6.60E-03	1.26E-02	3.15E-02	2.85E-01				
	Global Evacuation Mechanical Failure Factor		1.00	1.00	1.00	1.00				
	Mechanical Failure Frequency		3.61E-02	5.91E-02	1.82E-01	9.96E-01				
	Global Evacuation Casualty Factor		1.00E-02	2.00E-02	1.00E-01	5.00E-01				
	Human Error Casualty Probability		6.60E-05	2.52E-04	3.15E-03	1.43E-01				
	Mechanical Failure Casualty Probability		3.61E-04	1.18E-03	1.82E-02	4.98E-01				
	Evacuation Failure Casualty Probability		4.27E-04	1.43E-03	2.14E-02	6.41E-01				
	Unavailability		2.50E-03	2.50E-03	2.50E-03	2.50E-03				
	Evacuation Success Rate or Time		0.9996	0.9986	0.9787	0.3595	20.9	30.4	41.7	55.4
	Weather Weighted Average		**0.9900**				**28.5**			

Table 3.3 PROD embarkation and launch RPT analysis for drill evacuation scenario



	EVACUATION MODE 5		TEMPSC (Twin Davit)							
			Risk				Time			
	Activity	H or M	Activity Failure Probability				Activity Time [min]			
			Calm	Moderate	Severe	Extreme	Calm	Moderate	Severe	Extreme
			38%	48%	13%	1%	38%	48%	13%	1%
1	Evacuation order in TSR	**H**								
2	Life jackets/survival suits - available	**M**								
3	Don life jackets/survival suits	**H**								
4	Move to embarkation point	**H**								
5	Craft functional to launch	**M**								
6	Craft prepared to launch	**H**								
7	Embarkation	**H**	1.00E-03	2.00E-03	3.00E-03	1.00E-01	3.3	4.4	6.6	6.6
8	Engine starts	**M**	1.00E-04	1.00E-04	1.00E-03	5.00E-03				
9	Engine started correctly	**H**	1.00E-03	2.00E-03	5.00E-03	1.00E-02	0.4	0.4	0.4	0.4
10	Lowering mechanism functions	**M**	1.00E-03	2.00E-03	5.00E-03	1.00E-02				
11	Lowering mechanism activated	**H**	1.00E-03	2.00E-03	1.00E-02	5.00E-02	1.0	1.0	1.0	1.0
12	Craft descends under control to near sea level	**M**	1.00E-03	5.00E-03	2.00E-02	1.00E-01	3.0	4.4	6.0	9.0
13	Craft descends final distance to sea level	**M**	1.00E-03	5.00E-03	2.00E-02	2.00E-01	1.0	3.0	4.0	6.0
14	Craft release gear activated successfully	**M**	1.00E-03	1.00E-02	5.00E-02	3.00E-01	1.0	1.0	1.0	1.0
15	Boom tether disconnects	**M**	5.00E-04	5.00E-03	2.50E-02	1.50E-01				
16	Craft moves 50 m from installation	**M**	5.00E-04	1.00E-03	3.00E-02	2.00E-01				
17	Craft steered 50 m from installation	**H**	5.00E-04	1.00E-03	5.00E-03	1.00E-02	1.0	2.0	4.0	6.0
18										
19										
20										
21										
22										

Human Error Frequency Sum	3.50E-03	7.00E-03	2.30E-02	1.70E-01	5.1	7.4	12.0	14.0
Mechanical Failure Frequency Sum	**5.10E-03**	**2.81E-02**	1.51E-01	9.65E-01	2.4	3.2	11.0	16.0
Global Evacuation Human Error or Time Factor	1.00	1.00	1.00	1.00	1.10	1.10	1.10	1.10
Human Error Frequency	**3.50E-03**	**7.00E-03**	2.30E-02	1.70E-01				
Global Evacuation Mechanical Failure Factor	1.00	1.00	1.00	1.00				
Mechanical Failure Frequency	5.10E-03	2.81E-02	1.51E-01	9.65E-01				
Global Evacuation Casualty Factor	1.00E-02	2.00E-02	1.00E-01	5.00E-01				
Human Error Casualty Probability	3.50E-05	1.40E-04	2.30E-03	8.50E-02				
Mechanical Failure Casualty Probability	5.10E-05	5.26E-04	1.51E-02	4.83E-01				
Evacuation Failure Casualty Probability	8.60E-05	7.02E-04	1.74E-02	5.68E-01				
Unavailability	5.00E-02	5.00E-02	5.00E-02	5.00E-02				
Evacuation Success Rate or Time	0.9999	0.9993	0.9826	0.4325	8.3	11.7	25.3	33.0
Weather Weighted Average	**0.9917**				**12.4**			

The same general comments apply to Table 3.4, which represents the results of the modified RPT evacuation analysis under a heightened state of emergency, the precautionary emergency condition. Naturally, there is no change in the mechanical failure estimates for a conditions associated with heightened anxiety among the evacuees; rather, only the human error component changes, as indicated opposite Human Error Frequency. The resultant success rate is somewhat lower than that for the drill scenario.

Finally, Table 3.5 shows the results of the analysis for the life-threatening emergency evacuation scenario. Here, human error frequency has again further increased, with the resultant evacuation success rate expectations also reduced significantly.

To summarize the reliability results discussed above in detail, the salient figures have been entered into a table formatted to facilitate comparative evaluation. Table 3.6 summarizes the human error frequencies, the mechanical failure frequencies, and the success rates for each of the weather conditions for each of the evacuation scenario types. It should be noted that this table is based on the truncated evacuation activities, from embarkation to clearing of the installation. As can be seen, the human error component increases with heightened state of threat. This increase reflects the factors identified in Chapter 2 for the impact of psychological stress. The mechanical failure probability, as mentioned earlier, is entirely independent of psychological stress, and therefore remains invariant regardless of evacuation scenario. Mechanical failure, however, just as human error, increases with severity of environmental conditions. The two shaded figures are ones comparable directly with the PROD full-scale data described in Section 3.3. The agreement of these figures is within 10%.

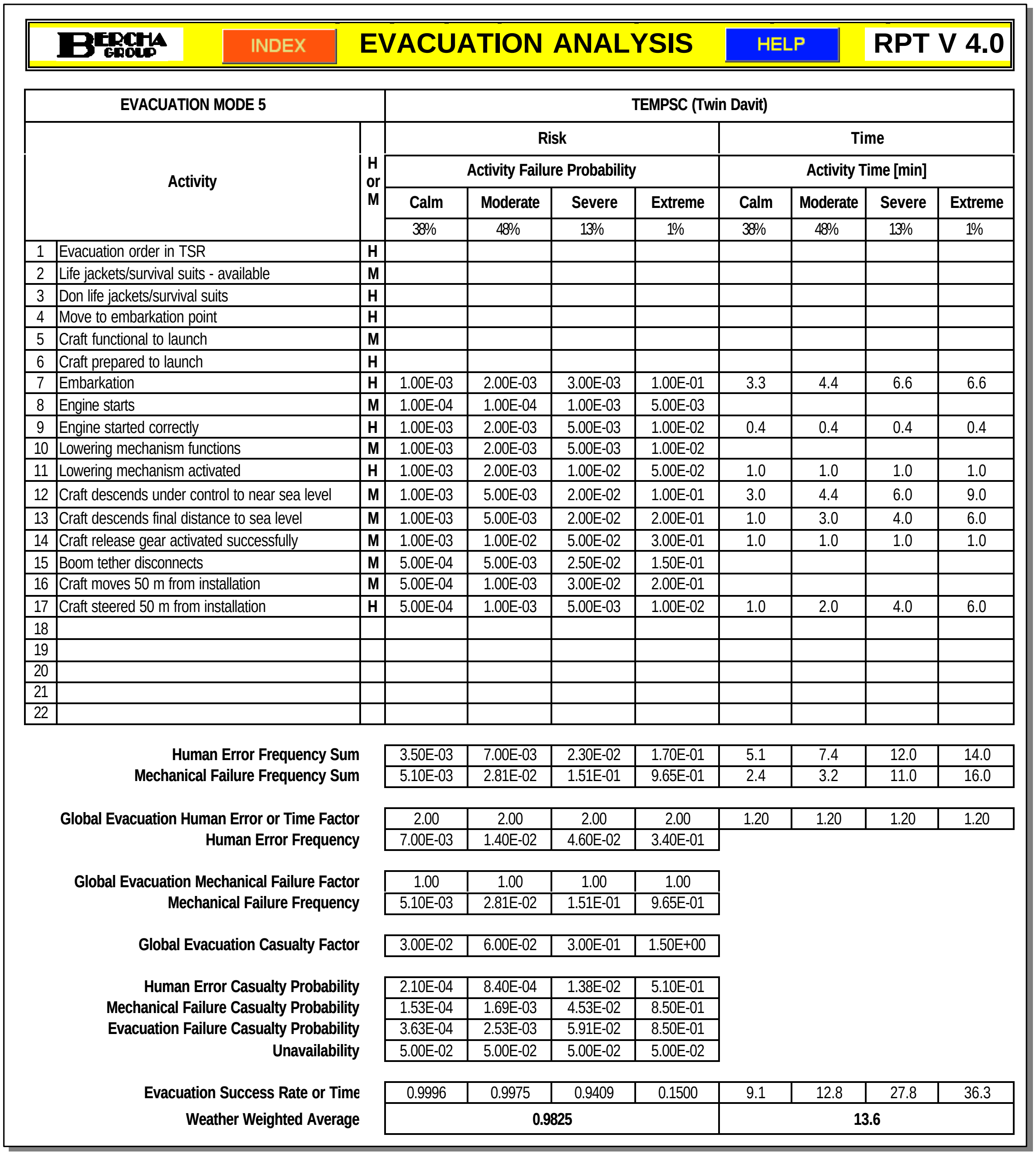
3.6 Activity Contributions to Estimated PROD Reliability

In addition to assessing the expected total human, mechanical, and combined reliabilities for a given evacuation process, the RPT also gives the absolute and relative contributions to these of the key activities. Based on the PROD truncated drill scenario represented in Table 3.3, relative contributions of the key activities to the system failure frequencies have been extracted and are represented in pie charts for human error (HE) and mechanical failure (MF). Only the calm weather scenario has been considered here; the relative contribution of these activities in the other three weather scenarios is not significantly different, although the absolute values of HE and MF change significantly.

As can be seen from Figure 3.4, the principal contributions of relative importance are the following human functions:

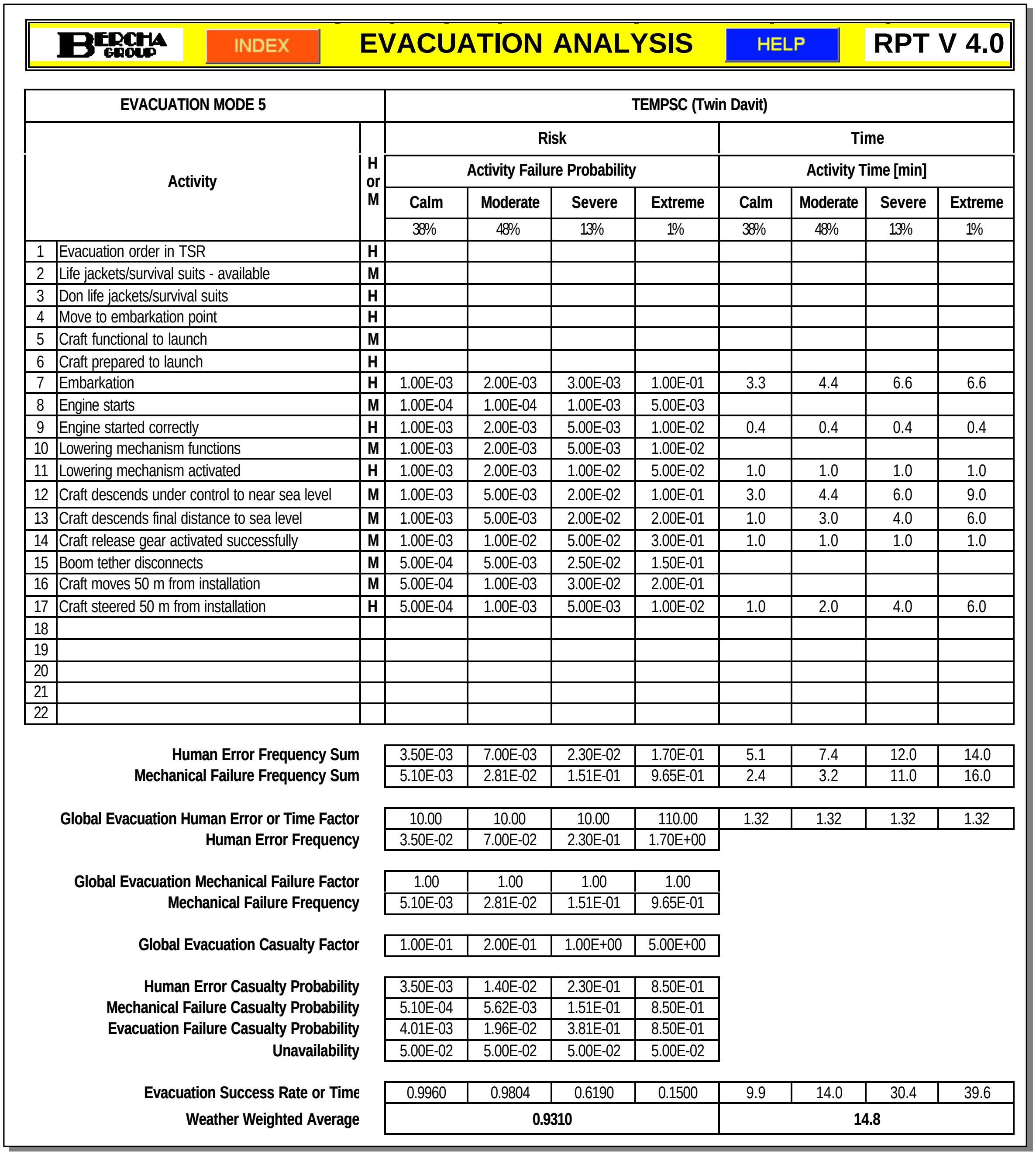
- #11 - 29% - Lowering mechanism activated.
- #9 - 29% - Engine started correctly.
- #7 - 28% - Embarkation.
- #17 - 14% - Craft steered 50 m from installation.

Table 3.4 PROD embarkation and launch RPT analysis for precautionary evacuation scenario



EVACUATION MODE 5			TEMPSC (Twin Davit)							
			Risk				Time			
	Activity	H or M	Activity Failure Probability				Activity Time [min]			
			Calm	Moderate	Severe	Extreme	Calm	Moderate	Severe	Extreme
			38%	48%	13%	1%	38%	48%	13%	1%
1	Evacuation order in TSR	H								
2	Life jackets/survival suits - available	M								
3	Don life jackets/survival suits	H								
4	Move to embarkation point	H								
5	Craft functional to launch	M								
6	Craft prepared to launch	H								
7	Embarkation	H	1.00E-03	2.00E-03	3.00E-03	1.00E-01	3.3	4.4	6.6	6.6
8	Engine starts	M	1.00E-04	1.00E-04	1.00E-03	5.00E-03				
9	Engine started correctly	H	1.00E-03	2.00E-03	5.00E-03	1.00E-02	0.4	0.4	0.4	0.4
10	Lowering mechanism functions	M	1.00E-03	2.00E-03	5.00E-03	1.00E-02				
11	Lowering mechanism activated	H	1.00E-03	2.00E-03	1.00E-02	5.00E-02	1.0	1.0	1.0	1.0
12	Craft descends under control to near sea level	M	1.00E-03	5.00E-03	2.00E-02	1.00E-01	3.0	4.4	6.0	9.0
13	Craft descends final distance to sea level	M	1.00E-03	5.00E-03	2.00E-02	2.00E-01	1.0	3.0	4.0	6.0
14	Craft release gear activated successfully	M	1.00E-03	1.00E-02	5.00E-02	3.00E-01	1.0	1.0	1.0	1.0
15	Boom tether disconnects	M	5.00E-04	5.00E-03	2.50E-02	1.50E-01				
16	Craft moves 50 m from installation	M	5.00E-04	1.00E-03	3.00E-02	2.00E-01				
17	Craft steered 50 m from installation	H	5.00E-04	1.00E-03	5.00E-03	1.00E-02	1.0	2.0	4.0	6.0
18										
19										
20										
21										
22										
	Human Error Frequency Sum		3.50E-03	7.00E-03	2.30E-02	1.70E-01	5.1	7.4	12.0	14.0
	Mechanical Failure Frequency Sum		5.10E-03	2.81E-02	1.51E-01	9.65E-01	2.4	3.2	11.0	16.0
	Global Evacuation Human Error or Time Factor		2.00	2.00	2.00	2.00	1.20	1.20	1.20	1.20
	Human Error Frequency		7.00E-03	1.40E-02	4.60E-02	3.40E-01				
	Global Evacuation Mechanical Failure Factor		1.00	1.00	1.00	1.00				
	Mechanical Failure Frequency		5.10E-03	2.81E-02	1.51E-01	9.65E-01				
	Global Evacuation Casualty Factor		3.00E-02	6.00E-02	3.00E-01	1.50E+00				
	Human Error Casualty Probability		2.10E-04	8.40E-04	1.38E-02	5.10E-01				
	Mechanical Failure Casualty Probability		1.53E-04	1.69E-03	4.53E-02	8.50E-01				
	Evacuation Failure Casualty Probability		3.63E-04	2.53E-03	5.91E-02	8.50E-01				
	Unavailability		5.00E-02	5.00E-02	5.00E-02	5.00E-02				
	Evacuation Success Rate or Time		0.9996	0.9975	0.9409	0.1500	9.1	12.8	27.8	36.3
	Weather Weighted Average		**0.9825**				**13.6**			

Table 3.5 PROD embarkation and launch RPT analysis for threatening evacuation scenario



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	EVACUATION MODE 5		**TEMPSC (Twin Davit)**							
			Risk				**Time**			
	Activity	**H or M**	**Activity Failure Probability**				**Activity Time [min]**			
			Calm	**Moderate**	**Severe**	**Extreme**	**Calm**	**Moderate**	**Severe**	**Extreme**
			38%	48%	13%	1%	38%	48%	13%	1%
1	Evacuation order in TSR	**H**								
2	Life jackets/survival suits - available	**M**								
3	Don life jackets/survival suits	**H**								
4	Move to embarkation point	**H**								
5	Craft functional to launch	**M**								
6	Craft prepared to launch	**H**								
7	Embarkation	**H**	1.00E-03	2.00E-03	3.00E-03	1.00E-01	3.3	4.4	6.6	6.6
8	Engine starts	**M**	1.00E-04	1.00E-04	1.00E-03	5.00E-03				
9	Engine started correctly	**H**	1.00E-03	2.00E-03	5.00E-03	1.00E-02	0.4	0.4	0.4	0.4
10	Lowering mechanism functions	**M**	1.00E-03	2.00E-03	5.00E-03	1.00E-02				
11	Lowering mechanism activated	**H**	1.00E-03	2.00E-03	1.00E-02	5.00E-02	1.0	1.0	1.0	1.0
12	Craft descends under control to near sea level	**M**	1.00E-03	5.00E-03	2.00E-02	1.00E-01	3.0	4.4	6.0	9.0
13	Craft descends final distance to sea level	**M**	1.00E-03	5.00E-03	2.00E-02	2.00E-01	1.0	3.0	4.0	6.0
14	Craft release gear activated successfully	**M**	1.00E-03	1.00E-02	5.00E-02	3.00E-01	1.0	1.0	1.0	1.0
15	Boom tether disconnects	**M**	5.00E-04	5.00E-03	2.50E-02	1.50E-01				
16	Craft moves 50 m from installation	**M**	5.00E-04	1.00E-03	3.00E-02	2.00E-01				
17	Craft steered 50 m from installation	**H**	5.00E-04	1.00E-03	5.00E-03	1.00E-02	1.0	2.0	4.0	6.0
18										
19										
20										
21										
22										

Human Error Frequency Sum	3.50E-03	7.00E-03	2.30E-02	1.70E-01	5.1	7.4	12.0	14.0
Mechanical Failure Frequency Sum	5.10E-03	2.81E-02	1.51E-01	9.65E-01	2.4	3.2	11.0	16.0
Global Evacuation Human Error or Time Factor	10.00	10.00	10.00	110.00	1.32	1.32	1.32	1.32
Human Error Frequency	3.50E-02	7.00E-02	2.30E-01	1.70E+00				
Global Evacuation Mechanical Failure Factor	1.00	1.00	1.00	1.00				
Mechanical Failure Frequency	5.10E-03	2.81E-02	1.51E-01	9.65E-01				
Global Evacuation Casualty Factor	1.00E-01	2.00E-01	1.00E+00	5.00E+00				
Human Error Casualty Probability	3.50E-03	1.40E-02	2.30E-01	8.50E-01				
Mechanical Failure Casualty Probability	5.10E-04	5.62E-03	1.51E-01	8.50E-01				
Evacuation Failure Casualty Probability	4.01E-03	1.96E-02	3.81E-01	8.50E-01				
Unavailability	5.00E-02	5.00E-02	5.00E-02	5.00E-02				
Evacuation Success Rate or Time	0.9960	0.9804	0.6190	0.1500	9.9	14.0	30.4	39.6
Weather Weighted Average	**0.9310**				**14.8**			

Table 3.6 Summary of PROD reliability results from RPT (% per launch)

EVACUATION SCENARIO	RELIABILITY COMPONENT	WEATHER			
		CALM	MODERATE	SEVERE	EXTREME
Drill	Human Error	0.35	0.70	2.3	17.0
	Mechanical Failure	**0.51**	**2.81**	15.1	96.5
	Success Rates	99.9	99.9	98.26	43.25
Precautionary	Human Error	0.70	1.40	4.6	34.0
	Mechanical Failure	0.51	2.81	15.1	96.5
	Success Rates	99.9	99.8	94.1	15.0
Life-threatening	Human Error	3.5	7.0	23.0	100.0
	Mechanical Failure	0.51	2.81	15.1	96.5
	Success Rates	99.6	98.0	61.9	15.0

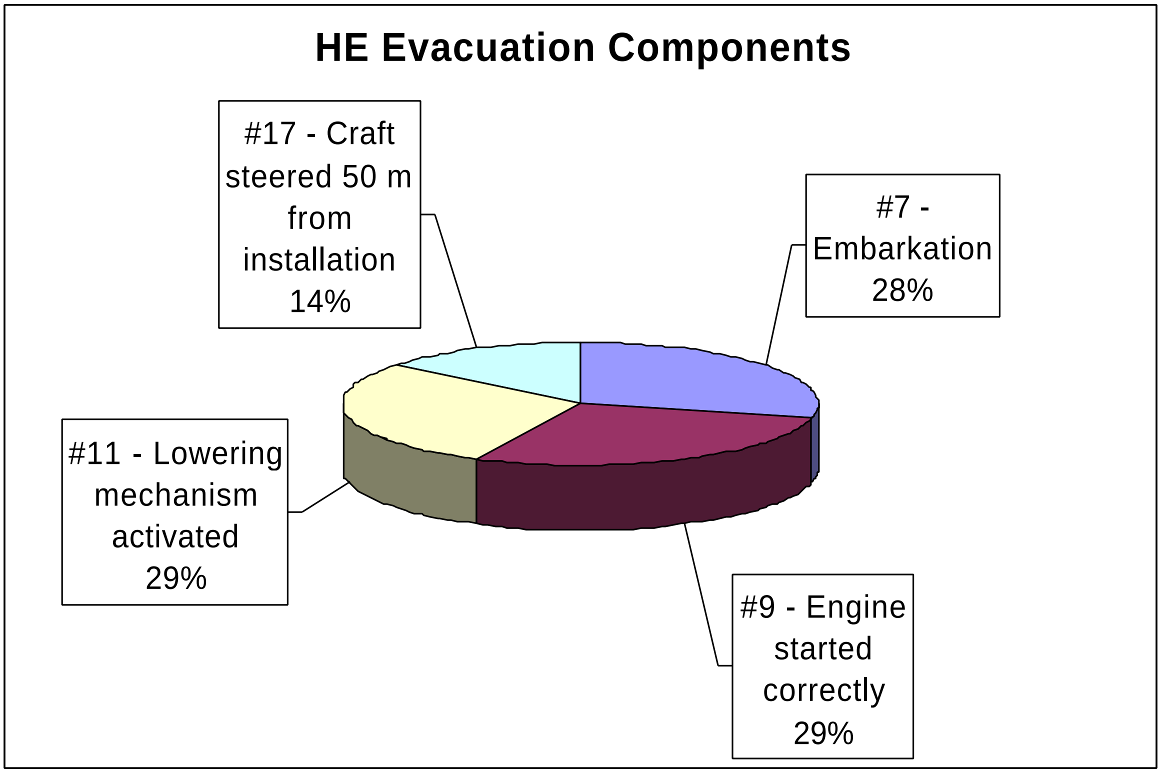


Figure 3.4 HE evacuation components

Similarly, from Figure 3.5, the following are the principal mechanical failure (MF) contributors to the PROD evacuation system failure:

- #14 - 20% - Craft release gear activated successfully.
- #13 - 20% - Craft descends final distance to sea level.
- #12 - 19% - Craft descends under control to near sea level.
- #10 - 19% - Lowering mechanism functions.
- #15 - 10% - Boom tether disconnects.
- #16 - 10% - Craft moves 50 m from installation.
- #8 - 2% - Engine starts.

3.7 HE and MF Relative Contributions to PROD Reliability for Different Weather Classes and Global Scenarios

As mentioned earlier, the mechanical failure probability contribution is independent of the global scenario psychological stress level. However, it varies with environmental conditions as represented by each of the four weather classes. The human error and mechanical failure data from Table 3.6 can be used as a basis for a comparative evaluation of contributions from human error and mechanical failure to PROD reliability for the stress and environmental condition variables.

Figure 3.6 shows a bar chart and the associated source data for the contributions of human error and mechanical failure for each of the weather classes and stress levels. As can be seen, there is a gradual increase in the values of HE as stress levels increase from drill to life-threatening. The relative values of MF and HE, however, change as threat level increases. In fact, for the drill and precautionary threat levels, the HE contribution to PROD reliability is generally less than the mechanical failure contribution. However, for the life-threatening situation, the contribution of HE to PROD reliability significantly exceeds that of mechanical failure for all weather conditions. This is attributable to the debilitating effect on human performance of high stress levels as presented in Chapter 2. Accordingly, there is a clear priority for the improvement of human performance through training in preparation for life-threatening emergencies. This is particularly true for these systems, as their primary intended use is, in fact, for the situation (life-threatening accident) where there is no other choice than emergency evacuation.

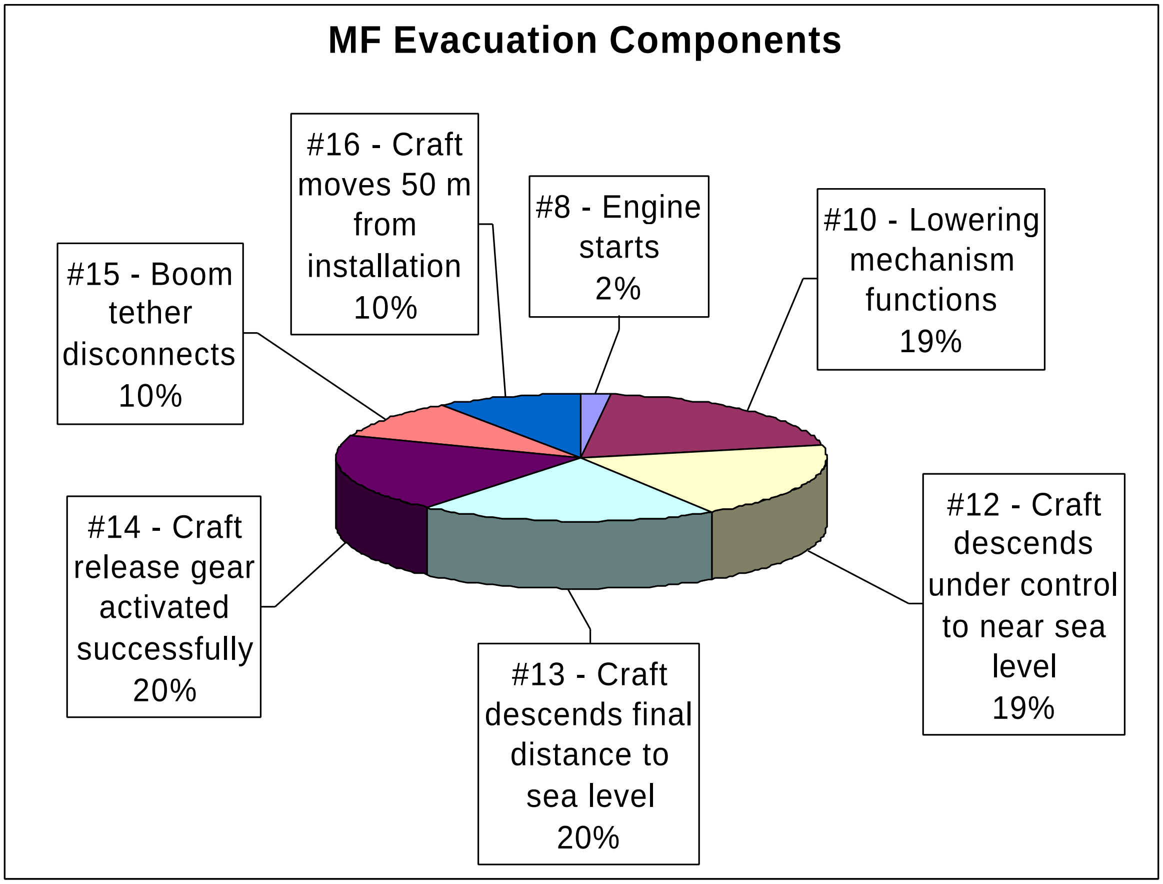
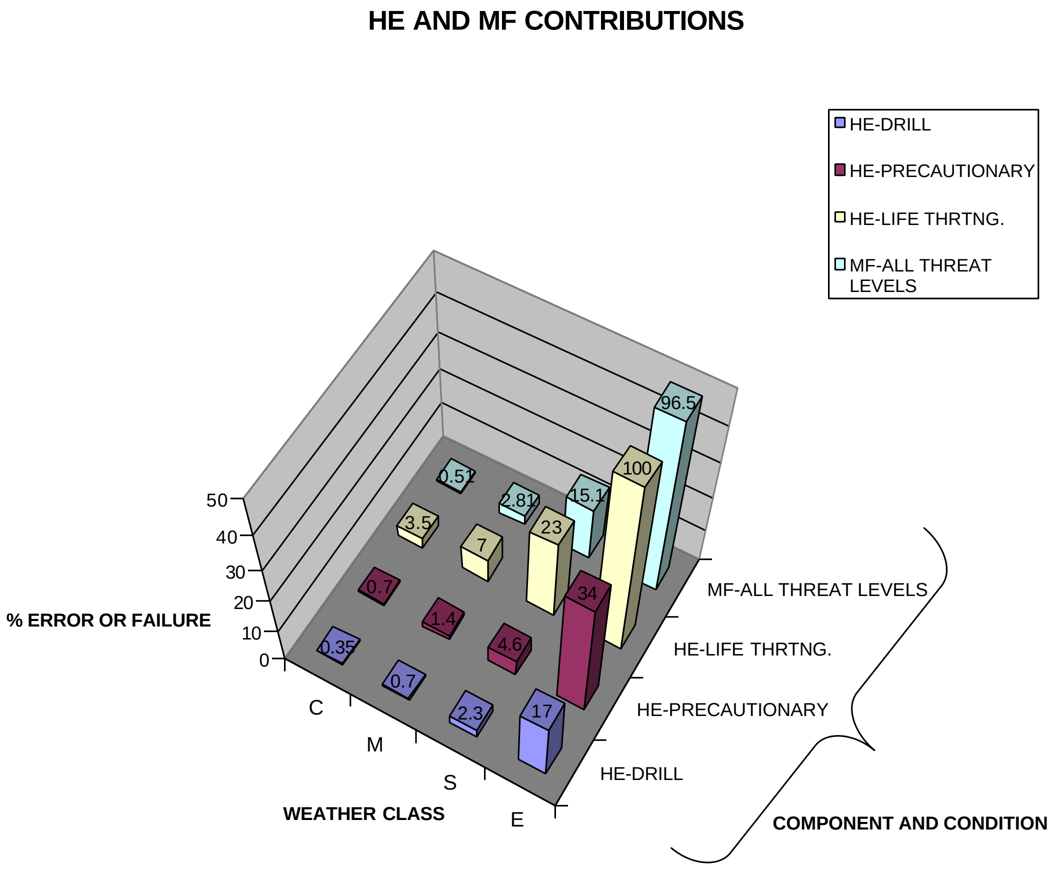


Figure 3.5 MF evacuation components



		% HE OR MF			
	CATEGORY	**C**	**M**	**S**	**E**
🟪	HE-DRILL	0.35	0.7	2.3	17
🟥	HE-PRECAUTIONARY	0.7	1.4	4.6	34
🟨	HE-LIFE THREATENING	3.5	7	23	100
🟦	MF-ALL THREAT LEVELS	0.51	2.81	15.1	96.5

Figure 3.6 Relative contributions to PROD reliability of HE and MF for different weather conditions and threat levels

3.8 Conclusions from PROD Reliability Analysis

The following conclusions may be reached from the PROD reliability analysis described in this chapter:

- PROD evacuation success rate is highly dependent on environmental state, with a significant decay as environmental conditions move from severe to extreme.
- Mechanical failure is independent of the emergency stress level, as the equipment is expected to function in the same manner regardless of the psychological stress. However, mechanical failure probability increases rapidly with severity of weather, approaching unity (100%) for extreme conditions.
- Human error performance decays significantly with increase in emergency psychological stress level, with human error probability doubling from drill to precautionary emergency, and increasing by approximately an order of magnitude (factor of 10) from drill to life-threatening emergency.
- The principal activities that can result in critical human errors are roughly equally distributed in their order of importance; however, the correct manoeuvring of the craft to clear the installation provides an increasing proportion of the human error failure probability as the weather becomes more severe.
- Of the mechanical functions, the reliability of the craft release gear and lowering mechanism outweigh the importance or the expected contribution to failure of boom tether disconnect, engine starting, and craft manoeuvrability function.

