




# BARENTS 2020



ASSESSMENT OF INTERNATIONAL STANDARDS  
FOR SAFE EXPLORATION, PRODUCTION AND  
TRANSPORTATION OF OIL AND GAS  
IN THE BARENTS SEA

*Harmonisation of Health, Safety, and Environmental  
Protection Standards for The Barents Sea*

FINAL REPORT PHASE 4



# BARENTS 2020

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## CONCLUSIVE SUMMARY

The Barents 2020 project commenced after the Norwegian Ministry of Foreign Affairs requested and funded a DNV led effort to seek industry cooperation with Russia to harmonize and agree HSE standards to be used in the Barents Sea. It was understood that the Barents Sea represents new safety challenges for both Norway and Russia, and that Russian cold climate experience fruitfully could be merged with Norwegian offshore competence.

The premise of the project was that industry cooperation should look at technical standards, which can be used internationally. Regulations and laws are national, and outside the remit of this project.

Phase 1 – (October 2007- October 2008) – produced five “Position Papers” and established the Norwegian – Russian partnership model for this project; DNV as Norwegian/international project manager and Technical Committee 23 (VNIIGAZ/Gazprom) as Russian project manager. This project management structure has been kept throughout the project.

In Phase 2 (November 2008 – March 2009) the financial industry sponsors prioritized and selected from a range of topics, seven key areas for further work in seven specialist working groups. In this phase the project participants agreed to use the existing safety level in the North Sea as a benchmark for the Barents Sea. With a more difficult consequence scenario – e.g. search, rescue, and clean-up – the project concluded that an acceptable safety level primarily can be reached through reducing the probability of incidents and accidents. This confirmed the project focus on improving standards.

The seven working groups in Phase 3 (May 2009-March 2010) worked on Barents Sea

<b>01</b>	Common offshore standards
<b>02</b>	Ice loads
<b>03</b>	Risk management
<b>04</b>	Escape, evacuation and rescue
<b>05</b>	Working environment
<b>06</b>	Loading/unloading and ship transportation
<b>07</b>	Operational emissions and discharges to air and water

The common report was issued in March 2010 and included a list of 130 – mostly functional – standards recommended for common use. Many of the standards could be used in the Barents Sea without revisions, while many others would need revisions or further written guidance.

This report – for Phase 4 (May 2010-March 2012) – is the final result from the Barents 2020 project. The industry sponsors – in phase 4 they were Gazprom, Statoil, ENI, Total, OGP and DNV – agreed to bring forward from phase 3 those issues and topics in greatest need of completion, revision and detailed guidance. In phase 4 the project formally became international, while there had been strong international participation of specialists already from phase 3. Such included French, American, and Dutch specialists – just to mention some. All in all approximately 100 specialists from 40 organizations and companies participated in phase 4.

The Steering Committee has consisted of the industry sponsors joined by Rosstandard of Russia, and Standard Norge of Norway, the two countries’ ISO-representatives.


The seven working groups from phase 3 were kept intact, and continued the work with renewed tasks and mandates in phase 4.

Five of the seven groups (2, 4, 5, 6, and 7) were tasked with detailing, and formulating recommendations to fill the main deficiencies within their focus areas. These recommendations are submitted to the relevant standardization body – primarily – ISO TC 67’s 19906 standard, and to the new TC67 Subcommittee 08, “Arctic Operations”. Independent of this, companies are free to use the deliverables as project specific standards, and national standardization bodies will also implement recommendations as they see fit.

Group number 1 was tasked with recommending and guiding the process to format and channel the deliverables and results to the correct standardization addresses.

Group number 3 – Risk management – did not recommend any new standards, and was tasked with running seminars with regulatory bodies and companies to exemplify through cases how risk management is applied in cold climate field developments.

The Steering Committee and Plenum Conference reviewed, commented and approved the results in Moscow 14-15<sup>th</sup> December 2011. This report documents the results and recommendations from all



the working groups. It reads as a sequel to the phase 3 report (March 2010). For full value of the results both reports should thus be read.

This is the final and conclusive deliverable from the Barents 2020 industry cooperation project. DNV and VNIIGAZ – as project managers – thus also conclude their work here.



# INTRODUCTION

## 1. DESCRIPTION OF THE PROJECT

The Barents 2020 project was initially aimed at creating a dialog between relevant Norwegian and Russian parties regarding safety of petroleum related activities in the Barents Sea. The aim was to arrive at common acceptable standards for safeguarding people, environment and asset values in the oil and gas industry in the Barents Sea, including transportation of oil and gas at sea.

Phase 3 identified 130 standards for common use of which 64 can be applied “as is” and the remaining 66 can be applied provided special considerations are made for low temperatures and/or ice loading. The result of the work after completion of phase 3 is contained in the report “Barents 2020 – Assessment of International Standards for Safe Exploration, Production and Transportation of Oil and Gas in the Barents Sea” issued in March 2010.

The phase 4 of this project was funded by Russian and international companies with support from the Norwegian Government’s Barents 2020 program.

The industry sponsors agreed to bring forward from phase 3 those issues and topics in greatest need of completion, revision and detailed guidance. The seven working groups from phase 3 were kept intact, and continued the work with renewed tasks and mandates in phase 4. Five of the seven groups (RN02, RN04, RN05, RN06, and RN07) were tasked with detailing, and formulating recommendations to update existing key industry standards to take into account the additional challenges related to arctic conditions.

The objectives of this Barents 2020 phase 4 project can be summarized as follows: Phase 4 will be carried out during 2010 and 2011, with the aim to provide concrete guidance for the industry within selected priority topics, as shown in the table below.

No	Task / project
<b>RN01</b>	Co-ordination of deliverables
<b>RN02</b>	Prepare guidance document to ISO 19906 for design of offshore installations against ice loads
<b>RN03</b>	Conduct workshops on the use of risk assessment, based on ISO and IEC, for Barents Sea installations
<b>RN04</b>	Prepare a guidance document to ISO 19906 on Escape, Evacuation and Rescue for the Barents Sea
<b>RN05</b>	Prepare guidance to ISO 19906 for safe working environment for offshore activities in the Barents sea
<b>RN06</b>	Prepare guidance for Ice Management based on ISO 19906, for Barents Sea operations
<b>RN07</b>	Develop a regional standard for the Barents Sea to reflect MARPOL Special Area (SA) requirements for discharges and emissions from oil and gas related ship traffic and offshore units
<b>RN00</b>	DNV Project Management and project support

The recommendations provided by RN02, RN04, RN05, RN06, and RN07 are submitted to the relevant standardization body – primarily – ISO TC 67’s 19906 standard, and to the new TC67 Subcommittee 08, “Arctic Operations”.

Independent of this, companies are free to use the deliverables as project specific standards, and national standardization bodies will also implement recommendations as they see fit.

In phase 4 the project formally became international and included French, American, and Dutch specialists – just to mention some. All in all approximately 100 specialists from 40 organizations and companies participated in phase 4.

The two reports together report represents the complete work done by the Barents 2020 project.

## 2. COOPERATION PARTNERS

The last Steering Committee Meeting of phase 3 held on March 3, 2010 in Moscow discussed and initiated phase 4 of the project. The meeting agreed that in addition to phase 3 sponsors additional sponsors should be invited to phase 4 to involve appropriate competence and to raise sufficient funding.

### International Cooperation Partners

In March 2010, several international companies were invited to participate as sponsors in phase 4, and finally the following eight partners were confirmed financial sponsors:

- Gazprom
- Statoil
- ENI Norge
- Total
- Shtokman Development AG
- Oil and Gas Producers Association (OGP)
- The Norwegian Ministry of Foreign Affairs
- DNV

### Russian Cooperation Partners

As for phase 3 the main project partner OAO Gazprom maintained the cooperation with Russian stakeholders throughout the project.

## 3. STEERING COMMITTEE

In accordance with the agreements between the sponsors and DNV as project manager, it is required that the work shall be controlled by a Russian – International Steering Committee.

A steering committee was therefore established which by December 2010 with representatives from: Gazprom, Rosneft, Rostekhnadzor, Rosstandard, Statoil, ENI Norge, Total, SDAG, OGP, Standard Norge and DNV

The meetings in the steering committee were chaired by Mrs Elisabeth Harstad, responsible for the Barents 2020 project in DNV.

The DNV project manager attends as secretary and prepares minutes of meeting.

The Steering Committee has met 09<sup>th</sup> June 2010, 08<sup>th</sup> December 2010, 20<sup>th</sup> May 2011 and 14<sup>th</sup> December 2011. In the first meeting (June 2010) the steering committee constituted itself as the governing body for the Barents 2020 phase 4 project.

## 4. PROJECT MANAGEMENT

DNV and TK23 represented by Gazprom/VNIIGAZ act as project managers (same as for phase 3) on the International respectively Russian side, closely cooperating through the project.

The project manager and the expert group coordinators have been responsible for preparing this report.

The DNV offices in Moscow and St Petersburg have also, together with the Russian side, been involved in arranging expert workshops and conferences.

## 5. EXPERT WORKING GROUPS

### Coordinators for the Work Groups

The project steering committee meeting on June 9<sup>th</sup>, 2010 approved the nomination of expert working group coordinators from the Norwegian and Russian side (most coordinators remained the same as for phase 3).

The coordinators plan, facilitate and lead the Russian-Norwegian expert working groups through the workshops to the final presentation of results. The coordinator is also responsible for compiling the group's recommendations in a written report.

The coordinators were as follows:

No	Group Topic	DNV Group Coordinator	VNIIGAZ Group Coordinator
1	Co-ordination of deliverables	Tore Sildnes	Denis Tikhomirov
2	Design of floating structures in ice	Per Olav Moslet (from Jan 2011)/ Lars Ingolf Eide	Sergey Kim
3	Risk Management of major hazards	Borre Johan Paaske	Valery Lesnykh
4	Escape, evacuation and rescue of people	Leif Nesheim (from June 2011)/ Gus Cammaert/	Sergey Kovalev
5	Working environment	Steven Sawhill	Alexander Terekhov
6	Ice management – state of the art	Morten Mejlænder-Larsen	Dimitry Onishchenko
7	Operational discharges to air and water	Steinar Nesse	Eduard Bukhgalter

### Nomination of Norwegian and Russian Experts to Work Groups

The sponsors were invited to nominate experts to the various expert groups. The project steering committee authorised DNV and Gazprom TC23 to decide the final participation in the expert groups.

The companies and institutions in the groups represent leading organisations within the maritime and offshore petroleum industries, and bring the required competence to the groups to assess the selected safety critical topics. Names of the expert group members are included in the expert group reports.

## 6. WORKSHOPS AND CONFERENCES

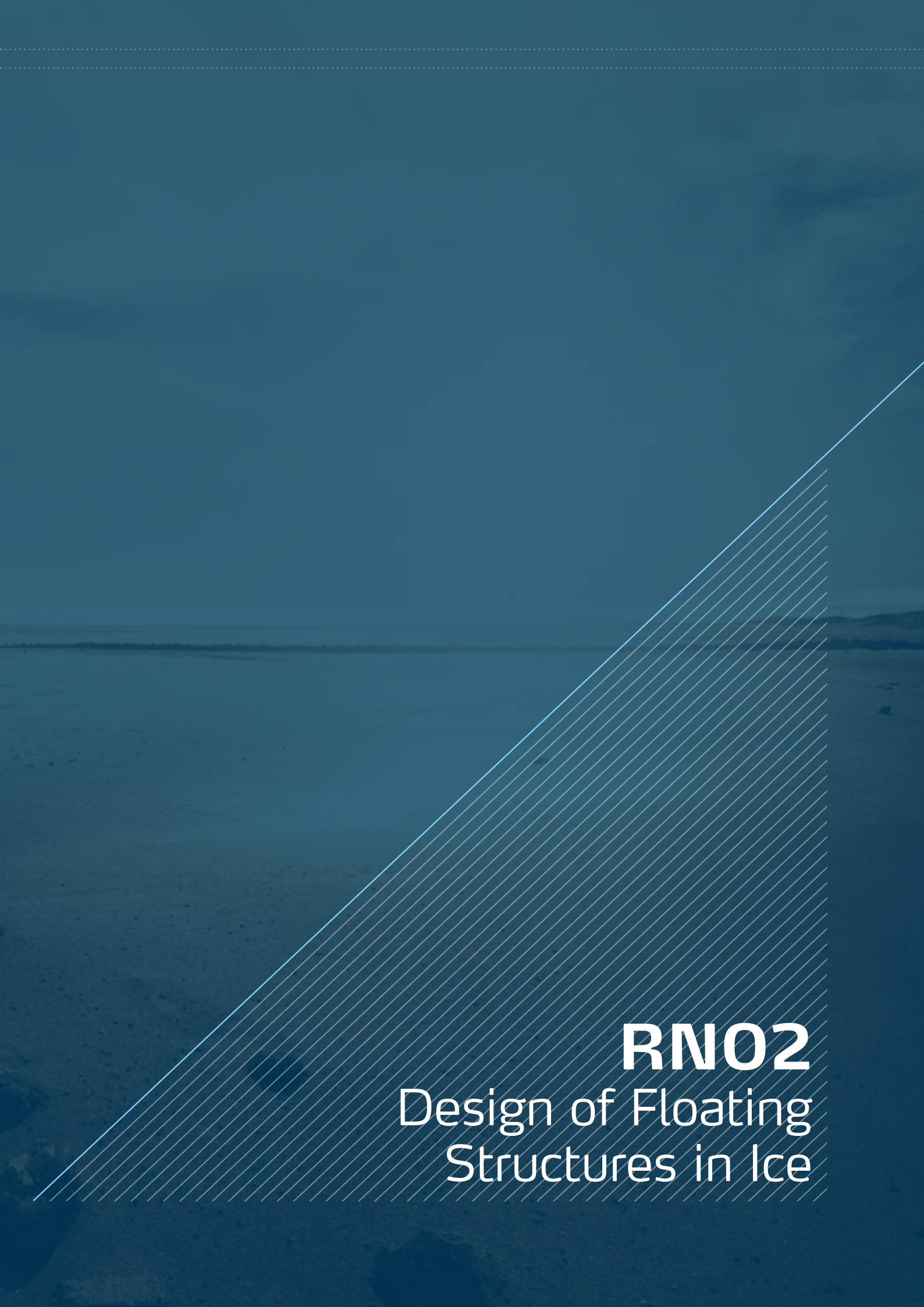
The core project activities have taken place in phone and video conferences in addition to the expert group workshops which took place in October 2010, February, March, April and September 2011, in total 7 workshops.

### 4 conferences:

Time	Topic	Venue
24–25 August 2010	Review and clarify topics for the 7 working groups.	VNIIGAZ, Moscow
December 2010	Review progress and coordinate between expert groups	VNIIGAZ, Moscow
May 2011	Review progress and coordinate between expert groups	DNV, Oslo
December 2011	Final conference	VNIIGAZ, Moscow







**RN02**  
Design of Floating  
Structures in Ice



# RN02: DESIGN OF FLOATING STRUCTURES IN ICE

## EXECUTIVE SUMMARY

This report is the result of Working Group 2 (RN02) of the Phase 4 of Russian- Norwegian Project Barents 2020, the objective of which is to recommend common standards and guidelines for safe offshore design and operations in the Barents Sea. RN02 dealt with “Design of stationary floating units against ice loads in the Barents Sea”.

In Phase 3 of the Barents 2020 Project RN02 recommended that the new standard ISO 19906:2010(E) Petroleum and Natural gas industries — Arctic offshore structures – should be adopted as the common standard but that the standard had some shortcomings regarding floating structures and that some additions and amendments would be necessary.

Working Group RN02 based its work on the definition of stationary structures suggested in Phase 3 of the Barents 2020 Project:

- Fixed structures, e.g. gravity based and jacket installations; and
- Floating structures kept in position by moorings and/or dynamic positioning e.g. ship-shaped and axi-symmetrical structures.

RN02 started Phase 4 with a thorough gap analysis of the “ready for Final Draft International Standard (FDIS)” version of the standard. As it turned out, the final version, ISO 19906:2010(E), had only insignificant changes from the “ready-for-FDIS” version. Therefore the gap analysis is valid also for ISO 19906:2010(E). The identified gaps were addressed by the members of RN02 in suggested additions and amendments to ISO 19906:2010(E). The suggested amendments were discussed in several meetings, e-mail exchanges and in a workshop with invited experts and developers of the standard.

Suggested major amendments to ISO 19906:2010(E) include:

- Add definition for stationary floating structure
- Clarification of the term ice event as the current use of the term is ambiguous.
- Add and amend requirements and guidance regarding inclusion of ice management in design, requiring that physical ice management can only change the design ice actions if it can be documented that the physical ice management system can break/divert the ice features responsible for the design ice actions.
- Amend several clauses in the standard to make it more relevant for floating structures with the ability to disconnect as the action level for the disconnection criteria should influence the design ice action.

Additionally it is cautioned that the environmental action factors for stationary floating structures in ice could deviate from the 1.35 specified in ISO 19906, therefore a recommendation is added that a site and project specific calibration of the partial actions factor for ice should be performed.

This report consists of four parts:

1. Introduction
2. The Gap Analysis
3. Background for the suggested changes and some additional information
4. A Guidance Document with the suggested additions and amendments.



## Recommendations

The recommendations from the Barents 2020 Working Group are:

1. That Part 4 – Guidance Document: Additions and Amendments to ISO 19906:2010(E) – of this report is submitted to the national standardisation organizations in Russia and Norway for approval as a regional supplement to ISO 19906:2010(E) until a new edition of the international standard is issued.
2. That additions and amendments suggested in Part 4 of this report – the Guidance Document – are also submitted to the ISO 19906 editing panel for consideration by WG8 and its relevant ISO technical panels when they reconvene to start work on a new edition of ISO 19906.
3. That immediate action is taken to have the definition of stationary floating structures suggested by RN02 adopted in all Russian regulations and standards.
  - That immediate action is taken to make the relevant ISO 19900 series, including ISO 19906 with the Barents 2020 supplement, valid for all offshore design in Russia and Norway.
4. That all standards in the ISO 19900 series (except ISO 19905-1 and 19905-2) are translated into Russian.

### Note on the adoption of ISO 19906 in Russia and the interface with existing Russian codes.

A final draft of GOST R ISO 19906, which is prepared as a Russian standard identical to the international standard ISO 19906 Arctic Offshore Structures, was adopted by Russian Technical Committee on standardization TK23 “Techniques and technologies for oil and gas extraction and processing” on 13 September 2011. At the end of September 2011 all the documentation on GOST R was officially sent to the Federal Agency on Technical Regulating and Metrology (Rosstandart) that is responsible for official approval and publishing of Russian standards. There could be some additional expertise and editing of the final draft, which can demand extra time, so the date of GOST R ISO 19906 coming into force is not fixed yet.

Currently, only GOST R ISO 19900 – General requirements for offshore structures – which is translated from ISO 19900:2002, is approved

for official publication. None of the other ISO standards of the 19900 series dealing with offshore structures, except ISO 19906, is translated officially into Russian yet. For this reason, the application of GOST R ISO 19906 to projects performed on the Russian shelf could be restricted in those aspects where GOST R ISO 19906 makes reference to other standards of the series. All such references have been kept in GOST R ISO 19906 due to its status as being identical to the original ISO 19906:2010.

At present, there are no Russian codes applicable to offshore structures in full. In addition, Russian codes of general purpose, e.g. codes for designing steel structures (not marine ships), concrete structures, foundations, use limit state equations in a form that essentially differs from that in ISO 19900 series, mainly due to different systems of safety factors and load combination factors used and due to some extra factors in Russian version. It seems that in case of design based on Russian codes, GOST R ISO 19906 can be used for determining representative values of ice action, not for design ones.

Furthermore, there is a need to clarify the terminology from ISO 19900 General requirements for offshore structures, 19904-1 Floating offshore structures and 19906 Arctic offshore structures regarding definitions, applicability and differences between artificial islands, installations and structures on the continental shelf.

ISO 19906 says:

*The series of International Standards applicable to the various types of offshore structure is intended to provide wide latitude in the choice of structural configurations, materials and techniques without hindering innovation.*

Therefore, it is important to define “Stationary Floating Structure”. In Russian, stationary = stands on the ground. Thus the terminology and its translations into Russian may create confusion. Therefore, it may be confusing which authority will regulate what ISO 19906 defines as “stationary floating structures”. RN02 recommends that ISO 19900 series should apply to the design of all stationary floating structures for oil and gas production in the Barents Sea and that ISO 19906 is adopted for use with the Barents 2020 supplement. It should be noted that ISO 19906:2010(E) states that the designer may utilize the appropriate formulations in guidelines for ice-strengthened vessels of a Recognized Classification Society (RCS). IMO guidelines and national requirements shall be incorporated in the design. In addition, the requirements of subclause 13.5 shall be met.



## 1. INTRODUCTION

This report is the deliverable of Barents 2020 Working Group RN02 “Design of stationary floating units against ice loads in the Barents Sea”. It consists of four parts:

1. Introduction with a brief history of the Barents 2020 Project and earlier results of Working Group RN02
2. A gap analysis performed by SDAG and Statoil that has identified where amendments to ISO 19906:2010 would be useful
3. Background information that explains why the amendments are suggested and, in some cases, additional information that may be found useful
4. A Guidance Document with recommended additions and amendments to ISO 19906:2010.

### 1.1. Brief history

#### Phases 1 and 2

Phase 1 of the project produced five Norwegian “position papers”, of which the one on Ice and Metocean conditions in the Barents Sea (Barents 2020, 2008) is relevant for the work performed by Working group RN02 in Phase 4. Phase 2 was a presentation of the “position papers” to the Russian partners in December 2008, with which Phases 1 and 2 ended.