4. RISK AND PERFORMANCE TOOL (RPT) DEVELOPMENT

4.1 General Introduction on Current RPT Developments

The Risk and Performance Tool (RPT) is a probabilistic computerized simulator capable of modeling all significant aspects of the EER process as well as its overall success likelihood for a variety of installation types, accident situations, and weather conditions. The final report for Phase I (Bercha Engineering, 2001) of the EER research project gives a detailed description of the basic structure and a function of the RPT (Version 3.5). This basic structure and function has not been fundamentally altered; rather, it has been modified to provide the necessary information on human performance, reliability and availability, and detailed inputs for selected combinations of conditions and situations.

Specifically, the following three principal areas have been included in the modifications of the RPT (Version 4.0) under Phase II of the EER research project:

(1) Incorporation of human performance explicitly into the RPT through the restructuring of the evacuation module and other modifications in input and output parameters.

(2) Creation of the Reliability Version of the RPT so that it can generate values of reliability without the inclusion of availability. Creation of the Success Version of the RPT, which does include component availability. The Reliability Version is needed to generate reliability values in support of the Performance-Based Standards (PBS) development program.

(3) Generation of a full spectrum of reliability values covering nine evacuation modes, four recovery platforms, and four weather conditions. Each combination includes single evacuation mode reliabilities for each weather condition, inter-modal transfer and recovery reliabilities for all combinations of evacuation and rescue modes, and four weather conditions. It is used as an appendix to the PBS.

In the balance of this chapter, following a brief description of the overall structure of the RPT, each of the above main areas is addressed in detail.

4.2 Incorporation of Human Performance Simulation into the RPT

4.2.1 General Description of the Methodology

Details of the impact of different EER stressors on human performance are given in Chapter 2. In this chapter, a description of the algorithms for incorporating the research findings on human performance under extreme conditions are described. Specifically, the factors necessary to modify human performance parameters to account for both psychological and physical high-stress levels are described and their methods of interaction with the EER simulation are presented. These have been incorporated into Version 4.0 of the RPT. In addition, the “Help” files of earlier versions of the RPT have been completely revised in Version 4.0.

The description is subdivided among the modules of the RPT, which, for the reader's convenience, are reproduced in Figure 4.1. A more detailed description of the RPT is given in the final report for Phase 1 of this research (Bercha Engineering, 2001).

4.2.2 RPT Global Level HP Incorporation

Table 4.1 summarizes the global inputs that result in impacts in human performance. Those having an impact on human performance have the letter "H" in the first column. Parameters are program sub-algorithms that compute effects or impacts from specified inputs. Table 4.2 summarizes the global parameters that are significantly affected by human performance. In the case of both tables, applicability to each of the three components or the entire EER process of the subject inputs or parameters is also indicated. Because the integrated EER calculation essentially integrates the results of the three EER component analyses, use of the subject variables for EER (last column on the right) is generally implicit rather than explicit.

4.2.3 RPT Escape Level HP Incorporation

Tables 4.3 and 4.4 summarize the inputs and parameters necessary for the quantification of the success and time for escape. The reader is reminded that the "escape" in EER herein means the movement of personnel from their location at the time of the alarm until their arrival in the Temporary Safe Refuge (TSR) or other designated muster point. All of the parameters given in Table 4.4 are human performance parameters and therefore their calculation is strictly a function of human performance. The geometrical and physical configuration of the escape routes inputs is described in Table 4.3. All of the psychological and physiological stressors affect escape parameters; the calculation of the associated final results is summarized in Table 4.5.

Because escape is primarily a human performance process, given a set of physical conditions, escape success is largely a function of human performance. Such items as failure of hatches to open, which would be considered mechanical failure, have not been included in the RPT escape module. Later modules (evacuation and rescue), which depend much more on technological performance, include mechanical failures in their computations.

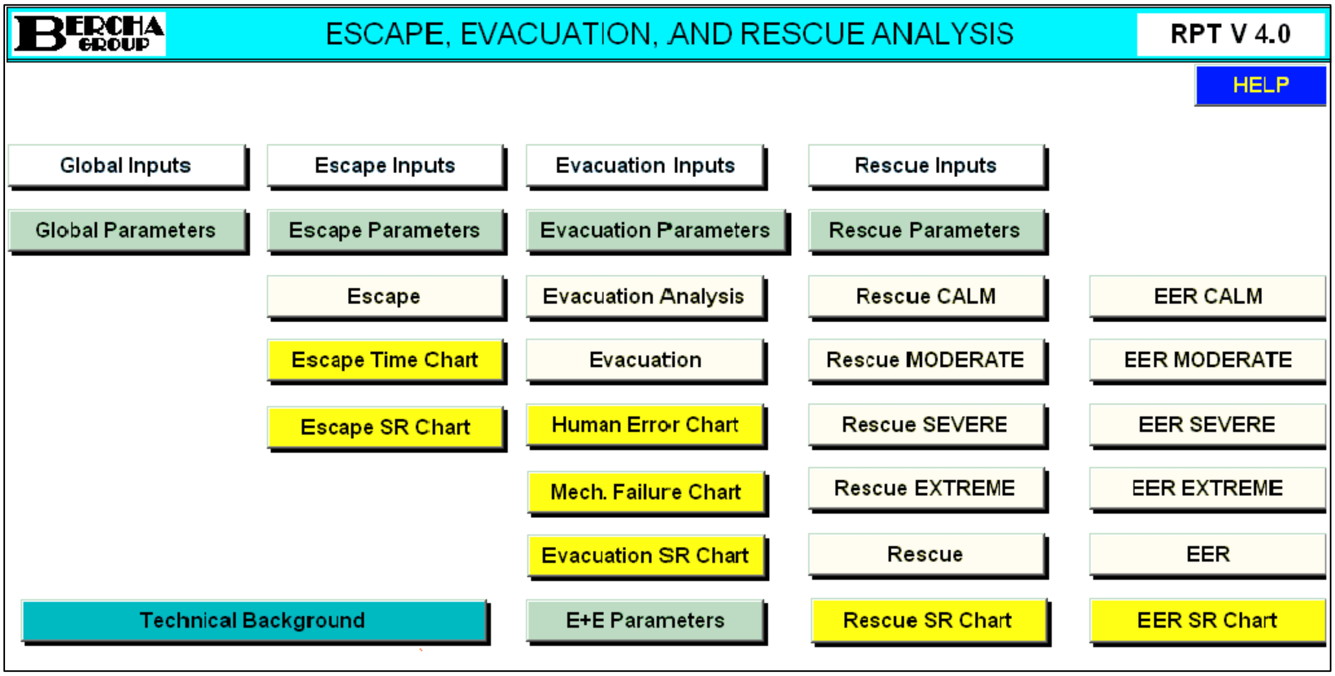


Figure 4.1 RPT modules

Table 4.1 Global inputs impacting human performance

IMPACT ON HUMAN PERFORMANCE*	GLOBAL INPUTS	DESCRIPTION	USED FOR			
			Escape	Evacua- tion	Rescue	EER
N	Version	1-Reliability, 2- Success	No	Yes	No	Yes
H	EER Global Scenario	1- Drill, 2-Precautionary, 3- Life Threatening	Yes	Yes	No	Yes
N	Installation Type	1- Fixed, 2-Floating Semi, 3-Floating Monohull	Yes	Yes	No	Yes
H	Weather	Calm, Moderate, Severe, Extreme %	No	Yes	Yes	Yes
H	Cold Weather	Less than -20 C, -20 C to 0 C, Above 20C months per year	Yes	Yes	Yes	Yes
H	Fog	Annual %	No	Yes	Yes	Yes
H	Escape Time Limit	Limit for Escape in min	No	No	No	Yes
H	Escape + Evacuation Time Limit	Limit for E+E in min	No	No	No	Yes
H	Number of People on Board	# of people for case study	Yes	Yes	No	Yes
H	Day/Night	1-Both, 2-Day only operation, 3-Night only	Yes	Yes	No	Yes
H	Heel	1-<10deg, 2-10-45deg, 3->45deg	Yes	Yes	No	Yes

* **H** = Has impact on human performance.
N = No impact on human performance.

Table 4.2 Global parameters impacting human performance

IMPACT ON HUMAN PERFORMANCE*	GLOBAL PARAMETERS	DESCRIPTION	USED FOR			
			Escape	Evacua-tion	Rescue	EER
H	Global Scenario Factors	Time(GSTF), Error(GSEF), Fatality(GSFF)	Yes	Yes	No	Yes
N	Installation Type Factors	Time(ITTF), Error(ITEF)	Yes	Yes	No	Yes
H	Heel Factors	Time(HTF), Error(HEF)	Yes	Yes	No	Yes
H	Day/Night Factors	Time(DNTF), Error(DNEF)	Yes	Yes	No	Yes
H	Weather Casualty Factors	Calm (WCFC), Moderate (WCFM), Severe(WCFS), Extreme (WCFE)	No	Yes	No	Yes
H	Cold Weather Time Factor	Average (CWTAF)	Yes	No	No	Yes
H	Global Escape Time Factor	Product of all Escape Time Factors	Yes	No	No	Yes
H	Global Escape Error Factor	Product of all Escape Error Factors	Yes	No	No	Yes
H	Global Escape Casualty Factor	=Global Scenario Casualty Factor (GSCF)	Yes	No	No	Yes
H	Global Evacuation Time Factor	Product of all Evacuation Time Factors	No	Yes	No	Yes
H	Global Evacuation Human Error Factor	Product of all Evacuation Error Factors	No	Yes	No	Yes
H	Global Evacuation Casualty Factor	Product of all Evacuation Casualty Factors	No	Yes	No	Yes
N	Global Mechanical Failure Factor	Product of all Mechanical Casualty Factors	No	Yes	No	Yes

* **H** = Has impact on human performance.
N = No impact on human performance.

Table 4.3 Escape inputs for each of six routes (maximum)

ESCAPE INPUTS (for each of 6 routes max.)	DESCRIPTION
Escape Mode:	1-Controlled to TR (No Initial delay), 2- Immediate to Muster Station (60 sec delay)
Number of People on the Route:	Number
Initial Location:	From Legend
Route Complexity:	1-Straight, 2-Several Turns, 3-Complex
Estimated Injured [%]:	Injured by accident or along escape route
Smoke on the Route [%]:	Percent smoke concentration
Internal Walkways Length [m]:	Length
External Walkways Length [m]:	Length
Internal Staircases Length [m]:	Length
External Staircases Length [m]:	Length
Internal Ladders Length [m]:	Length
External Ladders Length [m]:	Length
Number of Bottlenecks:	Hatches, doors, ladders, stairs
Number of Decisions:	Decision points are bifurcations or alternate doors or alternate levels
Escape Route Description:	Description for each route (up to 6)

Table 4.4 Human performance escape parameters

ESCAPE PARAMETERS	DESCRIPTION
Initial Location Delay [s]	Time delay for each initial location
Travel Speed Base[m/s]	Travel speed for Walkways, Staircases, and Ladders (Internal and External)
Survival Suit Time Factor	Suits On - Escape Mode 1, No Suits - Escape Mode 2
Bottleneck Delay [s]	Time delay at bottleneck
Route Complexity Factor	Computes effects for three route types
Base Error Rate per Demand	Average human error rate for specified conditions
Injury Factor:	Calculated for each route; depends on inputs for routes. Formulas for calculation given in RPT. See Table 2.7 for basis.
Smoke Factor:	
Congestion Factor:	

Table 4.5 Escape analysis results

CALCULATION	RESULT
Time Calculation	(Sum of all Times + Initial Delay + Bottleneck Delay) multiplied by Product of: (Injury Factor, Smoke Factor, Congestion Factor, Survival Suit Time Factor, Global Escape Time Factor)
Max Time	Maximum time
Failure Frequency Calculation	Product of: (Number of Decisions, Route Complexity Factor, Base Error Rate per Demand, Global Escape Error Factor)
Success Rate Calculation	1- Failure Frequency multiplied by Global Escape Fatality Factor Min 0, Max 1
Average Success Rate Calculation	Average for all given routes weighted by number of escapees per route

4.2.4 RPT Evacuation Level HP Incorporation

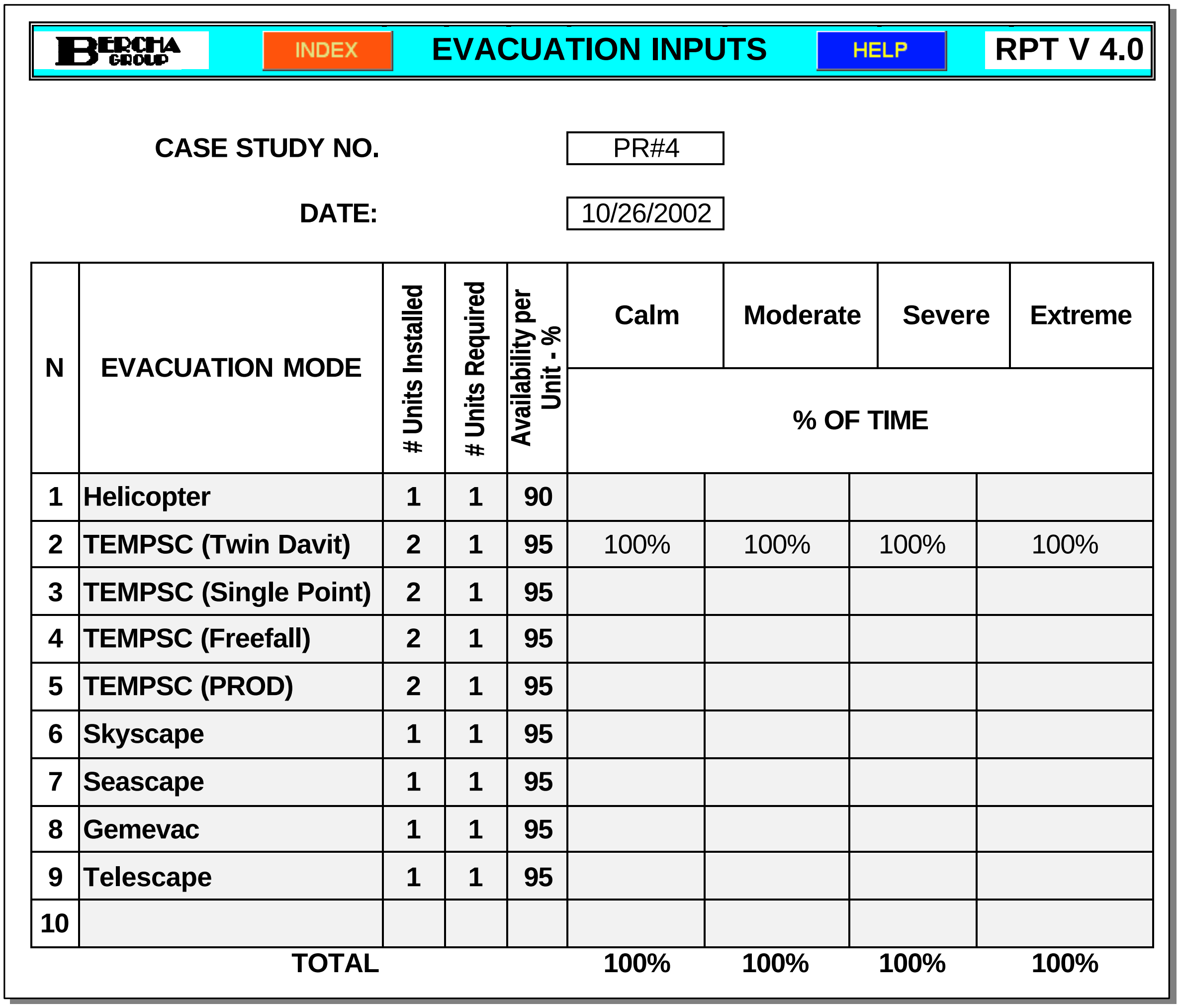
As before, inputs for the evacuation model include the specification of each evacuation mode and its probability (%) of utilization in any given scenario. Also, for the separation of the RPT into the success and reliability versions, a more detailed availability analysis is conducted. Accordingly, the number of units installed, the number of units needed to evacuate all persons on board (POB) and one unit's availability expressed as a percentage of installation service time are required inputs. Figure 4.2 shows the screen for Version 4.0 Evacuation Inputs; Table 4.6 describes the inputs.

In the evacuation process, a clear distinction is necessary between mechanical failures and human performance failures. Mechanical failure, as defined in the PBS (TDC, 2003), is used in the broad sense to include all non-human performance, including machinery, structures, electronics, electrical circuits, communication systems, and other non-human systems failures. Figure 4.3 shows the evacuation parameter screen for a typical evacuation mode, Evacuation Mode #2, the twin-davit TEMPSC. As can be seen, activities are subdivided into those that are predominantly governed by human performance (H) and those that are predominantly governed by mechanical performance (M). The numbers entered in this activity matrix represent the factors by which the base value of human error probability, mechanical failure probability, or activity time must be multiplied in order to generate the baseline value of the associated probability or time. Table 4.7 further describes these evacuation parameters.

Next, the evacuation analysis is carried out. The main steps are generally described in Table 4.8. The results of the analysis for the example evacuation mode, the twin-davit TEMPSC, are given in Figure 4.4. As can be seen, the baseline values of the probabilities and times for each activity are given in the top portion (matrix) of the display. The bottom portion gives the main steps of the computation of the risk component.

In the time simulation side (the right side of the display) only times that are additive are given. Thus, where both the mechanical and the human activity component for the specified activity overlap, such as the craft moving 50 m from the installation, only one of the times is given, while the other coincident activity time is given as zero.

The final results are also presented in histogram form. Dedicated histograms give the human error contribution to casualty probability (Figure 4.5), the mechanical failure contribution to casualty probability (Figure 4.6), and the combined success rate resulting from the inverse of human and mechanical failure contributions to casualty success rate (Figure 4.7).



EVACUATION INPUTS

CASE STUDY NO. PR#4

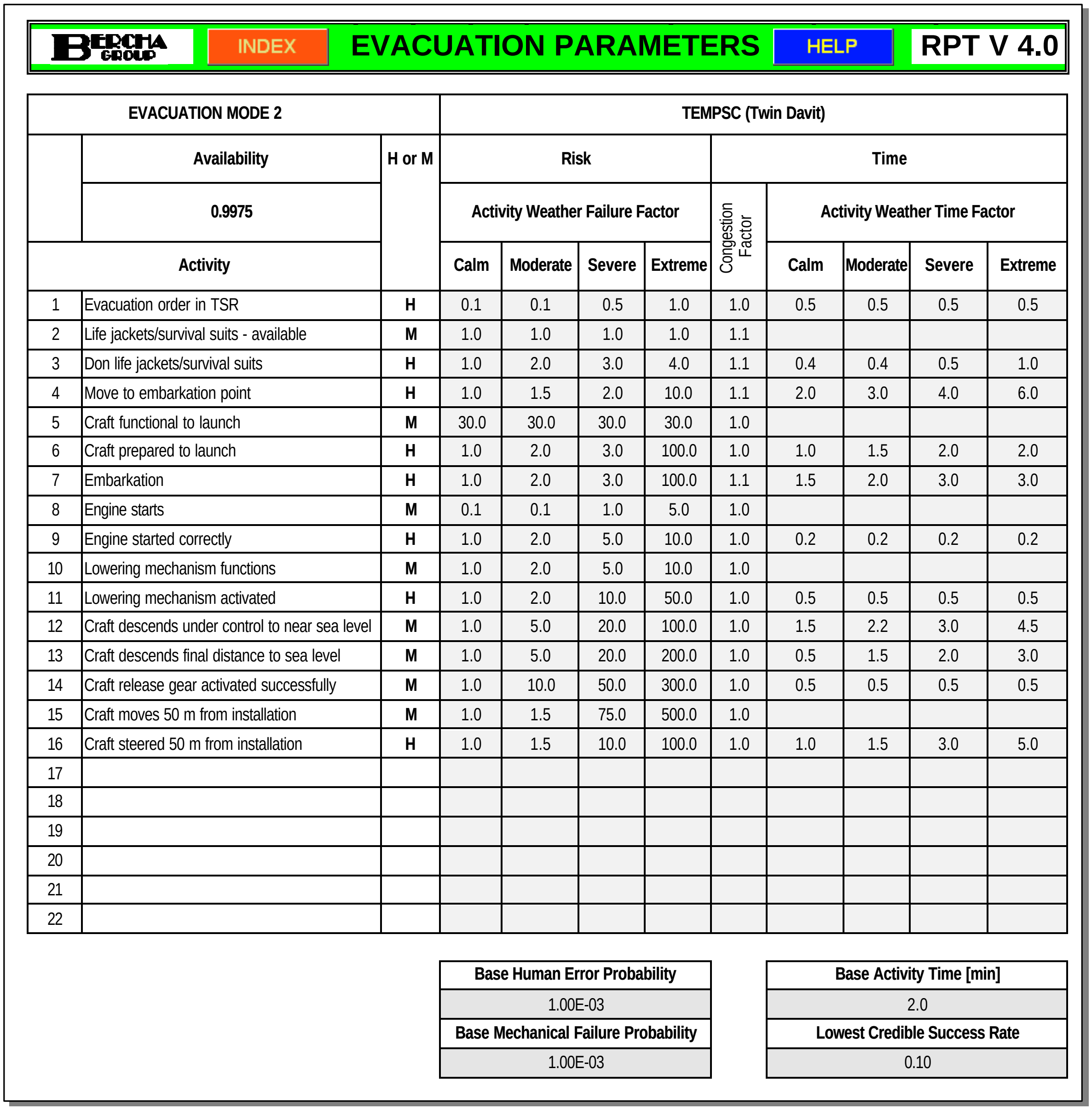
DATE: 10/26/2002

N	EVACUATION MODE	# Units Installed	# Units Required	Availability per Unit - %	Calm	Moderate	Severe	Extreme
					% OF TIME			
1	Helicopter	1	1	90				
2	TEMPSC (Twin Davit)	2	1	95	100%	100%	100%	100%
3	TEMPSC (Single Point)	2	1	95				
4	TEMPSC (Freefall)	2	1	95				
5	TEMPSC (PROD)	2	1	95				
6	Skyscape	1	1	95				
7	Seascape	1	1	95				
8	Gemevac	1	1	95				
9	Telescape	1	1	95				
10								
	TOTAL				100%	100%	100%	100%

Figure 4.2 Evacuation input screen – twin-davit TEMPSC

Table 4.6 Evacuation inputs

EVACUATION INPUTS	DESCRIPTION
Evacuation Mode	Up to 10 Evacuation Modes (Data for modes 7, 8, 9 not yet available)
Utilization	% of time used in Calm, Moderate, Severe, and Extreme Weather
Survival Time	Survival time in Calm, Moderate, Severe, and Extreme Weather
Number of Units Installed	Number of units on the installation
Number of Units Required	Number of units for evacuating 100% of POB
Availability per Unit	Ratio (%) of installation service time that one unit is available



EVACUATION MODE 2			TEMPSC (Twin Davit)								
	Availability	H or M	Risk				Time				
	0.9975		Activity Weather Failure Factor				Congestion Factor	Activity Weather Time Factor			
Activity			Calm	Moderate	Severe	Extreme		Calm	Moderate	Severe	Extreme
1	Evacuation order in TSR	H	0.1	0.1	0.5	1.0	1.0	0.5	0.5	0.5	0.5
2	Life jackets/survival suits - available	M	1.0	1.0	1.0	1.0	1.1				
3	Don life jackets/survival suits	H	1.0	2.0	3.0	4.0	1.1	0.4	0.4	0.5	1.0
4	Move to embarkation point	H	1.0	1.5	2.0	10.0	1.1	2.0	3.0	4.0	6.0
5	Craft functional to launch	M	30.0	30.0	30.0	30.0	1.0				
6	Craft prepared to launch	H	1.0	2.0	3.0	100.0	1.0	1.0	1.5	2.0	2.0
7	Embarkation	H	1.0	2.0	3.0	100.0	1.1	1.5	2.0	3.0	3.0
8	Engine starts	M	0.1	0.1	1.0	5.0	1.0				
9	Engine started correctly	H	1.0	2.0	5.0	10.0	1.0	0.2	0.2	0.2	0.2
10	Lowering mechanism functions	M	1.0	2.0	5.0	10.0	1.0				
11	Lowering mechanism activated	H	1.0	2.0	10.0	50.0	1.0	0.5	0.5	0.5	0.5
12	Craft descends under control to near sea level	M	1.0	5.0	20.0	100.0	1.0	1.5	2.2	3.0	4.5
13	Craft descends final distance to sea level	M	1.0	5.0	20.0	200.0	1.0	0.5	1.5	2.0	3.0
14	Craft release gear activated successfully	M	1.0	10.0	50.0	300.0	1.0	0.5	0.5	0.5	0.5
15	Craft moves 50 m from installation	M	1.0	1.5	75.0	500.0	1.0				
16	Craft steered 50 m from installation	H	1.0	1.5	10.0	100.0	1.0	1.0	1.5	3.0	5.0
17											
18											
19											
20											
21											
22											

Base Human Error Probability	Base Activity Time [min]
1.00E-03	2.0
Base Mechanical Failure Probability	**Lowest Credible Success Rate**
1.00E-03	0.10

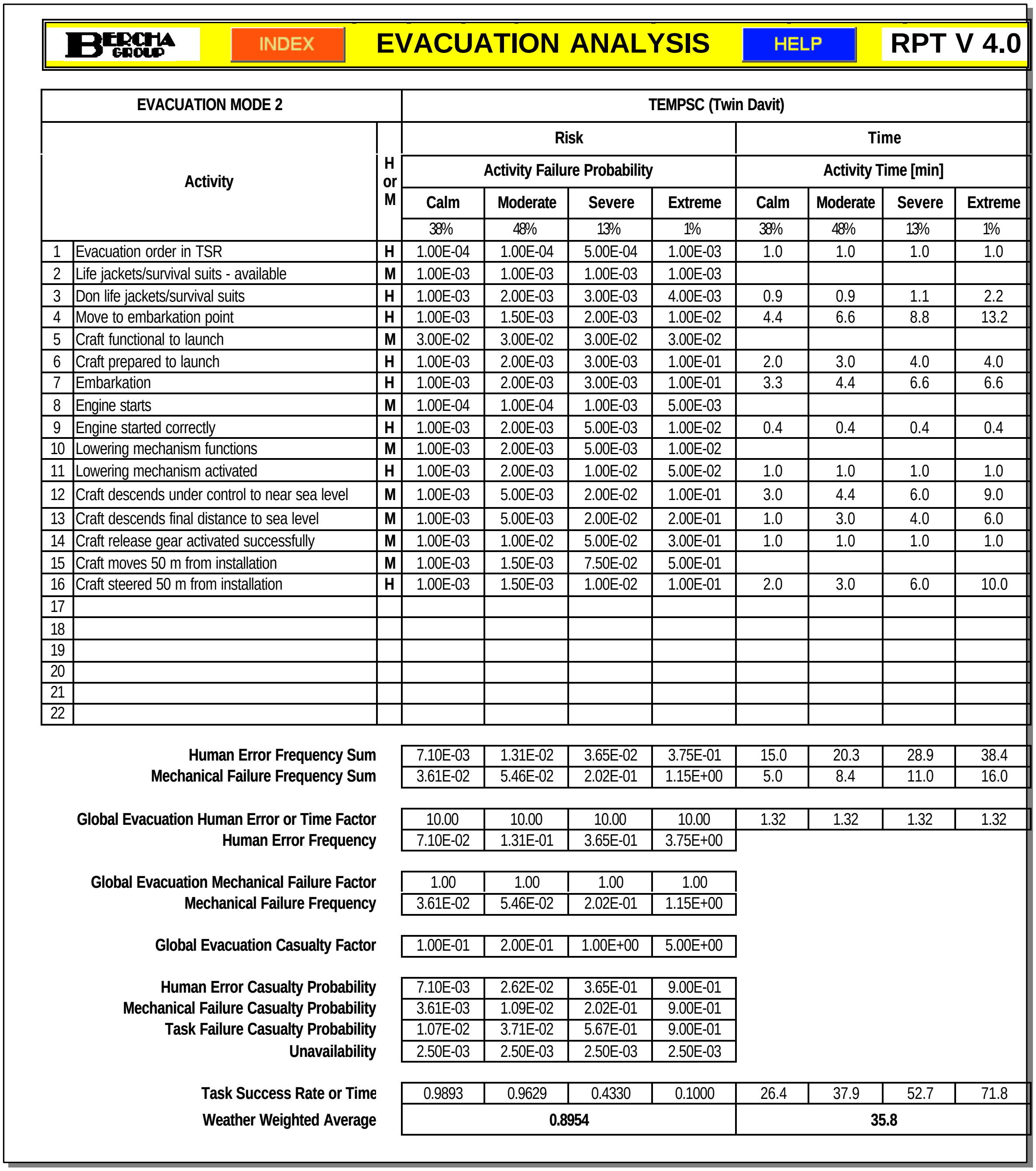
Figure 4.3 Evacuation parameter screen – twin-davit TEMPSC