The report on ice and metocean recommended that the basis for possible changes/additions should be ISO 19901-1 and ISO 19906. At that time, however, only an early draft of ISO 19906 was available. The following topics were recommended in the Norwegian “position paper” for a Russian-Norwegian working group in Phase 3 to achieve improvements and/or additions to these standards and codes:

- Evaluation of the need for and suggest additions regarding handling of uncertainties due to few data, e.g. revised load/safety factors
- Guidance/requirements on load combinations, in particular for ice in combination with metocean (e.g. waves and bergy bits)
- Narrow down ice load estimates from different approaches
- More ice load cases in one standard, e.g. critical load cases
- Update Regional Description for Barents Sea in the annexes to ISO 19901-1 and 19906

- Evaluation of the need for and suggest additions regarding data collection
- Evaluation of which parts of NORSOK N-003 can supplement ISO 19901-01, if any
- Improving descriptions/guidance on icing, topside as well as hull, from sea spray and atmospheric conditions
- Guidance on pipelines and sub-sea structures where ice scour may be expected
- Additions regarding ice management in pack ice and from icebergs in pack ice
- Consider the need for more specific guidance on probabilistic methods when going into a region where such methods have not been used

#### Phase 3

In Phase 3 it was decided to narrow the topics in the recommendations from Phase 1 and 2, and a working group, RN02, with the working title “Design of stationary offshore units against ice loads in the Barents Sea” was established. This working group consisted of Russian and Norwegian experts. The scope for Working Group RN02 was limited to loads coming from sea ice or glacial ice on stationary units and consisted of the following tasks:

- Evaluate existing maritime and offshore oil and gas standards relevant for design of stationary units in the Barents Sea against ice loads;
- Recommend standards for common use;
- Propose recommended amendments and/or changes to the identified standards.
- Stationary units/installations include:
  - Fixed structures, e.g. gravity based and jacket installations
  - Floating units kept in position by moorings or dynamic positioning, e.g. drilling and production vessels, spar and buoy shaped platforms.

Sub-sea installations such as pipelines are excluded from this review.

In Phase 3 the Working Group RN02 performed a joint Russian – Norwegian high level gap analysis of the most used Russian and Western standards and rules for ice loads against stationary structures.

The recommendations from the group to the Barents 2020 Steering Committee included:

- ISO 19906 shall be used as basis for design and operations of stationary units in the Barents Sea. Note: Phase 3 was based on the ISO/DIS (Draft International Standard) dated 15-Jan-2009.
- Internationally approved (direct translations) ISO 19906 are to be implemented as national standards
- The Working Group identified ten topics, of which four were prioritized, that should be amended in ISO/DIS 19906 (Draft International Standard). A Guidance Document has been identified as the best way to address these topics. The Guidance Document should
  - Be prepared in close cooperation with ISO WG8,
  - Pay due considerations to ongoing Joint Industry Projects (JIPs) and research projects.
  - Be ready in draft form by end 2010.
- The guidance document should
  - Meet the immediate and future needs for the Barents Sea
  - Be a common Russian-Norwegian supplement to ISO 19906 until an update is available
  - Be submitted to ISO as a proposed international supplement to ISO 19906 at the first update
- Of the ten topics, stationary floating structures in ice should be given first priority. Several of the other identified topics can be put under the umbrella of stationary floating structures.

Furthermore, the Working Group identified a need to harmonise the understanding and interpretation of ISO 19906 amongst Russian and Norwegian participants.

## 1.2. Scope of Work and Work Process Phase 4

### Objective

The objective for RN02 in Phase 4 was defined to be:

- Develop a Guidance Document that may serve as a common Russian-Norwegian Supplement to ISO19906 for use in the Barents Sea that fills identified gaps in ISO 19906 with respect to ice loads against and the response of stationary *floating* structures. The Guidance will be based on state-of-the-art.

Based on the definition of stationary structures from Phase 3, the term “stationary floating structure” is defined as:

- Floating unit kept in position by moorings and/or dynamic positioning, e.g. ship-shaped vessels, spar and buoy shaped platforms.

### 1.3. Expert Working Group

The Russian experts were nominated by the Russian sponsors Gazprom, Rosneft and Shtokman Development Company AG (Sdag). The Western experts were nominated by the Western sponsors, who were Statoil, ENI, Total, and OGP in addition to the Norwegian Foreign Ministry and DNV. The project steering committee approved the nominations. The companies and institutions in the groups represent leading organisations within the maritime and offshore petroleum industries in Norway and Russia, and bring the required competence to the groups to assess the selected safety critical topics.

The participating experts were:

#### Expert Group RN02

Name	Organisation	
Marat Mansurov	Gazprom - VNIIGAZ	Russian Coordinator
Irina Surikova	RMRS	
Marina Karulina	Krylov	
Nina A. Krupina	Arctic and Antarctic Research Institute	
Pavel Liferov	SDAG	
Sergey Kim	VNIIGAZ	
Yury A. Nemenko	Giprospetsgaz	
Sergey I. Chibakin	Gazprom Shelf Production	
Vakhtang M. Glonti	Gazprom Shelf Production	
Gleb Churkin	Agency of researches of industrial risks	
Vladimir A. Pestryaev	Sakhalinnipimorneft	
Alexander A. Nikitenko	Sakhalinnipimorneft	
Arne Gurtner	Statoil	
Hans M Sand	Moss Maritime	
Rod Allan	Transocean	
Jean-Marc Cholley	Total	
Graham Thomas	BP/OGP	
Mike Orr	Cairn/OGP	
Guido Kuiper	Shell/OGP	
Lars Ingolf Eide	DNV	Norw. Coordinator (until December 2010)
Per Olav Moslet	DNV	Norw. Coordinator (from January 2011)
Dmitry Onishchenko	VNIIGAZ	Invited guest
Richard McKenna	R.F McKenna Associates	Invited guest to workshop
Mitch Winkler	Shell/OGP	Invited guest
Sjoerd Wille	Shell/OGP	Invited guest

#### 1.4. Work process

During Phase 3 the Working Group had neither the time nor the resources to perform a detailed gap analysis of the individual clauses in ISO/DIS 19906. For Phase 4 the Group was joined by other experts, including a representative from SDag, who were gaining extensive experience applying ISO 19906 to a specific development project (Shtokman), and OGP representatives, who had been involved with the development of ISO 19906.

At the first group meeting in Phase 4 (24-25 August 2010), Statoil and SDag volunteered to produce the detailed gap analysis that was lacking. OGP provided the final draft of ISO 19906 that had been sent to ISO in August 2010 for issue as ISO/FDIS 19906 for final vote. Each clause in both the normative and informative parts of this “ready-for-FDIS” version of ISO 19906 was scrutinized for shortcomings, with the objective of working group RN02 in mind. With respect to floating structures,

and despite improvements from the ISO/DIS version, 75 clauses were identified to have shortcomings or potential for improvements of which some were very similar and could be considered together, resulting in 58 topics to be further investigated.

The gap analysis was distributed to the group in early November 2010 and at the second meeting (7-8 December 2010) group members signed up to contribute to selected topics and clauses by providing the following for each contribution:

1. Background information on why the Clause should be amended and, if relevant, reference to research or publications that substantiate the recommended additions or changes
2. Recommended text for the amendment

The first official version of ISO 19906:2010(E) was published on 14 December 2010, with no significant

changes from the “ready-for-FDIS” version used for the gap analysis. Therefore the gap analysis is valid for ISO 19906:2010.

The received texts for the Guidance Document were put together, with the necessary editing, by DNV, and a series of drafts and iterations were discussed at meetings in March, May and September 2011, and by e-mail exchanges. In addition, a workshop with external participants was arranged in connection with the September 2011 meeting, the topic of which was limit states methodology for the design of stationary structures in ice as explained in ISO 19906.

## 1.5. Deliverables

The deliverables from Working Group RN02 are:

1. A Gap Analysis – between ISO 19906:2010 and the most current learnings and knowledge in 2010
2. Background information as clause-by-clause comments to ISO 19906:2010, explaining the background for the suggested changes to ISO 19906, which will accompany the Guidance Document when it is forwarded to ISO TC67/SC7 WG8 for their consideration in future updates of ISO 19906.
3. An agreed Guidance Document that can be used to supplement ISO 19906:2010, which will be
  - a. Forwarded to Rosstandart and Standard Norway with the possibility to approve and adopt it as a National Annex in Russia and Norway until the standard itself is updated by ISO.
  - b. Forwarded to ISO TC67/SC7 WG8 for information and for their consideration in connection with the first update of ISO19906.

The gap analysis is found in Part 2 in this report; the Background information is found in part 3; and the Guidance Document makes up Part 4. The working group RN02 was not able to suggest amendments to all clauses identified in the gap analysis, either because the issue was minor or because industry knowledge remains insufficient.

## 2. GAP ANALYSIS BASED ON ISO/FDIS 19906

*This part was prepared by SDag and Statoil in cooperation*

### Memo

This memo presents the response to action from kick-off meeting Aug 24 - 25, 2010 at VNIIGAZ, Moscow, Russia: 'Identification of gaps according to floater design in ISO 19906'. In addition to general gap identification and analysis, Shtokman-specific comments and recommendations are also included.

The ISO/FDIS 19906:2010(E) 'Petroleum and natural gas industries – Arctic offshore structures' (hereafter only ISO19906) is part of the international standard in the ISO19-series. ISO 19906 'addresses design requirements and assessments for all offshore structures used in the petroleum and natural gas industry [...]'. The ISO 19906 builds upon the established practice of Arctic structures' design, supported by previous operational experience. It provides the general design philosophy (clause 7) and the guidelines for determination of ice actions and action effects (clause 8), common to all types of structures. Further requirements relating to ice actions and action effects for floating structures are provided in clause 13 of the ISO 19906. This section provides general design philosophy and considerations, based on the limited experience with design and operation of stationary floating structures in ice conditions.

In order to further detail recommendations for design of stationary floating installations in the Barents Sea according to provisions in ISO 19906 and include lessons learned from the recent design experiences, e.g. Shtokman, a gap identification and analysis is performed in sequel of which the objective is to:

- i) Identify the normative and informative provisions potentially relating to floaters' design;
- ii) Generally comment on the applicability of the former and particularly analyse the applicability of the former in view of the Shtokman project design experience;
- iii) Identify gaps based on i) and ii) above and recommend actions based on available knowledge and design experience.

It should be noted that *only* provisions specific to floater design to external environmental loading caused by ice are covered herein, whereas the general standard requirements are covered elsewhere (ISO 19904-1, Petroleum and natural gas industries - Floating offshore structures - Part 1: Monohulls, semi-submersibles and spars). Hence, emphasis herein lies on ice actions related to floater design and not necessarily on mechanical systems etc. It should further be noted that identification of ISO 19906 provisions relate to *stationary floating installations only*.

Table 1 and Table 2 summarize the ISO 19906 coverage and applicability with respect to stationary offshore structures concerning normative and informative provisions, respectively. The objective was to identify the main gaps associated with the application of ISO 19906 with respect to stationary floaters given available design experience. Based on this assessment, action items are recommended to further detail and enhance ISO 19906. Please note that it is unlikely that the Barents 2020 project will be able to address all recommended actions in Table 1 & 2 in detail. Hence, based on action items defined in Tables 1 & 2, a slightly more condensed list of actions to be particularly covered and discussed by the Barents 2020 group RN02 has been prepared as summarized in the companion document "*Action list\_Gaps Analysis Floaters ISO19906.doc (Table3)*", hereafter called "*Action List*".

"*Action List*" is a non-exhaustive list and its main objective is to provide input to further work for the Barents 2020 group RN02, which has to be agreed upon and discussed in the upcoming meetings. Each recommended action item will be evaluated in the light of available knowledge in order to rate the potential of addressing the particular action within Barents 2020. "*Action List*" will not be handled separately from Tables 1 & 2.

Table 1. ISO 19906 Normative coverage on floater design (Note that direct quotations from ISO are shown in *italic font*).

Applicable ISO 19906 provisions	Analysis and applicability for floaters	Recommendations
<p><b>1 Scope</b> This International Standard does not contain requirements for the operation, maintenance, service-life inspection or repair of arctic and cold regions offshore structures, except where the design strategy imposes specific requirements (e.g. 17.2.2).</p>	<p>This should be further clarified for floaters (with IM and disconnection). There could be conflicting views on this leading to insufficient evaluation of the operational measures (in particular IM) during design (with a number of consequences).</p>	<p>Define requirements to documentation of efficiency and reliability of operational measures to ensure target level of reliability for the floater.</p>
<p><b>2 Normative references</b> The following referenced documents are indispensable for the application of this document</p>	<p>Indispensability should be clarified with respect to application of the ISO 19906 recommendations to define e.g. representative ice actions for further use outside ISO 199XX framework, and visa versa (loads calculated not as per ISO19906 to be used within the ISO199XX framework). Section 5.2 touches this subject, but too generally (in particular if translated to other languages).</p>	<p>Clarify indispensability and identify possible use of ISO 19906 recommendations outside ISO design framework.</p>
<p><b>3 Terms and definitions</b> 3.9 broken ice <i>loose ice consisting of small floes, broken up as a result of natural processes, active or passive intervention</i> 3.10 characteristic value <i>Value assigned to a basic variable associated with a prescribed probability of being exceeded by unfavourable values during some reference period</i> <i>Representative value, reliability target, etc</i></p>	<p>This is incomplete definition, potentially misleading. Often used "managed ice" shall also be addressed. Objective shall be to cover ice conditions from 10/10th pack ice to brash ice. Partial ice concentration shall be introduced in this respect.  From ISO-19901-7: 3.4 characteristic value: <i>'Value assigned to a basic variable, an action or a resistance from which the design value can be found by the application of a partial factor'</i>.</p>	<p>Introduction and definition of i) partial concentration; ii) managed ice.  Harmonization of such basic terms between the ISO 199XX standards shall be performed. Also need to provide guidance for further use in LRFD and WSD methods. ISO 19906 has single focus on LRFD while e.g. 19901-7 (mooring) allows both to be used.</p>
<p><b>5.3.2 Long-term climate change</b> <i>Changes in [...] ice conditions, [...] can occur during the design service life of the structure. Consideration for such changes should be included in the design.</i></p>	<p>This is a dangerous statement given very limited consensus on this subject. It may open for "extreme right" opinions to pollute the concept selection and the design process. Effect on the structure may be impossible to quantify during design.</p>	<p>Effect of long-term climate change (variability) shall be further elaborated specifically for the Barents Sea.</p>
<p><b>5.3.3 Structural configuration</b> <i>The configuration of the structure should consider the following: [...]</i> <i>- protection of risers and conductors</i></p>	<p>The design should consider riser protection from ice. For floaters in the Barents Sea, suggest further elaborating with focus on "ice hazard minimization" and a list of mitigation measure particularly pertaining to subsurface ice impact.</p>	<p>Identify issues, define minimum design requirements and propose methods to be used for assessing the ice actions. Also propose possible mitigation measures.</p>
<p><b>5.5 Design considerations</b> <i>The combinations of actions and partial factors for determining action effects applicable to the different limit states shall be in accordance with the provisions of Clause 7.</i></p>	<p>This section shall be further elaborated to address issues already mentioned, such as: - overall moored floater design philosophy in ice conditions - overall harmonization of the structural reliability and operability to avoid weak links in design of a floater system with focus on interfaces (e.g. risers) - etc</p>	<p>Following shall be addressed: - overall moored floater design philosophy in ice; - harmonization of the structural reliability and operability</p>
<p><b>6.1.1</b> [...] <i>To obtain reliable and appropriate physical environmental parameters, experts in the field of metocean and ice technology shall be involved with the analysis of data and its interpretation for developing appropriate design situations and design criteria.</i></p>	<p>Also true for ice experts.</p>	<p>Make a clear note that expertise on ice loads and response is required to develop reliable and appropriate ice data, to satisfy 6.1.3.</p>



<p><b>6.5 Sea ice and icebergs</b></p> <p><b>6.5.4 Ice movement</b></p> <p><b>7.1.5 Limit states</b> abnormal limit states (ALS)</p>	<p>Estimating statistical distributions for sea ice and icebergs based on fairly limited databases should be addressed.</p> <p>For floaters, in particular ship-shaped, local ice movements (variable ice drift) is of great interest</p> <p>Difference to other standards ISO 19-series defining ALS as accidental limit states not clear. Why not using same terminology?</p>	<p>Provide recommendations with regard to the data extrapolation of sea ice and icebergs (from fairly limited statistics) in the Barents Sea.</p> <p>More specific guidance shall be provided as to how and what to do with regard to characterising the ice drift on the site.</p> <p>Including a note addressing particulars of abnormal limit state opposed to accidental limit state.</p>
<p><b>Table 7-4 ULS and ALS action factors and action combinations</b> As an alternative to Table 7-4, the partial action factors may be derived from a calibration analysis using a full probabilistic description of actions if this analysis demonstrates that the reliability targets of A.7.2.4 are achieved</p>	<p>- EL load factor of 1.35 has been "calibrated" based on the load distribution that approximates floater by a fixed downward breaking slope. Dynamic interaction and ice vaning with associated coupling between actions and action effect (could be highly non-linear) has been ignored.</p> <p>- Unclear if a different factors shall be used if e.g. representative load action includes altering ice regime.</p>	<p>A recipe of how partial load factors may be estimated for floaters shall be developed and included.</p>
<p><b>8 Action and action effects</b></p> <p><b>8.1 General;</b> Guidance on actions and action effects is found in [...] and 19904-1. [...] Structures or components subjected to ice interaction events... [...] there is a reasonable probability of Interaction...</p>	<p>Guidance on action effects of floaters are covered elsewhere and not part of ISO19906. This statement undermines the apparent influence of the hull response to ice loading.</p> <p>Suggest further elaborating on this for floater (mooring, risers, umbilicals, hull appendages)</p> <p>Better be defined, otherwise it could lead to a very subjective interpretation</p>	<p>Address ice load dependence on structural response.</p> <p>Add a note that A.8.2.2 pertains to load models for fixed structures and that the need to be modified for use in relation to floating structures.</p> <p>Add a note that coupled analyses shall be performed for assessing the effect of ice loading on mooring, risers, umbilicals, etc.</p>
<p><b>8.2.1 General principles for calculating ice actions</b> Direct ice actions and actions arising from the interaction between the ice and the structure shall be considered for both global and local considerations. Such actions can include: a) static, quasi-static, cyclic and dynamic actions (EL and AL); b) cyclic and dynamic actions that can cause structural fatigue, liquefaction and personnel discomfort; and c) spatial actions such as rubbing, pile-up, ride-up and similar ice behaviour that can hinder operations.</p> <p>Further requirements relating to ice actions are found in 10.3 for man-made islands, in 13.4 for floating structures and in 14.3 for subsea structures.</p>	<p>Both static and dynamic actions of floaters are included. For ice actions on floaters reference is made to clause 13.</p>	<p>No recommendation</p>
<p><b>8.2.2 Representative values of ice actions</b> Representative values for ice actions shall be calculated using probabilistic methods or deterministic methods for ELIE and ALIE.</p>	<p>- ... or using a combination thereof (i.e. application of semi-probabilistic methods need to be addressed)</p> <p>- For some locations in the Barents Sea (where floaters will be used) special care shall be given to deterministic methods for calculating "worst conceivable" based on the little data at hand.</p>	<p>Practical use of probabilistic methods shall be outlined, particularly for the case of limited available data to perform a fully probabilistic design.</p>

Applicable ISO 19906 provisions	Analysis and applicability for floaters	Recommendations
<p><b>8.2.3 Ice action scenarios</b>                      Design ice actions shall reflect; - the structural configuration and the relevant operational scenarios, including seasonal operation, ice detection, physical ice management, manoeuvring of the structure and disconnection, with reference to the provisions of 8.2.7.</p>	<p>Design ice actions shall include the effect of i) ice management; ii) manoeuvring and iii) effects of the disconnection philosophy.</p>	<p>Methods to quantify the effect of operational philosophy (IM, disconnection, etc.) in the design of a floating installation shall be outlined.</p>
<p><b>8.2.4 Global ice actions</b>                      Each of the following conditions shall be considered, and the governing ones shall be used to determine ice actions [...]                      Limit force scenario</p>	<p>Global ice actions shall consider i) pressured ice conditions; ii) ice rubble build-up and actions transmitted to the structure as well as freeboard; iii) compliance and damping of the structure and stationkeeping system; iv) dynamic and hydrodynamic effects; v) friction between the ice and the structure. Clarification is required between ii), iii) and iv) to cover dynamic interaction between compliant systems such as moored floater and ice ridges within pack ice.</p> <p>Limit force scenarios may potentially, be a key scenario if design and operation philosophy incorporates IM and disconnection. This scenario is not well described and formulated in ISO 19906.</p>	<p>Dependence between ice rubble, compliance and damping of the structure and dynamic and hydrodynamic effects should be outlined.</p> <p>Include a method for calculating limit force scenarios.</p> <p>The target design load on the floating system shall be determined as a function of heading where heading changes have effect on ice loads (i.e. ship-shaped FPSO)</p> <p>Frictional forces resulting from ice sliding along the hull shall be accounted for. This is especially the case for ship-shaped FPSO's penetrating ridges.</p> <p>Iceberg impact shall be assessed and in which the flexibility of the stationkeeping system should account for the dissipation of impact energy. An estimation approach based on energy should be provided.</p>
<p><b>8.2.5 Local ice actions</b>                      Local ice actions shall be based on relevant full-scale measurements or established theoretical methods. Due account shall be taken of geographical differences and water level changes in their specification.                      [...] Design contact areas shall be considered based on the local structural configuration, including frame spacing, plate thickness and appendage dimensions. [...]</p>	<p>Floater is likely to be classed; therefore first of all a reference should be made to RCS. Then it should be described how to deal with design as per RCS and "first principles" to address all ice features in ice interaction scenarios.</p>	<p>Interface between class and ISO to be detailed for local design of floaters.</p> <p>Local ice actions should be related to the actual structural arrangement (e.g. web frames).</p>
<p><b>8.2.6 Dynamic ice actions</b></p>	<p>Should provide recommendation on e.g. how to incorporate IM and disconnection on input for structure (incl. mooring) fatigue.</p>	<p>Outline a method to enable estimation of dynamic effects of significance to fatigue in case of IM.</p>
<p><b>8.2.7 Operational procedures to reduce ice actions</b>                      Operational procedures may be used to mitigate ice actions on fixed, floating and subsea structures provided that it can be shown that, in combination with structural resistance, the intended level of reliability is achieved.                      Operational procedures include ice management, disconnection and removal, clearing of snow and ice accumulations, rubble and spray ice barriers, and seasonal operation. Ice management can be used to alter the ice regime, through decreases in floe size and the destruction or removal of potentially hazardous ice features, and through local reduction in ice coverage.                      Ice action calculations for managed ice shall be performed when appropriate. [...]</p>	<p>Floater design may include operational procedures to reduce ice actions as long as it can be shown that the anticipated reliability level can be achieved. Obvious operational procedures for floating structures are; i) ice management and ii) disconnection.</p> <p>Ice actions arising from managed ice shall be calculated. No reference given.</p> <p>To summarize as it could be interpreted differently. One opinion (supported by some of the ISO 19906 co-developers) is that operational issues (e.g. IM) can be used to reduce design loads, and that this must be carefully documented. Another opinion is that design is design, and operations are operations, i.e. that ISO 19906 does not cover operations.</p>	<p>Clause need to be carefully clarified to enable (or disable) incorporating operational procedures in design (and documentation of reliability level).</p>