Table 4.7 Evacuation parameters (modes 1 to 10)

EVACUATION PARAMETERS	DESCRIPTION
Activity Weather Failure Factor	Factor for all activities in the mode (Human -H or Mechanical-M) C M S E Weather
Activity Weather Time Factor	Factor for all activities in the mode (Human -H or Mechanical-M) C M S E Weather
Base Human Error Probability	Base to be multiplied with factor to get probability
Base Mechanical Failure Probability	Base to be multiplied with factor to get probability
Base Activity Time [min]	Base to be multiplied with factor to get time

Table 4.8 Evacuation analysis

EVACUATION ANALYSIS	DESCRIPTION
Calculated Activity Failure Probability	Activity Weather Failure Factor X (Base Human Error Probability **OR** Base Mechanical Failure Probability) For Global Version Reliability all failures in the mode due to Availability =0 For Global Success Version Availability is in the calculation
Human Error Probability Sum	
Mechanical Failure Probability Sum	
Time Sum (M and H)	
Human Error Frequency	Human Error Probability Sum X Global Evacuation Human Error or Time Factor
Mechanical Failure Frequency	Mechanical Failure Probability Sum X Global Evacuation Mechanical Failure Factor
Human Error Fatality Probability	Human Error Frequency X Global Evacuation Fatality Factor
Mechanical Failure Fatality Probability	Mechanical Failure Frequency X Global Evacuation Fatality Factor
Task Failure Fatality Probability	Mechanical + Human Max 1.0
Task Success Rate	1-Task Failure Fatality Probability
Task Success Time	Time Sum X Global Evacuation Time Factor
Weather Weighted Average	% of weather from Global Inputs



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EVACUATION MODE 2			**TEMPSC (Twin Davit)**							
			Risk				**Time**			
	Activity	**H or M**	**Activity Failure Probability**				**Activity Time [min]**			
			Calm	**Moderate**	**Severe**	**Extreme**	**Calm**	**Moderate**	**Severe**	**Extreme**
			38%	48%	13%	1%	38%	48%	13%	1%
1	Evacuation order in TSR	H	1.00E-04	1.00E-04	5.00E-04	1.00E-03	1.0	1.0	1.0	1.0
2	Life jackets/survival suits - available	M	1.00E-03	1.00E-03	1.00E-03	1.00E-03				
3	Don life jackets/survival suits	H	1.00E-03	2.00E-03	3.00E-03	4.00E-03	0.9	0.9	1.1	2.2
4	Move to embarkation point	H	1.00E-03	1.50E-03	2.00E-03	1.00E-02	4.4	6.6	8.8	13.2
5	Craft functional to launch	M	3.00E-02	3.00E-02	3.00E-02	3.00E-02				
6	Craft prepared to launch	H	1.00E-03	2.00E-03	3.00E-03	1.00E-01	2.0	3.0	4.0	4.0
7	Embarkation	H	1.00E-03	2.00E-03	3.00E-03	1.00E-01	3.3	4.4	6.6	6.6
8	Engine starts	M	1.00E-04	1.00E-04	1.00E-03	5.00E-03				
9	Engine started correctly	H	1.00E-03	2.00E-03	5.00E-03	1.00E-02	0.4	0.4	0.4	0.4
10	Lowering mechanism functions	M	1.00E-03	2.00E-03	5.00E-03	1.00E-02				
11	Lowering mechanism activated	H	1.00E-03	2.00E-03	1.00E-02	5.00E-02	1.0	1.0	1.0	1.0
12	Craft descends under control to near sea level	M	1.00E-03	5.00E-03	2.00E-02	1.00E-01	3.0	4.4	6.0	9.0
13	Craft descends final distance to sea level	M	1.00E-03	5.00E-03	2.00E-02	2.00E-01	1.0	3.0	4.0	6.0
14	Craft release gear activated successfully	M	1.00E-03	1.00E-02	5.00E-02	3.00E-01	1.0	1.0	1.0	1.0
15	Craft moves 50 m from installation	M	1.00E-03	1.50E-03	7.50E-02	5.00E-01				
16	Craft steered 50 m from installation	H	1.00E-03	1.50E-03	1.00E-02	1.00E-01	2.0	3.0	6.0	10.0
17										
18										
19										
20										
21										
22										

	Calm	Moderate	Severe	Extreme	Calm	Moderate	Severe	Extreme
Human Error Frequency Sum	7.10E-03	1.31E-02	3.65E-02	3.75E-01	15.0	20.3	28.9	38.4
Mechanical Failure Frequency Sum	3.61E-02	5.46E-02	2.02E-01	1.15E+00	5.0	8.4	11.0	16.0
Global Evacuation Human Error or Time Factor	10.00	10.00	10.00	10.00	1.32	1.32	1.32	1.32
Human Error Frequency	7.10E-02	1.31E-01	3.65E-01	3.75E+00				
Global Evacuation Mechanical Failure Factor	1.00	1.00	1.00	1.00				
Mechanical Failure Frequency	3.61E-02	5.46E-02	2.02E-01	1.15E+00				
Global Evacuation Casualty Factor	1.00E-01	2.00E-01	1.00E+00	5.00E+00				
Human Error Casualty Probability	7.10E-03	2.62E-02	3.65E-01	9.00E-01				
Mechanical Failure Casualty Probability	3.61E-03	1.09E-02	2.02E-01	9.00E-01				
Task Failure Casualty Probability	1.07E-02	3.71E-02	5.67E-01	9.00E-01				
Unavailability	2.50E-03	2.50E-03	2.50E-03	2.50E-03				
Task Success Rate or Time	0.9893	0.9629	0.4330	0.1000	26.4	37.9	52.7	71.8
Weather Weighted Average	**0.8954**				**35.8**			

Figure 4.4 Evacuation analysis results – twin-davit TEMPSC

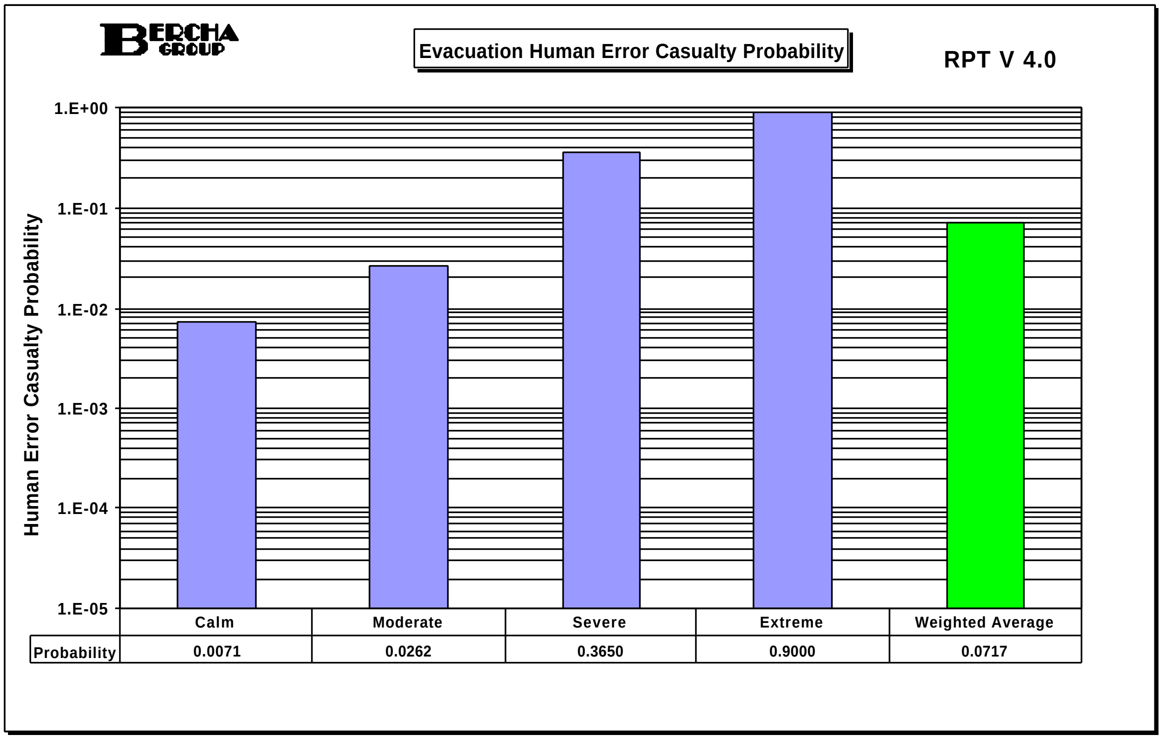


Figure 4.5 Evacuation human error casualty probability chart

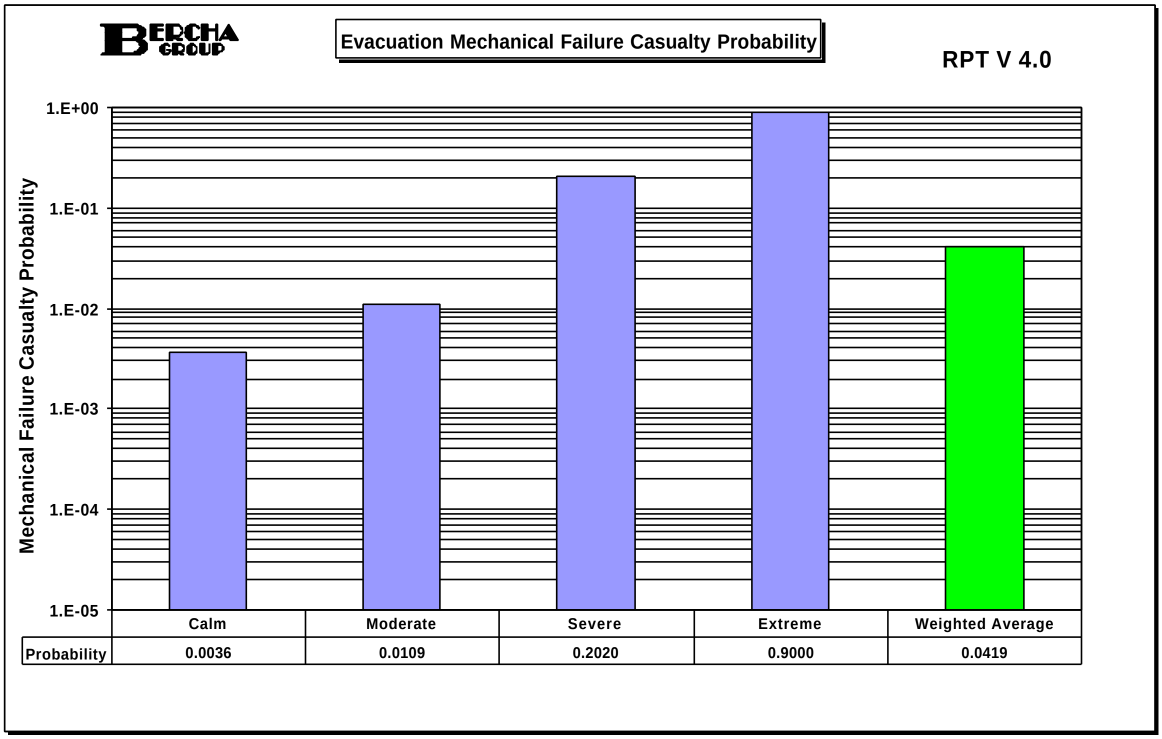


Figure 4.6 Evacuation mechanical failure casualty probability chart

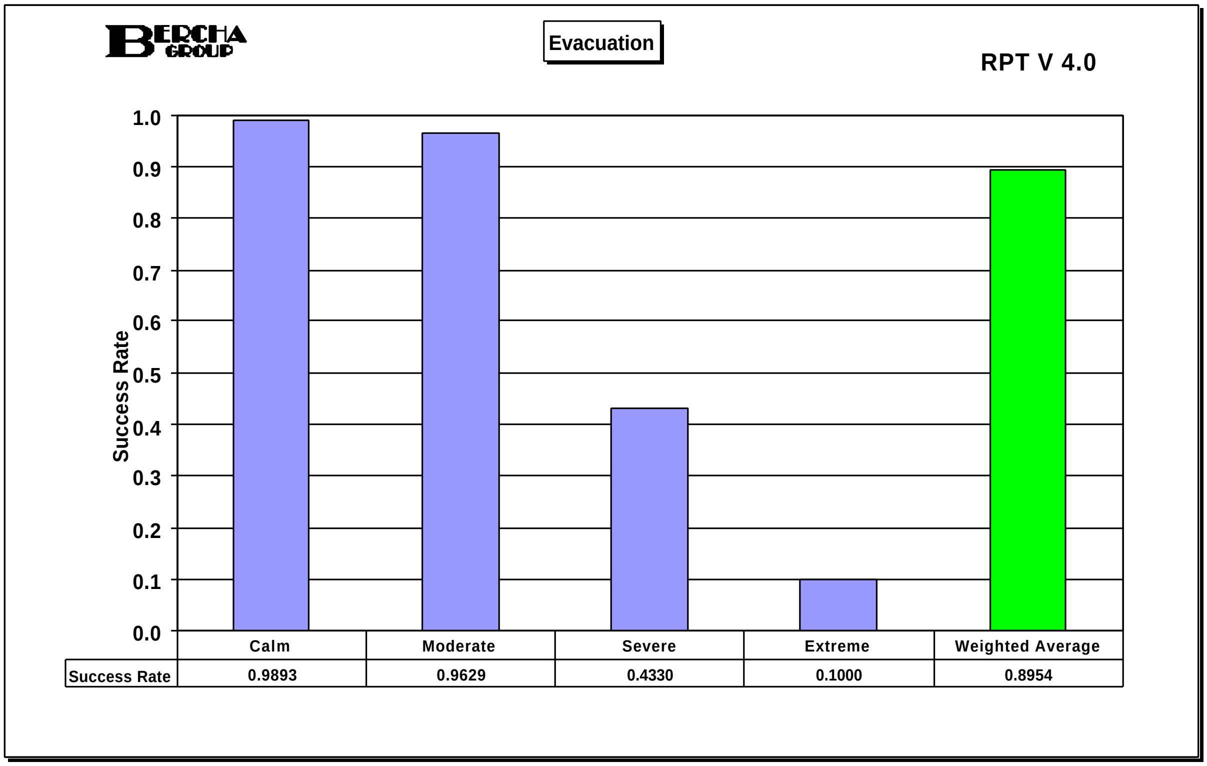


Figure 4.7 Evacuation success rate chart

4.2.5 RPT Rescue Level HP Incorporation

At this point in the development of the RPT, sufficient data to differentiate between mechanical and human failures during the survival process and the transfer process (the two components of rescue) have not been available. Rather, the large body of anecdotal information, together with expert opinion, has been used to provide the all-up probable survival times and inter-modal transfer success probabilities summarized in Table 4.9. These are then used in the inter-modal event tree for the designated rescue modes to evaluate rescue success probability. Figure 4.8 shows a typical rescue event tree from the RPT for severe weather. Finally, the integrated human and mechanical performance success rates in the rescue process are displayed in a graphical format as shown in Figure 4.9.

4.2.6 RPT Integrated EER Level HP Incorporation

The integrated EER results show the total performance of the EER system, including both human and mechanical performance in each main component of EER. Due to the intricate interactions between human performance and mechanical systems throughout each of the modules, it is unlikely that the component of human performance in the overall EER process would provide useful information. Figure 4.10 shows the integrated EER event tree (comparable to Figure 4.8, but including non-unity escape and evacuation success rates) for severe weather. Figure 4.11, the overall EER success rate histogram, shows the total EER system performance under each of the four distinct weather conditions together with their weather weighted average for the location under consideration. As noted earlier (Section 2.5), the weather weighted average is a function of a specific location; the individual weather class results are independent of location.

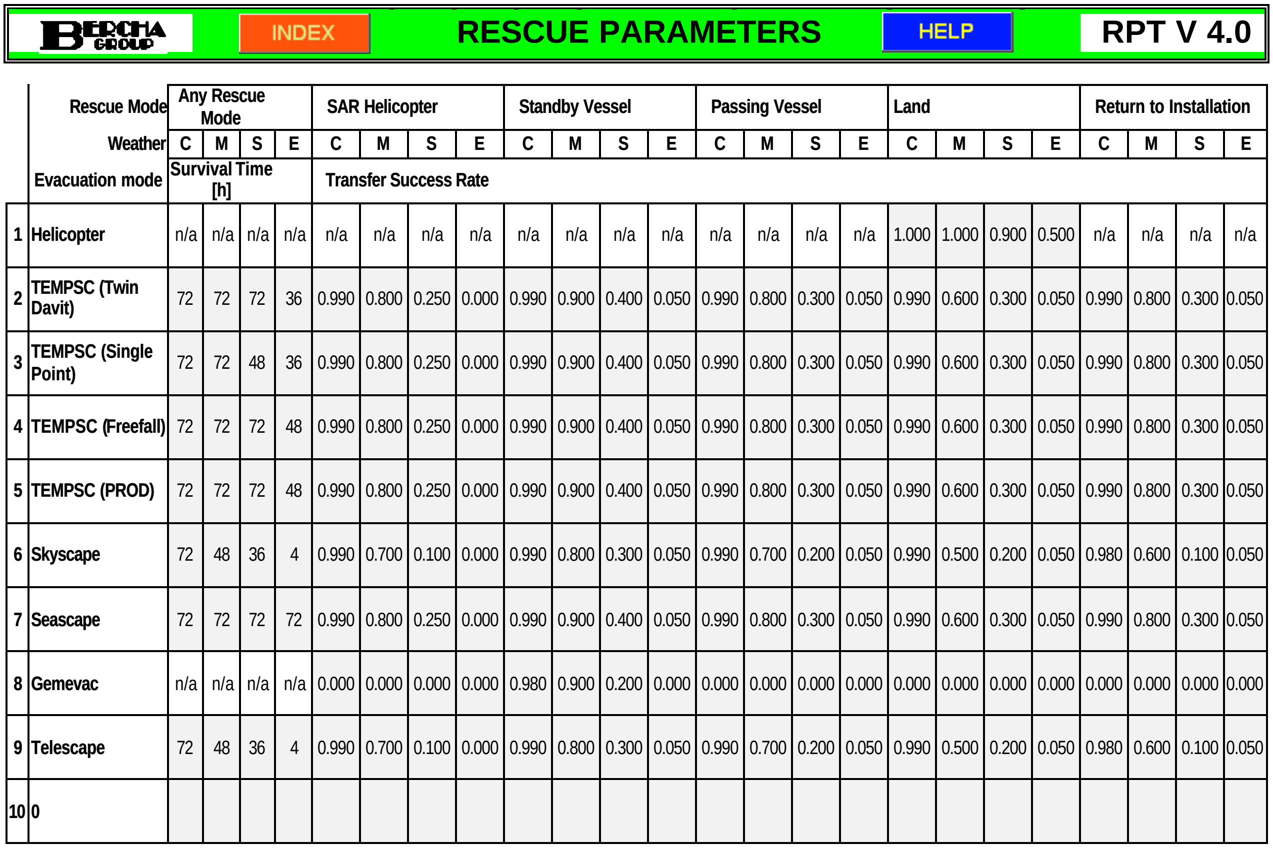
4.3 Reliability and Success Versions of RPT

4.3.1 General Description of Reliability and Success Versions of RPT

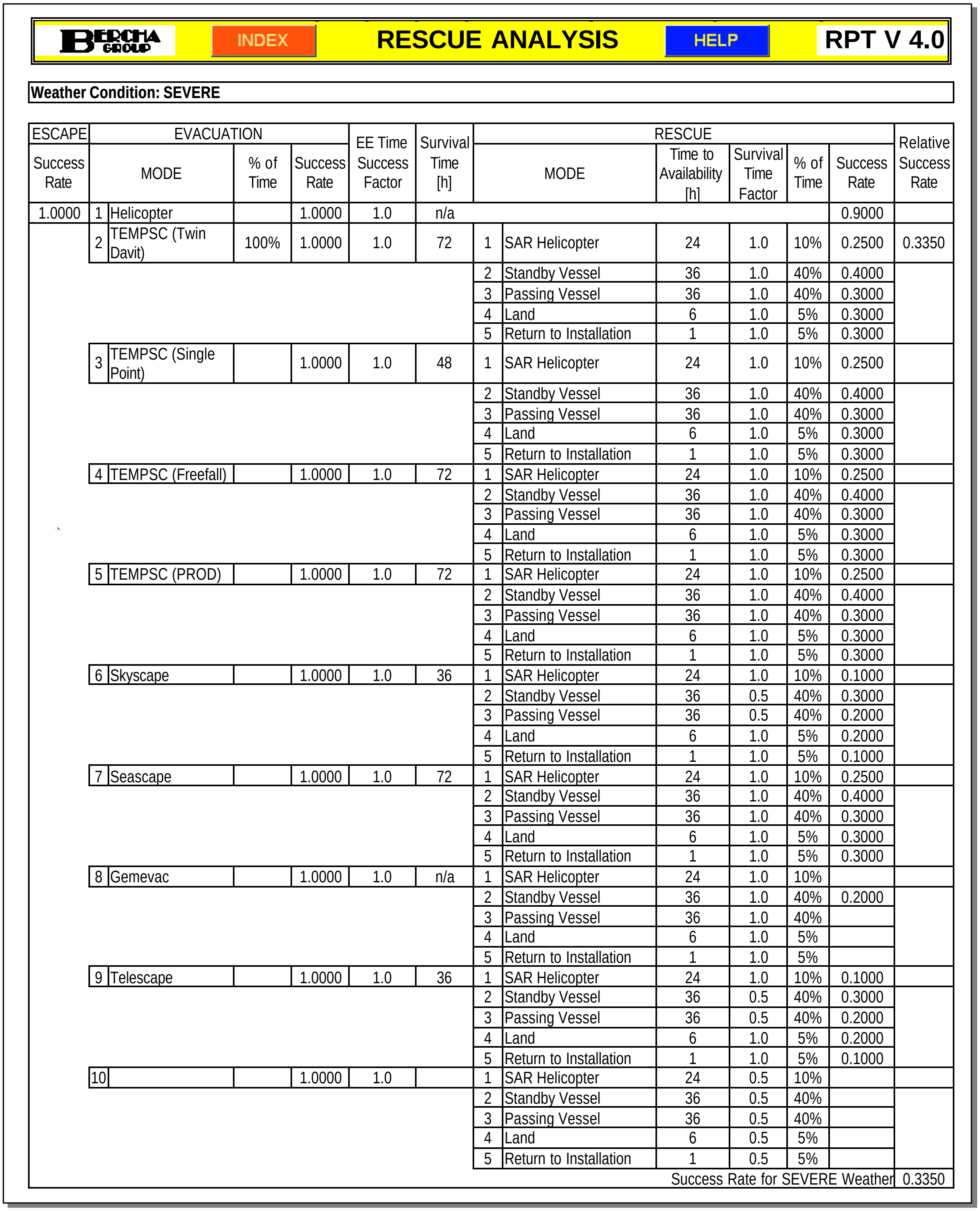
In RPT Version 3.5, the latest version prior to Version 4.0, success rate calculation included consideration of both the availability of systems and their reliability during the EER process. Naturally, success continues to be defined as the conduct of an operation without any casualties, while failure, its converse, is the conduct of an operation with one or more casualties. Reliability, on the other hand, pertains to the conduct of the operation without considering whether the system is available to begin with. Again, the reliability of an operation is the probability that it can be conducted without incurring any casualties. In the Performance-Based Standards (PBS), there is a requirement for stating targets of availability and reliability of individual systems and combinations of systems and processes. Accordingly, Version 3.5 was modified so that it runs in two modes called the “Reliability Version” and the “Success Version”. The Reliability Version excludes consideration of availability; the Success Version includes both availability and reliability.

To permit calculation of evacuation system availability, several new inputs as shown in Figure 4.12 are required. These were described in Section 4.2.4.

Table 4.9 Rescue parameters – survival and inter-modal transfer



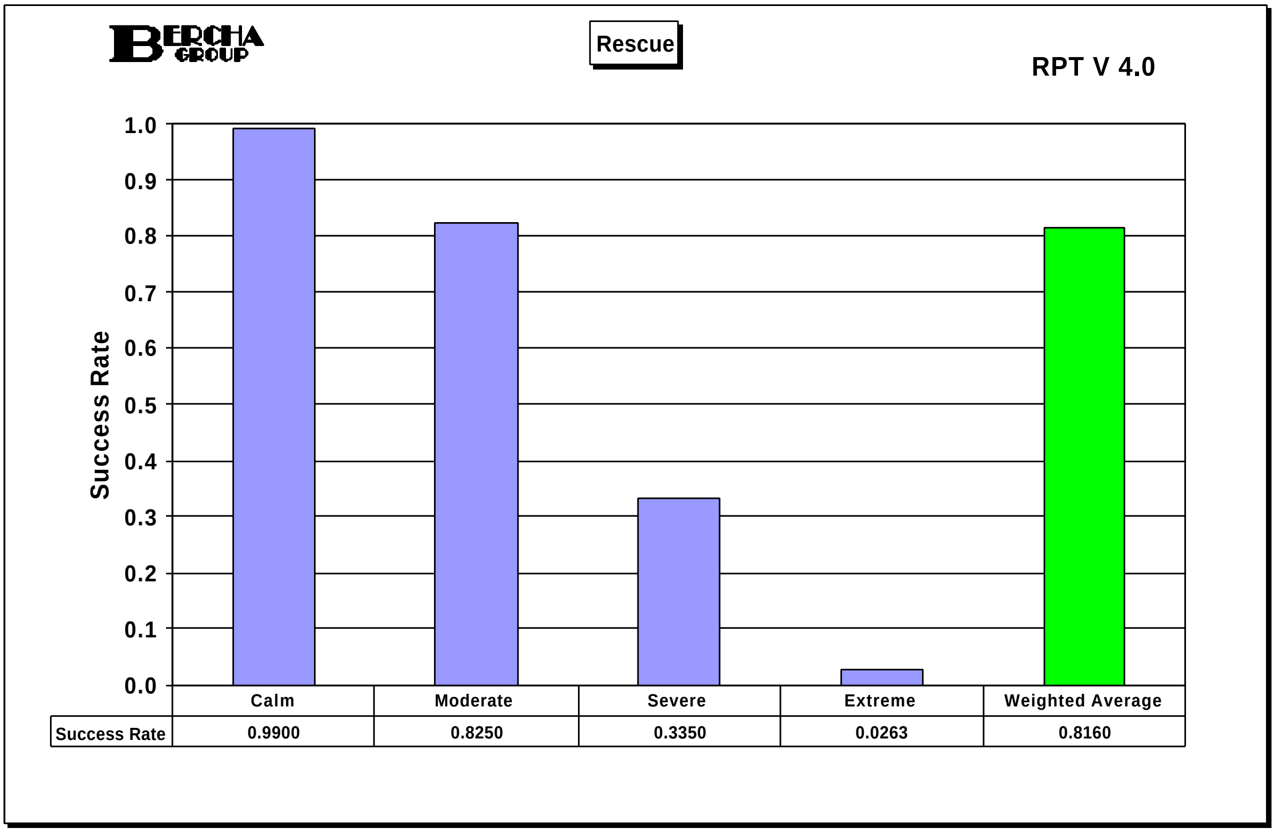
	Rescue Mode	Any Rescue Mode				SAR Helicopter				Standby Vessel				Passing Vessel				Land				Return to Installation			
	Weather	C	M	S	E	C	M	S	E	C	M	S	E	C	M	S	E	C	M	S	E	C	M	S	E
	Evacuation mode	Survival Time [h]				Transfer Success Rate																			
1	Helicopter	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	1.000	1.000	0.900	0.500	n/a	n/a	n/a	n/a
2	TEMPSC (Twin Davit)	72	72	72	36	0.990	0.800	0.250	0.000	0.990	0.900	0.400	0.050	0.990	0.800	0.300	0.050	0.990	0.600	0.300	0.050	0.990	0.800	0.300	0.050
3	TEMPSC (Single Point)	72	72	48	36	0.990	0.800	0.250	0.000	0.990	0.900	0.400	0.050	0.990	0.800	0.300	0.050	0.990	0.600	0.300	0.050	0.990	0.800	0.300	0.050
4	TEMPSC (Freefall)	72	72	72	48	0.990	0.800	0.250	0.000	0.990	0.900	0.400	0.050	0.990	0.800	0.300	0.050	0.990	0.600	0.300	0.050	0.990	0.800	0.300	0.050
5	TEMPSC (PROD)	72	72	72	48	0.990	0.800	0.250	0.000	0.990	0.900	0.400	0.050	0.990	0.800	0.300	0.050	0.990	0.600	0.300	0.050	0.990	0.800	0.300	0.050
6	Skyscape	72	48	36	4	0.990	0.700	0.100	0.000	0.990	0.800	0.300	0.050	0.990	0.700	0.200	0.050	0.990	0.500	0.200	0.050	0.980	0.600	0.100	0.050
7	Seascape	72	72	72	72	0.990	0.800	0.250	0.000	0.990	0.900	0.400	0.050	0.990	0.800	0.300	0.050	0.990	0.600	0.300	0.050	0.990	0.800	0.300	0.050
8	Gemevac	n/a	n/a	n/a	n/a	0.000	0.000	0.000	0.000	0.980	0.900	0.200	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
9	Telescape	72	48	36	4	0.990	0.700	0.100	0.000	0.990	0.800	0.300	0.050	0.990	0.700	0.200	0.050	0.990	0.500	0.200	0.050	0.980	0.600	0.100	0.050
10	0																								