<p><b>8.2.8 Physical and mechanical properties of ice</b> g) internal cohesion and friction of fragmented ice</p>	<p>Somewhat unclear where these values may come from. In general, "Expert judgement" could be introduced for "defining" ice properties and their distributions.</p>	<p>Add a note on expert judgement for defining ice properties.</p>
<p><b>8.3.1.4 Freeboard and deck elevation</b> Deck elevations, structure freeboard and bow wall or ice deflector height shall account for the wave-induced vertical motion of the water surface and incident ice features. Account shall be taken of ice accumulations on the structure, the underside of the topsides deck or the substructure. The routing of all risers, caissons, J-tubes and other appurtenances shall minimize the risk of impact by such ice features. Further guidance is provided in 15.1.1.3.</p>	<p>Sufficient freeboard is required. Bow to be designed such that incident ice features represent no harm. Minimization of impact frequency on risers and J-tubes (as well as other appurtenances).</p>	<p>Add a reference to list of mitigation measures for subsurface ice impact (discussed above).</p>
<p><b>9 Foundation design</b> <b>9.7.1 General</b> [...] For permanently moored systems, the design value of the resistance to failure in the soil surrounding anchors should normally exceed the breaking strength of the anchor and/or chain line. The design resistance shall be calculated on the basis of site-specific geotechnical data. [...]</p>	<p>Breaking strength of anchor lines should exceed the resistance of failing anchors in the surrounding soil.  For e.g. drilling it is worth recalling Kulluk's experience where mooring capacity varied from location to location depending on "installation success". In general, it is a factor not to be overlooked in the overall reliability assessment.</p>	<p>Include a note that it is the "as installed" capacity that ultimately defines mooring capacity.</p>
<p><b>13 Floating structures</b> <b>13.1 General</b> Floating systems operating in arctic and cold regions shall comply with the provisions of ISO 19904-1, while their mooring systems shall comply with the provisions of ISO 19901-7 and the additional provisions of this International Standard. Particular emphasis is placed on ice actions and hull design, cold weather materials and design of marine systems, and disconnection. [...] Floating structures considered within the context of this International Standard include; a) ship-shaped hull (e.g. FPSO, FSO) or barge units; b) column-stabilized (e.g. semi-submersible), spar and buoy type units. [...]</p>	<p>All floating production concepts covered, whereas reference is made to companion standards for floating system design and mooring design.</p>	<p>ISO's role in relation to class shall be detailed (already mentioned above).</p>
<p><b>13.2 General design methodology</b> <b>13.2.1 Design philosophy</b> The design philosophy and operational approaches for floating structures include the following: a) potential to suspend operations and move off location, to avoid any interactions with extreme or abnormal ice features; b) ice management support techniques to actively modify ambient ice conditions and thereby mitigate potential adverse ice actions. The design and operational components of a floating installation and its subsea components shall be treated jointly as a system, including ice management support where provided, for overall reliability assessment see Clauses 17 and 18.</p>	<p>Adverse ice action effects on floating systems can be reduced while adapting to mentioned design philosophies, i.e. i) disconnection; ii) ice management.  Reliability shall be assessed in relation to the joint system.</p>	<p>Provide a note on how a joint system reliability analysis can be performed. Also provide a list of requirements and identify possible limitations.</p>

Applicable ISO 19906 provisions	Analysis and applicability for floaters	Recommendations
<p><b>13.2.2 Design and operational approaches</b>                      (...) The type of ice management system deployed can have a significant influence on the design approach taken for a floating structure. This influence depends upon the expected ability to consistently detect potentially adverse ice conditions and successfully manage them before they interact with the structure (e.g. by towing icebergs or fragmenting thick sea ice features).                      The ability for a floating structure to move off location, the time that is required to do so, and acceptable levels of operational downtime shall be considered to ensure that the structure can move off site without incident if there is a failure of the ice management system. [...]                      For active and semi-active operating approaches, design values of ice actions on a floating installation can be considerably less than for a fixed installation. Any mitigation measures (i.e. ice management and move-off strategies) that are intended to ensure appropriate levels of safety should be properly identified, considered and quantified, along with expected levels of reliability. [...]</p>	<p>The effect of ice management as well as the impact of the chosen design philosophy shall be considered and quantified (reference to clause 17 should be made here).</p>	<p>Additional design and operational approach can be introduced: no move-off, disconnect risers with or without IM.</p>
<p><b>13.3 Environment</b>                      In addition to the environmental information requirements outlined in Clause 6, the following relevant factors shall be considered for the design of floating structures, particularly when ice management systems are involved. Relevant factors include, but are not limited to,                      a) the combined influence of ice, wave, wind and current action, and the effect of their respective orientations on the applied actions (e.g. on an FPSO that is designed to vane into oncoming pack ice);                      b) the joint effects of ice, waves and structure motions on ice action scenarios, and the areas of the structure where ice impacts can occur;                      c) the effects of factors such as low air and water temperatures and icing;                      d) the beneficial effects of ice management on modifying the ambient ice environment and potentially eliminating most of the hazardous ice features within it;                      e) the potentially adverse effects of secondary factors such as poor visibility, precipitation and darkness on the reliability of ice detection and ice management systems;                      f) the complicating effects of factors such as waves on sea ice and iceberg management methods, and the presence of sea ice on iceberg towing operations;                      g) the increased importance of factors such as ice pressure events and combined ice drift velocity and thickness information, particularly for sea ice management <b>considerations</b>;                      h) the degree of variability of many of the physical environmental parameters;                      i) the potential lack of long-term physical environmental data, from which proper designs and <b>operational</b> procedures and plans are developed;                      j) the identification of the full range of ice interaction scenarios that can give rise to adverse ice effects on floating installation, (e.g. excessive load levels on a mooring system, hull damage from undetected small ice masses, thruster damage in ice pressure, mooring line exposure to deep draught ice keels).</p>	<p>List of requirements on environmental effects that shall be accounted for in the design.</p>	<p>Additional guidance on all items needed!</p>

<p><b>13.4 Actions</b>  <b>13.4.1 Applicability</b>  <i>These provisions shall apply to actions on the hull and its components, including turret, buoy, risers, mooring lines and tension legs that materially influence the behaviour of the structure interacting with ice. [...]</i></p>	<p>Ice actions shall be determined for the entire structural system, i.e. the hull and all its components.</p>	<p>Note that actions on hull appendages should be included as well.</p>
<p><b>13.4.2 Ice scenarios</b>  <i>In addition to the provisions of Clause 8, pressure events due to convergence of surrounding ice or presence of a coastline shall be considered for floating structures.</i></p>	<p>Pressured ice conditions to be assessed. Unclear how to assess and quantify them in the middle of the Barents Sea.</p>	<p>A methodology of addressing pressured ice should be provided. (Maybe not achievable).</p>
<p><b>13.4.3 Interaction factors</b>  <i>In addition to the factors described in 8.2.4, the following should be considered: -physical ice management; -operational criteria, including ice detection, forecasting, threat analysis and decision-making as primary criteria (other operational factors, such as avoidance, measurement of actions, weathervaning, shutdown, flushing of risers and flowlines, disconnection, and seasonal operations).[...]          Appropriately scaled physical models can be used to determine the response (e.g. offsets, weathervaning, mooring line forces) of the floating structure and moorings to ice and current actions. Model tests can also be used to investigate ice accumulations on the mooring system and turret for monohull or buoy shapes, and ice accumulations to the legs of semi-submersibles.</i></p>	<p>Additional interaction factors to be considered (in addition to the ones mentioned in 8.2.4). Particularly ice management and other operational criteria need to be assessed in order to identify the correct nature of interaction.           In lack of existing numerical and/or analytical design models, ice interaction on the floating system may be assessed by means of physical scale models.           "Appropriately" scaled is a vague definition and shall be further clarified. To avoid subjective judgement, some kind of benchmarking shall be introduced. Appropriateness can also vary depending on the ice failure mode (which depends on the floater design).</p>	<p>Guidance to be provided on ice model basin tests.          List of requirements and limitations.</p>
<p><b>13.4.4 Determination of ice actions</b>  <i>Ice actions shall be considered in combination with motions of the floating installation due to actions from ice, wind, wave or current processes. The flexibility of the stationkeeping system shall be considered when determining ice actions.           The magnitude of ice actions may be altered through ice management measures, ice avoidance procedures, ice clearing and friction reduction systems (e.g. bubble or thrusters), seasonal operation, disconnection or displacement of the installation.[...]           Relevant, full-scale ice action data for floating structures should be used for the determination of design actions. Experience with icebreaking vessels and scaled ice basin experiments may also be used. Particular attention should be given to managed ice conditions. Where appropriate, the approaches outlined in A.8.2 may also be applied.</i></p>	<p>Ice action shall be assessed in combination with the structural response. Ice load magnitudes may be reduced due to ice management. Reference is also made to A.8.2 for applicable load models. No further guidance offered. It would be useful to address how ice bubble can reduce EL and AL ice actions.</p>	<p>Additional guidance on ice actions needed. Guidelines shall be further developed, to become one of the key parts of the RNO2 deliverables.</p>
<p><b>13.4.5 Other ice action considerations</b>  <i>Where relevant, the following factors shall be considered when calculating the magnitude and frequency of ice actions: [...]</i> (provided check-list, see page 82)</p>	<p>Check list for design is provided. There is however a little conflict here. A good check list is provided, and also it is assumed that "recognized" and "established" methods are to be used. However, these methods either don't exist or are not applicable for some of the listed items. The impression is that many know "what" but few (none) know "how".</p>	<p>Additional guidance to be provided where this guidance is available.</p>

Applicable ISO 19906 provisions	Analysis and applicability for floaters	Recommendations
<p><b>13.4.6 Action variations</b>                      The time-varying nature of the magnitude and direction of the ice action (including potential changes in failure modes and ice clearance behaviour) shall be considered where it materially influences the structural response (including stationkeeping system) to the ice action.[...]                      (...) and local effects (e.g. hull response) shall be considered when calculating response to ice actions.                      The effect of ice management on the behaviour of the system shall be taken into account.</p>	<p>Time varying nature of ice loading shall be assessed.                      Not clear what is meant. Performing fully coupled analysis of local ice – structure interaction is perhaps beyond the scope of what is achievable today. Otherwise clear recommendation shall be provided, also how to combine with design as per RCS.                      How? On what system?</p>	<p>Additional guidance to be provided where this guidance is available.</p>
<p><b>13.5.3 Structural analysis and design</b>                      The global and local structural models of the floating structure as discussed in ISO 19904-1 shall incorporate the ice actions given in 13.4. The following provisions apply for the ice/structure interaction analysis and for the design. a) Global ice actions shall be specified in accordance with 8.2.4. The global ice action shall be applied to determine whether the structure meets the ULS and ALS criteria for the floating structure as a whole and for the area in the vicinity of the impact point. b) The area of application for local ice pressures shall be selected to provide the design condition for shell plates, stiffeners, tubulars and other supporting members. Guidance on local ice pressures is provided in 8.2.5. c) Ice loads on appendages shall be calculated, and the limit states should be determined for the appendage, the local structure and the floating structure as a whole.</p>	<p>Beyond the coverage of ISO 19904-1, special consideration shall be taken wrt ice loading. Reference made to provisions on both global and local ice actions.                      This section is too general and shall be further elaborated. In practice, it includes some common sense statements and refers to places where no answers can be found. Different types of station-keeping systems shall be addressed separately</p>	<p>Additional guidance to be provided where this guidance is available.</p>
<p><b>13.5.4 Structural considerations</b>                      All section</p>	<p>Same as above. More shall be said on structural considerations, and probably additional limit states shall be included.</p>	<p>Additional guidance to be provided where this guidance is available.</p>
<p><b>13.5.5 Condition monitoring</b>                      All section</p>	<p>Performance requirements (FARSI format could be appropriate) to this system shall be specified. For disconnectable system, it will all be targeted towards the “decisions to suspend and eventually to disconnect or resume”. Ice Management Integration System is a part of it.</p>	<p>List of requirements of conditional monitoring of floaters in ice.</p>
<p><b>13.6 Hull stability</b>                      All section</p>		<p>To be amended with more specific input and reference to RCS documents. Interdependence with e.g. mooring system capacity shall be addressed. Also SLS design.</p>

<p><b>13.7 Station keeping</b>  <b>13.7.1 General</b>  <i>[...]. The values of EL and AL actions may be calculated through a risk assessment, taking into account the possible consequences of a failure of the stationkeeping system, the proximity to other installations, the nature of the operations (permanent or seasonal), the capability for disconnection (normal and emergency) and associated implications thereof, in accordance with ISO 19901-7.</i></p>	<p>Risk assessment of the floating system shall account for failure of the station keeping system.</p>	<p>All Section 13.7 shall be further elaborated. Performance requirements for different types of stationkeeping systems can be developed (w or w/o account for IM and / or disconnection).</p> <p>With reference to 6.4.2.2.3 Permanent moorings designed for disconnection of ISO 19901-7, the following shall be addressed:</p> <ul style="list-style-type: none"> <li>- Ice management "system" effect on ULS and ALS loads</li> <li>- Disconnection process and possibly additional operational safety factors</li> <li>- Load escalation characteristics (load rises)</li> <li>- Etc</li> </ul>
<p><b>13.7.2 Design of the stationkeeping system</b>  <i>The stationkeeping system shall maintain the installation in place under specified combinations of ice, wave, wind and current actions, and changes to ice actions as a result of ice management. The relevant action combinations shall be established based on available ice and metocean statistics.[...]</i></p>	<p>Necessary assessment of the floater's response and capacity of the mooring line system. 'Specified conditions' depending on operational philosophy.</p>	<p>No recommendation</p>
<p><b>16.5 Ice tank modelling</b></p>	<p>Details missing.</p>	<p>Additional guidance on all items needed. See comments to A.16.6</p>



Table 2. ISO 19906 Informative coverage on floater design (Note that direct quotations from ISO are shown in *italic font*).

Applicable ISO 19906 provisions	Analysis and applicability for floaters	Recommendations
<p><b>A.3 Terms and definitions</b></p> <p><b>A.4 Symbols and abbreviated terms</b></p>	<p>Applicable</p>	<p>To be amended – new items to be added specific to altering ice environment.</p>
<p><b>A.6.5.1.1 Nomenclature and modelling</b></p> <p><i>Statistical modelling from limited site-specific data sets is generally performed by Monte Carlo simulations where theoretical probability distributions are fit to the data and then randomly sampled [...]</i></p>	<p>Applicable when clarified.</p> <p>In the parts of the Barents Sea where floaters could be considered, ice and icebergs may be infrequent events. Moreover, sea ice does not form at the site but drifts to site from where it is formed.</p>	<p>Additional guidance on handling of limited data sets. Objective shall be to define distributions (with focus on tails and cut-offs) for probabilistic load calculations and not least define deterministic parameters for deterministic load calculation checks (in particular for AL). Where no data is available, recommendations shall be provided on which parameters to use.</p>
<p><b>A.6.5.2.2 Concentration and form</b></p> <p><i>The actual area in the denominator varies depending upon the viewpoint of the observer, i.e. from a ship, from an aircraft or viewing a satellite image.</i></p>	<p>Ice concentration is always reported based on data from low (med) res satellite images where resolution is many (tens) km.</p>	<p>Additional guidance on ice concentration to be provided, with particular focus on further use in assessing ice actions.</p>
<p><b>A.6.5.2.3 Icebergs</b></p>	<p>Shape coefficients for impact calculations shall be clarified. Iceberg stability shall be addressed, both with respect to towing and interaction with mooring lines. Adverse iceberg shapes (ice foos or caps) shall be mentioned if believed to exist in the Barents Sea.</p>	<p>Additional guidance to be provided on i) shape coefficients; ii) iceberg stability; iii) adverse iceberg shapes.</p>
<p><b>A.6.5.4 Ice movement</b></p>	<p>Ice movement measurements and interpretation should be addressed. Variability in ice drift shall be characterized and quantified. Ice pressure in the open areas (e.g. central part of the Barents Sea) shall be discussed and quantified (in engineering units).</p>	<p>Additional guidance to be provided on i) interpretation of satellite data; ii) variability of ice drift; iii) meso-scale ice pressure.</p>
<p><b>A.7.1.1 Governing principles</b></p>	<p>A paragraph on reliability of the complex system such as floater in ice (when operational measures such as IM and disconnection are optionally included) is lacking.</p>	<p>Include a note on reliability assessments of the joint system. To be understood by engineers.</p>
<p><b>A.7.2.2 Actions</b></p> <p><i>If there are insufficient data to calculate characteristic values, the representative values should be selected by expert judgement.</i></p>	<p>To be discussed for the Barents Sea conditions.</p>	<p>Recommendation shall be provided on what to consider "sufficient" or "insufficient". Assessing quality of data and benchmarking with similar regions shall be described.</p>
<p><b>A.7.2.3 Principal and companion environmental actions</b></p> <p>Most of the text</p>	<p>Applicable when clarified for floaters. Clarifications shall be provided on the statistical data "guessing" for further use in either deterministic or probabilistic calculations (may be not specifically related to this section). It shall be avoided that same uncertainties are accounted more than once (or missed).</p>	<p>Additional guidance on use of statistical data (already covered above).</p>

<p><b>A.7.2.4 Combinations of actions and partial action factors</b>                  The action factors for permanent and variable actions presented in Table 7-4 are based on ISO 19902 for fixed steel structures. For fixed concrete structures and for floating structures, ISO 19903 and ISO 19904-1 present different and sometimes lower values of these action factors. Therefore, if using ISO 19902, ISO 19903 and ISO 19904-1 for the respective structure types, the use of their action factors for permanent and variable, but not for environmental, actions is permitted. [...]</p> <p>This International Standard allows a user to perform a calibration of action factors for use in place of the action factors presented in Table 7-4, to the reliability targets presented in Table A.7-1, for all exposure levels. This can be necessary due to particular aspects of the physical environment, of the structure type, of the ice-structure interaction scenarios and of other factors such as ice management if these are an integral part of the system design. A methodology for such a calibration is presented in Reference [A.7-2]. The results of such a calibration can be values of action factors that are less than or are greater than the values in Table 7-4. In such a calibration, due account should be made of the relevant resistance factors, as specified in ISO 19902 and ISO 19903, as well as in other International Standards for offshore structures.</p>	<p>Concerning floating structures, environmental action factors apply according to ISO19906.</p> <p>It is assumed that calibration of action factors (Table 7-4) will be necessary for the design of floating systems. No approach, other than reference to A.7-2 (Calibration of action factors for ISO 19906 Arctic offshore structures, OGP Report: 422, International Association of Oil and Gas Producers, 2010), is provided (additionally some coverage in A.8.2.2). Regarding floaters partial ice action factors as presently provided in ISO 19906 have been calibrated based on load distributions for head-on interactions with "fixed" units. It is yet to be confirmed that the distribution used are representative for arbitrary heading interaction with compliant structures.</p> <p>It is not clear how to address very rare events.</p> <p>For Barents Sea (use in Russia), this very important section of ISO is nearly untranslatable in terms of the meaning.</p>	<p>Additional guidance shall be provided on improving the readability and applicability of this section to floating structures. Guidance also to be provided on partial factor calibration.</p>
<p><b>A.7.2.5 ULS and ALS design</b>                  [...] Representative values should be derived as characteristic values from a probabilistic description of the action, but otherwise can be a nominal value. "Nominal" refers to values of a basic variable determined on a non-statistical basis, typically from acquired experience or physical conditions. [...]</p>	<p>Ice actions (factored) should be derived on basis of a probabilistic design approach. Limited guidance given on the use in connection with floaters.</p> <p>Very important section which presently is far too general. To be further elaborated (and clarified) for floaters. WSD and "interface" with RCS shall be provided, as well as with ISO 19904-1. Operational procedures shall be addressed.</p>	<p>Additional guidance on use of probabilistic methods in floater design, including operational procedures.</p> <p>Link between ISO and different ISO codes, as well as class to be assessed.</p>
<p><b>A.8.2.2.1 Representative values</b>                  All Section</p>	<p>Applicable when clarified for floaters.</p>	<p>This section shall be updated</p> <ul style="list-style-type: none"> <li>- guidance shall be provided on selection of parameters for deterministic calculations;</li> <li>- guidance shall be provided on use of model tests and full scale data when determining representative values;</li> <li>- Figure A.8-1 shall be updated to include interdependence between operational measures and determining action values</li> <li>- etc</li> </ul>
<p><b>A.8.2.2.3 Deterministic approach</b>                  All section</p>		<p>More specific guidance shall be given with focus on floaters and Barents Sea conditions.</p>