Weather Condition: SEVERE

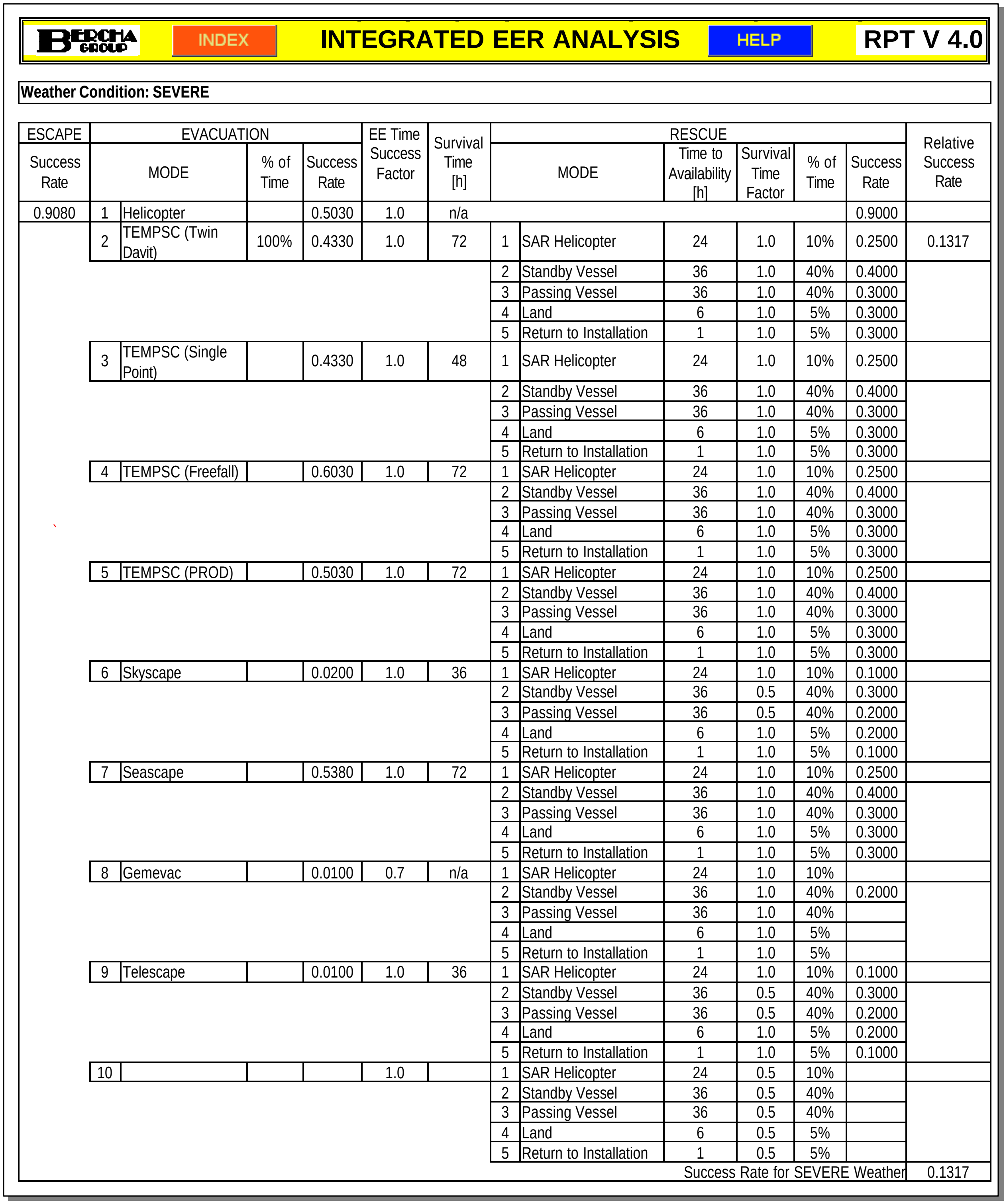
ESCAPE	EVACUATION				EE Time Success Factor	Survival Time [h]	RESCUE							Relative Success Rate
Success Rate		MODE	% of Time	Success Rate				MODE	Time to Availability [h]	Survival Time Factor	% of Time	Success Rate		
1.0000	1	Helicopter		1.0000	1.0	n/a						0.9000		
	2	TEMPSC (Twin Davit)	100%	1.0000	1.0	72	1	SAR Helicopter	24	1.0	10%	0.2500		0.3350
							2	Standby Vessel	36	1.0	40%	0.4000		
							3	Passing Vessel	36	1.0	40%	0.3000		
							4	Land	6	1.0	5%	0.3000		
							5	Return to Installation	1	1.0	5%	0.3000		
	3	TEMPSC (Single Point)		1.0000	1.0	48	1	SAR Helicopter	24	1.0	10%	0.2500		
							2	Standby Vessel	36	1.0	40%	0.4000		
							3	Passing Vessel	36	1.0	40%	0.3000		
							4	Land	6	1.0	5%	0.3000		
							5	Return to Installation	1	1.0	5%	0.3000		
	4	TEMPSC (Freefall)		1.0000	1.0	72	1	SAR Helicopter	24	1.0	10%	0.2500		
							2	Standby Vessel	36	1.0	40%	0.4000		
							3	Passing Vessel	36	1.0	40%	0.3000		
							4	Land	6	1.0	5%	0.3000		
							5	Return to Installation	1	1.0	5%	0.3000		
	5	TEMPSC (PROD)		1.0000	1.0	72	1	SAR Helicopter	24	1.0	10%	0.2500		
							2	Standby Vessel	36	1.0	40%	0.4000		
							3	Passing Vessel	36	1.0	40%	0.3000		
							4	Land	6	1.0	5%	0.3000		
							5	Return to Installation	1	1.0	5%	0.3000		
	6	Skyscape		1.0000	1.0	36	1	SAR Helicopter	24	1.0	10%	0.1000		
							2	Standby Vessel	36	0.5	40%	0.3000		
							3	Passing Vessel	36	0.5	40%	0.2000		
							4	Land	6	1.0	5%	0.2000		
							5	Return to Installation	1	1.0	5%	0.1000		
	7	Seascape		1.0000	1.0	72	1	SAR Helicopter	24	1.0	10%	0.2500		
							2	Standby Vessel	36	1.0	40%	0.4000		
							3	Passing Vessel	36	1.0	40%	0.3000		
							4	Land	6	1.0	5%	0.3000		
							5	Return to Installation	1	1.0	5%	0.3000		
	8	Gemevac		1.0000	1.0	n/a	1	SAR Helicopter	24	1.0	10%			
							2	Standby Vessel	36	1.0	40%	0.2000		
							3	Passing Vessel	36	1.0	40%			
							4	Land	6	1.0	5%			
							5	Return to Installation	1	1.0	5%			
	9	Telescape		1.0000	1.0	36	1	SAR Helicopter	24	1.0	10%	0.1000		
							2	Standby Vessel	36	0.5	40%	0.3000		
							3	Passing Vessel	36	0.5	40%	0.2000		
							4	Land	6	1.0	5%	0.2000		
							5	Return to Installation	1	1.0	5%	0.1000		
	10			1.0000	1.0		1	SAR Helicopter	24	0.5	10%			
							2	Standby Vessel	36	0.5	40%			
							3	Passing Vessel	36	0.5	40%			
							4	Land	6	0.5	5%			
							5	Return to Installation	1	0.5	5%			
												Success Rate for SEVERE Weather		0.3350

Figure 4.8 Rescue analysis screen – severe weather



	Calm	Moderate	Severe	Extreme	Weighted Average
Success Rate	0.9900	0.8250	0.3350	0.0263	0.8160

Figure 4.9	Rescue success rate histogram

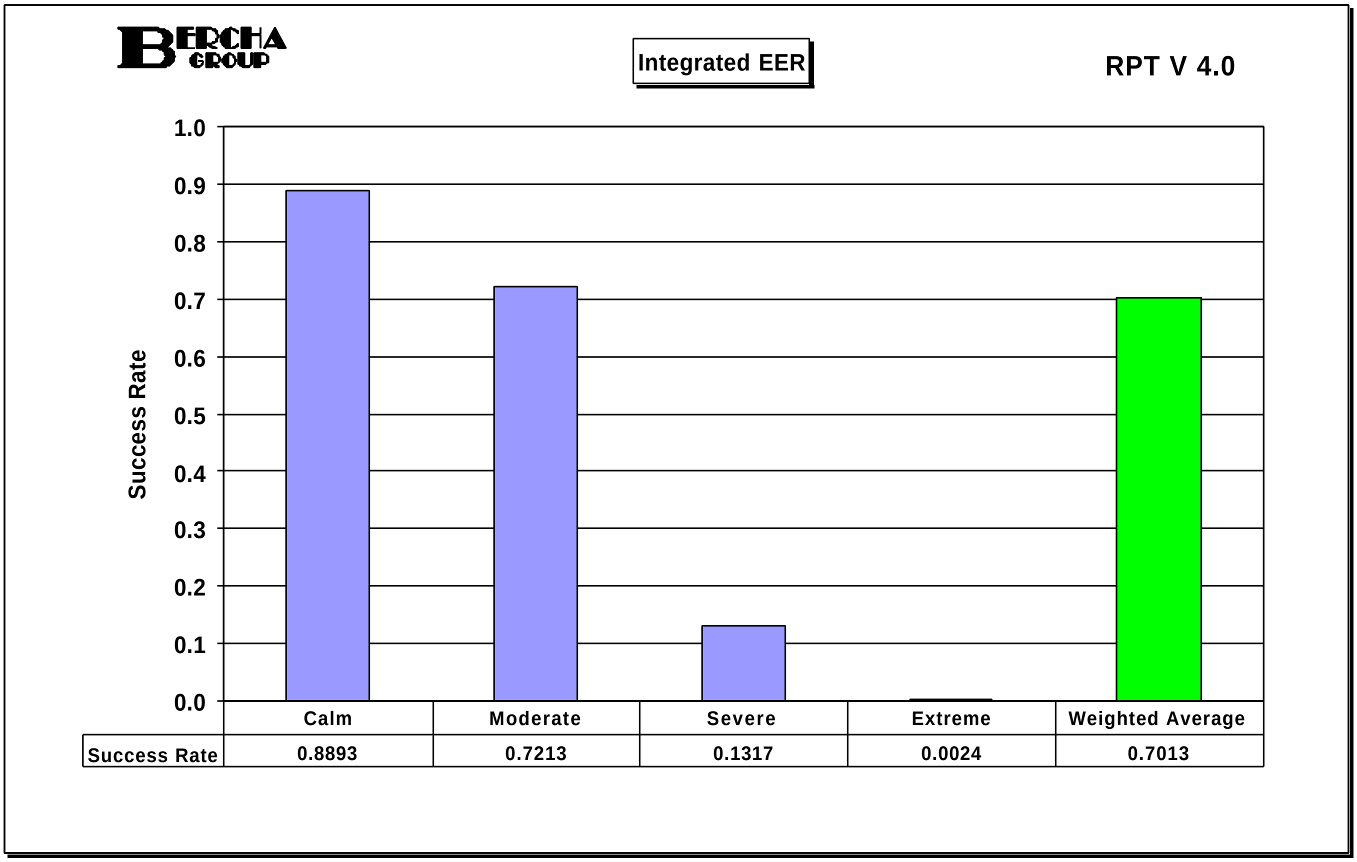


INTEGRATED EER ANALYSIS **RPT V 4.0**

Weather Condition: SEVERE

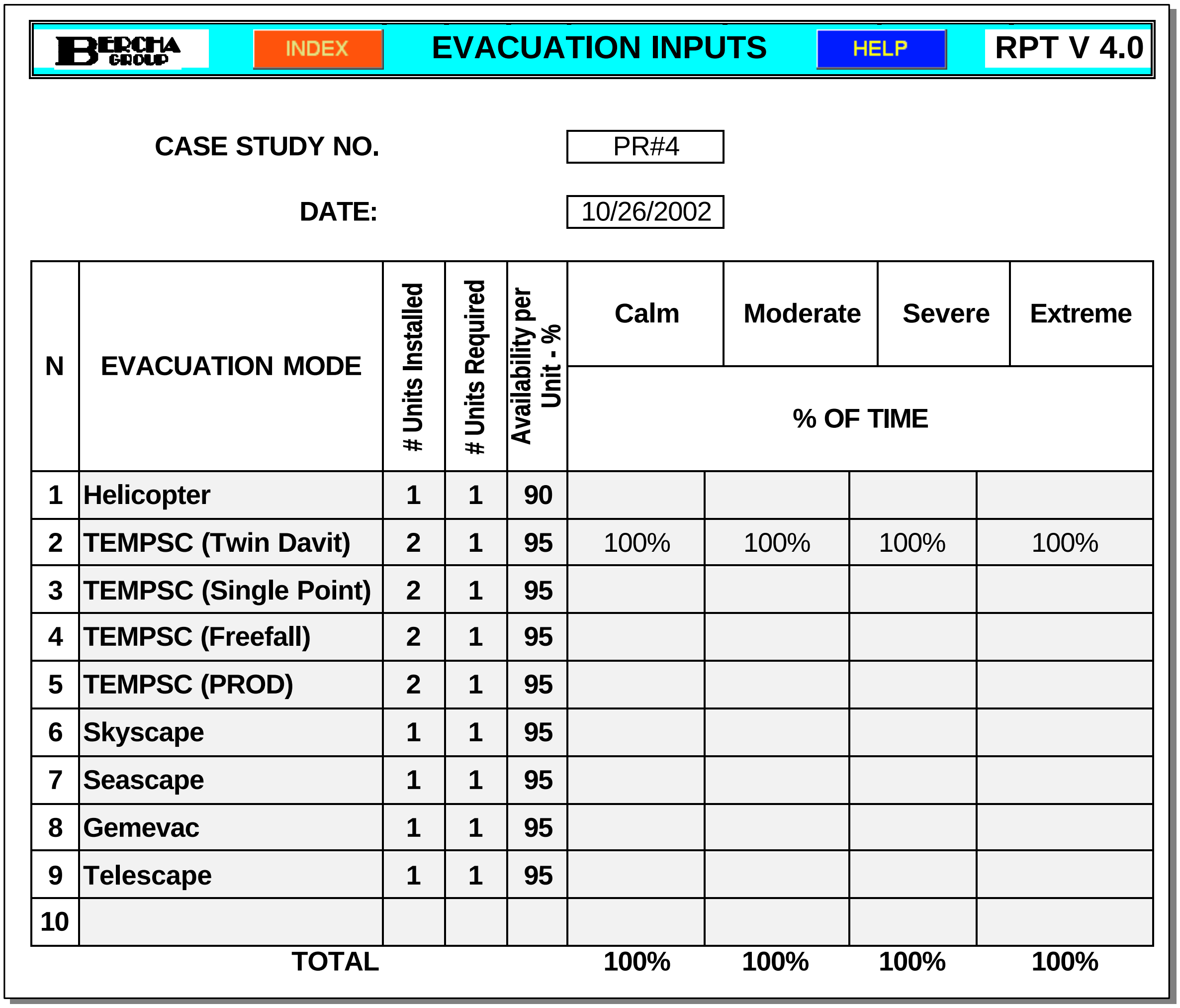
ESCAPE	EVACUATION				EE Time Success Factor	Survival Time [h]	RESCUE						Relative Success Rate
Success Rate		MODE	% of Time	Success Rate				MODE	Time to Availability [h]	Survival Time Factor	% of Time	Success Rate	
0.9080	1	Helicopter		0.5030	1.0	n/a						0.9000	
	2	TEMPSC (Twin Davit)	100%	0.4330	1.0	72	1	SAR Helicopter	24	1.0	10%	0.2500	0.1317
							2	Standby Vessel	36	1.0	40%	0.4000	
							3	Passing Vessel	36	1.0	40%	0.3000	
							4	Land	6	1.0	5%	0.3000	
							5	Return to Installation	1	1.0	5%	0.3000	
	3	TEMPSC (Single Point)		0.4330	1.0	48	1	SAR Helicopter	24	1.0	10%	0.2500	
							2	Standby Vessel	36	1.0	40%	0.4000	
							3	Passing Vessel	36	1.0	40%	0.3000	
							4	Land	6	1.0	5%	0.3000	
							5	Return to Installation	1	1.0	5%	0.3000	
	4	TEMPSC (Freefall)		0.6030	1.0	72	1	SAR Helicopter	24	1.0	10%	0.2500	
							2	Standby Vessel	36	1.0	40%	0.4000	
							3	Passing Vessel	36	1.0	40%	0.3000	
							4	Land	6	1.0	5%	0.3000	
							5	Return to Installation	1	1.0	5%	0.3000	
	5	TEMPSC (PROD)		0.5030	1.0	72	1	SAR Helicopter	24	1.0	10%	0.2500	
							2	Standby Vessel	36	1.0	40%	0.4000	
							3	Passing Vessel	36	1.0	40%	0.3000	
							4	Land	6	1.0	5%	0.3000	
							5	Return to Installation	1	1.0	5%	0.3000	
	6	Skyscape		0.0200	1.0	36	1	SAR Helicopter	24	1.0	10%	0.1000	
							2	Standby Vessel	36	0.5	40%	0.3000	
							3	Passing Vessel	36	0.5	40%	0.2000	
							4	Land	6	1.0	5%	0.2000	
							5	Return to Installation	1	1.0	5%	0.1000	
	7	Seascape		0.5380	1.0	72	1	SAR Helicopter	24	1.0	10%	0.2500	
							2	Standby Vessel	36	1.0	40%	0.4000	
							3	Passing Vessel	36	1.0	40%	0.3000	
							4	Land	6	1.0	5%	0.3000	
							5	Return to Installation	1	1.0	5%	0.3000	
	8	Gemevac		0.0100	0.7	n/a	1	SAR Helicopter	24	1.0	10%		
							2	Standby Vessel	36	1.0	40%	0.2000	
							3	Passing Vessel	36	1.0	40%		
							4	Land	6	1.0	5%		
							5	Return to Installation	1	1.0	5%		
	9	Telescape		0.0100	1.0	36	1	SAR Helicopter	24	1.0	10%	0.1000	
							2	Standby Vessel	36	0.5	40%	0.3000	
							3	Passing Vessel	36	0.5	40%	0.2000	
							4	Land	6	1.0	5%	0.2000	
							5	Return to Installation	1	1.0	5%	0.1000	
	10				1.0		1	SAR Helicopter	24	0.5	10%		
							2	Standby Vessel	36	0.5	40%		
							3	Passing Vessel	36	0.5	40%		
							4	Land	6	0.5	5%		
							5	Return to Installation	1	0.5	5%		
									Success Rate for SEVERE Weather				0.1317

Figure 4.10 Integrated EER analysis – severe weather



	Calm	Moderate	Severe	Extreme	Weighted Average
Success Rate	0.8893	0.7213	0.1317	0.0024	0.7013

Figure 4.11 Integrated EER success rate histogram (reliability version)



EVACUATION INPUTS

RPT V 4.0

CASE STUDY NO. PR#4

DATE: 10/26/2002

N	EVACUATION MODE	# Units Installed	# Units Required	Availability per Unit - %	Calm	Moderate	Severe	Extreme
					% OF TIME			
1	Helicopter	1	1	90				
2	TEMPSC (Twin Davit)	2	1	95	100%	100%	100%	100%
3	TEMPSC (Single Point)	2	1	95				
4	TEMPSC (Freefall)	2	1	95				
5	TEMPSC (PROD)	2	1	95				
6	Skyscape	1	1	95				
7	Seascape	1	1	95				
8	Gemevac	1	1	95				
9	Telescape	1	1	95				
10								
	TOTAL				100%	100%	100%	100%

Figure 4.12 Evacuation input screen – twin-davit TEMPSC

4.3.2 Reliability Version Results

To demonstrate the difference between results of the two versions, the same system, a twin-davit launched TEMPSC, under the current scenario (Section 2.5) weather conditions, was run using both RPT versions. Figure 4.13 shows the evacuation reliability results for that case.

4.3.3 Success Version Results

Figure 4.14 shows the results of the Success Version for the same case as that described in Section 4.3.2 for one unit installed and required. As can be seen, when availability is factored into the total performance, and only one system is available, there is a significant reduction in success rate compared to reliability. Essentially, with only one evacuation system installed, as has been posed here, the success is directly reduced by the availability, in this case 5%. Naturally, when more systems are installed, the effect of redundancy will mitigate the reduction in success rate as a result of non-availability of any one system. Figure 4.15 shows the same calculation, but for two lifeboats installed – and still only one required. No significant reduction in success (over reliability) is shown with two lifeboats. Success rate improves by the difference between the reliability and the product of two availabilities.

4.4 Reliability Results from RPT Version 4.0

4.4.1 Purpose of Reliability Results

As an appendix to the PBS (TDC, 2003), a set of distinct reliability results for evacuation and rescue processes was requested by TDC. Specifically, in the evacuation results, the reliability of one single system of each mode for each of the four weather conditions was required. For the rescue component, the combined inter-modal reliability of the rescue platform-rescue mode inter-modal combinations was provided.

4.4.2 Escape

Since the escape process is highly situation- and installation-specific, no such general results are possible, and accordingly, the integrated EER – without the escape – would also not be meaningful.

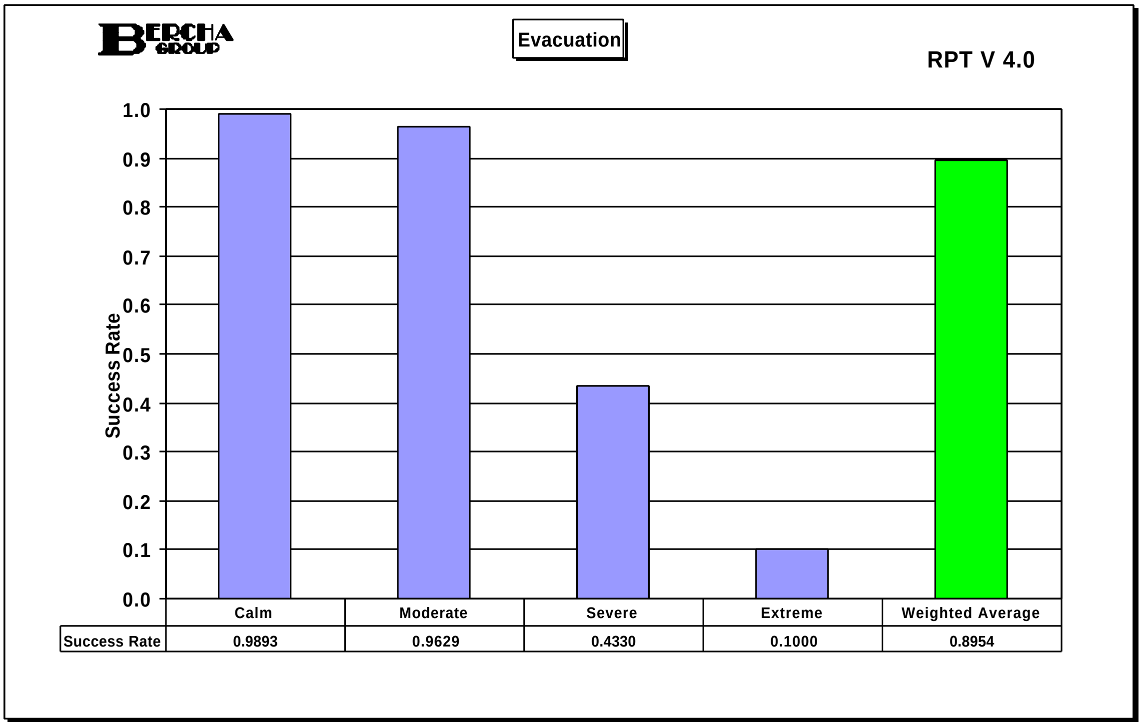


Figure 4.13 Reliability version results – twin-davit TEMPSC evacuation

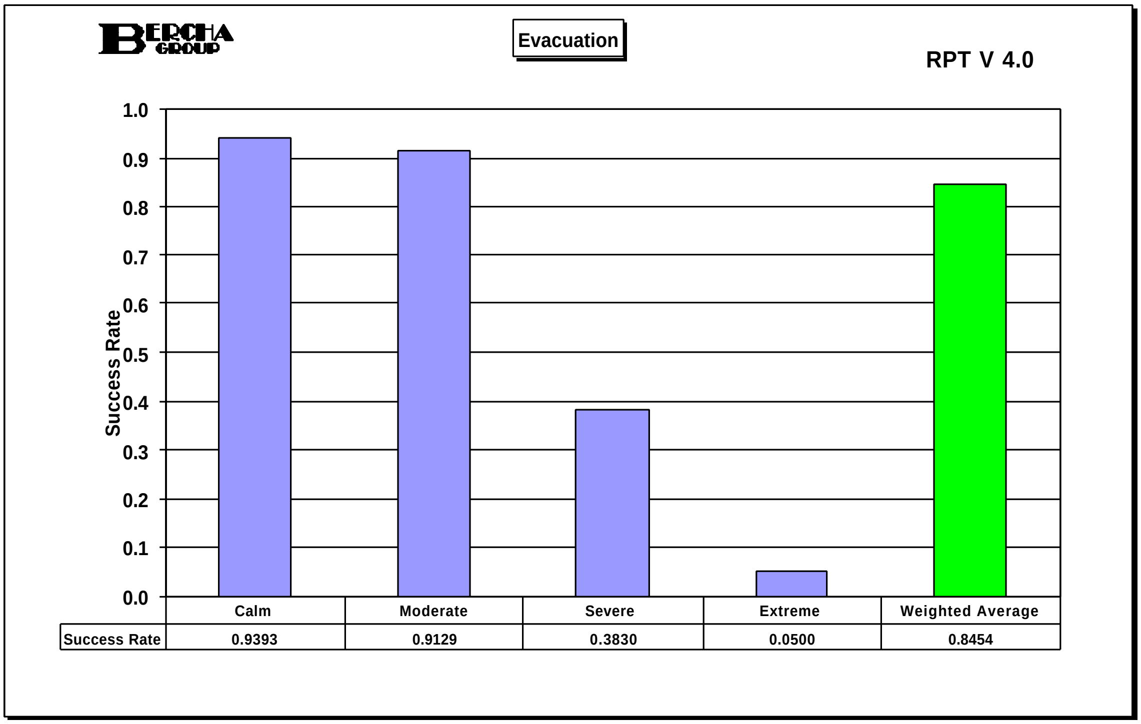


Figure 4.14 Success version results – twin-davit TEMPSC evacuation, one unit installed

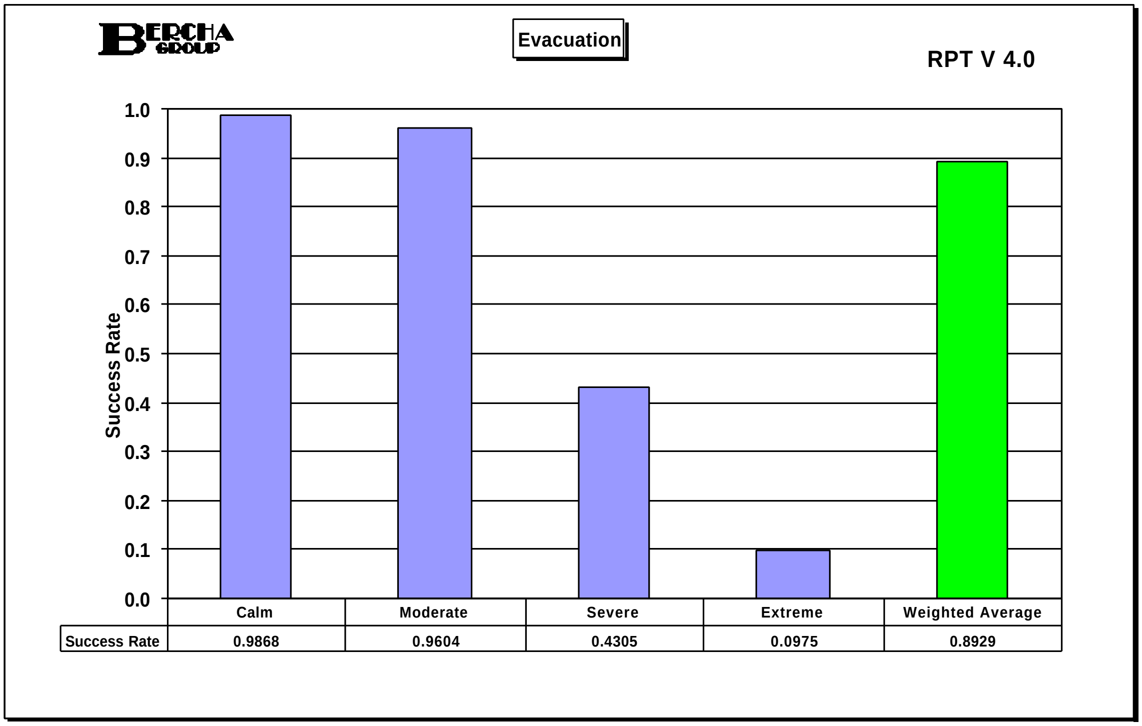


Figure 4.15 Success version results – twin-davit TEMPSC evacuation, two units installed

4.4.3 Evacuation Mode Results from Each Global Scenario Level and Weather Condition

To permit appraisal of the chances of success of evacuation by means of a given mode in a given weather condition, it would be desirable to provide the net reliabilities for each system operating by itself under each of the four weather conditions. The purpose providing the net reliabilities under each weather condition for each of the global scenario conditions, apart from regulatory interest, could possibly be for tactical application in considering the likelihood of successful evacuation (and later rescue) under each scenario and weather condition.

Table 4.10 shows the results of the application of the RPT in the Reliability Version to each of the scenario-weather condition-evacuation mode combinations. It should be noted that the results of each of these combinations are independent of the proportion of weather conditions; they are, in a sense, absolute for each weather class. It is the weather weighted averages that take into account the proportions of the weather classes in each study. Thus, the two right hand columns give the weather weighted averages for the base conditions and the hypothetical study area weather conditions to illustrate the effects of site-specific conditions. The matrix is set up as a spreadsheet so that the study weather proportions can be entered as an input. Here, an entirely hypothetical set of conditions has been entered under “STUDY”. “BASE” conditions are the same as used in earlier examples (Section 2.5).

4.4 Inter-Modal Evacuation and Rescue Mode Reliability for Each Weather Condition

Rescue consists of two principal components: the survival process and the transfer process. Both are dependent on the weather; however, the transfer process also varies with the inter-modal combination of evacuation mode and rescue mode. Survival is independent of the rescue platform type. Table 4.11 gives the parameters developed for the RPT, giving the survival times under each weather condition for each evacuation mode, as well as the full range of inter-modal (evacuation and rescue modes) combinations for each weather class for transfer success. It should be recalled that success means accomplishing a task with no casualties (fatalities or serious injuries), while failure means one or more casualties. Therefore, inter-modal reliabilities become very low for the more severe weather conditions; normally, transfers will not be attempted in conditions worse than moderate (UKOOA, 2001).

4.5 Recommendations on RPT Extensions, Modifications, and Developments

The RPT in its current version, Version 4.0, provides satisfactory function for support of the majority of the PBS requirements. From a practical application point of view, however, it lacks the ability to simulate post-accident scenarios, individual evacuation and rescue devices, and ice and cold weather performance. In addition, to be optimally useful to administrators having jurisdiction over the PBS, it should be further refined in its functionality in order to be more user-friendly. The following specific recommendations are intended to optimize the RPT:

- Individual and Mass Evacuation Systems Module

  Inclusion of individual and mass evacuation systems – such as abseil devices, buoys, Marine Survival Systems (MSS), ladders, etc. – in the RPT as designable evacuation and rescue modes is a modification and extension.

- Accident Inventory Module

  Development of accident inventory module and its integration into RPT is an extension of the current RPT. Currently the RPT operates normally in an undamaged mode and any installation damage or accident effects must be entered manually by the user, based on the user's knowledge and experience. The accident inventory module will provide a series of typical accident scenarios (e.g., fire, explosion, toxic gas, loss of stability) and guide the user in setting the RPT to account for these, so that RPT results will then relate to an accident or damaged installation condition.

- Ice and Cold Weather RPT (IRPT)

  The RPT can be expanded to include a set of ice conditions ranging from extreme to mild, analogous to the weather conditions, which can be integrated into the escape, evacuation, and rescue modules as well as the integrating module, to provide results for sub-Arctic ice EER. Generally, this is done by adjusting the mechanical failure rates and human performance to reflect what would be expected in the appropriate level of cold temperature, icing and adfreeze, and mechanical impediment of the ice. The resultant version of the RPT would be called the IRPT.

- Ice PBS Reliability Quantification

  Currently, the ice PBS, the PBS for cold weather and ice conditions, are in a qualitative form appended to the Standards as Appendix E. The necessary availability and reliability quantitative parameters for the Ice PBS should be generated for selected technologies and integrated into the Ice PBS. Next, appropriate quantitative goals can be established, and the parameters can be integrated into the RPT together with other changes necessary to provide an integrated set of Standards including ice and cold weather sub-Arctic conditions.

- User-Friendly RPT Development

  User-friendly RPT development will comprise the normal tasks in a transformation of a scientific Beta version of a software program to a technical user version. Specifically, these tasks may be summarized as follows:

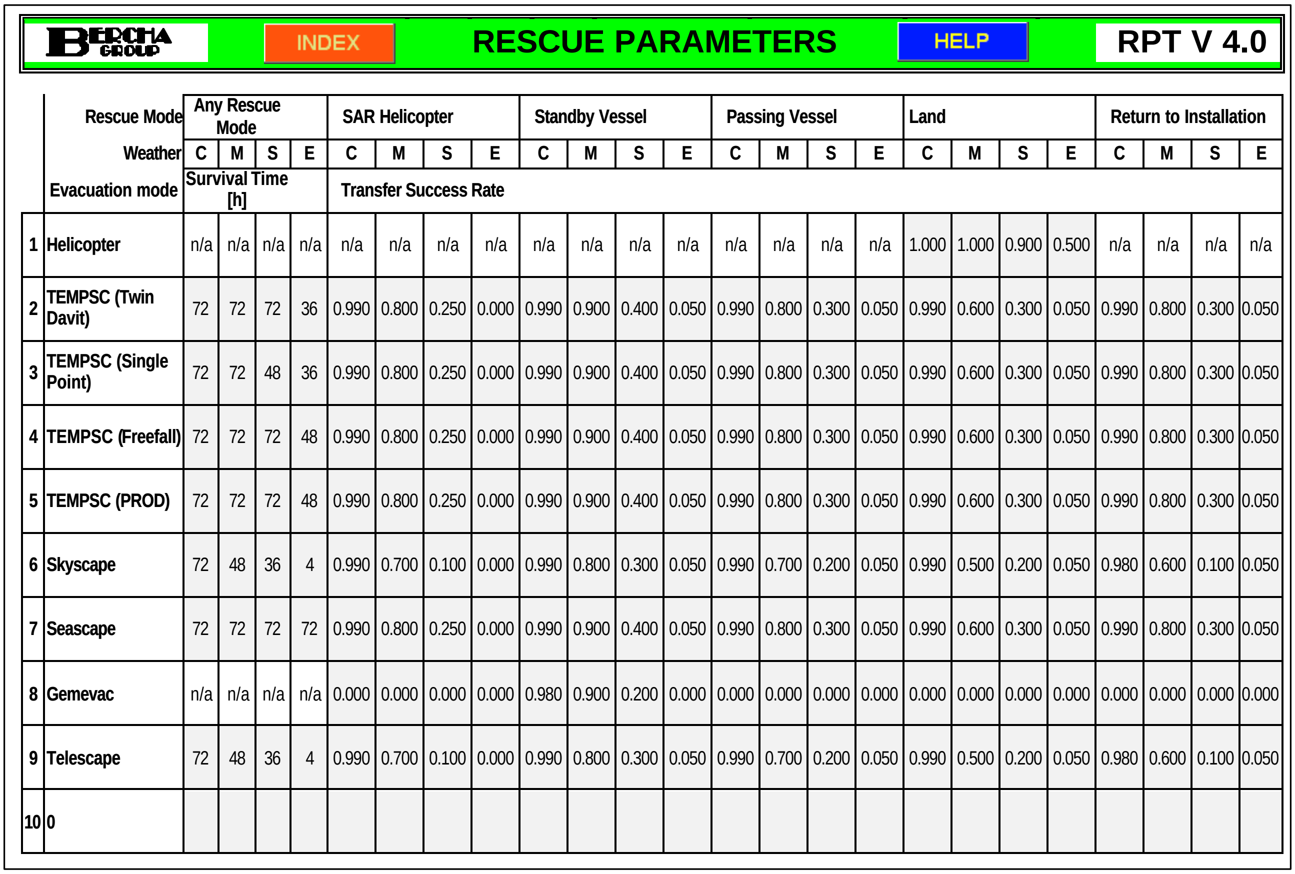
  - Definition of user requirements and capabilities.
  - Detailed design and high-level coding of user-friendly interfaces and RPT modifications.
  - Integration of other modifications (mentioned above) into user-friendly Beta version.
  - Generation of integrated user-friendly RPT.

Table 4.10 Evacuation reliability matrix

N	EVACUATION MODE	SCENARIO	C	M	S	E	BASE Weather Weighted Average	STUDY Weather Weighted Average
			BASE					
			38%	48%	13%	1%		
			STUDY					
			50%	30%	18%	2%		
1	**Helicopter**	**Drill**	0.9999	0.9998	0.9940	0.0100	0.9892	0.9790
		Precautionary	0.9997	0.9986	0.9673	0.0100	0.9850	0.9737
		Life Threatening	0.9948	0.9775	0.5030	0.0100	0.9127	0.8814
2	**TEMPSC (Twin Davit)**	**Drill**	0.9996	0.9986	0.9762	0.2395	0.9885	0.9799
		Precautionary	0.9985	0.9952	0.9175	0.1000	0.9774	0.9649
		Life Threatening	0.9893	0.9629	0.4330	0.1000	0.8954	0.8634
3	**TEMPSC (Single Point)**	**Drill**	0.9996	0.9986	0.9762	0.2395	0.9885	0.9799
		Precautionary	0.9985	0.9952	0.9175	0.1000	0.9774	0.9649
		Life Threatening	0.9893	0.9629	0.4330	0.1000	0.8954	0.8634
4	**TEMPSC (Freefall)**	**Drill**	0.9996	0.9990	0.9914	0.7545	0.9958	0.9930
		Precautionary	0.9985	0.9961	0.9637	0.2000	0.9848	0.9755
		Life Threatening	0.9889	0.9635	0.6030	0.2000	0.9187	0.8961
5	**TEMPSC (PROD)**	**Drill**	0.9996	0.9986	0.9787	0.3595	0.9900	0.9827
		Precautionary	0.9985	0.9949	0.9265	0.1500	0.9790	0.9675
		Life Threatening	0.9898	0.9630	0.5030	0.1500	0.9052	0.8773
6	**Skyscape**	**Drill**	0.9991	0.9972	0.9659	0.3620	0.9875	0.9798
		Precautionary	0.9965	0.9871	0.8494	0.0200	0.9631	0.9477
		Life Threatening	0.9634	0.8410	0.0200	0.0200	0.7726	0.7380
7	**Seascape**	**Drill**	0.9996	0.9988	0.9842	0.5345	0.9926	0.9873
		Precautionary	0.9986	0.9957	0.9430	0.1500	0.9815	0.9707
		Life Threatening	0.9899	0.9656	0.5580	0.1500	0.9137	0.8881
8	**Gemevac**	**Drill**	0.9985	0.9906	0.7715	0.0100	0.9553	0.9355
		Precautionary	0.9949	0.9574	0.0100	0.0100	0.8390	0.7867
		Life Threatening	0.9629	0.4746	0.0100	0.0100	0.5951	0.6258
9	**Telescape**	**Drill**	0.9991	0.9972	0.9659	0.3620	0.9875	0.9798
		Precautionary	0.9965	0.9871	0.8494	0.0100	0.9630	0.9475
		Life Threatening	0.9634	0.8410	0.0100	0.0100	0.7712	0.7360
10		**Drill**						
		Precautionary						
		Life Threatening						

Note: Results for Evacuation Modes 7, 8, and 9 are based on estimated parameters.

Table 4.11 Rescue parameters – survival and inter-modal transfer



	Rescue Mode	Any Rescue Mode				SAR Helicopter				Standby Vessel				Passing Vessel				Land				Return to Installation			
	Weather	C	M	S	E	C	M	S	E	C	M	S	E	C	M	S	E	C	M	S	E	C	M	S	E
	Evacuation mode	Survival Time [h]				Transfer Success Rate																			
1	Helicopter	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	1.000	1.000	0.900	0.500	n/a	n/a	n/a	n/a
2	TEMPSC (Twin Davit)	72	72	72	36	0.990	0.800	0.250	0.000	0.990	0.900	0.400	0.050	0.990	0.800	0.300	0.050	0.990	0.600	0.300	0.050	0.990	0.800	0.300	0.050
3	TEMPSC (Single Point)	72	72	48	36	0.990	0.800	0.250	0.000	0.990	0.900	0.400	0.050	0.990	0.800	0.300	0.050	0.990	0.600	0.300	0.050	0.990	0.800	0.300	0.050
4	TEMPSC (Freefall)	72	72	72	48	0.990	0.800	0.250	0.000	0.990	0.900	0.400	0.050	0.990	0.800	0.300	0.050	0.990	0.600	0.300	0.050	0.990	0.800	0.300	0.050
5	TEMPSC (PROD)	72	72	72	48	0.990	0.800	0.250	0.000	0.990	0.900	0.400	0.050	0.990	0.800	0.300	0.050	0.990	0.600	0.300	0.050	0.990	0.800	0.300	0.050
6	Skyscape	72	48	36	4	0.990	0.700	0.100	0.000	0.990	0.800	0.300	0.050	0.990	0.700	0.200	0.050	0.990	0.500	0.200	0.050	0.980	0.600	0.100	0.050
7	Seascape	72	72	72	72	0.990	0.800	0.250	0.000	0.990	0.900	0.400	0.050	0.990	0.800	0.300	0.050	0.990	0.600	0.300	0.050	0.990	0.800	0.300	0.050
8	Gemevac	n/a	n/a	n/a	n/a	0.000	0.000	0.000	0.000	0.980	0.900	0.200	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
9	Telescape	72	48	36	4	0.990	0.700	0.100	0.000	0.990	0.800	0.300	0.050	0.990	0.700	0.200	0.050	0.990	0.500	0.200	0.050	0.980	0.600	0.100	0.050
10	0																								

5. EER PERFORMANCE-BASED STANDARDS DEVELOPMENT

5.1 Introduction on Standards Development Program

The Transportation Development Centre (TDC) initiated a program to develop escape, evacuation, and rescue (EER) performance-based standards for offshore installations in Canadian waters. Performance-based standards (PBS) set expected activity, task, and process achievement levels and goals, rather than prescribing equipment quantities, types, dimensions, and other specifications. This chapter describes the standards and their development program, and generally summarizes associated research projects needed to fill relevant data gaps. The PBS development program description includes approaches to drafting of the Standards, composition of the Task Force, composition of the Steering Committee, regulatory review procedures, stakeholder consultations, and the plan for future implementation of the Standards. Anecdotal information is also given on the way that each of the steps described above has developed, together with suggestions on advantages and shortcomings learned from this process. In addition, resolution of some of the more significant issues, such as integration of existing requirements with future improved performance goals, is described.

The research program included physical model tests, full-scale equipment and human performance tests, data collection and analysis from the tests and other sources worldwide, study of human performance under extreme conditions (Chapter 2), and development of a probabilistic computer model, the EER Risk and Performance Tool (RPT) (Chapter 4), capable of simulating components of and the entire EER process. The physical model test program helped produce optimal equipment performance guidelines based on launch and deployment tests of various survival craft under conditions ranging from calm to extreme, including damaged installations. Human performance tests under benign EER conditions were designed to use as a basis for validating the computer model (RPT) (Bercha Engineering, 2001) and for computer extrapolation to more extreme conditions, as described in Chapter 2. The RPT is designed to assist in the generation of availability, reliability, and performance requirements and goals for the Standards. Practical integration of the availability, reliability, and performance distributions as requirements and goals into the Standards was a unique and unprecedented process in offshore EER guideline development, requiring not only appropriate technical interpretation, but also extensive regulatory and stakeholder consultation. Currently, the Standards are in final draft form, undergoing stakeholder and regulatory scrutiny.

5.2 Definitions and Background

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.

A prescriptive approach describes an acceptable solution while a performance approach describes the required result (Foliente, 2000). To clarify the difference between these two approaches, it is helpful to use an example from the building industry. Consider the goal of fire safety in a building. To achieve this goal, a prescriptive code would specify the materials of which the structural frame of the building should or should not be constructed. A performance-based code would state that the building structure should be able to withstand a fire long enough for the occupants to escape safely, but would not "prescribe" exactly which materials must or must not be used.

A criticism of PBS procedure has often been that it, too, is prescriptive, because it prescribes performance targets. This criticism ignores the main focus of PBS on the performance and not on the process. Undoubtedly, 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 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 How to Standards (HTS).

The two principal problems associated with HTS are as follows:

(1) HTS often will not result in achievement of the expected goal.
(2) HTS provides a barrier to innovation.

As indicated in the example on the fire code above, by simply prescribing the building materials for construction, the actual goal of fire safety long enough for the occupants to escape might not be achieved. Also referring to that example further, specification of materials would preclude the use of new materials or other innovative measures to achieve the desired goal.

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), Sweden (Leicester, 1984), USA (NBS, 1977), and Canada (Legget and Hutcheon, 1979) is undergoing a transition from HTS to PBS. On a more general level, educational and institutional procedures are being judged more and more from a performance-based measurement system (CJCA, 2001). Military organizations worldwide have long been the users 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 Defence, *Defence Planning Guide* (DND, 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.

Measures, Indicators, and Standards are established at all levels so that performance can be planned for and evaluated across the depth and breadth of the organization. Measures are attributes that must be evaluated in order to determine whether the expected results are being achieved. Derived from these measures are indicators which are the qualitative or quantitative values that must be assessed to determine performance. Standards corresponding to these measures and indicators establish the specific values against which actual outputs or outcomes will be compared".

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. Although the UK Health and Safety Executive has initiated development of performance-based offshore evacuation standards (Kingswood, 2000), only the more general high-level standards are PBS, while the detailed ones are substantially HTS. Thus, the current Transport Canada PBS initiative is relatively unique and promises to pioneer, to some extent, the development of performance standards and their measurement in offshore installation escape, evacuation, and rescue safety. The *Canadian Offshore Petroleum Installations Escape, Evacuation, and Rescue (EER) Performance-Based Standards* (PBS Development Task Force, 2002a) are a set of standards having jurisdiction over offshore installations in Canadian waters to assure adequate safety for all personnel in the event of a situation that requires emergency abandonment of an installation. Primary users of the PBS are intended to be the operators and the regulators.

5.3 Structure of the Standards

The Standards 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. 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 5.1.

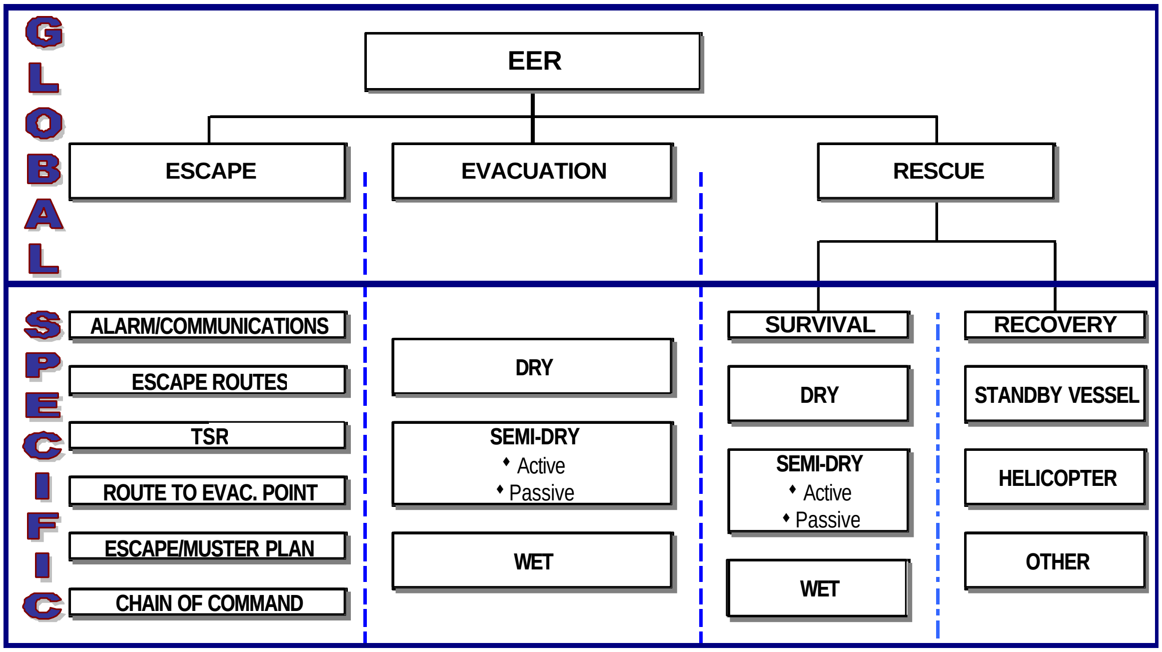


Figure 5.1 Structure of performance-based standards

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

- Design
- Performance
- Reliability
- Availability

5.4 Details of Standards

As shown in Figure 5.1, 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 summarized in Table 5.1. Only a selection of Standards in each of the main categories is given in this table; Appendix A provides the entire set of Standards.

From this table, we can see typical examples of 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 5.2.

Normally, the weather weighted average reliability set out in the Standards is intended to be invariant regardless of the weather conditions. Thus, 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 5.3 sets out the general contents of the ice and cold weather Standards. Appendix E of the Standards (in Appendix A hereto) gives the full version. Generally, because very limited quantitative information on cold weather performance exists (Bercha 2002, 2001, 2000; Bercha et al., 2001, 2000b), 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 the main Standards.

Table 5.1 Semi-dry active systems PBS

(a) Design	*(b) Performance*
i The system shall be 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 shall 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.
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.	iii The craft shall function in both orientations and must meet TP 7320E [3.8(e)] testing requirements.
vii The craft shall 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 two persons from inside the craft.
(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 5.2 Weather condition categories used in Standards

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

Table 5.3 Ice and cold regions EER PBS summary contents

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

Currently, the Standards are in what is expected to be the final draft, with the intent of evaluation of the final draft in the second quarter of 2003. Because Ice Standards have not been previously promulgated, either in HTS or PBS form, it is anticipated that this addendum to the Standards may remain in the pre-promulgation process somewhat beyond the main body of the Standards, which, as indicated above, is scheduled for promulgation in the second quarter of 2003.

5.5 Summary of Research Programs Supporting Standards Development

Although a good deal of information (Bercha Engineering, 2001) is found to exist in the literature and has been generated as part of the PBS development program, there are certain areas that have required further research to facilitate the development of quantitative performance-based targets, which are desirable wherever possible in these Standards. Specific areas requiring further research have been as follows:

- Human performance under extreme EER conditions (Chapter 2).
- Equipment performance under extreme EER conditions.
- Environmental and accident effects on EER systems and procedures.
- The development of a risk and performance model to set achievable quantitative performance targets (Chapter 4).
- Inclusion of ice and cold weather conditions under the Standards.

Because the EER process is intended to protect and save personnel in accident situations, it implicitly deals with life-threatening conditions; therefore, meaningful EER standards must also apply to such life-threatening conditions. Although we can now identify the aspects of life-threatening extreme conditions that must be considered at various phases of the EER process, quantification of performance goals under such conditions can only be achieved through analytical methods. A combination of the anecdotal and Delphi technique research, model and full-scale mechanical testing, and computer simulation is being used to generate quantitative extreme condition performance targets.

In consonance with the analytical research on human performance, mechanical and full-scale prototype tests are being conducted to evaluate and quantify extreme environmental and accident effects on the mechanical performance of EER system components. The model tests are being conducted at the Institute for Marine Dynamics laboratories at Memorial University in St. John’s, Newfoundland (Simões Ré et al., 2002). Full-scale tests are currently being contemplated for unmanned launches for a variety of semi-dry system configurations in cooperation with private operators.

Currently there are no approved operational evacuation systems for ice-covered waters. Although the author has published extensively on the technological approaches to Arctic EER systems (Bercha, 2002, 2001, 1995; Bercha & Cerovšek, 1997; Bercha et al., 2001, 2000a, 2000b, 1999; Cremers et al., 2001), no known operational systems have been identified to date. Usually, technology moves ahead of human factors; ironically, here, the opposite is true.

Although some work has been published on Arctic human performance (Bercha et al., 2000b; Canadian Marine Drilling Limited, 1982; Cremers et al., 2001), very little beyond what is cited above has been published on the technological side. Accordingly, in developing the ice PBS (PBS Development Task Force, 2002b), the reliance was based primarily on expert opinion and experience in the supporting research effort.

All of the results, from the human performance analyses to the model tests and full-scale unmanned tests, together with other available data, are being combined as a basis for the parameterization of an extensive computer model, the Risk and Performance Tool (RPT), also being developed under this program (Bercha Engineering, 2001; Bercha, 2000), with developments under Phase II of this work described in Chapter 4.

It should be emphasized that the quantitative goals and targets established in the PBS are based on ongoing research as well as historical data previously available.

5.6 The Regulatory Regime

The Government of Canada, through the Department of Natural Resources and the Department of Transport, has initiated the development of the EER Performance-Based Standards. Although the Standards are being developed for applicability throughout Canadian waters, current offshore exploration and production activity is focused largely on the territorial waters of the provinces of Nova Scotia and Newfoundland and Labrador. Accordingly, the current implementation plan centres on the interactions between the federal government and the provincial governments and agencies. In the future, it is intended that the Standards applicability will be expanded to the Arctic waters and the Pacific waters of the West Coast of Canada.

Figure 5.2 shows the general association among the parties, and acts and legal documents that are relevant to the EER PBS.

The boxes with double outline represent documents and the boxes with single outline represent government or government agencies. Initiation of the work was carried out through the Government of Canada, Departments of Natural Resources and Transport. Its implementation is intended to flow through the Atlantic Accord, which is an agreement between the federal government and the two Maritime provinces on the regulation of petroleum development in the offshore. Specifically, the Accord Implementation Acts for each of the provinces allow for a provincial offshore petroleum board, the Canada-Newfoundland Offshore Petroleum Board or the Canada-Nova Scotia Offshore Petroleum Board, to have jurisdiction over offshore oil and gas developments. Currently, both of these boards have offshore petroleum installations regulations. It is intended that the EER PBS will be under the jurisdiction of these two petroleum boards. Requirements of the PBS are not the same as those of the regulations, which are in the traditional prescriptive format. Accordingly, PBS requirements will generally exceed those of the existing regulations and may be generally expected to supplement, rather than detract from the existing regulations.

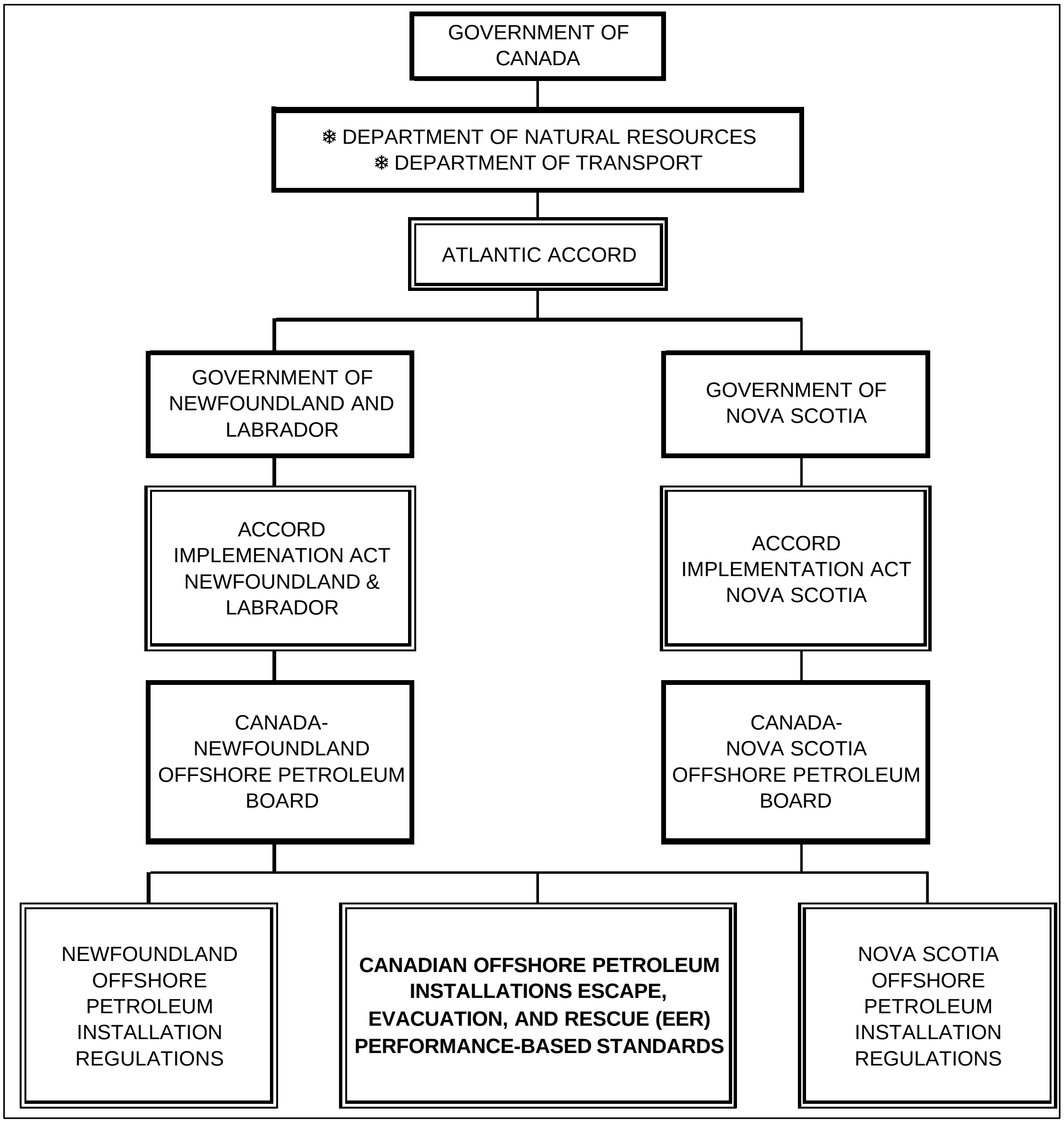


Figure 5.2 EER regulatory regime block diagram

5.7 PBS Development Program

The PBS development program was initiated by the Transportation Development Centre of Transport Canada, but much of its implementation has been contracted to the private sector. Specifically, the research program has been partially contracted to the author, the author's company, and the Institute for Marine Dynamics, a National Research Council Canada agency at Memorial University in St. John's, Newfoundland. The facilitation, drafting, and management of the stakeholder participation program has been largely contracted to Bercha Engineering Limited (Bercha). Bercha, in turn, has sub-contracted parts of the work to appropriate experts in the offshore survival, safety, operations, and supply industries.

There are basically two entities or task forces set up to carry out the work. The first is a Steering Committee, which is intended to provide guidance by incorporating representation from the principal stakeholders. These principal stakeholders are as follows:

- The federal government.
- The provincial governments as represented through their respective petroleum boards.
- Offshore operators as represented through the Canadian Association of Petroleum Producers (CAPP) and the Canadian Association of Oil Well Drilling Contractors (CAODC).

Thus, the Steering Committee consists of the operators and the regulators, together with representation from the suppliers (CAODC). Ex-officio members of the Steering Committee are also representatives of the principal research and implementation contractors (in this case, the author of this paper and the research director for the IMD research program).

Next, the day-to-day drafting, editing, and incorporation of research into the Standards were carried out by an appropriately qualified Task Force. Figure 5.3 shows several members of the Task Force in Survival Systems Offices in Dartmouth, Nova Scotia. This Task Force consisted of experts in the relevant disciplines necessary for development of the Standards, and may be summarized as follows:

- Facilitation and drafting of regulations,
- Offshore safety,
- Offshore survival,
- Offshore recovery, and
- Offshore oil and gas operations.

Task Force members remain current not only in research areas, but also in practical training. Figure 5.4 shows members of the Task Force following completion of offshore survival training in 2002.

Figure 5.3 Task Force at work in Dartmouth

Figure 5.4 Task Force members participate in offshore survival course

Figure 5.5 schematically shows the PBS development program components and temporal evolution. Following conduct of the research in 1999 and 2000, a preliminary set of guidelines was established. At that time, a specific contract was awarded to the facilitating organization (Bercha) to establish a Standards Task Force, as described above, to be guided by the Steering Committee. This Task Force then proceeded to create draft standards, which went through several cycles of review by the Steering Committee and implementation of recommendations by the Task Force.

It was agreed that a broader stakeholder participation than that allowed by the six individuals on the Steering Committee was necessary to gather input from all interested stakeholders: operators, equipment manufacturers and suppliers, offshore contractors, labour, regulatory agencies, and other interested parties. Accordingly, a draft of the Standards (PBS Development Task Force, 2002a) for wide distribution among representatives of all of the above stakeholders was approved by the Steering Committee in early 2002, and circulated to this wide group of stakeholders. A Stakeholder Information Workshop was convened for June 17, 2002, in St. John's, Newfoundland, with the stakeholders in attendance. The structure of the workshop was a series of presentations by the Task Force and Steering Committee, following the agenda shown in Table 5.4. Panels representing the administrative side (the Steering Committee) and the technical side (the Task Force) were seated at the front of the room, and available for questions directed through a third-party moderator. Figure 5.6 shows one of the Task Force members, Fred Leafloor, making a presentation. The all day workshop included lunch at the venue to facilitate informal discussion, as shown in Figure 5.7.

This workshop was quite successful and reflected a keen interest, although by no means unequivocal agreement, with the PBS. It was agreed at the workshop that a formal draft for comment, the current draft, would be sent out to the stakeholders, together with a commentary form, to solicit further comments to be provided within three months, by the end of September 2002. This stakeholder commentary form is reproduced in Appendix B. The form was made to facilitate explicit commentary or questions from stakeholders based on the draft, which was sent out in Adobe Portable Document Format (pdf) only. The pdf format for the PBS was used to avoid extensive spontaneous change management editing, which occurred with earlier drafts, making detection, understanding, and consolidation of significant changes virtually impossible.

Stakeholder comments were received from a number of interested stakeholders on the Stakeholders Comment Form given in Appendix B. Formal responses were drafted, and the responses together with the unexpurgated comments were posted on a website. All stakeholder comments received were constructive, but covered a wide range of aspects, including Standards jurisdiction, ownership, objectives, scope of coverage, and various technical aspects. A common concern expressed related to the confusion between PBS and HTS (see section 5.2).

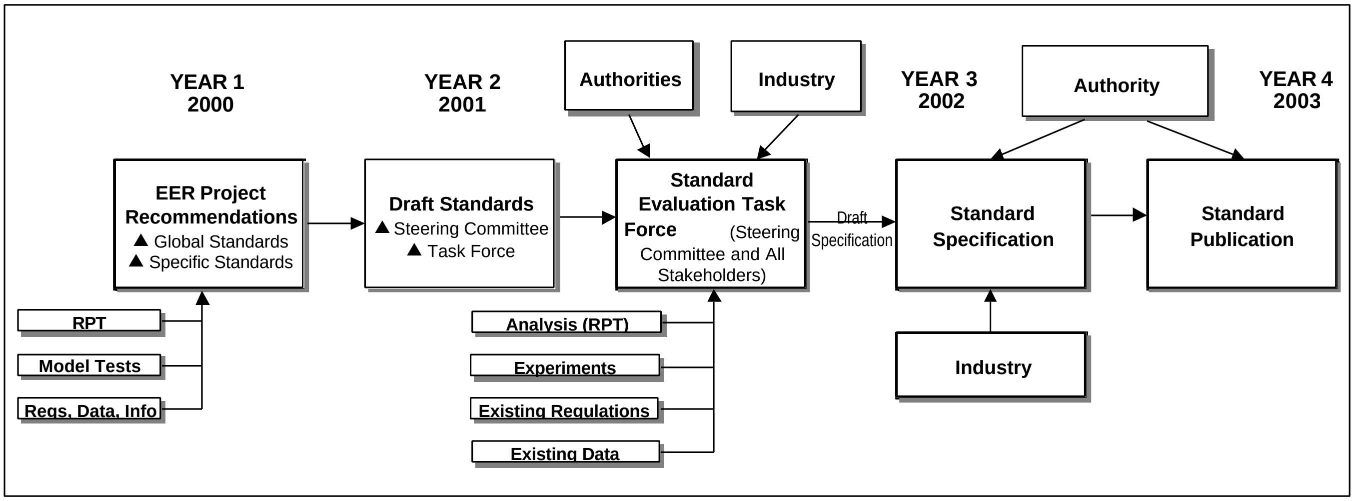


Figure 5.5 PBS development

Table 5.4 Stakeholder Information Workshop #1 Agenda (June 17, 2002)

Time	Activity
8:30	- Coffee and Registration
Morning Session:	**Performance-Based EER Standards**
9:00 – 9:10	- Welcoming Address – IMD
9:10 – 9:30	- Introduction – Ernst Radloff
9:30 – 10:15	- Review of Contents of Standards (LCD presentation) – Frank Bercha, Standards Facilitator, and Technical Panel
10:15 – 10:45	- *Break – Coffee*
10:45 – 11:00	- Summary of comments from web postings of Standards
11:00 – 12:00	- General discussion of PBS Standards – Moderator
12:00 – 1:15	- *Lunch – (provided) at Battery Restaurant*
Afternoon Session:	**Research Programs**
1:15 – 1:45	- Measures of capability for goal-based EER standards – António Simões Ré
1:45 – 2:00	- Questions on above – Moderator
2:00 – 2:30	- Full-scale evacuation test possibilities – Ian Deness
2:30 – 2:45	- Questions on above – Moderator
2:45 – 3:00	- Human factors in EER – Frank Bercha and Fred Leafloor
3:00 – 3:15	- Questions on above – Moderator
3:15 – 3:30	- *Break – Coffee*
3:30 – 3:50	- EER computer modelling – Frank Bercha
3:50 – 4:00	- Questions on above – Moderator
4:00 – 4:30	- General discussion: Issues and outcomes – Moderator
4:30 – 5:00	- Next steps – Ernst Radloff
5:00	- *Adjournment*

Figure 5.6 Presentation at Stakeholder Information Workshop #1

Figure 5.7 Luncheon at Stakeholder Information Workshop #1

Due to the nature of the comments and the volume of work still to be carried out on the Standards, it was agreed that a second stakeholder information session be convened in Halifax on March 19, 2003, with similar arrangements, but focusing on the implementation process. Table 5.5 gives the agenda for this workshop. Here, the focus was more pro-active, concentrating on process rather than content.