Applicable ISO 19906 provisions	Analysis and applicability for floaters	Recommendations
<p><b>A. 8.2.3 Ice action scenarios</b>                      Table A.8-2 — Sub clause references for various interaction scenarios.                      Floating structures: Ship-shaped; Spar/buoy vertical</p>	<p>Reference to global ice load algorithms for FY ice on vertical, sloping structures; FY ice ridges on vertical structures; MY ridges on vertical structures (and reference to model for conical structures); models for ridge building processes as limiting factor for ridges; models for limit energy of discrete floes.                      ONLY static load models are referenced.</p>	<p>Update table A.8-2 according to dependence on ice concentration and for floater design in general.</p>
<p><b>A. 8.2.4.2.1 Overview of failure modes</b></p>	<p>Ice crushing effect on total load level for floaters is missing.</p>	<p>General recommendation shall be provided that floater design shall prevent ice crushing with certain margin.</p>
<p><b>A. 8.2.4.3 Global ice pressures from ship ramming tests</b></p>	<p>Details are insufficient.</p>	<p>Include background information on ship rams.</p>
<p><b>A. 8.2.4.4.1 Description of the failure process</b></p>	<p>Background information concerning the velocity effect is missing. Ice drift speeds are limited by 2.5 knots in the Barents Sea.</p>	<p>For "ice in waves", background information on P-A shall be provided taking into account energies involved in collision.</p>
<p><b>A. 8.2.4.5.1 First-year ridges</b></p>	<p>Insufficient for downward bending 3D shapes.</p>	<p>Updated description to include downward bending 3D shapes.</p>
<p><b>A. 8.2.4.6 Limit force actions due to the ridge building process</b></p>	<p>Surcharge factor as provided in the original Dolgopolov reference is missing.</p>	<p>Numerical modelling (including validation) shall be presented as an important supplementary tool and recommendations provided on how it can be used.</p>
<p><b>A. 8.2.4.8 Floating structures</b>                      Floating structures in ice/berg and sea ice environments are unique in that they generally have disconnection capability and operate with ice management support. [...].                      When the floating structure is connected, it is necessary to consider global ice actions for the stationkeeping system and hull for the parameter distributions associated with managed ice. Of particular concern are those features at the upper end of the managed ice distribution for which the actions approach the capacity of the stationkeeping system.[...] Factors influencing ice actions on floating structures are provided in 13.4.[...].                      Actions from managed sea ice are best determined from full-scale data. Reference [A.8-30] outlines a method that uses full-scale load data from the Kulluk conical drilling platform in the Beaufort Sea, for which ice actions have been associated with the size and thickness of the managed ice.[...]</p>	<p>This is a very important section for ice actions from managed ice.</p>	<p>Additional guidance to be provided surcharge and ice clearing effects.</p>
	<p>No load models for floating structures provided, though global and local ice action shall be assessed. Implicitly stated that floating structures are in support of ice management. Emphasis that ice/berg impact shall be assessed, in which the flexibility of the stationkeeping system should account for the dissipation of impact energy. Actions from managed ice to be determined from full-scale experience from Kulluk.</p>	<p>Guidelines on applicability of the outlined method (including its limitations) shall be addressed.</p>



<p><b>A.8.2.5 Local ice actions</b>  <b>A.8.2.5.1 Overview of local ice actions</b>                  While global actions are calculated from average pressures over the nominal contact area, there can be many areas within the nominal contact area that are subjected to higher local pressures, see Figure A.8-8. Consequently, global average pressures should not be used for local design and a separate consideration of local pressures is necessary. Local pressures should be used, for example, in the design of shell or stiffening elements as illustrated in Figure A.8-17. [...]</p>	<p>General coverage for floaters.</p>	<p>To be harmonized with design as per RCS.                  Sea ice and iceberg belts shall be presented.</p>
<p><b>A.8.2.5.2.1 Overview</b>                  A method is described in A.8.2.5.2 for determining local pressures from first-year ice up to approximately 1.5 m thick. This method applies to level ice, rafted ice and consolidated layers of first-year ice ridges. Considerable data exist from full-scale local pressure measurements for level and rafted ice conditions.</p>	<p>Coverage of local pressures applicable for local floater design (though models are originally derived from local pressures on fixed structures for areas &lt; 1m). In case of floaters, ice belt is very likely to be inclined at the waterline. Is it realistic to define local pressures derived from crushing?</p>	<p>Clarification or justification of applicability shall be presented.</p>
<p><b>A.8.2.5.4 Probabilistic model for local ice pressures</b>                  A probabilistic local pressure model has been developed based on data from ship impacts with multi-year ice floes. Data are primarily from measurements of the Kigoriak ramming tests on multi-year ice and these are supplemented. [...]</p>	<p>Cumulative local pressure distribution (with exposure) based on ship rams.</p>	<p>Shall be specifically explained for deriving P-A curves for the iceberg belt.</p>
<p><b>A.8.2.7 Operational procedures to reduce ice actions</b></p>	<p>This section is very important. Details are, however, lacking.</p>	<p>Additional guidance to be provided where this guidance is available. Substantial further elaboration is desirable.</p>
<p><b>A.8.2.8.8.10 Material parameters for ridge keels, Density</b></p>	<p>Very limited possibilities exist to quantify the ridge morphology in full scale.</p>	<p>To be further elaborated. Also particular notice shall be given to determination of rubble parameters, such as rubble strength and density when performing model tests.</p>
<p><b>A.8.3.1.2.4 Dynamic and static responses</b>                  Information on static, dynamic and stability analyses is contained in the standard relevant to the structure type, i.e. ISO 19902, ISO 19903 and ISO 19904-1. Additional information on the stability of floating structures in intact and damaged conditions is contained in 13.6. [...]                  The mass of the icing adds additional static vertical actions that can be considerably offset from the centre of gravity of the ice-free structure. The vertical actions can influence static position, stability, resistance to other actions and dynamic response. For a floating system, the consequent list, increase in draught and reduction of freeboard can increase the possibility of green water (or floating ice) impacting the deck. Changes in the metacentric height can have consequences for stability, roll and pitch stiffness, and responses.</p>	<p>Advice on stability for floating systems. Cause of dynamic ice actions is missing.</p>	<p>Nature of dynamic ice actions (and response) on floaters shall be described and recommendations on when it can be of concern shall be provided.                  Additional guidance on how to assess dynamic actions.                  Methods of how to account for dynamic effects due to mooring compliance should be included. A factored approach by means of DAF could be utilized. Alternatively, based on quasi static maximum values, ice load ramp functions (i.e. ice ridge loads as a function of ridge penetration) may be applied.</p>

Applicable ISO 19906 provisions	Analysis and applicability for floaters	Recommendations
<p><b>A.13 Floating structures</b></p> <p><b>A.13.1 General</b></p> <p>Many design solutions, both global and local, are available to the designer of a floating structure for use in ice covered waters. There can, therefore, be cases where such a structure cannot be logically placed within this International Standard, or where specific requirements are found not to be relevant. In such cases, the design should be based upon the principles documented in this International Standard and should achieve a level of safety equivalent or superior to the safety level implicit in this International Standard. [...]</p> <p>This International Standard does not provide detailed instructions for producing reliable estimates of the environmental parameters to consider for all floating structure designs. In this regard, it is important to incorporate past experience for data gathering and analysis procedures, statistical techniques, and defining the key environmental influences and factors for a particular system, including those associated with ice management. [...]</p> <p><b>A.13.2.2 Design and operational approaches</b></p> <p>A variety of design and operating approaches can be selected for floating installations in ice-prone waters as follows:</p> <p>a) Active; b) Semi-active, c) Passive.</p> <p>[...] Some floating installations can be appropriately designed for specific ice interaction scenarios, according to vessel classifications, rather than according to the event-based strategy implicit in this International Standard. [...]</p> <p><b>A.13.4 Actions</b></p> <p><b>A.13.4.1 Applicability</b></p> <p>No additional guidance is offered.</p> <p><b>A.13.4.2 Ice scenarios</b></p> <p>No additional guidance is offered.</p> <p><b>A.13.4.4 Determination of ice actions</b></p> <p>No additional guidance is offered.</p> <p><b>A.13.4.5 Other ice action considerations</b></p> <p>No additional guidance is offered.</p> <p><b>A.13.4.6 Action variations</b></p> <p>No additional guidance is offered.</p> <p><b>A.13.5 Hull integrity</b></p> <p><b>A.13.5.1 Structural design philosophy</b></p> <p>Some rules for ice-strengthened vessels apply icebreaking mechanisms and load equations that are more appropriate for moving ships than stationary ship-shaped structures. Stationary floating structures cannot selectively avoid extreme features and can have limited manoeuvrability, and should be designed accordingly.</p>	<p>Recognition of the fact that the standard does not cover floater's design in detail. Though, the design methodology contained in the standard should apply also for floater design (i.e. same safety levels apply).</p> <p>Several suggested operational approaches. This provision advocates the implementation of the operational philosophy into the design.</p> <p>Link to vessel classification.</p> <p>NO guidance!</p> <p>Stationary floating systems cannot necessarily be designed only according to class rules tailored for moving ships.</p>	<p>No recommendation</p> <p>Additional guidance on use of probabilistic methods in floater design, including operational procedures. (Already provided above).</p> <p>To be updated and elaborated on. Additional guidance to be provided where this guidance is available.</p> <p>Link between class and ISO to be assessed and elaborated. Eventual additional requirements to be added (addressed above).</p>

<p><b>A.13.5.3 Structural analysis and design</b>  <i>For local ice actions, the maximum area over which local pressures are applied can be limited by the nominal contact area associated with the global ice action. [...]</i></p>	<p>No guidance offered on how to derive maximum local area of contact.</p>	<p>Additional guidance on deriving maximum area of local contact required.</p>
<p><b>A.13.7 Stationkeeping</b>  <b>A.13.7.1 General</b>  <b>A.13.7.1.1 Types of systems</b>  <i>For stationkeeping systems in arctic and cold regions, 13.7.1 stipulates that annual probabilities of exceedance for actions be calculated according to Clause 7. EL actions are specified in 7.2 at an annual probability of exceedance of 10<sup>-2</sup>, which corresponds to a return period of 100 years. This International Standard imposes the additional requirements of AL design for ice actions and that Clause 7 apply for all stationkeeping design, whether mobile or permanent. In 13.7.1, return periods shorter than 100 years are also permitted if the return period is determined through a risk assessment, taking into account the possible consequences of stationkeeping system failure.</i></p>	<p>The stationkeeping system shall be designed according to provisions in clause 7, implying EL and AL actions to be determined for 10<sup>-2</sup> and 10<sup>-4</sup>, respectively.</p>	<p>This sections needs additional guidance related to floater's design.</p>
<p><b>A.16.5 Ice tank modelling</b>  <b>A.16.5.1 General</b>  <i>Ice tank modelling can be used to investigate various ice-structure interactions and offers the advantage that relatively complex problems (that can difficult to analyze using other methods) can be studied and visualized at a small scale (i.e., smaller than full scale). [...]</i></p>	<p>Ice tank tests may be used to assess the ice load levels in complex situations where the ice loading cannot readily be derived by 'other methods' (implicitly meaning the models provided by this standard).                   No particular guidance offered for testing of floating systems in ice tanks.</p>	<p>To be updated specifically for model testing of floaters.                   Deviations between two modelling approaches should be assessed; i) towing or pushing the model through a stationary ice sheet; and ii) pushing the ice sheet towards the stationary model;                   A note that ice model test results should be corrected according to actual obtained ice characteristics.                   Special requirements to mooring system; e.g. i) Moored system stiffness to be quantified in model scale and compared to prototype design; ii) pull-out tests should be performed to assess the model scale mooring system; iii) Decay tests should be performed for deriving the natural periods of the model in open water;                   Ice-structure friction coefficient to be assessed in model scale;                   Structure motions and accelerations (6DOF);                   Ice ridge characteristics in model tests, particular notice shall be given to determination of rubble parameters, such as rubble strength and density.</p>

Applicable ISO 19906 provisions	Analysis and applicability for floaters	Recommendations
<p>A.17 Ice management</p> <p>A.17.1 General</p> <p>Floating structures that are deployed in ice-covered waters are often supported by highly capable ice management vessels, with the intended role of modifying the local ice environment, reducing ice actions on the structure and enhancing ice clearance around it. The requirement to identify potentially adverse ice features or situations requiring ice management and then to deal with them in a timely manner increases the range of environmental considerations that are normally associated with fixed structures. [...]</p>	<p>Adverse effect should be identified.</p>	<p>All section shall be reviewed and clear performance requirements to IM shall be outlined. Then, many sections above shall be revisited with objective to determine EL and AL ice loads.</p>
<p>A.17.2.2 Ice management to reduce ice actions</p> <p>The use of ice management to reduce the frequency and severity of ice actions on offshore systems is obvious in concept. [...]</p> <p>[...]. However, experience also shows that not every adverse ice situation can be managed with 100 % reliability in a timely manner, even with highly capable ice management systems.</p>	<p>Reduction of design ice actions resulting from design ice features (i.e EL or AL level) is not obvious. No guidance on methodology is offered.</p>	<p>As above! Additional guidance on use of IM in design to be provided.</p>

Provisions of the ISO 19906 applicable to the design of stationary floaters to resist or/and avoid ice and iceberg actions in the Barents Sea have been identified and evaluated in previous Tables. Based on the gap identification and assessment, the recommended actions are condensed and summarized in Table 3. All recommendations have been categorized into several main topics.

**Table 3. Summary of recommended actions to RN02**

Subject	Recommended Action Item
<p><b>Terminology, general provisions (Sections 1 – 7)</b></p>	<ul style="list-style-type: none"> <li>▪ Update the terminology based new input provided by Barents 2020</li> </ul>
<p><b>Global static ice loads</b></p>	<ul style="list-style-type: none"> <li>▪ Additional guidance on ice actions on floaters (ref. clause 13.4.4) in the Barents Sea is needed. Guidelines shall be further developed, to become one of the key parts of the RN02 deliverables.</li> <li>▪ The target design load on the floating system shall be determined as a function of heading where heading changes have effect on ice loads (i.e. ship-shaped FPSO)</li> <li>▪ Global loading from rubble fields to be assessed</li> <li>▪ Dependence between ice rubble, compliance and damping of the structure and dynamic and hydrodynamic effects should be outlined</li> <li>▪ Actions on hull appendages should be included</li> <li>▪ A methodology of addressing pressured ice should be provided. (Maybe not achievable)</li> <li>▪ Update table A.8-2 according to ; i) dependence on ice concentration; and for floater design in general (both symmetrical and ship-shaped)</li> <li>▪ Description of FY ridge failure processes;                         <ul style="list-style-type: none"> <li>– Updated description to include downward bending 3D shapes</li> <li>– Numerical modelling (including validation) shall be presented as an important supplementary tool and recommendations provided on how it can be achieved</li> <li>– Frictional forces resulting from ice sliding along the hull shall be accounted for. This is especially the case for ship-shaped FPSOs penetrating ridges.</li> <li>– Additional guidance to be provided on surcharge and ice clearing effects for FY ridges.</li> </ul> </li> </ul>
<p><b>Global dynamic ice loads</b></p>	<ul style="list-style-type: none"> <li>▪ Global dynamic ice actions shall consider i) compliance and damping of the structure and stationkeeping system; and ii) dynamic and hydrodynamic effects</li> <li>▪ Methods of how to account for dynamic effects due to mooring compliance should be included. A factored approach by means of DAF could be utilized. Alternatively, based on quasi static maximum values, ice load ramp functions (i.e. ice ridge loads as a function of ridge penetration) may be applied</li> <li>▪ Time varying nature of ice loading shall be assessed and quantified. Further, fatigue due to variable, cyclic actions need to be assessed.</li> <li>▪ Address ice load dependence on structural response</li> <li>▪ Add a note that A.8.2.2 pertains to load models for fixed structures and that the need to be modified for use in relation to floating structures</li> <li>▪ Add a note that fully coupled analyses shall be performed for assessing the effect of ice loading on mooring, risers, umbilicals, etc.</li> <li>▪ Outline a method to enable estimation of dynamic effects of significance to fatigue in case of IM.</li> <li>▪ Additional guidance on how to assess dynamic actions and according responses</li> </ul>
<p><b>Limit force</b></p>	<ul style="list-style-type: none"> <li>▪ Ice actions arising from ice floes, i.e. managed ice, shall be calculated. (so far, no relevant methods or methodology are provided for achieving this)</li> <li>▪ Include a method for calculating limit force scenarios</li> <li>▪ Guidelines on applicability of the outlined method (including its limitations) shall be addressed</li> </ul>



Subject	Recommended Action Item
<b>Managed ice loads</b>	<ul style="list-style-type: none"> <li>▪ Documentation of reduction of design ice actions resulting from design ice features (i.e. EL or AL level) in case of IM.</li> <li>▪ The effect of ice management as well as the impact of the chosen design philosophy on the overall design shall be considered and quantified</li> <li>▪ Actions from managed ice to be determined from full-scale experience from Kulluk. General findings and learning should be made available.</li> <li>▪ Adverse effects arising from IM should be assessed (ISO requirement). A list of so-called 'adverse effects' should be provided.</li> </ul>
<b>Local ice loads</b>	<ul style="list-style-type: none"> <li>▪ Local design will in most cases have to be checked according to class requirements. Link between ISO 19906 and class documents should be established (particular while considering local loads).</li> <li>▪ Guidance to be offered on how to derive maximum local area of contact for local design ice actions.</li> <li>▪ Probabilistic model for local ice pressures to be outlined</li> <li>▪ Local ice actions should be related to the actual structural arrangement (e.g. web frames).</li> </ul>
<b>Combined ice actions</b>	<ul style="list-style-type: none"> <li>▪ Combined actions from ice, wave, wind and current, should be assessed.</li> <li>▪ Ice impact due to accelerations from waves needs to be considered and a methodology for accounting this should be outlined</li> </ul>
<b>Probabilistic ULS and ALS design</b>	<ul style="list-style-type: none"> <li>▪ Additional guidance on use of probabilistic methods in floater design, including operational procedures</li> <li>▪ Link between ISO and different ISO codes, as well as class to be assessed</li> </ul>
<b>Ice model testing</b>	<ul style="list-style-type: none"> <li>▪ List of performance requirements for model testing of floaters to be provided</li> <li>▪ Deviations between two modelling approaches should be assessed; i) towing or pushing the model through a stationary ice sheet; and ii) pushing the ice sheet towards the stationary model;</li> <li>▪ Include a note that ice model test results should be corrected according to actual obtained ice characteristics in order to make them comparable to full scale</li> <li>▪ Outline special requirements to mooring system;                         <ul style="list-style-type: none"> <li>– Moored system stiffness to be quantified in model scale and compared to prototype design;</li> <li>– Pull-out tests should be performed to assess the model scale mooring system;</li> <li>– Decay tests should be performed for deriving the natural periods of the model in open water;</li> </ul> </li> <li>▪ Ice-structure friction coefficient to be assessed in model scale;</li> <li>▪ Include a note on importance of logging structure motions and accelerations, i.e. Degrees of Freedom, for various structure types</li> <li>▪ For ice ridge characteristics in model tests, particular notice shall be given to determination of rubble parameters, such as rubble strength and density</li> </ul>
<b>Iceberg impact</b>	<ul style="list-style-type: none"> <li>▪ Iceberg impact shall be assessed in which the flexibility of the stationkeeping system should account for the dissipation of impact energy. A methodology for achieving this should be presented - an estimation approach based on energy should be provided.</li> </ul>
<b>Risk assessment of the floating system</b>	<ul style="list-style-type: none"> <li>▪ Risk assessment of the floating system shall account for failure of the station keeping system due to ice actions. A methodology to account for this should be provided.</li> </ul>
<b>Calibration of action factors for floating systems</b>	<ul style="list-style-type: none"> <li>▪ Site- and structure- (configuration) specific calibration of action factors may be necessary for future developments in the Barents Sea. The approach outlined in the reference OGP-document should be worked and presented in an understandable manner.</li> </ul>
<b>Reliability assessment of the joint system</b>	<ul style="list-style-type: none"> <li>▪ Note on how a joint system reliability analysis can be performed. List of requirements and limitations.</li> </ul>

<p><b>ISO vs. class rules</b></p>	<ul style="list-style-type: none"> <li>▪ Matrix of coverage between ISO and class rules</li> <li>▪ Interface between class and ISO to be detailed for local design of floaters</li> </ul>
<p><b>Ice data</b></p>	<ul style="list-style-type: none"> <li>▪ Provide recommendations with regard to the data extrapolation of sea ice and icebergs (from fairly limited statistics) in the Barents Sea</li> <li>▪ More specific guidance shall be provided as to how and what to do with regard to characterising the ice drift on the site (as this is important for the design)</li> <li>▪ Add a note on expert judgement for defining ice properties where these are properties which cannot be measured readily in the field</li> <li>▪ Additional guidance on handling of limited data sets. Objective shall be to define distributions (with focus on tails and cut-offs) for probabilistic load calculations and not least define deterministic parameters for deterministic load calculation checks (in particular for AL). Where no data is available, recommendations shall be provided on which parameters to use.</li> <li>▪ Additional guidance on ice concentration to be provided. Clear definition is lacking.</li> <li>▪ Additional guidance to be provided on i) iceberg shape coefficients; ii) iceberg stability; iii) adverse iceberg shapes.</li> <li>▪ Additional guidance to be provided on i) interpretation of satellite data; ii) variability of ice drift; iii) geophysical scale ice pressure.</li> </ul>
<p><b>Limit states</b></p>	<ul style="list-style-type: none"> <li>▪ Including a note addressing particulars of abnormal limit state opposed to accidental limit state (used in other standards).</li> <li>▪ A recipe of how partial load factors may be estimated for floaters shall be developed and included.</li> <li>▪ Practical use of probabilistic methods shall be outlined (for defining ALIE and ELIE), particularly for the case of limited available data to perform a fully probabilistic design.</li> </ul>
<p><b>Operational procedures</b></p>	<ul style="list-style-type: none"> <li>▪ Methods to quantify the effect of operational philosophy (IM, disconnection, etc.) in the design of a floating installation shall be outlined.</li> <li>▪ Clause 8.2.7 need to be carefully clarified to enable (or disable) incorporating operational procedures in design (and documentation of reliability level).</li> <li>▪ Additional design and operational approach can be introduced: no move-off, disconnect risers with or without IM.</li> <li>▪ Lit of requirements on environmental effects that shall be accounted for in the design.</li> <li>▪ Ice management “system” effect on ULS and ALS loads</li> <li>▪ Disconnection process and possibly additional operational safety factors</li> </ul>
<p><b>Mooring</b></p>	<ul style="list-style-type: none"> <li>▪ Include a note that it is the actual mooring line installation which ultimately defines mooring capacity (see Kulluk’s experience)</li> <li>▪ List of requirements of conditional monitoring of floaters in ice.</li> </ul>
<p><b>Stationkeeping</b></p>	<ul style="list-style-type: none"> <li>▪ Performance requirements for different types of stationkeeping systems can be developed (w or w/o account for IM and / or disconnection).</li> </ul>



## 3. BACKGROUND FOR GUIDANCE DOCUMENT

### ISO 19906:2010(E) - Normative part

#### 3 Terms and definitions

##### 3.5 Action effect

The example from ISO 19900 has been added.

##### 3.9

###### Broken ice

The present definition is incomplete and can potentially be misleading. The often used term “managed ice” should also be explained. Objective is to cover ice conditions from 10/10th pack ice to brash ice.