5.8 General Conclusions on PBS Program

The conclusions summarized below encapsulate the lessons learned to date from the conduct of the PBS development program.

- Although extensive prescriptive regulations and guidelines (HTS) on offshore EER exist, no comprehensive set of PBS appears to be available.
- Development of new PBS, as undertaken here, is likely to require significant amounts of applied research to rigorously formulate and quantify the PBS targets or goals.
- In conducting a PBS development program, the separation of the administrative and management functions and the research and technical functions is desirable. Accordingly, in the present program, a Steering Committee and a Task Force were established to address the administrative and technical functions, respectively.
- An effective PBS development program requires consultation with all stakeholders, including regulators, operators, suppliers, labour, experts, and other interested parties. Although stakeholder information sessions can be successfully conducted in informal verbal form, stakeholder comments and PBS replies should be carried out in writing.
- An adequate schedule to accommodate all aspects of the PBS development program should be established. For a national level program such as the present one, the schedule should allow for identification of data gaps and research priorities, conduct of the research itself, Standards drafting, stakeholder consultation, and publication and final promulgation.

Table 5.5 Stakeholder Information Workshop #2 Agenda (March 19, 2003)

Time	Activity
8:30	- Coffee and Registration
Morning Session:	**Performance-Based EER Standards**
9:00 – 9:10	- Welcoming Address – Andy Parker (CNSOPB)
9:10 – 9:30	- Introduction – Ernst Radloff (TDC) ▪ Steering Committee, Technical Panel, Facilitators, PBS Program ▪ Summary of progress to date
9:30 – 10:15	- Review of contents of Standards “Final Draft” and Discussion – Frank Bercha, Stakeholders, Facilitator
10:15 – 10:45	- *Break – Coffee*
10:45 – 11:15	- Discussion of Standards content – Stakeholders, Facilitator
11:15 – 12:00	- Perspective on role of Standards – Mike Hnetka (NRC)
12:00 – 1:15	- *Lunch – (provided)*
Afternoon Session:	**The Standards Development Program**
1:15 – 1:45	- Full-scale and model tests – António Simões Ré (NRC)
1:45 – 2:15	- Discussion on above – Stakeholders, Facilitator
2:15 – 2:30	- EER reliability evaluation for Standards – Frank Bercha
2:30 – 2:45	- Discussion on above – Stakeholders, Facilitator
2:45 – 3:00	- Performance targets in Standards – Val Smith (TDC)
3:00 – 3:15	- Discussion on above – Stakeholders, Facilitator
3:15 – 3:30	- *Break – Coffee*
3:30 – 4:00	- Board perspectives on Standards – CNOPB, CNSOPB, NEB
4:00 – 4:20	- Discussion on above – Stakeholders, Facilitator
4:20 – 4:30	- Summary of outcomes of SIW2 (based on this workshop) – Facilitator
4:30 – 4:45	Summary of next steps – Ernst Radloff (TDC), Andy Parker (CNSOPB)
4:45 – 5:00	- Final discussion and adjournment – Stakeholders, Facilitator

6. CONCLUSIONS AND RECOMMENDATIONS

6.1 Summary of Work Done

The scope of work consisted of the provision of research support for, and the development of Escape, Evacuation, and Rescue (EER) Performance-Based Standards (PBS) for installations in Canadian waters.

The provision of research support can be best described under three areas as follows:

(1) Study of human performance under extreme conditions.
(2) Reliability analyses of specialized evacuation systems.
(3) Development of the Risk and Performance Tool (RPT).

In the study of human performance under extreme conditions, the effects of psychological and physiological stressors on error rate and time of performance by personnel was studied, quantified, and incorporated into the RPT. Psychological stressors within the context of EER are primarily the effects of life-threatening accident conditions that may occur in association with an emergency installation abandonment. Physiological stressors are the physical effects of the accident causing the emergency. Such physiological stressors include movements and deformations of the installation, toxic emissions, and thermal radiation and explosion overpressures. In this study, methods of quantifying the effects of these types of stressors were defined and incorporated into the RPT to expand its capability from that of simulating drill situations to that of simulating life threatening situations.

In the second area of research, two specialized evacuation systems, the Seascape system and Preferred Orientation and Displacement (PROD) system were reviewed, and the latter system was subjected to a reliability analysis. Specifically, the PROD system, an enhanced lifeboat launch system, was analyzed utilizing the RPT with validation from available full-scale launch data. The results from the analysis indicated the relative importance of human and mechanical failures, and priorities for maintenance and training based on the relative contributions of different activities and mechanical failures that result in launch failures.

A new version of the computer simulation program, the Risk and Performance Tool (RPT), was generated incorporating three principal improvements and modifications. The first improvement was the subdivision of the task analysis into human error and mechanical failure components, so that the users are able to trace system faults not only to the task, but also to the type of failure causing the task to fail. Second, two sub-versions of the RPT were created: one giving all-inclusive success rates, which include considerations of both system availability and reliability, and the second giving success rate without considering availability. These two versions were required in support of the PBS program. Finally, the RPT was used to generate a wide spectrum of results for all practical combinations of evacuation and rescue modes, and weather and accident conditions in order to provide strategic and tactical information to be included in the Standards.

The second principal area of work covered under this project was the development of the Performance-Based Standards (PBS). This work included facilitation, coordination, Standards drafting, meeting organization, information generation, and extensive communication and consultation to advance the draft Standards to their final draft for implementation. Three main organizational functions were required under this work: direction and participation in a technical Task Force, facilitation of Steering Committee meetings, and consultation with stakeholders through an appropriate process. During the tenure of the present contract, the PBS were advanced from a rough first draft to a polished final draft ready for implementation in March 2003.

6.2 Conclusions

6.2.1 Conclusions from Study of Human Performance Under Extreme Conditions

Human performance, as represented by error rate and time to perform tasks, is significantly affected by physical and psychological stressors. The effects of these stressors can be quantified through appropriate factors, which have been incorporated into the RPT to reflect the conditions under which tasks, activities, and process are performed.

Specific conclusions for evacuation, which was analyzed in detail for both human error and mechanical failure, may be summarized as follows:

- For Calm evacuation conditions, human error and mechanical failure made the same contribution.
- For Moderate and Severe conditions, human error contributed roughly twice as much to failure as mechanical failure.
- For Extreme conditions, both human error and mechanical failure were at the limit (90%), essentially meaning the probability of failure is very high.
- Evacuation success rate is high in calm and moderate conditions but decays rapidly from severe to extreme weather.
- The weighted average (WA) evacuation and total EER values represent average expectations for a specific site.
- For the example offshore location (a typical one) human error, on the average (WA), contributes roughly twice as much to evacuation failure as mechanical failure.

Table 6.1 provides results for a twin-davit lifeboat launch, substantiating the above conclusions, while Figure 6.1 graphically illustrates them.

Table 6.1 Twin-davit TEMPSC evacuation and EER human and mechanical performance contributions and success rates (%)

		Evacuation					**EER**
		Calm	**Moderate**	**Severe**	**Extreme**	**Evac. WA**	**EER WA**
TEMPSC	Human Error	1	2	36	90	7	-
	Mechanical Failure	1	1	20	90	4	-
	Success Rate	99	96	43	10	89	70

Note: **Evac.WA** - Evacuation weather-weighted average
EER WA - Total EER weather-weighted average success rate

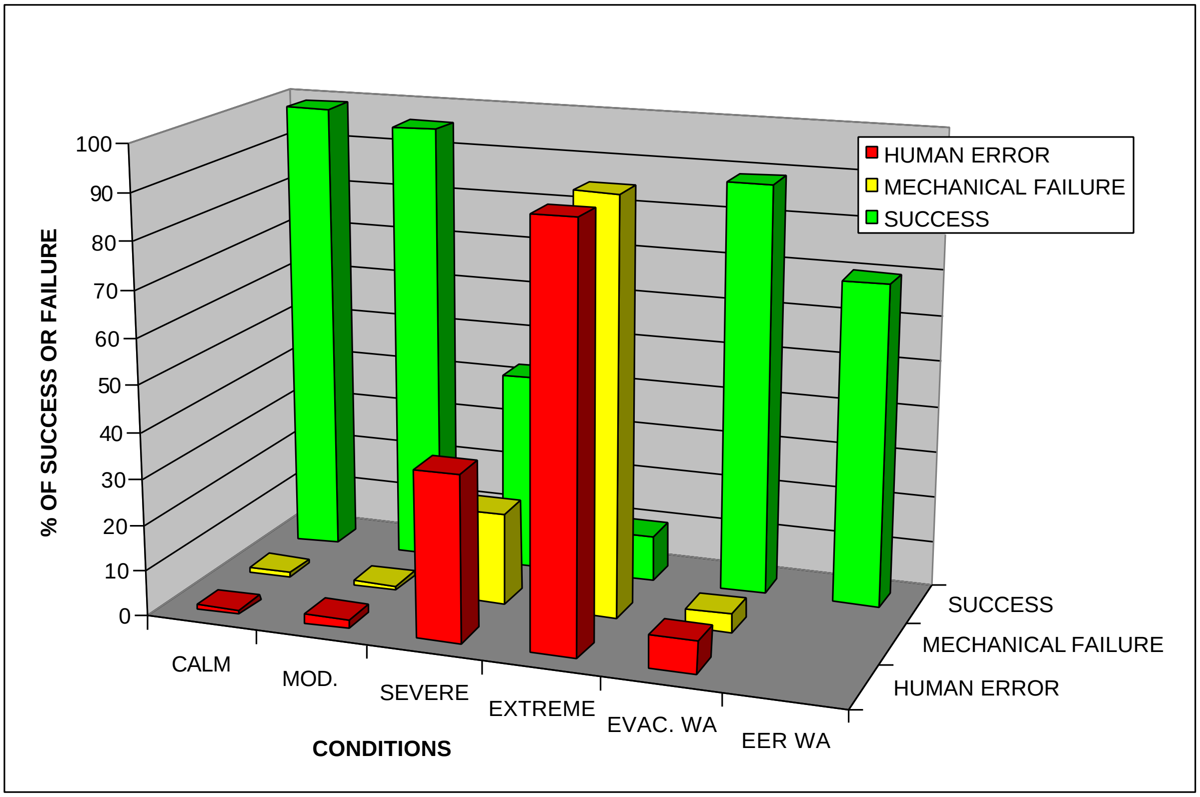


Figure 6.1 Twin-davit TEMPSC evacuation and EER human and mechanical performance contributions and success rates

6.2.2 Conclusions from PROD Reliability Analysis

The PROD reliability analysis demonstrated the contributions of human and mechanical performance to the success of a launch of the PROD system. The following conclusions may be drawn from the reliability analysis conducted:

- PROD evacuation success rate is highly dependent on environmental state, with a significant decay as environmental conditions move from severe to extreme.
- Mechanical failure is independent of the emergency stress level, as the equipment is expected to function in the same manner regardless of the psychological stress. However, mechanical failure probability increases rapidly with severity of weather, approaching unity (100%) for extreme conditions.
- Human error performance decays significantly with increase in emergency psychological stress level, with human error probability doubling from drill to precautionary emergency, and increasing by approximately an order of magnitude (factor of 10) from drill to life threatening emergency.
- The principal activities that can result in critical human errors are roughly equally distributed in their order of importance; however, the correct manoeuvring of the craft to clear the installation provides an increasing proportion of the human error failure probability as the weather becomes more severe.
- Of the mechanical functions, the reliability of the craft release gear and lowering mechanism outweigh the importance or the expected contribution to failure of boom tether disconnect, engine starting, and craft manoeuvrability function.

6.2.3 Conclusions from Risk and Performance Tool (RPT) Development

The RPT Version 4.0 is the most advanced and comprehensive EER computer simulation model currently in existence.

In addition to the capabilities possessed by Version 3.5, the current work has successfully incorporated the following additional RPT capabilities:

- Tracking of human performance contributions to all tasks, activities, and processes in the EER process.
- A reliability version and an availability version so that system reliability can be modeled with or without the inclusion of availability.
- Generation of a full spectrum of reliability values for all practical combinations of nine evacuation modes, four recovery platforms, four weather conditions, and three psychological emergency stress levels.

6.2.4 Conclusions from the EER PBS Development Program

The conclusions summarized below encapsulate the lessons learned to date from the conduct of the PBS development program.

- Although extensive prescriptive regulations and guidelines on offshore EER exist, no comprehensive set of PBS appears to be available.
- Development of new PBS, as undertaken here, is likely to require significant amounts of applied research to rigorously formulate and quantify the PBS targets or goals.
- In conducting a PBS development program, the separation of the administrative and management functions and the research and technical functions is desirable. Accordingly, in the present program, a Steering Committee and a Task Force were established to address the administrative and technical functions, respectively.
- An effective PBS development program requires consultation with all stakeholders, including regulators, operators, suppliers, labour, experts, and other interested parties. Although stakeholder information sessions can be successfully conducted in informal verbal form, stakeholder comments and PBS replies should be carried out formally in writing.
- An adequate schedule to accommodate all aspects of the PBS development program should be established. For a national level program such as the present one, the schedule should allow for identification of data gaps and research priorities, conduct of the research itself, Standards drafting, stakeholder consultation, and publication and final promulgation. Figure 6.2 shows a schematic of the PBS program and schedule to date.

6.3 Recommendations

6.3.1 Recommendations on Study of Human Performance Under Extreme Conditions

Further development of the understanding of parameters characterizing human performance under extreme conditions can be achieved through a combination of additional numerical simulation or Monte Carlo modeling, studies of the effects on human performance of training and equipment and procedure ergonomics, and expansion of stressors to include ice and cold weather effects. The following summarizes the recommendations:

- Derive distributions for human error and performance times and conduct Monte Carlo studies to assess the confidence intervals of the RPT predictions.
- Through a study similar to that used to date, including data assimilation and Delphi techniques, assess the effect of training on human performance under extreme conditions and integrate this into the RPT.

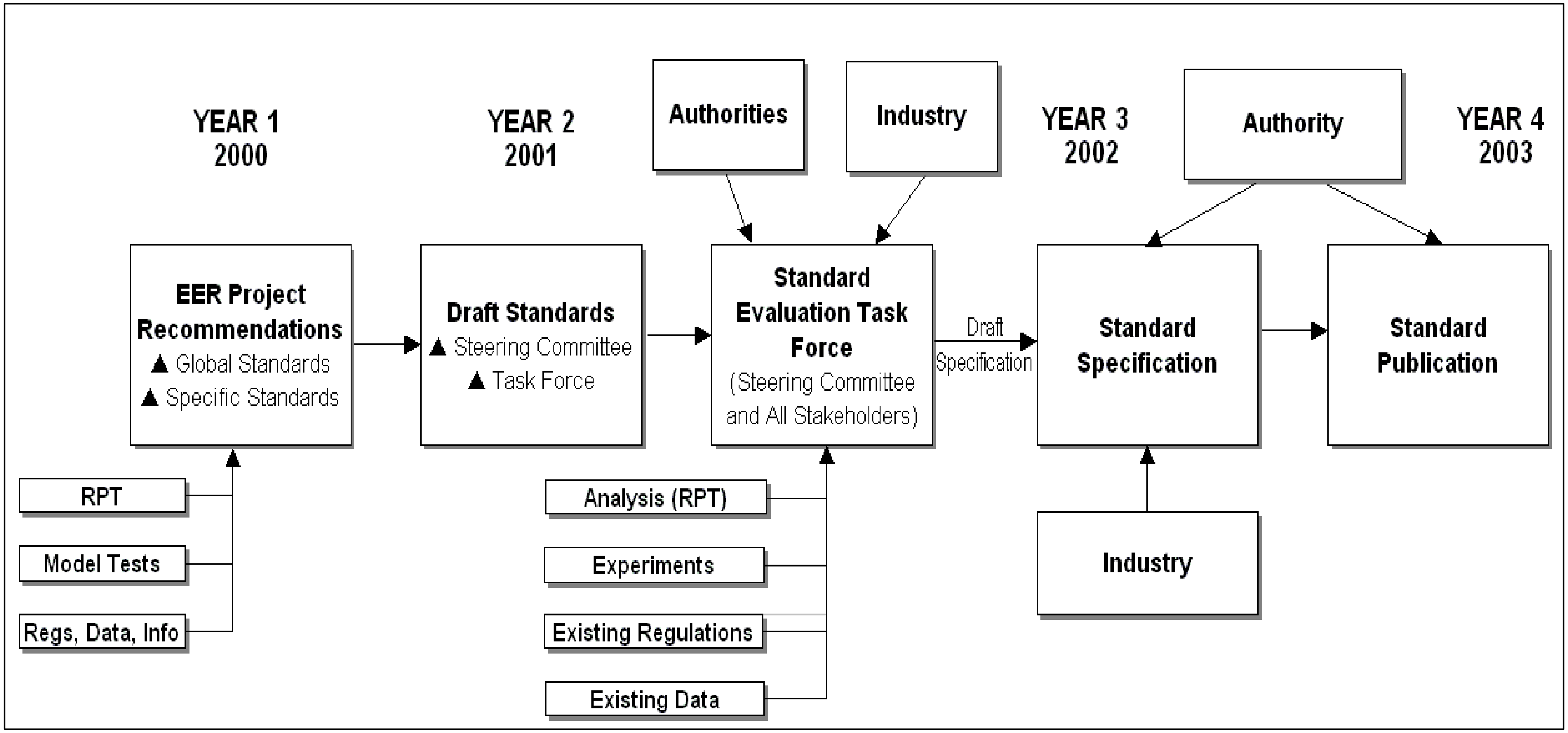


Figure 6.2 PBS development

- Conduct a similar study on equipment and procedure ergonomics and incorporate these into the RPT.
- Assess the physical and psychological effects of ice and cold weather on human performance in EER and incorporate this into the RPT.

6.3.2 Recommendations on PROD and Seascape Reliability Analysis

Results of the current PROD and reliability analysis should be used as inputs to the design of further PROD model and full-scale experiments, and PROD system implementation.

Although initially the scope of work included the analysis of the Seascape 2000 system, work with the system was restricted to two site visits involving inspections of the lifeboat comprising part of the system. In the future, a launch reliability analysis based on full-scale launches should be conducted utilizing reliability engineering techniques and the RPT.

6.3.3 Recommendations on the RPT Development

The RPT in its current version, Version 4.0, provides satisfactory function for support of the majority of the PBS requirements. From a practical application point of view, however, it lacks the ability to simulate post-accident scenarios, individual evacuation and rescue devices, and ice and cold weather performance. In addition, to be optimally useful to administrators having jurisdiction over the PBS, it should be further refined in its functionality in order to be more user-friendly. The following specific recommendations are intended to optimize the RPT:

- Develop an individual and mass evacuation systems module to include evacuation methods such as abseil devices, buoys, and ladders.
- Develop an accident inventory module and integrate it into the RPT to provide methods for assessing and incorporating the effects on EER of different emergency initiating accidents such as fires, explosions, or loss of stability.
- Develop an ice and cold weather RPT (IRPT) that would involve the expansion of the RPT to include ice conditions and cold weather effects on EER.
- Generate ice and cold weather reliabilities for the scope of EER systems addressed in the PBS.
- Develop user-friendly RPT comprising the normal tasks in the transformation of the scientific Beta version of a software program to a technical user version.

6.3.4 Recommendations on EER Performance-Based Standards Development

Since the EER Standards are largely under the control of the Steering Committee, the petroleum boards, the National Energy Board, and Transport Canada, specific recommendations on their implementation will largely depend on inter-agency agreements and priorities. However, general recommendations on the continuation of the standards development program and implementation of the Standards can be made as follows:

- Conduct inter-agency meetings and discussions to determine the precise regulatory framework for the Standards. Options include Transport Canada federal regulations, board regulations, or industry guidelines.
- Adjust the final version of the Standards to be fit for purpose for the regulatory framework chosen. Maintain an open consultative process with stakeholders through appropriate forums such as the stakeholder information workshops.
- Maintain an expert technical body to answer stakeholder concerns, expand the Standards as required for their regulatory framework, and address new issues associated with the Standards. The most effective way to do this with continuity is to maintain the current Task Force for the Standards.
- Provide an adequate time schedule, in the order of two to three years for final implementation.
- Budget the necessary resources to accomplish the above tasks.

REFERENCES

1. Bercha Engineering Limited, *Escape, Evacuation, and Rescue Research Project*, TP 13789E, Transportation Development Centre, Transport Canada, 2001.
2. Bercha Engineering Limited, *RPT Version 4.0*, developed for the Transportation Development Centre, Transport Canada, 2003.
3. Bercha, F.G., "Escape, evacuation, and rescue modeling for frontier offshore installations", *Proceedings of 2000 Offshore Technology Conference*, OTC 12158, Houston, TX, 2000.
4. Bercha, F.G., "Arctic offshore risk assessment", *Proceedings of 2nd International Conference on Development of the Russian Arctic Offshore* (RAO-95), St. Petersburg, Russia, 1995.
5. Bercha, F.G., *Escape, evacuation, and rescue (EER) for ships and platforms in ice*, European Union Workshop, Brussels, Belgium, 2001.
6. Bercha, F.G., "Emergency evacuation of installations in Arctic ice conditions", *Proceedings of the International Association of Hydraulic Engineering and Research (IAHR) 16th International Symposium on Ice*, Dunedin, New Zealand, 2002.
7. Bercha, F.G., and M. Cerovšek, "Large Arctic offshore project risk assessment", *Proceedings of the 3rd International Conference on Development of the Russian Arctic Offshore* (RAO-97), St. Petersburg, Russia, 1997.
8. Bercha, F.G., M. Cerovšek, A.C. Churcher, and D.S. Williams, "Escape, evacuation and rescue modeling for the Arctic offshore", *Proceedings of the 4th International Conference on Development of the Russian Arctic Offshore* (RAO-99), St. Petersburg, Russia, 1999.
9. Bercha, F.G., M. Cerovšek, P. Gibbs, C.J. Brooks, and E. Radloff, "Arctic offshore EER systems", *Proceedings of the 16th International Conference on Port and Ocean Engineering under Arctic Conditions* (POAC-01), Ottawa, ON, 2001.
10. Bercha, F.G., A.C. Churcher, and M. Cerovšek, "Escape, evacuation, and rescue modeling for frontier offshore installations", *Proceedings of the 2000 Offshore Technology Conference* (OTC-2000), Houston, TX, 2000a.
11. Bercha, F.G., A.C. Churcher, and M. Cerovšek, "Risk assessment of marine evacuation systems for Arctic conditions", *Proceedings of the 6th International Conference on Ships and Marine Structures in Cold Regions* (ICETECH-2000), St. Petersburg, Russia, 2000b.
12. *Canada Oil and Gas Operations Act*, R.S. 1985, c-07, Amended 1994, c.10 ss.3, 15, 1994.
13. *Canada-Newfoundland Atlantic Accord Implementation Act*, c.3, 1987.
14. *Canada-Nova Scotia Offshore Petroleum Board Regulations* (CNSOPBR), Sections 19 and 22, 2001.

15. *Canada-Nova Scotia Offshore Petroleum Resources Accord Implementation Act*, 1988.
16. Canadian Department of National Defence (DND), *Defence planning guide*, Chapter 5, http://www.vcds.dnd.ca, 1998.
17. Canadian Marine Drilling Limited, *Tarsiut Island alert and evacuation procedures, Handbook*, Calgary, AB, 1982.
18. Canadian Maritime Law Association, *Policy submission on the desirability and feasibility of a comprehensive international convention on offshore units and related structures*, St. John's, NF, http://www.wob.nf.ca, 1998.
19. Center for Chemical Process Safety (CCPS), *Guidelines for chemical process quantitative risk analysis*, American Institute of Chemical Engineers, New York, NY, 1989.
20. Center for Chemical Process Safety (CCPS), *Guidelines for evaluating characteristics of vapor cloud explosions, flash fires, and BLEVEs*, American Institute of Chemical Engineers, New York, NY, 1994.
21. Council of Juvenile Correctional Administrators (CJCA), *Performance based standards for juvenile correction and detention facilities*, South Easton, MA, http://www.performance-standards.org/contact.htm, 2001.
22. Cremers, J., S. Morris, I. Stepanov, and F.G. Bercha, "Emergency evacuation from ships and structures and survivability in ice-covered waters: Current status and development", *Proceedings of the 16th International Conference on Port and Ocean Engineering under Arctic Conditions* (POAC-01), Ottawa, ON, 2001.
23. Cullen, W.D., *The public inquiry into the Piper Alpha disaster*, Department of Energy, London, UK, 1990.
24. Edita Ltd., *On the capsizing on the 28th Sept. 1994 in the Baltic Sea of the Ro-Ro passenger vessel Estonia*, P.O. Box 800 FIN- 00043 EDITA, Helsinki, Finland, 1999.
25. Energy Resources Conservation Board (ERCB), *GASCON - A model to estimate ground level* H_2S *and* SO_2 *concentrations from uncontrolled sour gas release*, volume 5, preliminary draft, Calgary, AB, April 1990a.
26. Energy Resources Conservation Board (ERCB), *Public safety and sour gas*, Appendix C, Technical Information, Calgary, AB, February 1994.
27. Energy Resources Conservation Board (ERCB). *Gas Risk - A model to estimate risks to public safety from uncontrolled sour gas releases*, preliminary draft, Calgary, AB, April 1990b.
28. Environment Canada, Meteorological Service of Canada, *Manual of standard procedures for observing and reporting ice conditions*, 9th Edition, April 2002.
29. E&P Forum, *Offshore Database*, London, UK, 1996.
30. Foliente, G.C., "Developments in performance-based building codes and standards", *Forest Products Journal*, Vol. 50, No. 7/8, 2000.

31. Galea, E.R. and S. Gwynne, "Estimating the flow rate capacity of an overturned rail carriage end exit in the presence of smoke", *Fire Mater*, No. 24, 2000.
32. Galea, E.R., *Issues relating to passenger egress from rail carriages: Ladbrooke Grove incident, 5 Oct. 1999,* Fire Safe Emergency Group, Univ. of Greenwich, 2000.
33. Gross, J.G., "Developments in the application of the performance concept in building", *Proceedings of 3rd CIB-ASTM-ISO-RILEM International Symposium*, R. Becker & M. Paciuk (eds.), Vol 1, National Building Research Institute, Haifa, Israel, 1996.
34. International Maritime Organization (IMO), *Safety of life at sea* (SOLAS), including the Articles of the Protocol of 1988, including 2000 Amendments, effective January and July 2002, London, UK, 1974.
35. Jin, Tadahisa, "Visibility through fire and smoke", *Journal of Fire & Flammability*, Vol. 9, April 1978.
36. Kingswood, Andrew, *Evacuation standards development and quantification*, EER Workshop, Aberdeen, UK, 2000.
37. Koss, L.L., A. Moore, and B. Porteus, *Fire at sea. Human mobility data for movement on ships*, RINA, London, UK, ISBN 0903055-33-3, 1997.
38. Legget, R.F., and N.B. Hutcheon, "Performance testing standards for buildings", *Canadian Building Digest*, CBD-237, http://www.nrc.ca/irc/cbd/cbd210e.html, 1979.
39. Leicester, R.H., "Closed form solutions for cost-optimised reliability", *Proceedings of IUTAM Symposium on Probabilistic Methods in the Mechanics of Solids and Structures*, Stockholm, Sweden, 1984.
40. National Bureau of Standards (NBS), *Performance criteria resource document for innovative construction*, NBSIR 77-1316, Office of Housing and Building Technology, NBS, US Dept of Commerce, US Gov Printing Office, Washington, DC, 1977.
41. *Newfoundland Offshore Petroleum Installations Regulations* (NOPIR), Section 2.(1), SOR/95-104, 2001.
42. NUREG-75/014, WASH-1400, *Reactor safety study – An assessment of accident risks in U.S. commercial nuclear power plants*, U.S. Nuclear Regulatory Commission, Washington, DC, October 1975.
43. PBS Development Task Force, *Canadian offshore petroleum installations escape, evacuation, and rescue (EER) performance-based standards*, draft for comment, 2002a.
44. PBS Development Task Force, "Ice and cold regions EER performance based standards", Appendix E to *Canadian offshore petroleum installations escape, evacuation, and rescue (EER) performance-based standards*, draft for comment, 2002b.
45. Rasmussen, J., "Human errors: A taxonomy for describing human malfunction in industrial installations", *Journal of Occupational Accidents*, 4, Elsevier Scientific Publishing Company, Amsterdam, Netherlands, 1982.

46. Rasmussen, J., and O.M. Pedersen. "Human factors in probabilistic risk analysis and risk management", *Operational safety of nuclear power plants* (Vol. 1), International Atomic Energy Agency, Vienna, Austria, 1984.
47. Rasmussen, Jens, *Information processing and human-machine interaction: An approach to cognitive engineering*, Elsevier Science Publishing Co., Inc., Amsterdam, Netherlands, 1985.
48. Rasmussen, Jens, Keith Duncan, and Jaques Leplat (eds.), *New technology and human error*, John Wiley & Sons Inc., London, UK, 1988.
49. Rasmussen, Jens, Annelise Mark Pejtersen, and L.P. Goodstein, *Cognitive systems engineering*, John Wiley & Sons Inc., New York, NY, 1994.
50. Royal Commission on the Ocean Ranger Marine Disaster, *Hearings – Royal Commission on the Ocean Ranger Marine Disaster (Canada)*, Toronto, ON, Micromedia Limited, 1984.
51. Sefton, A.D., *The development of the UK Safety Case regime: A shift in responsibility from government to industry*, Offshore Technology Conference, Houston, TX, 1994.
52. Simões Ré, A., B. Veitch, and D. Pelley, *Evacuation by TEMPSC*, National Research Council Canada, Institute for Marine Dynamics, St. John's, NF, 2002.
53. Spouge, J., "Escape from partly capsized ferries", *RINA Conference Proceedings*, 19 November 1996.
54. Swain, A., and H. Guttman, *Handbook of human reliability analysis with emphasis on nuclear power plant applications*, US Nuclear Regulatory Commission Technical Report NUREG/CR-1278, Washington, DC, 1983.
55. Swain, A.D., *A method for performing a human factors reliability analysis*, Monograph SCR-685, Sandia National Laboratories, Albuquerque, NM, 1963.
56. Transportation Development Centre (TDC), *Canadian offshore petroleum installations escape, evacuation, and rescue (EER) performance-based standards, final draft*, Transport Canada, 10 February 2003.
57. Transport Canada, *Life saving equipment regulations*, 1978, amended to SOR/2001-179, May 17, 2001.
58. Transport Canada, *Guidelines for ship operating in Arctic polar waters (polar guidelines)*, http://www.tc.gc.ca/polarcode/Menu.htm, 2002.
59. UK Offshore Operators Association (UKOOA), *Guidelines for the safe management and operation of vessels standing by offshore installations*, Issue 2, 2001.