##### 3.38

###### Ice management

The definition corresponds to what is reported several places in the literature as “physical ice management”. It indicates that activities such as ice detection, tracking and forecasting not is a part of ice management operations. It is also unclear whether disconnect operations are included in the definition.

It is recommended to distinguish in terms and definitions between “Physical Ice Management” and “Ice Management Activities”. It could also be distinguished between “Decision Support Actions” and “Physical IM Actions”.

An unambiguous definition of ice management needs to be used when starting discussions regarding the efficiency of ice management. It is crucial to assess the efficiency of ice detection means, forecasting, disconnection operations etc. when considering efficiency of ice management. The suggested definition of ice management is as specified in Eik (2008).

##### 3.83 (new)

###### ice event

The term “ice event” may lead to different interpretations. The term appears in several places but does not seem to be specifically defined, except perhaps in Clause A.8.2.2.2.1, so a definition could be needed in the normative part of the standard. Fig.A.8-1 implies that “ice events” is short for “ice-structure interaction events.” The body of ice could be an iceberg, an ice island, an ice floe, an ice ridge or, perhaps, a sheet of level ice. The action is presumably the maximum load imposed by the ice on the structure in the course of the event. The “event” part of the term implies that it is discrete rather

than continuous, although ice-structure interaction events tend not to fall neatly into either of these two categories. An iceberg might hit a structure but the interaction process may be modelled as a continuous process of short duration with varying geometry and ice properties. A sheet of level ice might be present for months, with varying thickness and other properties. Various peak actions would arise, dependent on ice properties, and on driving forces such as wind and current causing persistent or periodic movement of varying durations.

It is concluded that the term “event” is used ambiguously in ISO 19906. Therefore a definition of “ice event” is proposed to clarify that the term is specific to the ice-structure interaction event and is not interchangeable with “ice action”. A discussion is included below under clause 7.2.

##### 3.84 (new)

###### Surcharge

Term is needed in description of ice ridges.

##### 3.85 (new)

###### ice belt

Term is needed in description of ice action on hull.

##### 3.86 (new)

###### Stationary floating structures

It is important to define “Stationary Floating Structure”. In Russian, stationary = stands on the ground. Thus the terminology and its translations into Russian may create confusion. In particular, it may be confusing which authority will regulate what ISO 19906 defines as “stationary floating structures”.

## 5 General requirements and conditions

### 5.3 Site-specific considerations

#### 5.3.2 Long-term Climate Change

Experience shows that during e.g. optimization (value engineering) exercises, such a phenomenon as a long-term climate change may be used as an argument to relax the design basis, in which case all aspects and uncertainties need thorough consideration. In application to the stationary floating structures in the Barents Sea, the long-term climate change can include the following opposite opinions: either one could argue that there will be less ice, more icebergs and more bad weather or that it was a warming part of the approx. 40-years cycle starting from 1980s and that the sea ice data collected during this period is

potentially optimistic. Therefore it is deemed prudent to clarify the possible climate change scenarios and the corresponding consequences relevant for design and operations of the stationary floating structures.

### 5.3.3 Structural Configuration

The design should consider riser protection from ice. For stationary floating structures in the Barents Sea, it is therefore suggested to address this, with focus on “ice hazard minimization” and add a few words regarding mitigating measures particularly pertaining to subsurface ice impacts. It appears that existing knowledge, experience and recommendations (including ISO 19906 and RCS) to optimize the floater design and ensure protection of risers, mooring lines and floater’s appendages against the underhull and the surface-level (in case of e.g. semi-submersibles or external turrets) ice transport are insufficient. Moreover, what concerns risers may be an interface issue and iterations to optimize e.g. hull shape, disconnection system and riser design may take place at the same time. Therefore, it is important to highlight this topic so it will be given particular attention during all design phases.

## 5.5 Design Considerations

This section is expanded to address issues already mentioned, such as:

- overall design philosophy for a stationary floating structure in ice conditions
- overall harmonization of the structural reliability and operability to avoid weak links in design of a floater system with focus on interfaces (e.g. risers)

The advantage of a stationary floating structure is that it can disconnect and move away should the environmental actions be anticipated to exceed the operational/design limits. This complicates the questions related to:

- What kind of ice actions shall one design for?
- How to define EL and AL ice actions?
- How to ensure that the operational measures will provide the required level of reliability?

One interpretation is that there is no need to design the structure against the unmodified EL and AL ice actions, but to select operational limitations such that ULS capacity of the weakest link in the system is not exceeded. Another interpretation is that EL ice action should be related to the ULS capacity of the weakest link in the system, and therefore be reduced from the unmodified value. For potentially complex systems such as disconnection system, the time factor shall also be accounted for. There is freedom to find an optimal trade-off between CAPEX (design

of hull and station-keeping system), OPEX (ice management) and operational downtime (arising from progressive ice alerts to disconnection). Design of the overall system shall be performed to satisfy the required reliability level. With respect to ice actions such approach requires determination of the stationary floating structures’ response to ice actions for all anticipated ranged of ice conditions and interaction scenarios, including for interactions with managed ice and load rise times.

## 6 Physical environmental conditions

### 6.1 General

#### 6.1.1 Physical environment requirements

When designing a stationary disconnectable floating structure supported by ice management, the physical ice environment design parameters can

- a) be more complex than what is commonly used for fixed structures or navigation in ice and
- b) vary throughout the design stages. As mentioned earlier, the response of the stationary floating structure to a large range of ice conditions shall be studied, including for altered (managed) ice conditions. Ice data collection and presentation as part of the standard “metocean package” has limitations. The “100-years ice ridge” approach alone is no longer valid. It is, therefore, necessary to extend the range of experts to be included when developing the ice scenarios to be used for design.

### 6.5 Sea ice and icebergs

#### 6.5.1 General

Shtokman field is a typical example of the challenge at hand when it is difficult to obtain data from exact location (Liferov and Metge, 2009):

- Sea ice does not form there but comes from North East or in rare occasions from South East
- Sea ice is relatively rare on the field, that makes it difficult to perform repetitive ice data collection
- Icebergs are even rarer and large variability in sizes exists. Given the remoteness of the location, it is appreciated that amount of small glacial ice formations (bergy bits & growlers) is underestimated in the existing database

For the reasons above, much, if not most, data for use in design of structures at Shtokman have been collected up to several degrees latitude north and northeast of the field.

#### 6.5.4 Ice movement

For ship-shaped stationary floating structures and for specific operations such as offloading, supply and EER, the ice drift is no longer characterized by the drift speed only and local ice movement (variable ice drift) is of significant interest.

## 7 Reliability and limit states design

There could be conflicting views and insufficient evaluation of the operational measures (in particular Ice Management) during design (with a number of consequences) thus there is a need for clarification with respect to stationary floating structures (with IM and disconnection). Experience shows that in cases where the design strategy partly incorporates operational measures such as physical ice management and disconnection, there can be a different understanding between various specialists (including ice specialists) with regard to design and documentation of the reliability of the operational measures. This is particularly so for ice management operations. Therefore it is deemed prudent to emphasize this important issue, particularly in the additions to subclauses 7.1.6 and 7.2.4.

### 7.1 Design philosophy

#### 7.1.6 Alternative design methods

Text added to take account for possible inclusion of the effects of ice management on the design.

### 7.2 Limit state design method

#### Ice Events and Ice Actions

Feedback from first users of ISO 19906:2010 is that there is a need to clarify the use of terms related to “actions” and “events” in ISO 19906:2010, such as environmental action, ice action, ice event, SLIE (service-level ice event), ELIE (extreme-level ice event) and ALIE (abnormal-level ice event). It is concluded that the acronyms SLIE, ELIE and ALIE are not necessary, and that ISO 19906 could reduce any confusion by re-phrasing its provisions to use appropriate words more consistently. However, because the Barents 2020 Guidance document is supplementing the existing ISO 19906, amendments on this issue have been minimised and the following discussion is offered in order to provide some clarification now and for future consideration by the ISO 19906 committee.

The thinking for ISO 19906 was originally based on the earthquake standard (ISO 19901-2), however the thinking in 19906 was extended to include service-level “events” and in some cases to use the term “event” interchangeably with “action” so that ELIE,

for example, is the result of a calculation. It should be remembered that in ISO terminology “action” means “load”; “load” is not normally considered to be interchangeable with “event”. This has caused some confusion for the users of the standard who are more familiar with the normal meanings of these terms.

The need for using the terms ELE and ALE in ISO 19901-2 arises due to these events being defined not by annual probabilities and not as values of actions, but by a site-specific hazard curve of spectral accelerations, and with special provisions given in ISO 19901-2 for assessing action effects, resistance and response. In ISO 19906 an ice action is one of several environmental actions (waves, wind, etc.) for which values are to be calculated at pre-defined annual probabilities (EL and AL levels) before being applied to the structure in order to calculate action effects. There is not the same need to use acronyms ELIE, ALIE and, especially, SLIE for ice. Elimination of these acronyms, and instead to use the terms “ice action” and “ice event” in the correct context will help to clarify the meanings of the provisions of ISO 19906 without causing any loss of precision.

The following are some examples of the use of terms related to EL ice actions and ELIE in ISO 19906 where the meaning and consistency is not always clear:

- The ULS design condition for ice shall be the extreme-level ice event (ELIE). – 7.2.1.2
- The representative value for actions arising from extreme-level ice events (ELIE) shall be determined ... – 7.2.2.3
- Action combinations for each environmental action shall be derived by considering each EL ... representative value of the action, in turn, as the principal action – 7.2.3
- The principal and companion EL actions for ice are extreme-level ice events (ELIE). – 7.2.3
- The design shall be carried out for extreme-level ice events (ELIE) ... as defined in 7.2.2.3. – 8.2.2
- Representative values for ice actions shall be calculated using probabilistic methods or deterministic methods for ELIE. – 8.2.2
- The ELIE ... shall be determined for each relevant ice loading scenario – 8.2.3

In some cases, the use of ELIE is ambiguous and can be interpreted either way without significant consequences. However, the second bullet above uses ELIE as an event which causes an action, but the fourth and the last bullets above suggest that the ELIE is the value of the action resulting from calculation. For example, the fourth bullet seems

intended to mean the same as the second bullet, and the meaning of the last bullet is as follows:

- The EL ice action ... shall be determined for each relevant ice event scenario – 8.2.3 modified

### Types of “Event”

The overall approach of ISO 19906:2010 is to not distinguish between discrete and persistent scenarios. If the action is governed by limiting kinetic energy (e.g. iceberg collision), a single value at the end of the interaction usually governs, corresponding to the maximum area developed. This can be treated as a point in time, but other “discrete” processes, such as ridge interactions, can have multiple values of the action so that “transient” is a better description, i.e. continuous process of short duration. The same applies to ice island interactions which will likely result in full envelopment of the structure (and high loads). “Continuous” stochastic processes are modeled approximately, but in reality they have beginnings and ends e.g. resulting from periodic ice movements.

Ice events of whatever duration give rise to actions for which the values depend on various parameters some of which will be characterized probabilistically. Therefore “ice event” is defined in the Guidance document (report Part 4) as an ice-structure interaction event for which ice actions are calculated. This concept of an “event” includes both discrete events and an extreme or abnormal peak or maximum within a continuous (stochastic) process arising from persistent ice conditions with no clear evidence of individual or discrete features. This is not clearly stated in ISO 19906. Also, more guidance on how to model persistent ice conditions as discrete ice features has been provided in the Guidance document (report Part 4, see the new subclause A.8.2.2.6).

Extreme-level (EL) ice actions and abnormal-level (AL) ice actions are required by ISO 19906 to be calculated for both persistent ice conditions such as level ice, and for discrete ice events such as iceberg impact, except that EL ice actions are not applicable for ice events having an annual probability of occurrence of less than  $10^{-2}$  (these are obviously “discrete” events).

## 7.2.2 Actions

### 7.2.2.1 General

For stationary floating structures it may be kind of “chicken and egg” situation to define ULS/ALS design conditions for a system from unmodified EL and AL ice actions or the opposite (for disconnectable systems, to modify the EL and AL ice actions to take account of the operational procedures). The following simplified example is given:

- **Alternative 1:** Design mooring/disconnection system based on EL (and AL) ice actions that are not modified by consideration of the operational procedures
- **Alternative 2:** Choose allowable ice conditions (before disconnection) from the pre-defined ULS capacity of the mooring/disconnection system. The probability of reaching the unmodified EL and AL ice actions is reduced by consideration of the operational procedures, therefore the magnitude of the “ $10^{-2}$ ” ice action, which is the definition of the extreme-level (EL), is reduced.

E.g. the ISO 19906 provision “*ULS design condition for ice shall be the extreme-level ice event (ELIE)*” is over-generalized for disconnectable stationary floating structures. It shall be emphasized that when designing disconnectable stationary floating structures, special attention shall be paid to capacity (strength, stiffness and time related) of all components having potential to be a weak link in the system. The addition is based on experience from the Shtokman Project.

## 8 Action and action effects

### 8.2 Ice actions

#### 8.2.2 Representative value of ice actions

As already mentioned under Clause 5.5, there is no need to design the disconnectable stationary floating structure against unmodified EL and AL ice actions. Herein it is emphasized that ice management alone can not be used as an argument not to design for unmodified EL and AL ice actions. The weakest link in the system (it can be e.g. stationkeeping system capacity, allowable offset/motions, disconnection capacity (including time aspect), riser capacity against under-hull ice transport, etc.) will eventually determine the tolerable ice conditions and interaction scenarios. The design actions for ULS and ALS for the weakest link may be reduced from the unmodified EL and AL ice actions.

Fully probabilistic methods in determining representative ice actions can be used for locations where ice conditions can be reliably described using statistical methods and where structure response to actions is linear, or can be assumed to be such. Experience (from the Shtokman project) shows that probabilistic methods can to some extent be applied to disconnectable stationary floating structures in the Barents Sea, but there also exist limitations with respect to their traditional application. Semi-probabilistic methods are much better adapted

for assessing the floater's response to variable ice interactions, including those from managed ice. Deterministic methods have proven to be useful in mapping the response of the structure to pre-defined ice interactions and evaluating the "worst conceivable" interactions as well as particular ice scenarios in managed ice environment.

### 8.2.3 Ice actions scenarios

As already mentioned under Clauses 5.5, 7.2.2.1 and 8.2, there is no need to design the disconnectable stationary floating structure against unmodified EL and AL ice actions if operational procedures can be developed and substantiated and the anticipated reliability level can be achieved.

The Clause says that "Design ice actions shall reflect

- ...
- The structural configuration and the relevant operational scenarios, including.... physical ice management..."

without specifying neither how to reflect physical ice management nor how the effects of physical ice management may be included and documented. Examples of how this may be done can be found in the Informative part, Clause A.17.2.1.

### 8.2.6 Dynamic ice actions

Moored stationary floating structures are very compliant structures, and time-varying ice actions can cause dynamic response. Depending on the system properties and the nature of ice actions, both slow-varying action and high-frequency (around slow varying mean) shall be accounted for in design of the stationkeeping system.

Experience (from the Shtokman Project) with moored floating structures subjected to ice actions shows that dynamic response to the time-varying actions may exceed the one to the static (or quasi-static) actions. Design of the mooring system shall account for the possible dynamic amplification for the full range of the anticipated ice interaction scenarios. This can be achieved by performing model tests with adequately scaled dynamic properties of the system as well as by analytical and numerical modeling.

### 8.2.7 Operational procedures to reduce ice actions

The design of stationary floating structures may include operational procedures to reduce ice actions as long as it can be shown that the anticipated reliability level can be achieved. Two potential operational procedures for floating structures are; i) ice management and ii) disconnection.

ISO 19906 Clause 8.2.7 states that "Ice action calculations for managed ice shall be performed when appropriate". This means that the efficiency and reliability of IM operation and as well as the reliability of the disconnection system shall be evaluated, alerting and decision making processes shall be designed (and followed) properly etc. There is guidance or reference given on how to do it.

Experience (from the Shtokman Project) with designing moored disconnectable floating structures supported by IM shows that demonstrating a reduction in design actions for EL and AL ice events through changes to the magnitude and frequency of ice actions for all applicable scenarios is not straightforward as there are a number of uncertainties inherent in the input data and modeling techniques. In particular, when ice actions corresponding to low exceedance probability are concerned, the uncertainty tends to increase.

## 13 Floating structures

### 13.2 General design methodology

#### 13.2.2 Design and operational approaches

Reference to clause 17 should be made, otherwise the link between design and description of operational approaches is weak. It is also possible to introduce additional design and operational approaches.

#### 13.3 Environment

- a. FPSO is not related to weather / ice vaning (it may well be axi-symmetrical)
- b. It is not appropriate to introduce the possible benefits of ice management in the present context

### 13.4 Actions

#### 13.4.2 Ice scenarios

Pressured ice conditions to be assessed. The present text is unclear on how to assess and quantify them in the middle of the Barents Sea.

- Quantification of the pressured ice conditions is not obvious, in particular in the middle of the Barents Sea
- Ice scenarios involving altered ice environment (managed ice) are not mentioned here.

#### 13.4.3 Interaction factors

"Appropriately scaled" is a vague definition that opens for subjective opinions. E.g. the same "scaling" may be appropriate for some interaction scenarios and not appropriate for the others. Another typical issue related to using results from the ice basin model tests is interpretation and further use of the results in design.



Additional interaction factors should be considered (in addition to the ones mentioned in 8.2.4). Particularly ice management and other operational criteria need to be assessed in order to identify the correct nature of interaction.

In the absence of existing numerical and/or analytical design models, ice interaction on the floating system may be assessed by means of physical scale models.

#### 13.4.4 Determination of ice actions

Ice action shall be assessed in combination with the structural response. Ice load magnitudes may be reduced due to ice management. The present text refers to A.8.2 for applicable load models. No further guidance is offered. It would be useful to address how ice bubblers can reduce EL and AL ice actions

For stationary floating structures, the question is often not to determine “ice load” but the floater’s response. For simple shape stationary floating structures (axi-symmetrical with vertical sides) one may pre-determine the load (as quasi-static or dynamic action) and apply it to a dynamic system (station-keeping floater). The possible effect of the floater’s response on the action can be included. For complex shape stationary floating structures and complex ice interactions, pre-determination of ice actions is not feasible unless for simplified interactions (e.g. unidirectional such as head-on for a ship-shape floater). Furthermore, for stationary floating structures the question is often not in determination of EL or whatever level ice action, but in e.g. assessing response to a wide range of ice actions, including those resulting from managed ice. The present text also makes reference to A.8.2 for applicable load models, but those may only be applied to a limited range of structure types and interaction scenarios. It is neither considered feasible to consider ice bubblers as a mean to reduce EL and AL ice actions.

#### 13.4.6 Action variations

The time-varying nature of ice loading shall be assessed. Is not clear what is meant by the present text. Performing fully coupled analysis of local ice – structure interaction is perhaps beyond the scope of what is achievable today. Otherwise clear recommendation is provided.

It is unclear what system the present text refers to when it says “The effect of ice management on the behaviour of the system shall be taken into account”.

### 13.5 Hull integrity

#### 13.5.5 Condition monitoring

For supporting ice management, for structural integrity and for data acquisition purposes, appropriate ice and physical environmental conditions shall be monitored and documented on a regular basis. A list of requirements of conditional monitoring of stationary floating structures in ice has been added.

### 13.7 Stationkeeping

#### 13.7.1 General

For floating structures with disconnection possibilities it may be permissible to define the maximum allowable actions.

#### 13.7.2 Design of the stationkeeping system

The present text contains incomplete normative recommendations. It is necessary to include assessment of the floater’s response and capacity of the mooring line system and a warning not to forget that hull may represent a weak link.

#### 13.7.3.4 Design modes for disconnection

The present text is incomplete.

#### 13.7.3.5 Reconnection

The present text is incomplete.

## 16 Other ice engineering topics

### 16.5 Ice tank modelling

#### 16.5.1 General

Ice tank tests can be used to assess the ice load levels in complex situations where the ice loading cannot readily be derived by ‘other methods’ (implicitly meaning the models provided by this standard). The clause has been expanded specifically for model testing of floater.

Ice transport along and around floating installations is now explicitly mentioned. It is important to predict the broken ice behaviour around a moored floating structure correctly in order to be able to apply analytical formulae as suggested by ISO.

#### 16.5.2 Scaling

Important details were missing. The update is based on project experience (the Shtokman Project).

#### 16.5.4 Model ice properties

The ice scaling should be targeted to achieving full scale properties in relation to the failure mode and ice interaction investigated and the text has been expanded to include this.



Scaling of ridges, rubble, level ice, at the same time may pose problems in an ice tank. Therefore, scaling should be targeted to the actual ice-interaction scenario.

## **17 Ice management**

### **17.4 Ice management planning and operations**

#### **17.4.2 Ice events, threat evaluation and decision making**

There is no unambiguous definition of ice season in the present text, thus a need for either a definition or for a requirement that is independent of the definition of ice season. The amendment has chosen the latter option.

The monitoring should be performed throughout the year for permanent operations and prior to + during operations of limited duration. The monitoring activities and frequency between observations should however be allowed to vary with the seasons.

Both with respect to iceberg and sea ice occurrence there are usually large interannual variations. Even in periods outside the “ice season” it will be wise to perform some monitoring activities. By doing this, there is a reduced risk for unforeseen events and a better basis for deciding ice management support during the ice season. For instance, satellite monitoring of some dynamic glaciers may give an early warning regarding production of ice islands.

# ANNEX A (INFORMATIVE)

## ADDITIONAL INFORMATION AND GUIDANCE

### A.6 Physical environmental conditions

#### A.6.1 General

##### A.6.1.1 Physical environment requirements

The proposal for additional text to 6.1.1 addresses inter-annual variability. The proposal for new text to A.6.1.1 gives a bit more details.

As ice observations are made with a variety of objectives and scope it may be prudent to remind of the necessity for good documentation of the measurement program.

#### A.6.5.2 Ice types

##### A.6.5.2.3 Icebergs

As stated in the present text the most commonly used terminology for iceberg shapes is not well suited for engineering purposes. It is generally based on the above-water shape and says little if anything about the underwater shape. Adverse iceberg shapes (ice foots or caps) shall be mentioned if believed to exist in the Barents Sea. Protrusions have been shown to exist both on icebergs (2 out of 3, with extensions of up to 40m) and bergy bits (3 of 3) in the Barents Sea [Spring, W. 1994. Ice Data Acquisition Summary Report. Mobil Research and Development Corporation. Dallas E&P Engineering, Dallas Texas].

Some concerns are expressed by McKenna (2004):

*“Iceberg shape data are required to assess risk for a variety of installations off Canada’s east coast.*

*Requirements include:*

- determining the frequency of contact with fixed platforms, floating platforms and seabed installations;*
- determining contact location;*
- estimating the risk to topsides of production facilities;*
- calculating the inertia of the iceberg relating to the point of impact; and*
- the development of the ice contact area on impact.*

*Although many field initiatives have been undertaken to document iceberg geometry, some inherent deficiencies become apparent when these data are used for the design of offshore installations. The deficiencies include:*

- gaps in the data due to difficulties with measurement near the water surface;*
- a virtual absence of data from the base of the keels; and many circumstances when only partial profile data are available.”*

There is, therefore, a need characterize iceberg shape in a way that ties the above and below water portions of the iceberg in a consistent manner, satisfies hydrostatic considerations, represents measured relationships between waterline length, waterline width, height, draft and mass, and can be used for probabilistic simulations. Such an approach is suggested in McKenna (2004). The approach involves the characterization of three dimensional iceberg shape in terms of the overall average shape and a random component based on the concepts of spatial statistics. The approach opens for a predictive capability that provides for the generation of a large number of complete iceberg shapes, each with the statistical attributes of measured data.

Knowledge of an iceberg’s stability characteristics is very important when attempting to perform towing operations. Without this knowledge, improper tow force, speed and angle can all have a detrimental effect on the safe and efficient removal of an iceberg. C-CORE (2004) elaborates more on this. Should attempts to deflect the iceberg from collision course fail, the iceberg may get entangled in the mooring lines. If this leads to an unstable iceberg additional adverse effects may occur.

#### A.6.5.4 Ice movement

##### A.6.5.4.1 Processes

Variability in ice drift is important for floating structures and should be characterized and quantified. Nesterov et al. (2009) and Nesterov (2011) give some guidance that is suggested to be referred.

### A.7 Reliability and limit state design

#### A.7.1 Design philosophy

##### A.7.2 Limit state design method

###### A.7.2.2 Actions

The present text is unclear on what is considered “sufficient” or “insufficient” in the Barents Sea context. Assessing quality of data and benchmarking with similar regions shall be described.

Given the shortcomings of the ice data sets it seems prudent to add text related to the uncertainties in estimation of extreme ice events to the ISO 19906 International Standard and to recommend a set of statistical distributions with parameters that have been used before. Additional details follows below.

In the case of few data it will be useful to get a measure for the uncertainty in the extreme estimates. The statistical uncertainty can be addressed by e.g. a parametric bootstrapping technique, the simulation procedure that can go as follows:

- a. A set of parameter values is determined by fitting the distribution to the set of N observation by a selected fitting method.
- b. These parameter values are taken as the true parent parameter values, and n samples of N outcomes of the parent distribution are generated.
- c. For each sample, new parameter sets are estimated by the fitting method
- d. The statistics of the distribution parameters, e.g. the 4 lower moments and correlation coefficients, are estimated from the n realizations. Alternatively, the statistics of the pertinent estimator for the extreme event is estimated directly from the n realizations.

Note that it is implicitly assumed that the original realization is representative for the variability of the quantity, i.e. that its salient features are reflected. The simulation procedure gives an adequate measure of the statistical uncertainty only if this assumption is fulfilled.

Alternatively, one can estimate the coefficient of variation, CoV, which is the ratio of the standard deviation to the mean, of the probability that an event will happen, e.g. the  $10^{-2}$  event.

Let the  $P_E$  be the probability of the event. Then

$$\text{CoV}[P_{E,\text{est}}] = \frac{\sqrt{\text{Var}[P_{E,\text{est}}]}}{\sqrt{(\text{Av}[P_{E,\text{est}}])^2}} = \sqrt{\frac{(1-P_E)}{NP_E}}$$

For  $P_E=10^{-2}$  and  $N=100$  the CoV is for all practical purposes equal to 1, i.e. the standard deviation equals the mean.

The equation above can be used to estimate the number of observations that is required to obtain a limited uncertainty in the probability of the event, i.e.

$$N = \left( \frac{1}{\text{CoV}[P_{E,\text{est}}]} \right)^2 \times \frac{(1-P_E)}{P_E}$$

or, for small  $P_E$ ,

$$N \approx 10^2 \times P_E^{-1}$$

Hence, for a target event probability of  $10^{-2}$ , the required number of sample points is  $N = 10^4$ ; for a target event probability of  $10^{-4}$ , the required number is  $N = 10^6$ .

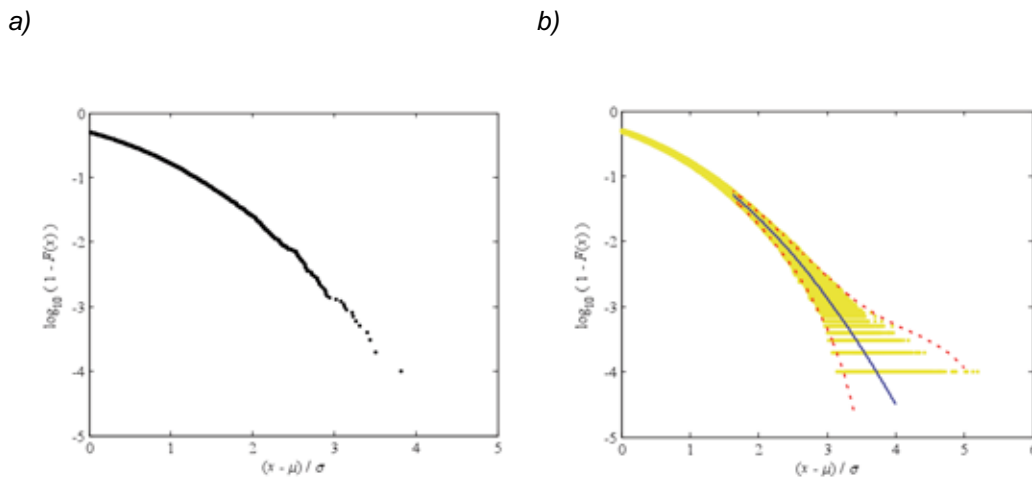


Fig. 3.1.

- a) ‘Experimentally’ obtained estimates of the underlying cumulative distribution function  $F_x(x)$  evaluated at discrete values of  $x$ . In this case the underlying distribution is that of a Gaussian random variable, and the sample contains  $N = 10,000$  sample points.
- b) The underlying distribution based on the distribution in a) (black dotted curve) and the results from 1000 repeated experiments (yellow horizontal bars) for the estimated values of  $F_x(x)$ . Notice increasingly larger spread in estimated values of the variable for low probabilities.

#### A.7.2.4 Combinations of actions and partial action factors

The overall objective of the Barents 2020 Project is to secure that all operations in connection with oil and gas activities in the Barents Sea, both in Russian and Norwegian sectors, are conducted with the same safety level as in the North Sea.

It is not clear from the stated objective if “safety” means “risk” or just “probability of failure” (reliability). Risk is usually defined to as a combination of both probability and consequence. The consequences of a given accidents or failure in the Barents Sea is considered more severe than it would be in the North Sea. This is valid both for the environment and for humans. If safety is interpreted as risk, keeping the same risk level means that the probability of failure must be lower for operations in the Barents Sea than in the North Sea, as the consequences are more severe. Thus, the exact definition of safety will be important.

The target reliability level in ISO 19906 is consistent with the other standards in the ISO 19900 series, which are valid worldwide. One may therefore be faced with a decision on whether to recommend higher target reliability (lower probability of failure) than that given in ISO 19906 or to keep them as recommended.

Safety is understood as safety for humans, environment and assets. Many factors contribute to safety, including, but not limited to:

- The structure itself
- Process and other equipment on the topside
- Design of the topside
- Well design and integrity
- Mitigation measures such as evacuation, rescue, safe haven and oil spill contingency plans
- Operational procedures

Due to the presence of sea ice and icebergs, structures in the Barents Sea are exposed to additional actions and action effects compared to structures in the North Sea. Thus, the probability of structural failure may be slightly higher in the Barents Sea than in the North Sea. However, all of the other factors can be worked on to reduce either the probability of failure or the consequences, be it for personnel, the environment and assets, in case of accidents. This can mitigate a higher probability of structural failure by itself. The relative contributions of the various factors to the overall risk are not known, but it will be unbalanced to let one factor (the structure) alone make the whole contribution necessary to obtain the same risk level as in the North Sea.

It therefore seems reasonable to use the same reliability level for offshore structures in the Barents Sea as proposed by ISO 19906, Clause A.7.2.4. For stationary floating structures, environmental action factors apply according to ISO19906.

It is recommended that project-specific calibration of action factors (Table 7-4) is carried out for the design of stationary floating structures. No approach, other than reference to A.7-2 (*Calibration of action factors for ISO 19906 Arctic offshore structures, OGP Report 422, International Association of Oil and Gas Producers, 2010*), is provided (additionally some coverage in A.8.2.2.2). Regarding stationary floating structures, partial ice action factors as presently provided in ISO 19906 have been calibrated based on load distributions for head-on interactions with “fixed” units, not taking into account the distinctive characteristics of floating structures in ice.

## A.8 Actions and action effects

### A.8.2 Ice actions

#### A.8.2.2 Representative values of ice actions

##### A.8.2.2.6 Characterization of the sea ice cover (new subclause insertion)

As presently written, encounter frequency (Clause A.8.2.2.5) deals exclusively with discrete ice features. In some circumstances, it can be necessary to provide representative ice actions for persistent ice cover, remembering also that although the cover may be “continuous” the actions may not be if caused by intermittent movement of the ice. Persistent ice cover can be treated either in continuous or in discrete representations, and guidance is provided for both circumstances. In this connection, certain caution should be taken to distinguish between the two representations. For instance, one should adjust Equations (A.8-19) and (A.8-20) for the discrete representation when applying them to the calculation of global ice action component due to the consolidated part of a ridge for impact events, while it is necessary to implement Equations (A.8-19) and (A.8-20) for the continuous representation when calculating the representative value of global ice action due to level ice with reference to the whole year. The two representations differ with respect to the probability distributions describing the random ice thickness and the random strength parameter. A new subclause A.8.2.2.6 is recommended for insertion immediately following clause A.8.2.2.5, thereby incrementing the numbering of existing clauses A.8.2.2.6 and higher.

#### A.8.2.4 Global ice actions

##### A.8.2.4.4 Sloping structures

###### A.8.2.4.4.1 Description of the failure process

For floating structures in ice the downward bending shape may be the governing design. For ship-shaped stationary floating structures the bow area may be perceived as a downward bending cone. For symmetrical floating structures a downward cone is frequently the design of choice for the water plane area. It is important to outline the peculiarities involved with the failure processes on these shapes.

#### A.8.2.4.4.4 Effect of ice rubble

It seems implicit in the present text that long structures, such as ship-shaped, are not considered.

We know from ice model tests that the effect of ice rubble cannot be disregarded. Ice rubble plays an important role for the total global load. The importance of underwater ice rubble should clearly be identified in the text.

#### A.8.2.4.5 Ice rubble and ridges

##### A.8.2.4.5.1 First-year ridges

The rubble ice load formulation outlined in ISO does not take the effect of downward sloping structures into account.

The ice failure process on a sloping structure will be different from that on a flat wall. Firstly the consolidated layer which is failing in bending presses the rubble formation downwards. Secondly, as we assume a granular failure model of the rubble, a failure plane will be introduced which results in ice rubble to be displaced downwards. This process is termed surcharge and is actually part of the original formulation developed by Dolgoplov et al. (1975). Surcharge, hence, provides an additional measure for the inability of ice rubble to clear around the structure until a surcharge is built up.

#### A.8.2.8 Physical and mechanical properties of ice

##### A.8.2.8.10 Density

Very limited possibilities exist to quantify the ridge morphology in full scale and this applies in particular to the full scale density. Though, it should be noted that the density is one of the most important parameters as it influences the ice load heavily. Deviation from density between full scale and model scale may lead to fundamental wrong conclusion/results about the actual ice load.

Experience shows that modelling of the ice density and the rubble density in particular has a strong effect on the ice load level. It is important to highlight this.

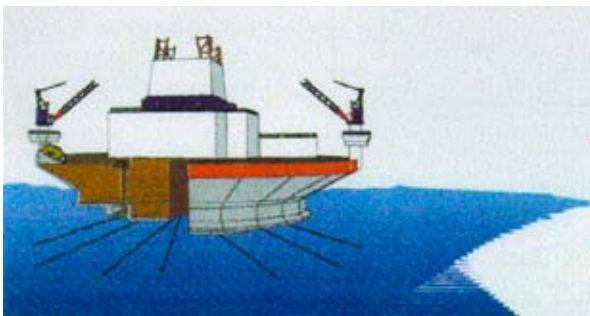
## A.13 Floating structures

### A.13.4 Actions

#### A.13.4.4 Determination of ice actions

The current ISO 19906 is considered to be rather limited in describing ice-structure interaction for floating offshore structures. The findings and learnings from full scale experience with the Kulluk drilling vessel in a variety of ice conditions should provide helpful insights.

The vast majority of experience in the Arctic with moored structures has been in the Beaufort Sea. From the mid 1970's till the early 1990's, ice reinforced drillships and a conical drilling unit named the Kulluk were used here for exploratory drilling in intermediate to deeper waters (20m-80m). The Kulluk was purpose built to extend the drilling season. As a result, the Kulluk operated in a much wider and more difficult range of ice conditions than the drillships.





Extensive ice and performance monitoring programs were used to provide real time support to the stationkeeping of the Kulluk. Along with this, a large full scale data set was obtained on the mooring loads and the motions of the vessel in different ice conditions. Additionally, records were made on the nature of the ice interactions and the (observed) ice conditions, the mooring line arrangement at each location and details of the different ice management techniques used and its effectiveness. This makes the Kulluk the primary source of full scale data on moored vessels stationkeeping in moving sea ice. In March 1999, a study was presented by B. Wright & Associates Ltd (PERD/CHC Report 26-200), that evaluated the full scale load dataset obtained from the Kulluk.

General findings and learnings from the Kulluk drilling vessel are:

- The Kulluk has shown that a downward conical hull provides relatively good icebreaking and ice clearance capabilities and it minimizes downtime compared to ship-shaped structures.
- Both managed and unmanaged level ice loads were found to increase almost linearly with the ice thickness for an ice thickness up to 1 meter. This is the case under both good clearing and tight ice conditions.
- No overall dependency of level ice loads on the ice drift velocity was observed, both in managed and unmanaged ice.
- Level ice loads in managed ice were found to be about five times lower than in unmanaged ice.
- Managed ice loads were found to increase with the ice concentration.
- No significant influence of the managed ice fragment size on the ice load level was found.
- Level ice loads in tight managed ice conditions with poor clearance were found to be higher than in managed ice conditions with good clearance, however still lower than in unmanaged ice.

Additional information on a floater's response to ice actions can be found in Bruun et al. (2009), Murray et al. (2009), Bonnemaire et al. (2009) and Bonnemaire et al. (2011b).

### **A.13.5 Hull integrity**

#### **A.13.5.5 Condition monitoring**

Extensive ice and performance monitoring programs were used with the Kulluk to provide real time support to the stationkeeping of the vessel. Along with this, a large full scale data set was obtained on the mooring loads and the motions of the vessel in different ice conditions. Additionally, records were made on the nature of the ice interactions and the (observed) ice conditions, the mooring line arrangement at each location and details of the different ice management techniques used and its effectiveness. Ice conditions need to be monitored in real time to detect possible extreme loads that require ice management measures.

Details about ice conditions that were present in the vicinity of the Kulluk during stationkeeping operations were documented onboard by environmental observers on an hourly basis including: ice concentration, ice thickness, floe size, ridge frequency, ridge height and ice drift speed. These observations were visual estimates in accordance with the WMO 2004 and MANICE (Canadian Ice Service, 2005) guidelines, with the exception of the ice drift speed, which was obtained from sequential radar fixes on specific features.

A performance monitoring system was installed onboard the Kulluk that provided real time information on the tension in each of the mooring lines, offsets from the wellhead and the vessel's rotational (roll, pitch, yaw) and heave motions, at a frequency of 1Hz. This information, together with global ice loads that were vectorially calculated from the individual mooring line tensions, were displayed onboard in real time and recorded for analysis. This provided very detailed information about the magnitude and nature of the loads that the Kulluk experienced, and its response to these loads. The global loads that were obtained this way are considered to be accurate to about 15%.

Additional information on hull monitoring can found in Krupina et al. (2009) and Iyerusalimskiy et al. (2011).

## **A.16 Other ice engineering topics**

### **A.16.5 Ice tank modelling**

#### **A.16.5.1 General**

Ice tank tests may be used to assess the ice load levels in complex situations where the ice loading cannot readily be derived by 'other methods' (implicitly meaning the models provided by this standard). The clause needs to be updated specifically for model testing of floater, as a role of ice tank modelling for the floater design is not indicated. In ISO 19906 there are insufficient recommendations on determination of global ice loads on stationary floating structures. Ice model test is necessary tool for study of ice action on such structures. It

is expedient to apply developed numerical models for the stationary floating structures design to evaluate ice action on them. In this case one more task of the ice model tests is arisen: the model tests results can be used for calibration and verification of numerical model.

No stationary floating structures types are identified. There are three basic types of stationary floating structures that can be used in Barents sea: axisymmetric structures (cones), multi-legged structures (semi-submersible platforms), ship-shape turret units, and these have been added to the list. Each of them has specific features of behaviour on ice conditions that should be taken into account when the ice model tests are planned.

Ice tank tests may be used to assess the ice load levels in complex situations where the ice loading cannot readily be derived by 'other methods' (implicitly meaning the models provided by this standard). No particular guidance offered for testing of floating systems in ice tanks.

Text has been added as guidance to the more practical aspects of ice tank model tests, based on specifications that were used by SDAG for the tests of the Shtokman FPSO.

When testing in ice model basins it is common to adhere to and satisfy standard HSE requirements. Minimizing risks for accidents should be accomplished by performing safe job analysis, which must include, but not necessarily be limited to:

- Avoidance of slippery surfaces
- Ensuring adequate access around the basin
- Availability of sufficient rescue equipment in case of fall
- Availability of first aid kits in case of other type of accidents

#### **A.16.5.2 Scaling**

Text has been added as guidance to the more practical aspects of ice tank model tests, based on specifications that were used by SDAG for the tests of the Shtokman FP.

#### **A.16.5.3 Test methods**

##### **A.16.5.3.2 Testing technique**

No particular guidance is offered in the present text of ISO 19906 for testing of floating systems in ice tanks. A basic feature of stationary floating structures is that they have a mooring system, and parameters of this system influence on the floater's behaviour under ice action. As opposed to fixed structures the stationary floating structures' models have 6 DOF, and it is necessary to record linear and angular displacements of the model during the ice tests. ISO 19906 does not give any recommendations on simulation of the mooring system of the stationary floating structures, and no peculiarities of performing ice model tests of such structures have been indicated.

Hydrodynamic effects associated with the testing techniques should explicitly be mentioned.

The objective of ice model testing is often to quantify the global ice load on a structure. If the model is pushed through a stationary ice sheet the measured force also contains a contribution from the hydrodynamic effect, i.e. an equivalent current force, on the structure. Ice load measurements should be corrected for this effect.

Requirements for instrumentation and equipment should be specified.

Tolerances in model fabrication should be specified for important parameters like geometrical characteristics. Added mass, inertia characteristics, metacentric height and global restoring force and momentum are parameters that should be included in the acceptable tolerance list.

Test matrices should be defined. These should include combinations of the test mode (e.g. moored or fixed), ice conditions (e.g. level, rubble or ridge), ice drift speed and curvature, ice approaching angle, etc.

Requirements to recording, analysis and reporting should be specified, e.g. in form of a matrix showing what parameters to sample (e.g. system forces, pitch, roll, yaw, mooring line forces), the sampling frequency and any explanatory comments.

The reporting should include complete test set-up descriptions, so that it is possible to reproduce the tests, including but not limited to, necessary information on the physical model design and configuration, including natural frequencies of the system, model ice properties and conditions, sensor locations, reference system, error or noise sources and mooring characteristics.

Important tools of the ice model tests are surface and underwater video records. It is recommended to synchronize video records and time histories of measured parameters (components of global ice action, kinematical parameters of the model motion, the mooring line tensions). Based on this information relationship between the physical processes and quantitative assessments of the measured parameters can be obtained.

#### **A.16.5.3.3 Ice conditions**

Consistent descriptions of both ice ridges and managed ice in model scale tests together with the most important associated parameters seem to be missing in the informative part of the present text. It is considered to be of value for the interested reader to amend the text with the most important parameters that should be controlled when attempting model tests with ridges and managed ice. For offshore structures this kind of testing represents the main parts of all model tests performed.

#### **A.16.5.4 Model ice properties**

##### **A.16.5.4.1 General**

Not all mechanical properties of ice ridges are or can be investigated before or after the test. However, ridge interaction often gives the maximum global load on a structure. It is furthermore crucial to state that the scaling of both surrounding level ice and ice ridge at the same time is difficult to obtain.

It is generally difficult to obtain all necessary mechanical properties from the ice ridge. Destructive testing is often necessary. There is no recommended or formally accepted testing procedure for ice ridge properties which results in large uncertainties about these properties. It is important to highlight the uncertainty potentials and measure to cope with them.

## **A.17 Ice management**

### **A.17.1 General**

Ice management was a very important factor in improving the Kulluk's stationkeeping performance in ice. The vessel mainly worked in managed ice, which means that the incoming ice cover has already been broken into smaller fragments by supporting icebreakers. These smaller blocks usually cleared around the Kulluk without breaking again. Besides that, the vessel had no propulsion, so it had to be towed when moving from one location to another. Therefore, the Kulluk was supported by two to four CAC 2 icebreakers during its Beaufort Sea operations.

It was found that the load levels in managed were reduced by up to 80%. Therefore it can be concluded that a structure significantly benefits from ice management in terms of load reductions. However, there are a few side effects of IM that should be considered during planning and some have been added to A.17.1.