Appendix A

Final Draft: Canadian Offshore Petroleum Installations Escape, Evacuation, and Rescue (EER) Performance-Based Standards

FINAL DRAFT

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

Transportation Development Centre

Montreal
Canada

February 10, 2003

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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 is intended to be used as part of a continuous improvement process for managing safety and risk in the offshore. Some of the standards developed are within current requirements while others exceed current requirements. It is intended that the Standards will enhance existing requirements by setting them out as performance rather than prescriptive goals, by augmenting them, and by setting new standards such as quantitative reliability levels.

Performance-based standards (PBS) are verifiable attributes or benchmarks that provide qualitative levels or quantitative measures of performance, which must be achieved. The key characteristic of PBS is their focus on what must be achieved rather than on how it should be done. The difference between PBS and the more traditional prescriptive standards is that PBS set out the desired result, while prescriptive standards set out details of a process or tools, which may or may not achieve the desired result. A criticism of PBS has been that it, too, is generically prescriptive, because it prescribes performance targets. This criticism ignores the fact that the focus of PBS is on performance and not on process or equipment specification. Thus, PBS target performance; traditional standards prescribe how to do something or what tools to use. Although the present Standards are intended to set performance targets in all aspects of EER, they have not yet achieved this unilaterally. The goal remains to evolve these Standards to pure performance standards during their implementation and continued development.

The EER Performance-Based Standards define the expected performance of EER systems under specified environmental and damage conditions for offshore petroleum installations in Canadian waters. The standards are intended to foster a system for continuous EER improvement incorporating advances in EER technology, training, and procedures, and applications of risk assessment and 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.

2.1.10 Marine Survival System (MSS)

A *Marine Survival System* (MSS) is a suit or system in which an individual is protected from marine environmental effects. 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.

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. These Standards recognize the As Low as Reasonably Practicable (ALARP) principle as a reasonable approach to managing risk.

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. Success considers both availability and reliability.

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. Thus global failure, the inverse of success, is a function of both availability and reliability.

(b) On an activity level, *failure* means a human error or mechanical failure 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 when the system is available) within a required time limit (if a time limit exists). Reliability is independent of availability; reliability assessment is carried out on the assumption that the system is available. Several different measures of reliability are used in the Standards, as follows:

- Reliability for a specified condition, such as severe weather (Beaufort Force 8 to 10), means the subject reliability in that weather condition only. Estimated reliabilities for evacuation in each of the weather classes used in the Standards are given in Appendix F, Table F.1. For example, from Table F.1, the reliability of a twin davit TEMPSC in severe weather (S) in a drill evacuation is 0.9762 or approximately 98%. Reliability under the specified single condition is not a function of location as the condition (e.g. Beaufort Force 8-10) can occur at different offshore locations.

- Weather-weighted average reliability means the sum of the products of each weather class proportion (at a given location) and the associated reliability. For the same example as above, the STUDY weather weighted average was obtained as 0.9799 or 98%. The weather-weighted average depends on location because it is a function of the proportions of each weather class likely to occur at that location. However, a minimum weather-weighted average can be specified, regardless of location; locations with low proportions of dangerous weather will be well above the minimum, while locations in more dangerous weather conditions will often need to make special provisions to achieve the minimum reliability Standard.

All of the reliability values given in the Standards are the “drill” reliabilities, as these are the most likely to be measurable.

2.2.8 Critical

An adjective used to describe any activity, task, or process, which can lead to casualties if it fails. Casualties are fatalities or severe (life threatening) injuries.

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 machine, mechanical, structural, 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 affecting 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 (Under review February 7, 2002)

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))

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, updated to Dec. 31, 2000.

(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.

(d) UK Department of Energy, the Public Inquiry into the Piper Alpha Disaster, Lord Cullen, 1990.

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 intended 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.

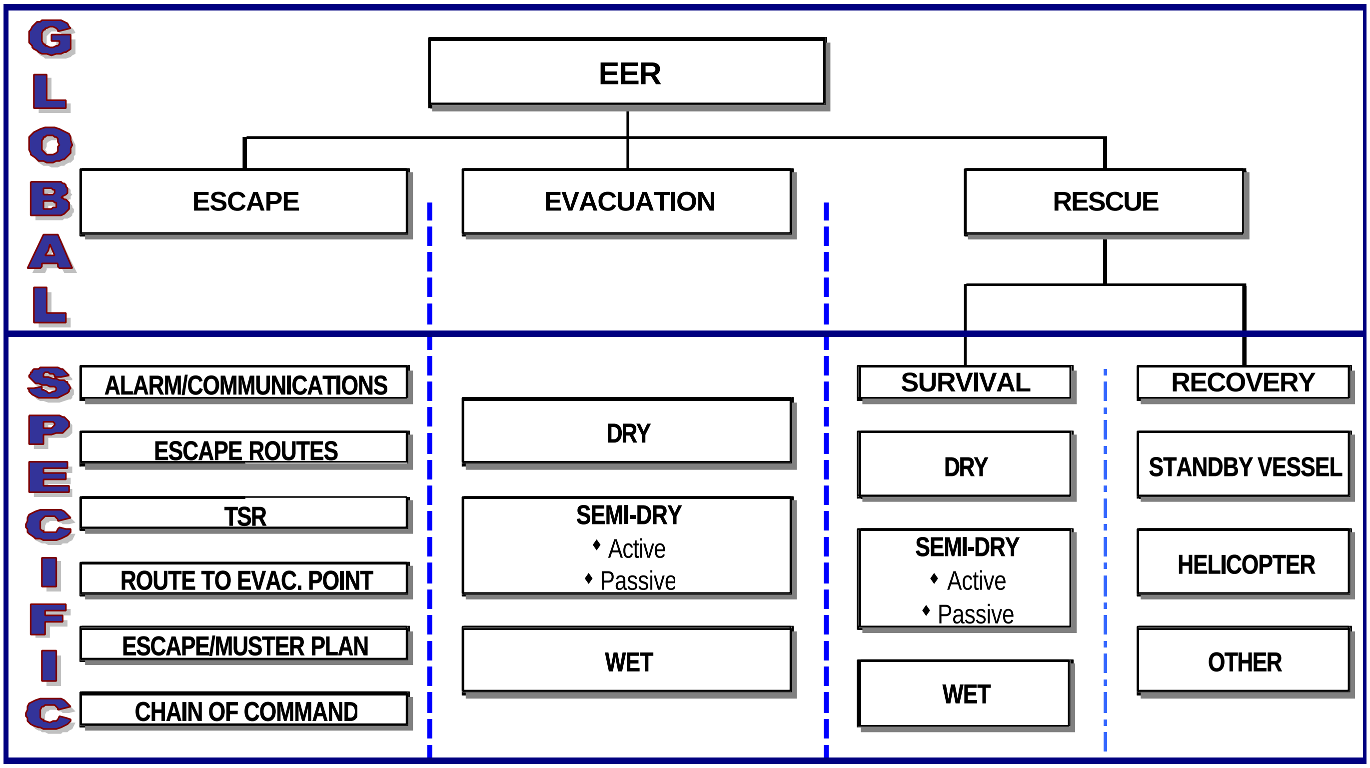

Figure 1
Structure of Performance-Based Standards

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 shall have at least two modes of operation, a primary mode, and an independent secondary mode such that in the case of common mode failure, malfunction 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 the ALARP principle 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, and full documentation on the program shall be maintained.

(k) Drills shall be conducted regularly, including movement of personnel from their location at time of alarm, to TSR, muster, and to embarkation point, and their embarkation. All personnel shall participate in these drills.

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

(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) MODU Code [3.7(b)] stipulates that survival craft embarkation arrangements be 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) Each installation shall have a command structure and established procedures escape that are conducive to effective and efficient, escape evacuation and rescue. The command structure and procedures shall be simple provide for adequate redundancy and shall be communicated to all personnel. The procedures shall include provisions for frequent drills to train personnel and validate procedures.

(o) Optimal provision shall be included in the EER systems and procedures for injured persons.

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 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. There shall be at least one escape route between every two levels, capable of accommodating stretcher transport.

(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.

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[*] Note: Certain installations, which are temporarily (not permanently) manned, are called “unmanned”; but have visiting maintenance crews for which these 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 including breathable air, fire and heat resistance, command and control functions, communications and access to evacuation systems including MSSs shall be maintainable for a sufficient period to allow the escape and mustering of personnel, command assessment and communication of the situation and an orderly evacuation where necessary in all credible accident scenarios.

(b) There shall be a sufficient number of MSS to provide for 100% of the complement, stowed in the TSR, and additional 100% stowed in strategic locations in proximity to the escape routes and 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 shall be conducted for all credible accident scenarios. The drills shall be realistic and designed to train personnel and to assure sufficient practice to prove and improve procedures. The 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) [3.6(a)].

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 and each system must be capable of evacuating all personnel in all credible accident scenarios prior to loss of TSR integrity.

(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 regularly inspected, tested, and maintained by trained personnel in accordance with manufacturers' requirements. Documentation of all inspection, testing, and maintenance procedures shall be maintained.

(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 for 100% of the personnel on an installation shall be available 99.9% of the time at sea.

(h) Reliability

- The minimum combined reliability of the evacuation systems of an installation shall be 97% for severe weather (Beaufort 8-10).
- The minimum weather-weighted average combined reliability of the evacuation systems on an installation shall be 99%.

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).	- The minimum reliability of each dry evacuation system under severe weather conditions (Beaufort 8-10) shall be 98%.
- 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).	- Minimum weather-weighted average reliability for each dry evacuation system shall be 99%.

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 davit-launched TEMPSC or other launching systems and crafts. Semi-dry passive evacuation systems include inflatable life rafts and chutes with rafts or other crafts. The semi-dry system includes the launching system and the craft 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: - Capable of being launched with all personnel in severe weather - On floating installations, capable of being launched clear of all obstructions in damaged condition as defined by IMO-MODU code [3.7(b)]. - On fixed installations, capable of being launched clear of all obstructions from damage from all credible accidents - For all installations in undamaged condition, shall be capable of being launched in severe weather into the target “splash down zone” and remaining outside the “danger zone” (see Appendix

7.2.3 Semi-Dry Active Systems

(a) Design		(b) Performance	
			B for zone definitions). ▪ Operate under its design accident, environmental and operational conditions. ▪ The craft 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 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: ▪ Craft 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 the craft without impact with the structure of the offshore installation. ▪ Craft shall be maneuverable in a sea state up to Beaufort 8. ▪ *Speed* – The speed of craft 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 vessel.

7.2.3 Semi-Dry Active Systems

(a) Design	(b) Performance
	▪ *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 craft 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)]. ▪ *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)].

7.2.3 Semi-Dry Active Systems

	(a) Design		(b) Performance
iii	The craft 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 craft must be stowed at a minimum interior cabin temperature of (10°C).
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**	Craft interior 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	Vessel designed with operator positioned	**xi**	Operator positioned with a full 360°

7.2.3 Semi-Dry Active Systems

(a) Design		**(b) Performance**	
	providing a full 360° horizontal field of view around the craft.		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.
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) (i.e. 99.9%).	▪ The minimum reliability of each semi-dry active evacuation system in severe weather (Beaufort 8-10) shall be 98%. ▪ The minimum weather-weighted average reliability of each semi-dry active evacuation system shall be 99%.

7.2.4 Semi-Dry Passive Systems

Semi-dry passive systems generally consist of transfer or launch mechanism and a craft to which or within 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. Transfer or Launch System			
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 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 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. ▪ System will have the capability to launch without impact that would affect its functioning.

7.2.4 Semi-Dry Passive Systems

(a) Design		**(b) Performance**	
			▪ 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 craft shall be designed with static and dynamic stability to function right side up or inverted.	**iii**	Craft 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 for entry and egress of evacuees wearing MSS 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.

7.2.4 Semi-Dry Passive Systems

(a) Design		**(b) Performance**	
v	Designed with stowage for provisions and water for the complement for 72 hours.	**v**	Provide lighting 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)] and TP7321E [3.8(f)]. Colour shall be optimised to be 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 (transfer system 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 (each unit) shall have a minimum reliability of 97% for severe weather conditions (Beaufort 8-10). ▪ The weather-weighted average reliability of each semi-dry passive evacuation system (each unit) shall be a minimum of 98%.

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 90%. ▪ 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 within 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. The demonstration is normally conducted by the manufacturer during the government approval and certification process.
v	The craft shall be designed to be towed.	**v**	Towing (as towed vessel)-UNDER TF REVIEW ▪ 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	**vii**	Capability to recover personnel from the water

(a) Design		**(b) Performance**	
	recovery of 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 event 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. Demonstration is normally done by manufacturer during the government approval and certification process.
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. A sea anchor is one of the means for maintaining heading.
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 (as required by TP7321E Section 3.1.6 [3.8(f)]) for 24 hours. ▪ Maintain a connection under tow in weather conditions up to Beaufort 7. Towing patch to function at a given tension distribution for a given time period, regardless of

(a) Design		**(b) Performance**	
			towing vessel characteristics. - Performance verification by the manufacturer to occur during the approval process [3.8(f)].
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%.

8.2.1.4Wet 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 suitability for the appropriate lifting procedure.	**iii**	The lifting procedure 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

(a) Design		**(b) Performance**	
			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 97%.

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 evacuation 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 craft 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 all 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	**iii**	System shall have markings and lights to allow

(a) Design		**(b) Performance**	
	optimize visibility shall be included in the design.		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 96% for up to Beaufort 8 conditions.

<u>8.2.2.3 Semi-Dry Passive Systems Recovery Standards</u>

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 using communication equipment such as portable VHF marine radios.
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% 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% 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 close to midships as practicable and away from propellers and thrusters.

(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 unique circumstances, returning to the original installation is a possible best option. Alternatively, when there are several installations in the same area, transfer to the nearest other installation may also be an option.

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 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 Semi-Dry Active Systems

(a) Exclusion Zone – The zone around the installation into which the craft should never go. The exclusion zone should encompass any collision hazards, such as the installation's legs or hull, and be large enough to accommodate launching in the damaged conditions for which evacuation is a planned contingency. In practice, the size and arrangement of the exclusion zone will be specific to each installation and lifeboat station arrangement. See Figure B.1 for a schematic representation of the exclusion zone.

Note: An exclusion zone, for example, of a gravity-based structure might reasonably be expected to be smaller than that of a semi-submersible.

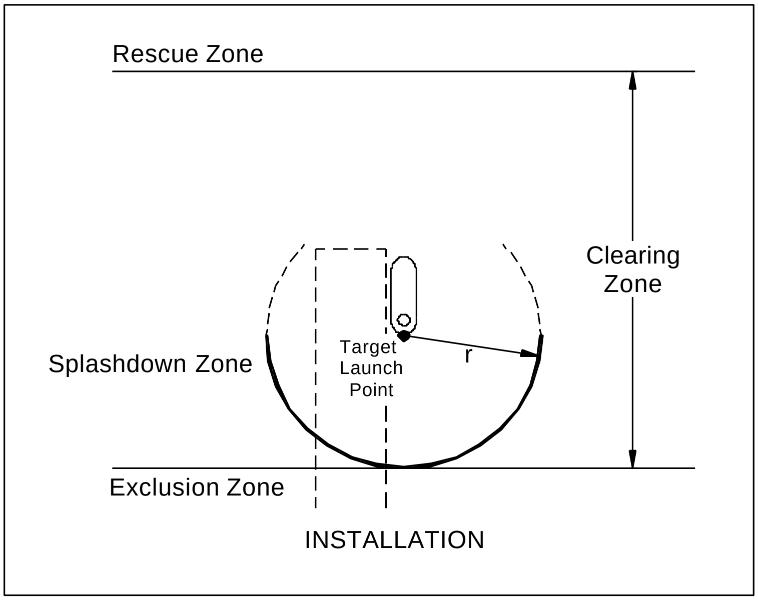

Figure B.1
Evacuation Zones

(b) Splash-down zone - Zone that bounds the area in which the lifeboat moves immediately after splash-down, but before it begins to make way towards the *rescue zone*.

The size of the splash-down zone will be based on the weather conditions that are determined by an operator to be the upper limit for planned evacuation, and the target level of safety deemed to be as high as reasonably practicable.

This is illustrated in Figure B.2 where the splash-down zone is shown for three different limiting weather conditions. The conditions denoted as A, B, and C in the figure represent weather of increasing severity.

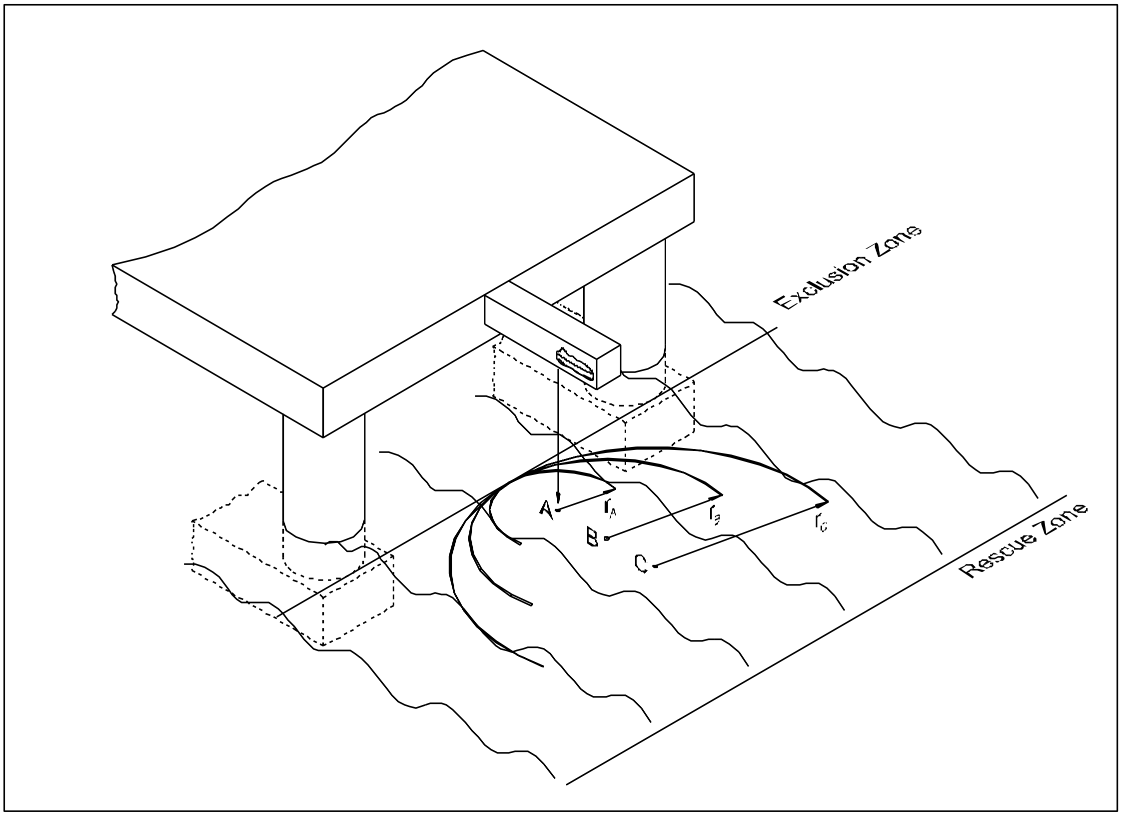

Figure B.2
Design Weather Limits

***(c) Clearing zone* –** The region bounded by the exclusion and rescue zones.

***(d) Rescue zone* –** Zone that starts at some distance from the installation with a boundary that depends on the installation type, modes of rescue, and nature of the credible hazards.

Note: The distance from the installation to the rescue zone is not a fixed distance, but rather it may be defined as the closest distance to the installation that a stand by vessel can come in an emergency situation.

B.2 Other Definitions

1. ***Target Launch Point*** - Position of the planned launch relative to the installation. For example, for a conventional davit launched craft the target launch point is vertically below the craft in its deploy ready position.

2. ***Missed Target* –** The amount by which the craft misses the intended drop point. This reflects the degree of control that the launch system exercises over the delivery of the craft to the water.

3. ***Clearance*** - The distance between the target launch point and the installation. This distance is expected to play a major role in the likelihood of a successful evacuation, particularly in terms of avoiding collisions after launching. This is illustrated in Figure B.3.

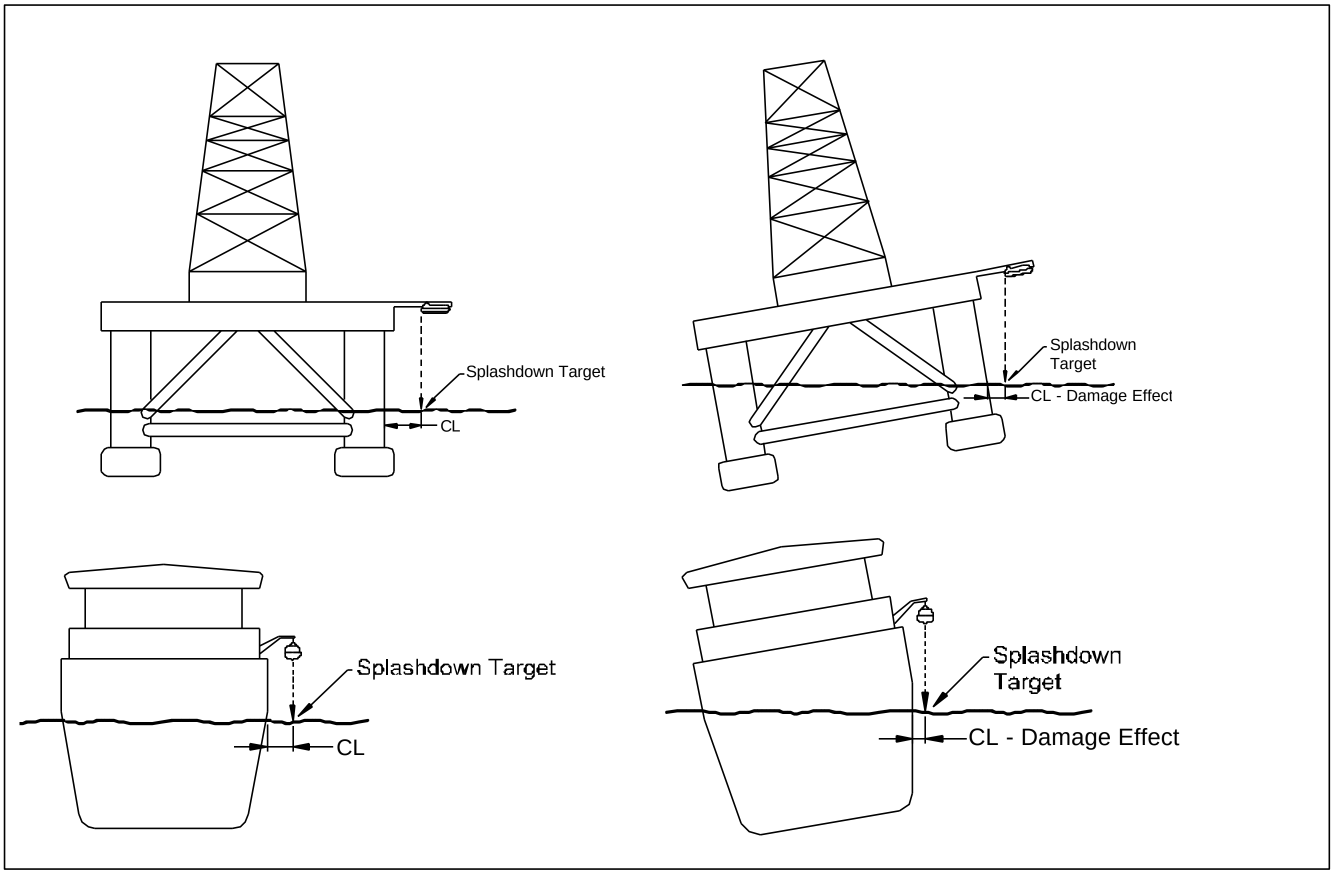

Figure B.3
Clearance

4. ***Setback –*** The distance that the craft is pushed back due to its first wave encounter. This is illustrated in Figure B.4.

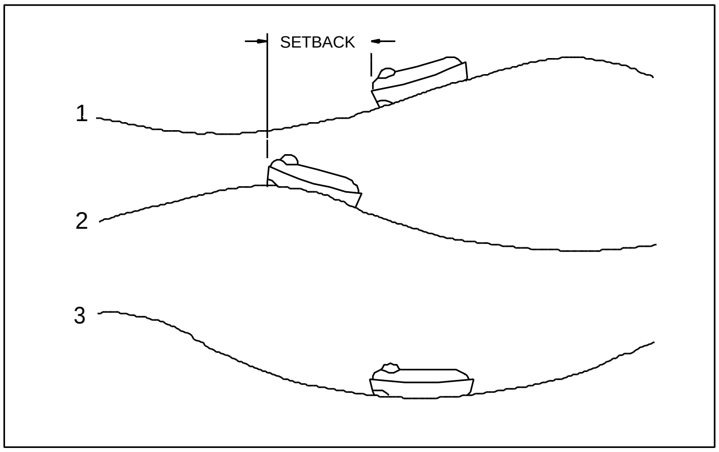

Figure B.4
Set Back

5. ***Progressive Setback –*** The process by which the craft is unable to make head way after the first wave encounter, but rather gets set back progressively farther upon subsequent wave encounters, as illustrated in Figure B.5.

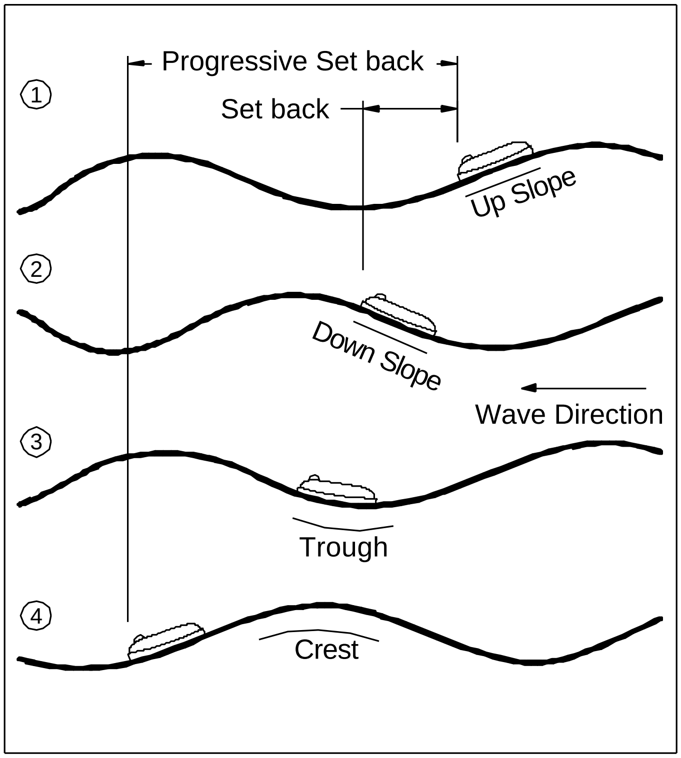

Figure B.5
Progressive Set Back

B.3 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. 7-8° pitch and roll in emergencies, 3-4° in normal operations) by conventional simple main rotor helicopters or 20° pitch, 6° roll in emergency (15° pitch, 3° 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% [3.7(d)].

(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 [3.7(d)].

B.4 UKOOA Limits for Rescue Operations

Table B.1 gives the UKOOA [3.7(c)] 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

D.1 PBS Development Task Force

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D.2 PBS Steering Committee

(CTF – Final participation to be defined).

Appendix E

Ice and Cold Regions EER Performance Based Standards

Table of Contents

SECTION ***PAGE***

E.1 Introduction

E.1.1 General Introduction

Canadian east coast offshore regions are subject to cold weather. The degree of effects of cold weather varies among the regions. In the more southerly regions off Nova Scotia freezing temperatures causing icing and ice fog are the main effect. On the Grand Banks, in addition to the above effects, incursions of marine ice in the form of ice packs or formation of ice sheets can occur. Icebergs also occur, but these are not treated under these Standards, as they do not directly impact on EER procedures. Icebergs are glacial ice formations that have calved from land glaciers, and float under the action of deep currents posing a threat of impact to offshore installations. Further north, in the Labrador Sea, Davis Strait, and Flemish Cap (is this in Canadian waters?) sheet ice and pack ice can be thicker, and ridging and rafting can occur causing localized accumulations of ice of thickness equivalent to that of several ice sheets. These cold weather and marine ice effects need to be considered in establishing EER systems and procedures to assure safe EER in the affected regions. This section of the Standards is intended to address cold weather and marine ice provisions for safe EER.

This draft is a preliminary version, intended to form a basis for discussion in Task Force and Steering Committee. Input was restricted to two members (F. Bercha and F. Leafloor) of the TF.

The structure of the ice and cold weather Standards in this appendix is intended to be the same as those of the PBS in the body of the Standards, but the content is more general and qualitative. The approach taken in developing the ice and cold weather Standards was to identify the unique problems and simply state that they must be dealt with adequately; that is, the problems shall either be eliminated or mitigated to a level As Low as Reasonably Practicable (ALARP).

E.1.2 Ice and Cold Weather Effect Categories

In these Standards, ice and cold weather effects have been subdivided into the following categories according to their causes:

- Cold Temperature
- Ice fog

- Icing
- Marine Ice

In addition, marine ice is broadly classified according to its structural characteristics as follows:

- Sheet Ice
    - Thin sheet ice
    - Thick sheet ice
- Pack ice

The subdivision between thin and thick sheet ice is important because thin ice will not bear (support) EER equipment and personnel, while thick ice has sufficient bearing capacity to support a given evacuation craft and personnel. Therefore, thick ice precludes navigation; thin ice allows it (with impediment).

Ice and cold weather regions are also classified into four severity classes, as follows (and as detailed in Appendix A.1 to this appendix): *Note – we use names different from the Beaufort/weather classes to avoid confusion.*

- Mild - Subzero temperatures, but no marine ice.
- Medium - Subzero temperatures and light first year ice inclusions.
- Major - Subzero temperatures and permanent first year massive ice for more than 1 month.
- Arctic - Subzero temperatures and fast and multi-year ice conditions for 6 months of the year.

The Arctic category does not occur on the East Coast regions considered here. Arctic includes multi-year ice.

Important to note that some installations will not work in ice due to their ice class restriction – therefore can work in ice region only in summer when no ice. Ice observations and surveillance are main provision for cold weather/ice operation.

Cold water repairs category can also be combined with Beaufort class to create additional condition. However the effect of wind decreases as the ice severity increases due to damping effect of ice.