### **A.17.2 Ice management system**

#### **A.17.2.1 Overall reliability and design service life**

It should be noted that physical ice management alone may not justify reduction of the design action. In particular, if the physical ice management is unable to handle ice conditions that contribute to the action effects with frequency  $10^{-2}$  and  $10^{-4}$  per year, by e.g. towing icebergs or breaking large ridges, the abnormal-level action effects will still occur with the same probability and the extreme-level actions will remain unchanged.

This can be illustrated by Figure 3.2 (adopted and modified from Eik, 2011), which shows the cumulative distributions of action effects without ice management and with five different cases of physical ice management, using a Peak over Threshold (POT) approach. It is seen that physical ice management reduces action effects up to around the  $10^{-3}$  probability level. However, the effects corresponding to an abnormal event (an annual exceedance probability of  $10^{-4}$ ) were not reduced unless both a multiyear traditional icebreaker and a multiyear azimuth icebreaker acted together or the structure was disconnected. It may seem as the icebreakers contribute to more

extreme ice conditions. Due to this, the distributions fitted to data from the icebreaker scenarios are only valid up to the probability level where they cross the initial distribution (i.e., no management).

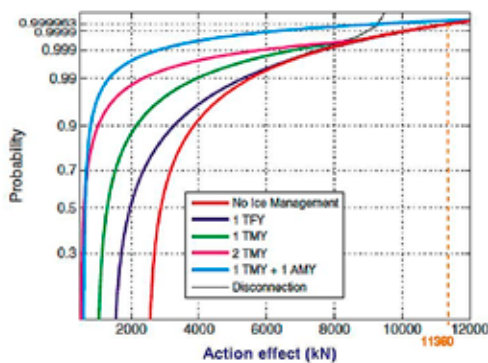


Figure 3.2. Illustration of cumulative distribution function for action effects with different ice-management scenarios. The level corresponding to an annual exceedance probability of  $10^{-4}$  is indicated. Modified from Eik (2011).

TFY= Traditional First-Year Icebreaker. (examples: Vidar Viking, Terry Fox, B $\approx$ 20m–P $\approx$ 15MW).

TMY= Traditional Multiyear Icebreaker. (examples: Krasin, USCGC Healy, B $\approx$ 25m–P $\approx$ 25MW).

AMY= Azimuth Multi-Year Icebreaker. (examples: Fennica, Yuri Topchev).

To quantitatively demonstrate that the intended level of IM success is achieved is more or less the same as to determine the level of system reliability (requirement in Clause 17.2.1). As stated above it must be clear how to assess the reliability of the Ice management.

More information may be found in Fuglem, (1997) and Eik and Gudmestad (2010) in addition to Eik (2011).

#### A.17.2.2 Ice management to reduce ice actions

Given the lack guidance on how to estimate ice actions from managed ice, it seems prudent to add some references.

#### A.17.2.3 Characterization of ice management performance

There is no requirement in the present text for systematic documentation of future IM activities. ISO 19906 states in this clause that the actual full scale experience of IM performances is limited and that systematic documentation of future ice management activities is highly recommended. The information required in order to evaluate the overall reliability of structural resistance combined with IM operations will never be available unless future operators put some efforts in documenting experiences in a systematic manner.

The information required in order to evaluate the overall reliability of structural resistance combined with IM operations will never be available unless future operators put some efforts in documenting experiences in a systematic manner.

Examples of environmental conditions that might be monitored in order to characterize the performance of the physical ice manage system include but are not limited to the factors described in Table 3.1:

Table 3.1 – Overview of environmental monitoring systems

Environmental monitoring	Common methodology
Water depth	Sonar
Wind speed	Anemometer
Current speed	Venturi meter / Doppler log
Ice density	Sonar
Ice drift velocity	Sonar / Radar
Ice drift direction	Sonar / Radar
Fraction of time without ice movement	Sonar / Radar
State of the ice cover	Visual
Ice concentration	Sonar / Visual
Average floe diameter	Visual
Level ice thickness	Sonar / Visual
Type of ice interaction	Visual
Amount of rubble accumulation	Visual
Rubble pile angle	Visual
Ridge encountering frequency	Visual / Analytical
Ridge width	In-situ measuring / Visual
Ridge sail height	In-situ measuring / Visual
Ridge consolidated layer thickness	In-situ measuring / Visual
Ridge keel depth	In-situ measuring / Visual
Ridge spacing	In-situ measuring / Visual
Ridge length	In-situ measuring / Visual
Average ice breaking length	Visual / Sonar
Ice breaking shape	Visual / Sonar

Further information can be found in Dunderdale and Wright (2005), Keinonen et al. (2006), Martin et al. (2008), Liferov et al. (2011), Hamilton et al. (2011) and Bonnemaire et al. (2011a).

With respect to iceberg deflection operations, operations are typically documented and characterized by using the same parameters in a way that is consistent with the PERD comprehensive iceberg management database [Rudkin et al. 2005]

### A.17.3 Ice management system capabilities

#### A.17.3.1 Requirements

There is no guidance on personnel requirements in ISO 19906, as it is a standard for design, except some statement in Clause 17.3.1 that personnel should be trained in the relevant topics. A better description of what responsible personnel is, is lacking. Should the forecaster be trained with respect to performance capabilities of the installations? How can this be done? ISO 19906:2010(E) is a design code and such requirements should be the subject of a new document with this specific scope, but meanwhile the following guidance is offered, based on examples from Kulluk (Wright, 2000; PetroCanada, 2005) on role definitions, training and communication.

An ice management team must be established with sufficient staff to cover all parts and to meet all the objectives of the ice management system as stated in the ice management plan. The team must be able to ensure the safety of personnel, protection of the environment, integrity of relevant offshore facilities and a high level of operational efficiency. Responsibilities are usually divided between an offshore organization that carries out the tactical functions and shore-based personnel who compile and distribute all available ice and metocean information from a range of occurrences. It is, therefore, required that responsibilities are clearly defined.

All operators have well defined onshore and offshore organizations where responsibilities are clearly divided, including such functions as Offshore Installation Manager or Platform Manager and onshore and offshore drilling superintendents. These functions will usually have the overall responsibilities for the operations, including ice management, and will not be dealt with here.

An essential part of ice management, particularly for stationary floating structures, will be the education and training of personnel involved in ice management. This applies to the people in the special ice management

positions as well as in regular positions with ice management responsibilities. Many regions of the Barents Sea will not experience sea ice or icebergs every year, e.g. at the Shtokman Field ice will occur on the average every three to four years. It is, therefore, important that the ice management team get the opportunity to develop, update and test their skills at regular intervals.

Training the ice management team should include both in-ice field training and simulator training. For in-ice training one may have to move away from the actual location to areas with relevant ice conditions. In-ice training should be carried out once a year. Simulator training should be available on a year-round basis. The simulator must be able to support training in strategic management operations for integrated multi-facility. Several operations must be included:

- ice and iceberg detection (from multiple sensors varying in time and space),
- operational status of each production facility in the region,
- ice, iceberg and metocean tracking,
- assignment of vessels for iceberg reconnaissance,
- assessment of threats from ice feature and icebergs,
- prioritization of threats,
- evaluation of alternative physical management scenarios for threatening events, e.g. towing scenarios for threatening icebergs,
- execution of physical management operations through dispatching management vessels, and
- monitoring physical management operations and assessing extent of risk mitigation.

Good communication between the support vessels and the stationary floating structure is an essential part of ice management operations. Obviously, information about ice conditions and movements, ice management priorities and strategies, and the effectiveness of the work being carried out by each icebreaker has to be continually exchanged. It is important that relevant information transfer from the structure, or to it, does not “fall between the cracks”. The approach that to be adopted should involve the following key elements:

- communicating with and obtaining feedback from the icebreakers regarding the progress and effectiveness of their ice management activities, and any hazardous
- ice conditions or situations they felt may be arising
- assessing this ice management information as a key input to the ice alert system

#### **A.17.3.3 Threat evaluation**

The content in 17.3.3 is too general and no guidance is given in A.17.3.3. An example should be included in the informative part (A.17.3.3). Some text is added to elaborate on Figure A.17-1. Further references are Coche et al. (2011) and Wright (2000).

### **A.17.4 Ice management planning and operations**

#### **A.17.4.1 Scope of ice management plan**

A standard for ice management operations should address HSE requirements and risk assessments and developments of procedures for safe execution of these activities. Due to the fact that ISO 19906 is a structural design code, consideration should be given to developing a new document with this scope.

#### **A.17.4.5 Maintenance of ice management plan**

For all operations in the Arctic (not only those involving physical ice management) the principles of safe learning’s should be utilized. Due to the large uncertainties which will be prevalent both with respect to available ice data, capabilities in ice load calculations and effect of physical ice management, the effect ice features will have on most installations will be difficult to predict in the early operations. Due to this, one may expect the risk in the early operation phases to be higher than at later stages. In order to ensure acceptable risks already in the early stages the principles of safe learning’s may be applied.



# ANNEX B (INFORMATIVE) REGIONAL INFORMATION

## B.16 Barents Sea

### B.16.1 Description of region

The division is not suitable for ice conditions. The proposed one may be better suited as it follows more closely the ice conditions.

### B.16.2 Barents Sea technical information

#### B.16.2.3 Sea ice and icebergs

There is need for some guidance in cases where data are not available. The proposed supplementary tables were used by OGP/ISO in the calibration study for ISO 19906 ( OGP, 2010).

The Russian sources mentioned in the Guidance document, Clause B.16.2.3 is based on data and observations of sea ice and icebergs that go back decades. AARI holds much of these data, of which a parts are proprietary. Nevertheless, AARI provided the data that is in ISO 19906.

The first occasional observations of sea ice in Barents Sea started in the first half of the 19th century. Occasional aerial ice reconnaissance in the Barents Sea started in late 1920s. From 1934 it was conducted on the regular basis in certain winter months and monthly in the summer period. After 1992 regular aerial reconnaissance had stopped.

Satellite ice observations in the Barents Sea started in 1972. From 1972 to 1985 satellite observations were performed on a monthly basis in the period from November to May and each 10 days in the period from June to September.

In total 40 field surveys were performed in the period from 1980 to 1990, most of them in the Northern part of the Barents Sea passing across the Shtokman area.

In 1991–92 Russian Arctic researchers in co-operation with foreign partners conducted complex field study of sea ice and icebergs in the central and northern sections of the Barents Sea. In particular, iceberg drift was studied in the area of Franz Joseph Land, Spitsbergen and Novaya Zemlya using 20 Argos drift buoys.

The main results of these observations are:

- Sea ice occurrence in the Barents Sea and its seasonal and annual variability.
- General information about ice edge location, concentration, ridging, floe configuration and size, ice drift, snow cover, as well as main iceberg parameters and their sources.
- General information about sea ice temperature, salinity, density, physical, morphological and mechanical properties, texture and structure and sea ice drift.

Since 2000 several ice expeditions were conducted in the North-Eastern Barents Sea, targeting at collection of ice and iceberg data for the Shtokman field. The following main activities have been performed within the scope of the ice expeditions:

- Monitoring synoptical and sea ice conditions over the entire ice season.
- Measurements of sea ice morphological, physical and mechanical properties.
- Underwater survey of ice ridges and icebergs.
- Sea ice and iceberg drift using measurements from onboard icebreaker at ice stations (drifting with ice), drift buoys and satellite images.
- Survey of glaciers surging icebergs into the Barents Sea.
- Metocean forecast record during the period of buoys deployment.
- Fixed wing aircraft survey with focus on sea ice mapping and iceberg detection.

The main results of these ice expeditions are as follows:

- Qualitative and quantitative description of sea ice cover and icebergs in the North-Eastern Barents Sea and at the Shtokman field in particular.
- Data for main ice and iceberg parameters required for design of the Shtokman offshore facilities and operations.
- Sea ice and iceberg drift data.
- Validation of available iceberg detection means.

Further, desk studies have been performed to analyse and report the following:

- Statistical description of sea ice and iceberg properties relevant for design and operations.
- Basic ice and iceberg drift statistics, including changes of drift direction and stationary events.

Site specific metocean data sets are not abundant in the Barents Sea but metocean specialists enjoy the possibility to employ sophisticated and proven hindcast models to establish long term data sets, particularly with respect the temperature, wind and waves. The quality of metocean hindcast data in the Barents Sea may be slightly inferior to those in the North Sea due to fewer meteorological observations and less calibration data for waves and other oceanographic parameters. The metocean data will, however, have less uncertainty than the ice data sets. A good source of hindcast metocean data is the NORA10 hindcast database by the Norwegian Meteorological Institute (met.no), covering the years 1958 – 2009 for winds and waves. Met.no also holds hindcast data for other meteorological data.

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## 4. GUIDANCE DOCUMENT: ADDITIONS AND AMENDMENTS TO ISO 19906:2010(E)

This Guidance document is drafted in accordance with the rules given in the ISO/IEC Directives, Part 2. Guidance document was prepared by working group RN02 in the Barents 2020 Phase 4 project and constitutes Part 4 of RN02's final report for Barents 2020 Phase 4.

The original text from ISO 19906 is in boxes. Whenever changes are made to the original text within a paragraph, these are marked in the boxed text with an underlined italic font for additional text and strikethrough for deleted text. All proposed major additions to ISO 19906 are in underlined Italics.

Most of the suggested additions and amendments relate to the design of stationary floating structures in ice.

### 4.1. A Note on Events and Actions

#### Ice Events and Ice Actions

Discussion on ISO 19906:2010(E) in Barents 2020 Working Group RN02 revealed that there is a need to clarify the use of terms related to “actions” and “events” in the standard, such as environmental action, ice action, ice event, SLIE (service-level ice event), ELIE (extreme-level ice event) and ALIE (abnormal-level ice event). In particular, it became evident that the terms are difficult to translate into Russian and that they may be more confusing than helpful as most current design practice is to calculate characteristic actions for given return periods. The discussion has concluded that the acronyms SLIE, ELIE and ALIE are not necessary, and that ISO 19906 could reduce any confusion by re-phrasing its provisions to use appropriate words more consistently. Suggesting changes in ISO 19906 relating to these terms was deemed outside the scope of the Working Group and also would require wider discussion in order to be accepted for general use. Nevertheless, the Working Group RN02 has found the issue to be important and has decided to include this note to emphasise the topic and to make an attempt to clarify the problem until the ISO 19906 is updated. The Working Group RN02 supports a revision to eliminate these acronyms from ISO 19906. Additional discussions is offered in Barents 2020 Phase 4, RN02 Part 3.

A document suggesting possible revisions to ISO 19906 has been prepared and submitted to ISO for consideration by ISO TC67/SC7/WG8 independently of Barents 2020.

It should be remembered that in ISO terminology “action” means “load”; “load” is not normally

considered to be interchangeable with “event”. Thus, the fact that the abbreviated terms SLIE (service-level ice event), ELIE (extreme-level ice event) and ALIE (abnormal-level ice event) are used to represent both actions and events has caused some confusion for the users of the standard. An “action” should be the result of and calculated from an “event” and the terms should not be used interchangeably.

Examples of the use of terms related to EL ice actions and ELIE in ISO 19906 where the meaning and consistency is not always clear are given in Barents 2020 Phase 4, RN02 Part 3. In some of the discussed examples, the use of ELIE is ambiguous and can be interpreted either way without significant consequences. However, one of the examples uses ELIE as an event which causes an action, whereas two other suggest that the ELIE is the value of the action resulting from calculation.

A further consideration is that although the acronyms SLIE, ELIE and ALIE are used for ice in ISO 19906, there is no parallel for wave actions with the same exceedence or occurrence probabilities and for which the same resistance descriptions apply. In the ISO 19900-series, special terms have been used only for earthquakes, (ISO 19901-2), using the acronyms ELE and ALE. There the need for using the terms ELE and ALE arises due to these events being defined not by annual probabilities and not as values of actions, but by a site-specific hazard curve of spectral accelerations, and with special provisions given in ISO 19901-2 for assessing action effects, resistance and response. Barents 2020 Working Group RN02 supports the proposal to eliminate these acronyms from ISO 19906 and to use the following terminology consistently throughout ISO 19906:

EL environmental action = EL ice action (principal)  
+ “other” actions  
(companion)  
= EL “other” action  
(principal) + ice  
and “other” actions  
(companion)

AL environmental action = AL ice action (principal)  
+ “other” actions  
(companion)  
= AL “other” action  
(principal) + ice  
and “other” actions  
(companion)

where

EL ice action =	extreme-level ice action (each type of ice action to be considered in turn)
AL ice action =	abnormal-level ice action (each type of ice action to be considered in turn)
EL “other” actions =	extreme-level wave or other metocean action (each to be considered in turn)
AL “other” actions =	abnormal-level wave or other metocean action (each to be considered in turn)

The usual understanding in Russian as well as international codes, is that a DS is characterized by a corresponding action combination with relevant partial factors, every separate action being taken at the appropriate exceedence level. If ISO 19906 made more use of the term DS this could further help to ensure that the term “event” is used more precisely.

The suggested changes will affect the following subclauses of ISO 19906:2010:

7.2.1.2, 7.2.1.3, 7.2.1.5, 7.2.2.1 - 7.2.2.6, 7.2.3, 8.2.2, 8.2.3, 8.2.7, 8.3.1.2.1, 8.4.2, 11.5, 12.3.5.4, 16.3.3.2, A4., A.7.1.4, A.7.2.2, A.8.2.2.1, A.8.2.2.2.1, A.8.2.2.2, A.8.2.2.3, A.8.2.2.4, A.8.2.4.3.3, A.8.2.5.1, A.8.2.5.2.2, A.14.3.5.1 and A.14.3.5.3.

#### Types of “Event”

Extreme-level (EL) ice actions and abnormal-level (AL) ice actions are required by ISO 19906 to be calculated for both persistent ice conditions such as level ice, and for discrete ice events such as iceberg impact; however, the overall approach of ISO 19906:2010 is to not distinguish between discrete and persistent scenarios. A discrete event is a “binary” occurrence: the iceberg either hits or it does not hit. If it hits, it is an event which gives rise to actions for which the value depends on various parameters some of which can be characterized probabilistically. The concept of an “event” also being an extreme or abnormal peak or maximum within a continuous stochastic process arising from persistent ice conditions is not clearly stated and is proving to be unclear for the users of the standard. Therefore it is proposed to define “ice event” as an ice-structure interaction event for which ice actions are calculated (see proposal for definition in new subclause 3.83). Guidance on modelling a persistent scenario as discrete ice features is provided in the proposed new subclause A.8.2.2.6. For further discussion of types of events, see Barents 2020 Phase 4, RN02, Part 3.

The Working group also draws attention to the term “design situation” (hereinafter DS), which in ISO 19900:2002(E), subclause 2.13, is defined as: “design situation: set of physical conditions representing real conditions during a certain time interval for which the design will demonstrate that relevant limit states are not exceeded”.



## 1 Scope

This International Standard specifies requirements and provides recommendations and guidance for the design, construction, transportation, installation and removal of offshore structures, related to the activities of the petroleum and natural gas industries in arctic and cold regions. Reference to arctic and cold regions in this International Standard is deemed to include both the Arctic and other cold regions that are subject to similar sea ice, iceberg and icing conditions. The objective of this International Standard is to ensure that offshore structures in arctic and cold regions provide an appropriate level of reliability with respect to personnel safety, environmental protection and asset value to the owner, to the industry and to society in general.

This International Standard does not contain requirements for the operation, maintenance, service-life inspection or repair of arctic and cold region offshore structures, except where the design strategy imposes specific requirements (e.g. 7.1.6 and 17.2.2).

While this International Standard does not apply specifically to mobile offshore drilling units (see ISO 19905-1), the procedures relating to ice actions and ice management contained herein are applicable to the assessment of such units.

This International Standard does not apply to mechanical, process and electrical equipment or any specialized process equipment associated with arctic and cold region offshore operations except in so far as it is necessary for the structure to sustain safely the actions imposed by the installation, housing and operation of such equipment.

Design experience with stationary floating structures in ice is scarce. Most of the experience on which this standard is based applies to fixed (bottom founded) structures. Not all experience is directly transferable to floating structures in ice and the standard should be used with appropriate caution.

## 3 Terms and definitions

### 3.5

#### **action effect**

effect of actions on the structure or its components

*EXAMPLE: Internal force, moment, stress or strain.*

### 3.9

#### **broken ice**

*varying sizes of ice* floes, broken up as a result of natural processes, active or passive intervention

*NOTE: Active intervention includes ice management resulting in managed ice; passive intervention includes the channel, or wake, caused by a stationary structure in moving ice cover.*

### 3.38

#### **ice management**

*sum of all activities where the objective is to reduce or avoid actions from any kind of ice features.*

*NOTE: ice management includes, but is not limited to:*

- *Detection, tracking and forecasting of sea ice, ice ridges and icebergs*
- *Threat evaluation and alerting*
- *Physical management, such as ice breaking and iceberg towing*

### 3.83 (new)

#### **ice event**

*ice-structure interaction event for which ice actions are calculated*

*NOTE: an ice-structure interaction event can be associated with discrete ice features such as icebergs, ice islands, ice ridges, stamukhi and ice floes, or with a specified length or duration arising from the interaction process.*

### 3.84 (new)

#### **surcharge**

*increase in ridge keel depth used in calculations arising from the downward extrusion of ice rubble during ice ridge interaction on sloped and/or conical structures*

### 3.85 (new)

#### **ice belt**

*strengthened hull region around the waterline, accounted for all loading conditions, given by ice class requirements*

**3.86 (new)**

***stationary floating structure***  
*floating units kept in position by moorings or dynamic positioning.*

*EXAMPLES: ship-shaped vessels, spar or buoy shaped platforms*

## 5 General requirements and conditions

### 5.3 Site-specific considerations

#### 5.3.2 Long-term Climate Change

Changes in storm frequency and magnitude, ice conditions, ocean circulation, air temperatures, permafrost, wave heights and water levels can occur during the design service life of the structure. Consideration for such changes should be included in the design.

*Site-specific assessments shall be made with regard to potential consequences of the long-term climate change and variability. They shall include, as minimum:*

- *change in magnitude and persistence of the metocean and ice conditions;*
- *change in frequency of iceberg invasion to the area of operations; and*
- *representativeness of the data collected within a particular climate cycle.*

#### 5.3.3 Structural Configuration

The configuration of the structure should consider the following:

- protection of risers and conductors;
- concept for oil storage and export;
- wet or dry storage system;
- layout of facilities and separation distances from hazards;
- potential for future expansion under phased development;
- potential for platform removal;
- environmental constraints;
- capability of local construction facilities and materials; and
- available construction season for offshore operations.