E.2 Definitions – (*based on [E.3.2(a]*)

Marine Ice (Also known as Sea Ice)

- **New:** A general term for recently formed ice which includes frazil ice, grease ice, slush and shuga. These types of ice are composed of ice crystals which are only weakly frozen together (if at all) and have a definite form only while they are afloat.
- **Grey:** Young ice 10-15 cm thick. Less elastic than nilas and breaks on swell. Usually rafts under pressure.
- **Grey-white:** Young ice 15-30 cm thick. Under pressure it is more likely to ridge than to raft.
- **Thin first-year:** First-year ice of not more than one winter's growth, 30-70 cm thick.
- **Medium first-year:** First-year, ice 70-120 cm thick.
- **Thick first-year:** First-year ice over 120 cm thick.
- **Old ice:** Sea ice which has survived at least one summer's melt. Topographic features generally are smoother than first-year ice. May be subdivided into second-year ice and multi-year ice.
- **Second-year ice:** Old ice which has survived only one summer's melt.
- **Multi-year ice:** Old ice which has survived at least two summer's melt.

▪ **Iceberg**

- A massive piece of ice of greatly varying shape, protruding 5 meters or more above sea level, which has broken away from a glacier and which may be afloat or aground. (Bergy Bits and Growlers are smaller forms of icebergs)

▪ **Sheet Ice**

- Any relatively flat piece of ice more than 20 m across, and may include Drift Ice and Land Fast Ice.

▪ **Pack Ice**

- Any area of sea ice with a concentration of greater than 7/10 coverage. Pack ice may be Close Pack, Compact or Consolidated depending upon the pressures forcing the ice together.

▪ **Ice Concentration**

The ratio expressed in tenths describing the amount of the water surface covered by ice as a fraction of the whole area.

- **Ice free:** No ice present. If ice of any kind is present, this term shall not be used.
- **Open water:** A large area of freely navigable water in which ice is present in concentrations less than 1/10. No ice of land origin is present.

  - **Drift ice/Pack ice:** Term used in a wide sense to include any area of ice, other than fast ice, no matter what form it takes, or how it is disposed. When concentrations are high, i.e., 7/10 or more, drift ice may be replaced by the term pack ice.
  - **Very open drift:** Ice in which the concentration is 1/10 to 3/10 and water dominates over ice.
  - **Open drift:** Floating ice in which the concentration is 4/10 to 6/10, with many leads and polynyas. Floes generally not in contact with one another.
  - **Close pack:** Floating ice in which the concentration is 7/10 to 8/10, composed of floes mostly in contact with one another.
  - **Very close pack:** Floating ice in which the concentration is 9/10 to less than 10/10.
  - **Compact ice:** Floating ice in which the concentration is 10/10 and no water is visible.
  - **Consolidated ice:** Floating ice in which the concentration is 10/10 and the floes are frozen together.

- **Ice Fog** (Also known as Frost Smoke)
  - Fog-like clouds formed by the contact of cold air with relatively warm water. These can appear over openings in ice or leeward of the ice edge and may persist while ice is forming

- **Icing**
  - **Ice growth:** Caused by the freezing of water by cold air, and its rate will depend on the air temperature, wind conditions, and water salinity. Terms used are descriptive: little or no ice growth, slow or light, moderate, and rapid.

- **Ice Distribution**
  - **Ice cake:** Any relatively flat piece of ice less than 20 m across.
  - **Ice Openings:** Includes all forms of fractures and cracks.
  - **Crack:** Any fracture of fast ice, consolidated ice, or a single floe which may have been followed by separation ranging from a few centimetres to 1 m.
  - **Lead:** A separation of more than 1m width between edges of floes or sheets.
  - **Strips:** Long narrow area of drift ice, about 1 km or less in width, usually composed of small fragments detached from the main mass of ice, which run together under the influence of wind, swell or current.
  - **Ice edge:** The demarcation at any given time between the open water and sea, lake or river ice whether fast or drifting. May be termed compacted or diffuse.

- **Ice Pressure**

  - Caused by convergence of ice floes under the influence of wind or water currents, forming ice deformation of several forms (fractures, hummocks, ridges, rafting). Terms used are descriptive: light, moderate, strong.

- **Ice Management**
  - Ice surveillance, planned approaches, and operational procedures (including icebreaker support if needed), and emergency response plans designed to respond to forming or encroaching ice, that are put into place by the Owner to ensure that an installation or vessel will operate safely in conditions for which it is designed, or will avoid operating in marine ice conditions that are outside the installation or vessel's design capabilities.

- **Ice Class**
  - Refers to the hull materials strength, structural arrangement and (for mobile vessels) the propulsion capability of a vessel or installation to withstand service in marine ice. The Ice Class designation refers to the type and thickness of ice in which the vessel or installation is designed to safely operate.

E.3 Relevant Publications

E.3.1 Private Investigators

(a) Bercha, Frank G., "Arctic Offshore Risk Assessment", Proceedings of 2nd International Conference on Development of the Russian Arctic Offshore (RAO-95), St. Petersburg, Russia, 18-22 September 1995.

(b) Bercha, Frank G., and Milan Cerovšek, "Large Arctic Offshore Project Risk Assessment", Proceedings of the 3rd International Conference on Development of the Russian Arctic Offshore (RAO-97), St. Petersburg, Russia, 23-26 September 1997.

(c) Bercha, F.G., M. Cerovšek, A.C. Churcher, and D.S. Williams, "Escape, Evacuation and Rescue Modeling for the Arctic Offshore", Proceedings of the 4th International Conference on Development of the Russian Arctic Offshore (RAO-99), 06-09 July 1999.

(d) Bercha, F.G., A.C. Churcher, and M. Cerovšek, "Escape, Evacuation, and Rescue Modeling for Frontier Offshore Installations", Proceedings of the 2000 Offshore Technology Conference (OTC-2000), Houston, Texas, USA, 01-04 May 2000.

(e) Bercha, F.G., A.C. Churcher, and M. Cerovšek, "Risk Assessment of Marine Evacuation Systems for Arctic Conditions", Proceedings of the 6th International Conference on Ships and Marine Structures in Cold Regions (ICETECH-2000), St. Petersburg, Russia, 12-14 September 2000.

(f) Bercha, F.G., M. Cerovšek, P. Gibbs, C. Brooks, and E. Radloff, "Arctic Offshore EER Systems", Proceedings of the 16th International Conference on Port and Ocean Engineering under Arctic Conditions (POAC-01), Ottawa, ON, Canada, 12-17 August 2001.

(g) Cremers, Jörg, Stanley Morris, Igor Stepanov, and Frank Bercha, "Emergency Evacuation from Ships and Structures and Survivability in Ice-Covered Waters: Current Status and Development", Proceedings of the 16th International Conference on Port and Ocean Engineering under Arctic Conditions (POAC-01), Ottawa, ON, Canada, 12-17 August 2001.

(h) Bercha, F.G., "Escape, Evacuation, and Rescue (EER) for Ships and Platforms in Ice", European Union Workshop, Brussels, September 2001.

(i) Bercha, F.G., "Emergency Evacuation of Installations in Arctic Ice Conditions", Proceedings of the International Association of Hydraulic Engineering and Research (IAHR) 16th International Symposium on Ice, Dunedin, New Zealand, 2-6 December 2002.

(j) Bercha, F.G., C.J. Brooks, and F. Leafloor, "Human Performance in Arctic Offshore EER", In preparation, the 13th International Offshore and Polar Engineering Conference and Exhibition (ISOPE), Honolulu, Hawaii, USA, 25-30 May 2003.

E.3.2 Federal Government of Canada

(a) Environment Canada, Meteorological Service of Canada: *Manual of Standard Procedures for Observing and Reporting Ice Conditions* (Ninth Edition, April 2002).

(b) Transport Canada, *Guidelines for Ship Operating in Arctic Polar Waters* (Polar Guidelines), http://www.tc.gc.ca/polarcode/Menu.htm, 2002.

E.4 General Requirements

The ice and cold weather Standards shall have the same structure and objectives as those in the body of the Standards. These ice and cold weather Standards are intended to supplement, but in no way replace or negate, the Standards for situations where ice and cold weather occur.

E.5 Global Standards

There shall be provisions to eliminate or manage to ALARP the following general impacts or effects:

- Provision for effects of all three categories of ice and cold weather.
- Training, briefing, provisioning, equipment and systems for cold temperature performance in EER.
- Cold temperatures affect human physiology/psychology, equipment, metallurgy, thermoplastics, gas volumes (inflation), consumable supplies – cold temperature performance needs to be optimized according to the expected/maximum region of operation.
- Ice fog affects visibility, curtails airborne operations, coats windows windshields, may cause vision and breathing problems.

- Icing accumulates on external surfaces, creating additional mass (which can affect buoyancy, air flow, metacentric height, impede mechanisms, seal hatches shut, etc.
- Cold weather operations generally slower, requiring additional precautions.
- Marine ice
    - Requires addition of expertise in operational ice observation and monitoring (AES ice charts, satellite imagery, dedicated radar systems), ice forecasting, active and passive ice management.
    - While it dampens sea, also impedes or eliminates navigation for non-ice class craft.
    - Launch mechanisms need to include consideration of solid ice or ice rubble in normal (non-ice) launch zone.
    - Navigation in ice (safety craft and rescue craft) need to consider interaction of dynamic ice pressure.
    - If severe enough ice can capsize or crush safety craft when under effects of convergent forces (wind, current, sea, other vessel).
    - If thick enough a safety craft will sit on top of the ice unable to navigate.

E.6 Escape Standards

The following effects of ice and cold weather shall be eliminated or mitigated to ALARP or dealt with as specified.

E.6.1 Cold Temperature

- Selection of optimal escape routes and procedure for cold temperature – could be minimizing external routes-alternate escape plan for cold temperature.
- Freezing of hatches equipment.
- Thermoplastics-cracking of inflating membranes.
- Extra inflation volumes; reduction in stiffness of items inflated with warm gas.
- Clothing, goggles.
- Appropriate food and water provisioning – avoid freezing of water supply.
- MSS maintenance for cold temperature: store MSS in warm locations – OK for YSR but may need additional heated lockers for the non-TSR locations throughout installation.
- Adjust escape procedure for cold temperature: bulkier clothing, goggles, possible stiffening of external suit layer, etc.

E.6.2 Ice Fog

- Compensation for reduced visibility in ice fog area.
- Aircraft operations suspended-need alternative plan.
- Ice formation on external surfaces (also applies to icing but ice fog creates a thin layer only – icing includes massive build-up).
    - Canopy, window, windshield.
    - Antenna icing-range and quality of communication impaired.
    - Light, colour, detection visibility reduced.

E.6.3 Icing

- External escape routes.
    - Need de-icing.
    - Need ice anti-slip provisions (e.g. sand) if de-icing not done in time.
    - Cover with canopy to shield from impacts of dropping ice fragments (from rig, etc).
    - Route protection/location to minimize sea spray.
- TSR
    - Arctic escape/EER procedure.
    - Arctic provisioning-food, water (insulated in case need to hike on top of ice), clothing, medicines/first aid for frostbite, etc.
- Hatches, doors, windows (if needed in EER).
    - Provided to avoid freezing shut – de-icing, force (hydraulics).
    - Where visibility through windows needed also provide for its maintenance using wipers, de-foggers, de-fogging fluids).

E.6.4 Marine Ice

- Escape residence in TSR must be timed to optimize EER success considering ice conditions – i.e. don't leave TSR until ice is ok for evacuation (if possible). This requires ice monitoring and analysis in real time.

E.7 Evacuation Standards

The following effects of ice and cold weather shall be eliminated or mitigated to ALARP or dealt with as specified.

E.7.1 Cold Temperature

- Adapt movement to evacuation station, muster, and boarding to cold weather.
- Design launch system to be maintained functional in cold temperature.
- Maintain inflation requirements in cold conditions.
- Consider thermoplastic behaviour of plastic components.
- Effects of cold on hydraulics, oils.
- Brittle fracture of metals at low temperature.
- Engine operation in cold weather-start, fuel mix, cooling.
- Any internal items, such as sea anchors, water desalinizers, provisions need to be heated or cold temperature capable.
- Inflated craft water pockets will freeze and become solid ballast-design r to avoid this.

E.7.2 Ice Fog

- Visibility will be reduced.
- Aircraft operations suspended – first evacuation option (helicopter) usually eliminated.
- Dry systems affected most – difficult to connect to SBV.
- Thin ice layer on surfaces.
    - Canopy, window visibility.
    - Antenna.
    - Lights, colour, dimmed.

E.7.3 Icing

- Route from TSR and access to craft must be maintained clear and passable (no slipping, no ice obstructions, no falling ice fragments).
- Craft/system must be maintained clear of ice build-up.
    - Hatches, windows functional both open/close and visibility capable.
    - Any ice/snow on superstructure/canopy removed to avoid extra mass, which could affect stability.
    - Launch mechanism clear of ice to ensure functioning.
    - Ice build-up or fragments clear of membranes to avoid penetration/abrasion
    - Lines clear of ice to function in pulleys, etc.
    - Propulsion, steering equipment functional.
- Provisioned with ice/snow removal equipment usable after launch if snow/ice build-up continues – should be operable from inside craft.

E.7.4 Marine Ice

The following effects of ice and cold weather shall be eliminated or mitigated to ALARP or dealt with as specified.

E.7.4.1 General

- For operation in ice conditions there shall be sufficient numbers and locations of systems such that an evacuation of 100% personnel is safe (specify reliability) in all design ice conditions combined with relevant weather conditions for the installation/location.
- Such systems shall be capable of safe operation, including launch, clearing, and (later) rescue in all design ice conditions. So free fall in frozen in thick ice condition is out!
- Ice observations and short term forecasting need to be maintained throughout evacuation.
- Real time choice of evacuation system must be compatible with ice conditions surrounding the installation.
- Real time choice of evacuation system location (updrift, downdrift) must be compatible with optimum safety.

E.7.4.2 Sheet Ice

- Thin ice is ice which lacks bearing capacity to support the laden evacuation system and its operation; thick ice has sufficient bearing capacity to support the system and its operation. Some guidelines will need to be developed in appendix on conditions to use in determining what is capacity of different observed ice sheet thicknesses and types. Much work was done on this – the bearing capacity of floating ice sheets – in the 60's and 70's by CRREL, NRC (Gold), and private investigators (Bercha, Meyerhof).
- The quantitative definition of thick and thin sheet ice therefore varies with the mass and dynamic forces of different evacuation systems.

E.7.4.2.1 Thin Sheet Ice

- The evacuation craft when launched will break the ice and float in the water.
- Launch dynamics must be such that no damage is sustained in interaction with thin ice cover at sea level.
- Manoeuverability and speed in thin ice will be reduced.
- Ice breaking capability and ice resistance for thin ice needed.
- Ice convergence under wind or effects of rescue platform can increase ice forces on craft – must be designed for this.

- Inflated craft need ice protection for abrasion, fragment impact puncture, stability – underpinning ice.
- Protection of external propulsion systems (e.g. props) from ice fragments.
- Timing of launch needs to consider dynamics of ice (constantly changing ice conditions).

E.7.4.2.2 Thick Sheet Ice

- The evacuation craft will remain on the ice surface-no marine propulsion is useful.
- It is assumed required to move away from the installation to protect evacuees from accident effects.
- Three alternatives exist.
  - Move laden craft-see Bercha propulsion systems [E.3.1 (e), (f), (i)].
  - Move unladen craft – especially for inflatables can drag craft on ice surface, avoid adfreezing, design inflatable to use as shelter.
  - Abandon craft on foot on ice surface – provide equipment and provisions for survival component of rescue.
- Consider alternative launch technologies, including chutes, deployment arms, inflation of craft/shelter on ice surface, sled runners on craft. [E.3.1 (c), (d), (e), (f)].
- Rapid deterioration in engine function without cooling water – need alternate heat source.

E.7.4.3 Pack Ice

- This situation differs from the thin ice situation in that pack ice is thicker than the thin ice, and can have a range of concentrations from 7/10 to 10/10 (down to 1/10 for open drift).
- Launch must be timed for splash down well within a lead among ice floes or in down drift location (usually lee side of platform) – this can be problem if windward side launch necessitated by accident (e.g. fire, toxic) conditions or installation drift.
- Lead navigation much slower; maneuverability restricted to open sufficiently wide leads; could end up in blind lead and need to backtrack or abandon craft if converging.
- Threat of ice convergence capsizing or crushing craft.
- Threat of ice abrasion/damage to membrane or rigid hull.
- Need to protect against convergence and resultant ice compression on evacuation craft resulting from approach of SBV in case it assists in clearing, and later in rescue.
- If floes large and thick enough may consider launching to floe surface as for thick sheet ice.

- Continued threat of ice build-up on superstructure, and on propulsion and steering from cavitation supercooling.

E.8 Rescue Standards

- The nature and details of the rescue component are intrinsically related to then configuration of the evacuees following clearing from the installation – as noted the evacuees can be:
    - Within the safety craft in the water in thin ice or lead in an icepack.
    - Within the craft on the ice surface.
    - Camped on the ice surface away from the craft.
    - On the ice surface using the safety craft in modified form (e.g. inverted liferaft) as a shelter.
- There is also a strong dependence on rescue mode availability in both survival and transfer components.

E.8.1 Survival

E.8.1.1 Low Temperature

- Survival time will be reduced due to low temperature effects in all configurations.
- Damage to provisions through freezing can accelerate dehydration starvation.
- Damage to the craft will be exacerbated through the low temperature.
- Water pockets will freeze.

E.8.1.2 Ice Fog

- Will hamper visibility – require location methods and locators adequate for ice fog.
- Restricts pyrotechnics also – need alternate.
- Psychological effects may cause panic in ice fog.

E.8.1.3 Icing

- If craft is floating during ice and snow accumulation conditions require means to clear ice and snow from superstructure, antenna, exhausts, and windows.
- If on ice surface accumulating ice/snow should be used for additional shelter.

E.8.1.4 Marine Ice

E.8.1.4.1 Thin Sheet Ice

- Reduces mobility of safety craft.
- Needs thin ice capable propulsion, steering, and hull – semi-dry active system.
- Can cause damage to hull or membrane, accelerating demise of craft and shortening survival time – require protection against hull/membrane ice damage through abrasion or puncture.

E.8.1.4.2 Thick sheet ice

- Survival is function of ability to maintain habitable conditions and supplies on ice surface.
- Mobility to lead or ice edge may be an option; however, heat loss is always much more rapid in water.

E.8.1.5 Pack Ice

- Craft will be floating in lead, navigability will depend on ice concentration:
  - < 7/10 can move adequately
  - = 7/10 < 9/10 will be restricted
  - = 9/10 will encounter major problems due to pack closure
- Convergence will threaten craft as before-capsize, crush, of puncture.

E.8.2 Recovery

- Recovery standards must provide for all main survivor configurations as specified above.
- Recovery platforms shall be of ice capability and low temperature performance specification.
- Appropriate recovery procedures for the class of environmental conditions shall be developed, promulgated, and drilled as deemed necessary.

E.8.2.1 Low Temperature

E.8.2.2 Ice Fog

- Visual signals and recovery procedures for ice fog conditions shall be developed and used.

E.8.2.3 Marine Ice

- In the recovery process due consideration shall be given to ice conditions and recovery procedured designed for the appropriate combination of evacuee configuration and rescue platform shall be used.
- In thin ice due attention to the interaction through the ice of the evacuee craft and rescue platform will be given.
- On thick ice, for marine transfers, specific methods to bridge over the ice edge will be used.
- In airborne recoveries on thick ice consideration needs to be given to ice stability under the added load from the aircraft.
- For pack ice, convergence caused by the recovery vessel manoeuvres or wake needs to be avoided.

Appendix F – Reliability Results for PBS

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F.1 General Description

As an appendix to the PBS, a set of distinct reliability results for evacuation and rescue processes has been requested. Specifically, in the evacuation results, the reliability of one single system of each mode for each of the four weather conditions has been requested. For the rescue component, the combined inter-modal reliability of the rescue platform-rescue mode inter-modal combinations is provided.

F.2 Escape

Since the escape process is highly situation and installation specific, no such general results are possible, and accordingly, the integrated EER – without the escape – would also not be meaningful.

F.3 Evacuation Mode Results from Each Global Scenario Level and Weather Condition

Discussions with the Task Force made it evident that it would be desirable to provide the net reliabilities for each system operating by itself under each of the four weather conditions. So far in the current investigation, the Sable Island conditions have been used as a base case, and they are so used in the results given herein as well. The purpose providing the net reliabilities under all weather conditions for each of the global scenario conditions, apart from regulatory interest, could possibly be for tactical application in considering the likelihood of successful evacuation (and later rescue) under each scenario and weather condition.

Table F.1 shows the results of the application of the RPT in the Reliability Version to each of the scenario-weather condition-evacuation mode combinations. It should be noted that the results of each of these combinations are independent of the proportion of weather conditions; they are, in a sense, absolute for each weather class. It is the weather weighted averages that take into account the proportions of the weather classes in each study. Thus, the two right hand columns give the weather weighted averages for the base (Sable) conditions and the hypothetical study area weather conditions. The matrix is set up as a spreadsheet so that the study weather proportions can be entered as an input. Here, an entirely hypothetical set of conditions has been entered under STUDY. As mentioned earlier, BASE conditions correspond to the Sable location.

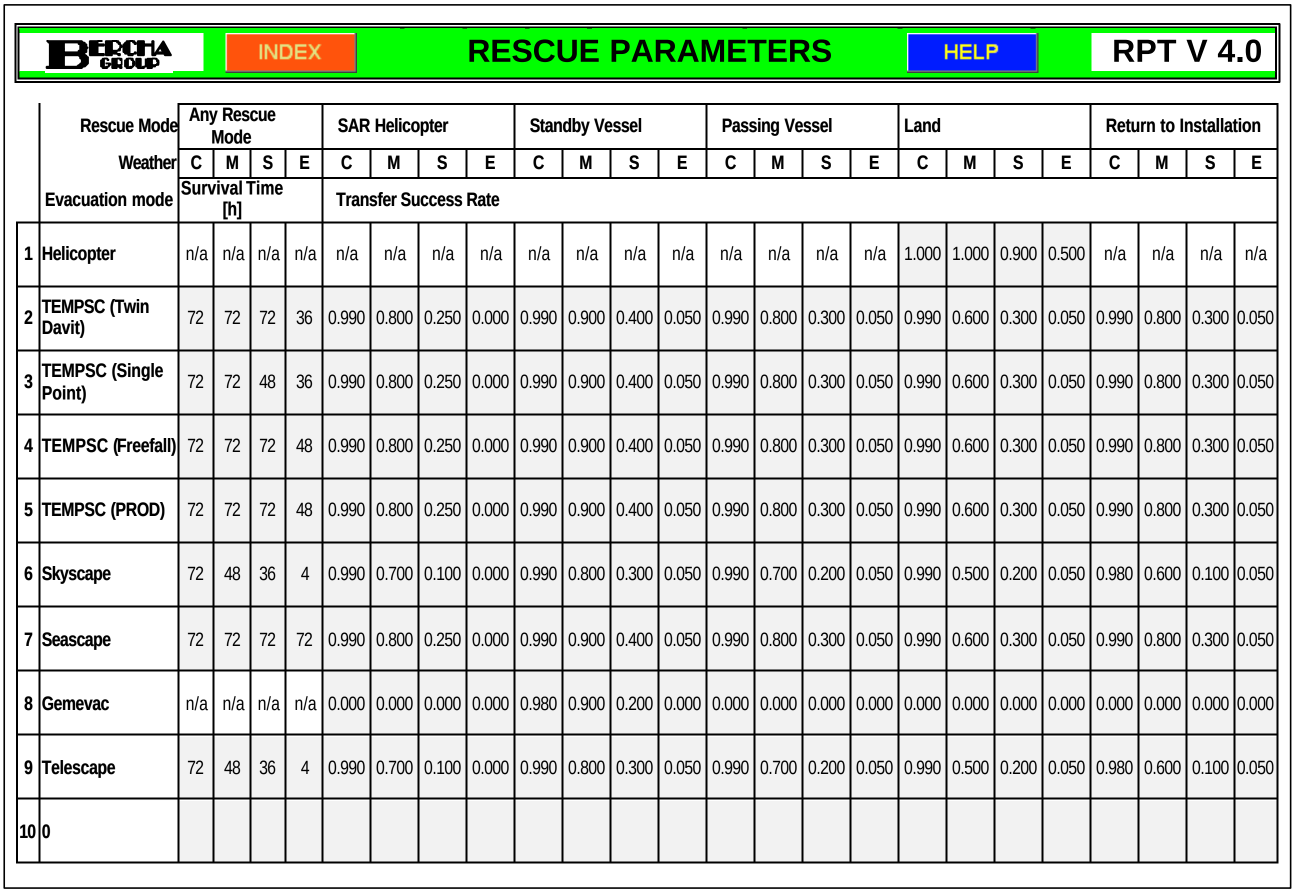
F.4 Inter-Modal Evacuation and Rescue Mode Reliability for Each Weather Condition

Rescue consists of two principal components; namely, the survival process and the transfer process. Both are dependent on the weather, however, the transfer process also varies with the inter-modal combination of evacuation mode and rescue mode. Table F.2 gives the parameters developed for the RPT, giving the survival times under each weather condition expected for each evacuation mode, as well as the full range of inter-modal combinations for each weather class for transfer success. It should be recalled that success means accomplishing a task with no casualties (fatalities or serious injuries), while failure means one or more casualties. Therefore, inter-modal reliabilities become relatively low for the more severe weather conditions.

Table F.1
Evacuation Reliability Matrix

N	EVACUATION MODE	SCENARIO	C	M	S	E	BASE Weather Weighted Average	STUDY Weather Weighted Average
			BASE					
			38%	48%	13%	1%		
			STUDY					
			50%	30%	18%	2%		
1	**Helicopter**	**Drill**	0.9999	0.9998	0.9940	0.0100	0.9892	0.9790
		Precautionary	0.9997	0.9986	0.9673	0.0100	0.9850	0.9737
		Life Threatening	0.9948	0.9775	0.5030	0.0100	0.9127	0.8814
2	**TEMPSC (Twin Davit)**	**Drill**	0.9996	0.9986	0.9762	0.2395	0.9885	0.9799
		Precautionary	0.9985	0.9952	0.9175	0.1000	0.9774	0.9649
		Life Threatening	0.9893	0.9629	0.4330	0.1000	0.8954	0.8634
3	**TEMPSC (Single Point)**	**Drill**	0.9996	0.9986	0.9762	0.2395	0.9885	0.9799
		Precautionary	0.9985	0.9952	0.9175	0.1000	0.9774	0.9649
		Life Threatening	0.9893	0.9629	0.4330	0.1000	0.8954	0.8634
4	**TEMPSC (Freefall)**	**Drill**	0.9996	0.9990	0.9914	0.7545	0.9958	0.9930
		Precautionary	0.9985	0.9961	0.9637	0.2000	0.9848	0.9755
		Life Threatening	0.9889	0.9635	0.6030	0.2000	0.9187	0.8961
5	**TEMPSC (PROD)**	**Drill**	0.9996	0.9986	0.9787	0.3595	0.9900	0.9827
		Precautionary	0.9985	0.9949	0.9265	0.1500	0.9790	0.9675
		Life Threatening	0.9898	0.9630	0.5030	0.1500	0.9052	0.8773
6	**Skyscape**	**Drill**	0.9991	0.9972	0.9659	0.3620	0.9875	0.9798
		Precautionary	0.9965	0.9871	0.8494	0.0200	0.9631	0.9477
		Life Threatening	0.9634	0.8410	0.0200	0.0200	0.7726	0.7380
7	**Seascape**	**Drill**	0.9996	0.9988	0.9842	0.5345	0.9926	0.9873
		Precautionary	0.9986	0.9957	0.9430	0.1500	0.9815	0.9707
		Life Threatening	0.9899	0.9656	0.5580	0.1500	0.9137	0.8881
8	**Gemevac**	**Drill**	0.9985	0.9906	0.7715	0.0100	0.9553	0.9355
		Precautionary	0.9949	0.9574	0.0100	0.0100	0.8390	0.7867
		Life Threatening	0.9629	0.4746	0.0100	0.0100	0.5951	0.6258
9	**Telescape**	**Drill**	0.9991	0.9972	0.9659	0.3620	0.9875	0.9798
		Precautionary	0.9965	0.9871	0.8494	0.0100	0.9630	0.9475
		Life Threatening	0.9634	0.8410	0.0100	0.0100	0.7712	0.7360
10		**Drill**						
		Precautionary						
		Life Threatening						

Table F.2
Rescue Parameters – Survival and Inter-Modal Transfer



	Rescue Mode	Any Rescue Mode				SAR Helicopter				Standby Vessel				Passing Vessel				Land				Return to Installation			
	Weather	**C**	**M**	**S**	**E**	**C**	**M**	**S**	**E**	**C**	**M**	**S**	**E**	**C**	**M**	**S**	**E**	**C**	**M**	**S**	**E**	**C**	**M**	**S**	**E**
	Evacuation mode	**Survival Time [h]**				**Transfer Success Rate**																			
1	**Helicopter**	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	1.000	1.000	0.900	0.500	n/a	n/a	n/a	n/a
2	**TEMPSC (Twin Davit)**	72	72	72	36	0.990	0.800	0.250	0.000	0.990	0.900	0.400	0.050	0.990	0.800	0.300	0.050	0.990	0.600	0.300	0.050	0.990	0.800	0.300	0.050
3	**TEMPSC (Single Point)**	72	72	48	36	0.990	0.800	0.250	0.000	0.990	0.900	0.400	0.050	0.990	0.800	0.300	0.050	0.990	0.600	0.300	0.050	0.990	0.800	0.300	0.050
4	**TEMPSC (Freefall)**	72	72	72	48	0.990	0.800	0.250	0.000	0.990	0.900	0.400	0.050	0.990	0.800	0.300	0.050	0.990	0.600	0.300	0.050	0.990	0.800	0.300	0.050
5	**TEMPSC (PROD)**	72	72	72	48	0.990	0.800	0.250	0.000	0.990	0.900	0.400	0.050	0.990	0.800	0.300	0.050	0.990	0.600	0.300	0.050	0.990	0.800	0.300	0.050
6	**Skyscape**	72	48	36	4	0.990	0.700	0.100	0.000	0.990	0.800	0.300	0.050	0.990	0.700	0.200	0.050	0.990	0.500	0.200	0.050	0.980	0.600	0.100	0.050
7	**Seascape**	72	72	72	72	0.990	0.800	0.250	0.000	0.990	0.900	0.400	0.050	0.990	0.800	0.300	0.050	0.990	0.600	0.300	0.050	0.990	0.800	0.300	0.050
8	**Gemevac**	n/a	n/a	n/a	n/a	0.000	0.000	0.000	0.000	0.980	0.900	0.200	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
9	**Telescape**	72	48	36	4	0.990	0.700	0.100	0.000	0.990	0.800	0.300	0.050	0.990	0.700	0.200	0.050	0.990	0.500	0.200	0.050	0.980	0.600	0.100	0.050
10	**0**																								

Appendix B

Stakeholder Comment Form

COMMENT FORM

FOR

PBS FINAL DRAFT

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

This is a MS Word file for stakeholders to enter detailed comments on the February 10, 2003 Final Draft of the *Canadian Offshore Petroleum Installations Escape, Evacuation, and Rescue (EER) Performance-Based Standards*.

Please email your completed form to
bgroup@berchagroup.com
by June 30, 2003.

Respondent Information

Please provide the following information.

Name: ______________________
Organization: ______________________
Address: ______________________
Phone: ______________________
Email: ______________________

Directions: Each section and subsection has a shaded comment box below it. Simply click the cursor on the box (below the word “Comments”), and begin typing. The box will automatically expand as text is added.

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B. Format, Layout, Organization

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C. Any Other Comments

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Thank you!