Different structural shapes, orientations and profiles for the structure and the topsides should be considered for resisting sea ice or iceberg actions. In defining the orientation of the structure at the site, consideration should be given to the ice

conditions, prevailing ice drift directions and ice rubble build-up. The topsides should be arranged with respect to the functional and operational requirements, such as re-supply, offloading, flaring and EER, and with respect to wind and ice encroachment.

The reliability of EER, platform supply and offloading systems can potentially be improved through

- a) ice management to prevent ice rubble accumulation;
- b) duplication of facilities on opposite sides of the platform; and
- c) large crane booms to reach over accumulated rubble.

*For stationary floating structures the configuration shall address protection of risers, mooring lines and hull appendages from the surface-level and underhull ice interactions. The hull shape should be designed in order to minimize and as much as possible avoid direct contact between ice and risers, mooring lines and hull appendages for the range of the anticipated operating conditions. If ice interactions are unavoidable, the ice actions shall be quantified.*

### 5.5 Design Considerations

The combinations of actions and partial factors for determining action effects applicable to the different limit states shall be in accordance with the provisions of Clause 7.

*Design of stationary floating structures shall account for operational measures such as disconnection or/and ice management. Appropriate interactions between different parts of the structure should be considered through the design phases. Ice actions on all relevant structural elements and appurtenances such as risers shall be identified and defined for a range of the anticipated operating and design conditions. The weakest element in the system shall be identified and relevant ice actions shall be studied in detail.*

## 6 Physical environmental conditions

### 6.1 General

#### 6.1.1 Physical environment requirements

The owner shall be responsible for selecting appropriate physical environmental design parameters and operating conditions. The owner shall take regulatory requirements into account, where they exist. These requirements can include a minimum duration of site-specific data (according to country regulations), the type of data and a definition of extreme design parameters. Interpretation of the collected data shall take into consideration inter-annual variability of ice conditions on site.

General guidelines on metocean information are given in ISO 19900 and specific requirements in ISO 19901-1.

A realistic assessment of the physical environmental parameters affecting the proposed offshore structure shall be made. All relevant environmental data, as well as applicable physical, statistical, mathematical, and numerical models, shall be used to develop the appropriate information.

The following information shall be determined:

- a) normal environmental conditions that are required to carry out checks for serviceability limit states, to develop actions and action effects to determine when particular operations can safely take place, and to plan construction activities (fabrication, transportation and installation) or field operations (e.g. drilling, production, offloading, underwater activities);
- b) long-term distributions of physical environmental parameters, in the form of cumulative conditional or cumulative marginal statistics that are used to define design situations and to perform design checks for the fatigue limit state, or to make evaluations of downtime/workability/operability during a certain period of time for the structure or for associated items of equipment;
- c) extreme and abnormal physical environmental parameters that are required to develop extreme and abnormal environmental actions and/or action effects, which are used to define design situations and to perform design checks for ultimate limit states and abnormal limit states;
- d) regional environmental oscillations, cycles, and long-term trends associated with the parameters in a) through c).

The relevant physical environmental parameters can be dependent on the chosen structural form. To obtain reliable and appropriate physical environmental parameters, experts in the field of metocean and ice technology and, if relevant, ice management operations shall be involved with the analysis of data and its interpretation for developing appropriate design situations and design criteria.

### 6.5 Sea ice and icebergs

#### 6.5.1 General

Information required to characterize site-specific ice criteria shall be determined for the location of the structure under consideration. This information should consider all phases of the structure's design service life.

Data can be obtained from direct observations at a location, interpretation of satellite imagery, or historical information at the geographic region of the installation. Where local ice data are unavailable or are not representative of relevant severe ice conditions, or where ice incursions are infrequent, data from nearby sites or geographical regions with similar ice environments may be used. Numerical or statistical modelling may be used to extend these data sets, with due account for uncertainties. Long-term trends shall be taken into account. Interrelationships between the various parameters listed in 6.5.2 through 6.5.5 shall be considered, where relevant for the development of design criteria.

The potential for incursion of ice features that can give rise to adverse ice actions on the structure, including those from managed ice shall be evaluated. Particular attention shall be paid to the detectability of such ice features. Sea and ice data statistics shall be evaluated to ensure that they adequately represent the range of actual scenarios, and uncertainties shall be quantified. In particular, potentially undetected small glacial ice features shall be included in this evaluation. Physical limits for maximum values of ice parameters may be introduced if justified and documented. If ice invading the site comes from a "more severe" environment, degradation/deterioration models can be used to evaluate any potential for "scaling down" relevant ice parameters from the data collected in the "more severe" environment.

#### 6.5.4 Ice movement

Wind, waves, current and thermal expansion affect ice movement and pack ice pressure. Statistics, such as probability distributions, means and extremes, of movement rates for pack ice, ice floes and discrete features such as icebergs and ice islands, shall be

determined on the basis of field data. Ice movement rates affect the number of ice features encountered, ice actions, and operations. Ice pressure can affect vessel traffic, ice management and evacuation procedures.

*Variability in ice drift speed and direction shall be specifically addressed. For floating structures the rate of change and abrupt changes in ice drift directions, resulting in small ice drift turning radii (or curvature of change) are important.*

If field data do not exist for these parameters, numerical modelling or analysis of the interaction of winds, waves, ocean currents and ice may be performed to obtain this information, with due account for uncertainties in the data and modelling procedures.

Inter-annual and seasonal variations in ice presence, polynyas and physical parameters shall be considered.

## 7 Reliability and limit states design

### 7.1 Design philosophy

#### 7.1.6 Alternative design methods

Alternative design methods may be used if the reliability of the structure and its components is shown to be equivalent to or better than that of the limit state design approach as set out in 7.2.

*If operational procedures such as ice management or/and disconnection are a part of the design philosophy for a floating structure, all relevant elements of the operational procedures which are required for an appropriate level of structural reliability shall be determined and documented.*

### 7.2 Limit states design method

#### 7.2.1 Limit states

##### 7.2.1.5 Abnormal (accidental) limit states

The ALS requirement is intended to ensure that the structure and foundation have sufficient reserve strength, displacement or energy dissipation capacity to sustain large actions and other action effects in the inelastic region without complete loss of integrity. Some structural damage can be allowed for ALS. The ALS design condition for ice shall be the abnormal-level ice event (ALIE). Both local and global actions shall be considered.

*For ALS, non-linear methods of analysis may be used. Structural components are allowed to behave plastically, and foundation piles are allowed to*

*reach axial capacity or develop plastic behaviour. The design resistance is based on considerations of static reserve strength, robustness, flotation capacity, ductility, alternative load paths and energy dissipation as applicable.*

### 7.2.2 Actions

#### 7.2.2.1 General

Permanent actions (G), variable actions (Q), environmental actions (E), repetitive actions (F) leading to fatigue, and accidental actions (A) are defined in ISO 19900. Further details on their specification are found in ISO 19902, ISO 19903 and ISO 19904-1.

For structures in arctic and cold regions, the design shall be based on both extreme-level (EL) and abnormal-level (AL) events, which include ice actions arising from ELIE and ALIE.

*If a stationary floating structure is designed to be disconnectable, the EL and AL environmental actions can be limited by the pre-defined conditions for disconnection. See also 13.4.4.*

Representative values shall be assigned to each action. The main representative value is the characteristic value, which is a value associated with a prescribed probability of being exceeded by unfavourable values during a reference period, which is generally one year.

In arctic and cold regions, there can be additional accidental events that should be evaluated, such as ice-driven ship impacts on a structure.

#### 7.2.4 Combinations of actions and partial action factors

The action combinations specified in Table 7-4 shall be used in design. For each action combination, the representative value of an action or combined environmental action shall be multiplied by a partial action factor not less than that specified in Table 7-4, except that, alternatively, action factors for permanent and variable actions may be taken from ISO 19902, ISO 19903 or ISO 19904-1 for the respective structure types. These action factors apply to both local and global actions. ISO 19900 provides further information on the classification of types of action.

The combination of actions and the partial action factors for earthquakes shall be in accordance with ISO 19902 for fixed steel structures and in accordance with ISO 19903 for fixed concrete structures. Further guidance is provided in 8.4.

Action factors and action combinations for SLS and FLS shall be in accordance with ISO 19902, ISO

19903 or ISO 19904-1 as relevant to the structure type.

For action combinations where an abnormal or accidental action is the principal action (action combinations 4 and 5 in Table 7-4), the action effects shall be checked for ALS only.

The partial action factors for environmental actions other than earthquakes specified in Table 7-4 have been calibrated to the reliability targets given in Table A.7-1. When these partial action factors are applied to ULS and ALS action combinations for arctic offshore structures and their components within the scope of this International Standard of exposure levels L1 and L2, the reliability targets given in Table A.7-1 are deemed to be achieved.

As an alternative to Table 7-4, the partial actions factors may be derived from a calibration analysis using a full probabilistic description of actions and resistances if this analysis demonstrates that the reliability targets are achieved.

When considering design of floating structures in ice, the environmental action factors as specified in Table 7-4 should be reconfirmed by project specific calibration analysis, since the underlying calibration cases did not account for:

- flexibility of the mooring system
- the degrees of freedom of a floating structure
- the non-linear interaction between a moored structure and ice
- the change in direction of the incoming ice for a turret-moored ship-shaped floater
- relevant operational procedures, such as physical ice management and disconnection, and their uncertainty

## 8 Actions and action effects

### 8.2.6 Dynamic ice actions

The time-varying nature of ice actions and the corresponding ice-induced vibrations shall be considered in the design. The potential for dynamic amplification of the action effects due to lock-in of ice failure and natural frequencies shall be assessed. Particular attention shall be given to dynamic actions on narrow structures, flexible structures and structures with vertical faces exposed to ice action. Structural fatigue and foundation failure as a consequence of dynamic ice actions shall be considered.

In application to stationary floating structures, dynamic properties of the system shall be accounted for. Design of the mooring system shall account for the possible dynamic amplification due to ice action for the full range of anticipated ice interaction scenarios.

### 8.2.7 Operational procedures to reduce ice actions

Operational procedures may be used to mitigate ice actions on fixed, floating and subsea structures provided that it can be shown that, in combination with structural resistance, the intended level of reliability is achieved, *see 7.1.6 and 7.2.2.1*. Operational procedures include ice management, disconnection and removal, clearing of snow and ice accumulations, rubble and spray ice barriers, and seasonal operation. Ice management can be used to alter the ice regime, through decreases in floe size and the destruction or removal of potentially hazardous ice features, and through local reduction in ice coverage.

Ice action calculations for managed ice shall be performed when appropriate.

Any reduction in design actions for ELIE and ALIE shall be demonstrated through changes to the magnitude and frequency of ice actions for all applicable scenarios. The effectiveness of operational procedures shall be founded on documented experience, where applicable, and the approach shall reflect the uncertainty inherent in the input data and modelling techniques.

If physical ice management is required in order to justify a reduction of the design action, it shall be documented that the physical ice management is able to handle the conditions that may lead to EL and AL ice actions.

#### 8.3.1.2 Ice accumulation on the structure

##### 8.3.1.2.1 General

The expected effects of icing shall be accounted for in the ELIE and ALIE analyses of the structure. Icing of structures or structural members can result from fog, freezing rain, green water trapped on decks, wind- and wave-driven seawater spray, or tidal variation. Icing modifies the aerodynamic and hydrodynamic properties, static stability and dynamic responses of the structure. Icing can also modify the buoyancy and stability of floating structures. Icing can be a direct action (e.g. weight) for which EL and AL representative values are required, an influence on other actions (e.g. wind) as a companion process, or an influence on the response of the structure.



Icing can be measured in terms of the thickness, volume or mass of ice adhering to the structure. Such estimates may be obtained from observations of icing on similar existing structures in the same area or from available theoretical models. When theoretical models are used, they should be suitably calibrated against observations.

## 13 Floating structures

### 13.2 General design methodology

#### 13.2.2 Design and operational approaches

Floating structures that are deployed in ice covered waters are often supported by ice management vessels, with the intended role of modifying the local ice environment, reducing ice load levels on the structure and enhancing ice clearance around it, the intention of which is to detect ice threats, alert the installation and reduce (in case of sea ice breaking and clearing) or avoid (in case of iceberg deflection) ice actions.

The type of ice management system deployed can have a significant influence on the design approach taken for a floating structure. This influence depends upon the expected ability to consistently detect potentially adverse ice conditions and successfully manage them before they interact with the structure (e.g. by towing icebergs or fragmenting thick sea ice features). Clause 17 provides a description and requirements to the ice management system.

The following design and operating approaches may be used for floating petroleum installations in ice-prone waters:

- a) passive: no move-off capability, no ice management capability;
- b) semi-passive: no move-off capability, ice management capability;
- c) combined: no move-off capability, riser disconnect capability, ice management capability;
- d) semi-active: move-off capability, no physical ice management capability;
- e) active: move-off capability, ice management capability.

For active, semi-active and combined operating approaches, design values of ice actions on a floating installation can be considerably less than for a fixed installation. Any mitigation measures (i.e. ice management, disconnection and move-off strategies)

that are intended to ensure appropriate levels of safety should be properly identified, considered and quantified, along with expected levels of reliability.

Operational strategy may be used to influence the consequence category or life-safety category of a floating structure. Life-safety category and consequence category are discussed in Clause 7.

In application to stationary floating structures the following shall be accounted for when evaluating and documenting the effectiveness and reliability of the operational procedures:

- Availability and performance of the ice management fleet
- Probability of detection of potential ice threats, including weather-dependency
- Capability and reliability of the disconnection system, including documentation of capability and reliability under situations in which the disconnection system is under loading from outer environmental loads transferred to the system, if applicable.
- Assess the consequences of component failures in the ice management operational system, including detection, monitoring, ice management vessels, and disconnection.

Assessing actions from managed (broken) ice shall be founded on a combination of model tests, validated analytical and/or numerical models and, where applicable, documented full scale experience.

Operational limits shall be defined to ensure sufficient redundancies so that the ice actions do not exceed the design values. If the design relies on operational measures, it must be ensured that there is sufficient time to put mitigating measures into effect whenever the operational limits may be exceeded.

#### 13.2.3 Design considerations

The designer shall take into account all relevant issues and associated parameters for each scenario considered, including, but not limited to,

- the type of structure, e.g. permanent, temporary;
- the operating period, e.g. seasonal, all year;
- design conditions, e.g. metocean and ice conditions;
- the ice features, e.g. first-year ice (ridges, rubble fields, landfast ice, pack ice), glacial (small ice masses, icebergs), multi-year (floes, ridges);
- the ice situations, e.g. high ice drift speeds,



changing drift directions, ice pressure events, poor visibility;

- the ice management, e.g. none, low capability, comprehensive capability;
- the brash ice and its influence on ice management effectiveness;
- the stationkeeping method, e.g. moored, dynamically positioned;
- the operations, e.g. operating, standby, disconnecting, reconnecting;
- the human factors, e.g. cold stress, isolation;
- the system components, e.g. risers, subsea, offloading tanker;
- the storage capacity, i.e. with or without;
- the on-site maintenance, e.g. hull, station-keeping system including anchors, ballast system.

*In application to disconnectable stationary floating structures, it is necessary to evaluate the structure response to a wide range of ice conditions and interaction scenarios. Numerical or analytical models combined with model testing can be used to map the response of the floating structure to a wide range of ice conditions and interactions scenarios. The results of such mapping can be used to evaluate the structure response to other levels of ice actions.*

### 13.3 Environment

In addition to the environmental information requirements outlined in Clause 6, the following relevant factors shall be considered for the design of floating structures, particularly when ice management systems are involved. Relevant factors include, but are not limited to,

- a) the combined influence of ice, wave, wind and current action, and the effect of their respective orientations on the applied actions (e.g. on an ship-shape floating structure that is designed to vane into oncoming pack ice);
- b) the joint effects of ice, waves and structure motions on ice action scenarios, and the areas of the structure where ice impacts can occur;
- c) the effects of factors such as low air and water temperatures and icing;

the beneficial effects of ice management on modifying the ambient ice environment with due account for its efficiency in all anticipated ice and metocean situations;

- d) the potentially adverse effects of secondary factors such as poor visibility, precipitation and darkness on the reliability of ice detection and ice management systems;
- e) the complicating effects of factors such as waves on sea ice and iceberg management methods, and the presence of sea ice on iceberg towing operations;
- f) the increased importance of factors such as ice pressure events and combined ice drift velocity and thickness information, particularly for sea ice management considerations;
- g) the degree of variability of many of the physical environmental parameters;
- h) the potential lack of long-term physical environmental data, from which proper designs and operational procedures and plans are developed;
- i) the identification of the full range of ice interaction scenarios that can give rise to adverse ice effects on a floating installation, (e.g. excessive action levels on a mooring system, hull damage from undetected small ice masses, thruster damage in ice pressure, mooring line exposure to deep draught ice keels).

## 13.4 Actions

### 13.4.2 Ice scenarios

In addition to the provisions of Clause 8, pressure events due to convergence of surrounding ice or presence of a coastline shall be considered for floating structures. Ice scenarios where pressure events may lead to adverse ice actions shall be identified. Quantification of pressure in the ice cover shall be based on relevant full scale measurements and observations with due consideration for the possible difference in the ice area boundaries. Supplementary to the full scale information, analytical and numerical models can be used to quantify the pressure ice situations. When ice management is used, ice scenarios involving altered ice environment shall be considered. The effect of stationary and pressured ice situations shall be accounted for, including possible over-management situations. If the effect of physically managed ice is included in the calculation of ice action effects, the following should be documented (see also 7.1.6 and 7.2.2.1):

- The assumptions on efficiency and reliability of the physical ice management system to reduce ice actions effects
- That the extreme ice action effects are reduced due to the physical management

### 13.4.3 Interaction factors

In addition to the factors described in 8.2.4, the following should be considered:

- physical ice management;
- operational criteria, including ice detection, forecasting, threat analysis and decision-making as primary criteria (other operational factors, such as avoidance, measurement of actions, weathervaning, shutdown, flushing of risers and flowlines, disconnection, and seasonal operations).

These can act in combination with the ice scenarios and features or influence the nature of the interaction.

Appropriately scaled physical models can be used to determine the response (e.g. offsets, weathervaning, mooring line forces) of the floating structure and moorings to ice and current actions. Model tests can also be used to investigate ice accumulations on the mooring system and turret for monohull or buoy shapes, and ice accumulations to the legs of semi-submersibles.

If model tests results are used to calibrate analytical / numerical models, the potential bias with respect to full-scale effects and targets shall be taken into account. If possible, at least two different supplementary methods (e.g. numerical model calibrated on the model tests and analytical calculations) should be used for ice scenarios. Model tests can also be used to investigate the under-hull ice transport and ice clearing / jamming mechanisms (e.g. ice accumulations on the mooring system and turret for monohull or buoy shapes, and ice accumulations around the legs of semi-submersibles).

### 13.4.4 Determination of ice actions

The ice action effect (e.g. mooring action & motions) of a floating structure to ice actions shall be determined based on a combination of at least two methods: ice basin model testing and validated analytical or / and numerical model. The flexibility of the stationkeeping system shall be considered when determining the structure's response to ice actions.

The magnitude of structure's response to ice actions may be altered through ice management measures, seasonal operation and/or disconnection of

the installation. In cases where operational measures are accounted for in design, these shall be included in the operational procedures for the installation.

Relevant, full-scale ice action data for floating structures should be used for the determination of design actions.

Where the global action on the hull is limited by the capacity of the stationkeeping system, the unfactored failure resistance of the stationkeeping system shall be used for the calculation of actions on the hull; see ISO 19904-1.

With reference to 7.2.1, if a stationary floating structure is designed to be disconnectable, the reliability of the system including the structure, its components and the operational procedures shall be shown to be equivalent to or better than that of the limit state design approach as set out in 7.2, see 7.1.6. Nevertheless, EL and AL ice actions corresponding to the ULS/ALS design conditions shall be investigated to enable appropriate definition of the operational limitations and associated procedures.

When several ice and operational scenarios are relevant for a particular structure, those resulting in the largest ice action effects for each limit state shall be considered in the design.

For local ice actions on stationary floating structures, deviations from RCS rules may be considered if deemed necessary. The consequences of such deviations in comparison to design in accordance with RCS rules shall be assessed and should be discussed with relevant regulators. The extent and partitioning of the sea ice belt and any other zones of structural strengthening shall be assessed based on realistic ice-structure interaction scenarios, including local ice actions during ice drift reversal situations which can apply for non axi-symmetrical units.

### 13.4.6 Action variations

Varying nature of the magnitude and direction of the ice action (including potential changes in failure modes and ice clearance behaviour) shall be considered when determining the structure's response to ice actions. As minimum, variability in ice drift speed, ice drift path curvature and discontinuities, initial relative heading and different combinations of ice features within the "ice" interacting with the structure shall be evaluated.

## 13.5 Hull integrity

### 13.5.5 Condition monitoring

With reference to the provisions of 8.2.4 and 13.4, appropriate ice and physical environmental conditions shall be monitored and documented on a regular basis.

Continuous monitoring of global hull girder bending moments and shear forces shall be undertaken in accordance with ISO 19904-1.

The monitoring system shall be incorporated into the ice management and alert monitoring systems in accordance with Clause 17.

*A non-exhaustive list of structural monitoring systems is included in Clause A.13.5.5.*

## 13.7 Stationkeeping

### 13.7.1 General

The design of the positioning system for the floating structure shall be in accordance with ISO 19901-7 and ISO 19904-1, where appropriate. The specification of actions on all stationkeeping systems, whether mobile or permanent, should satisfy the requirements of Clause 7. The values of EL and AL actions may be calculated / *defined* through a risk assessment, taking into account the possible consequences of a failure of the stationkeeping system, the proximity to other installations, the nature of the operations (permanent or seasonal), the capability for disconnection (normal and emergency) and associated implications thereof, in accordance with ISO 19901-7.

### 13.7.2 Design of the stationkeeping system

The stationkeeping system shall maintain the installation in place under specified combinations of ice, wave, wind and current actions, and changes to ice actions as a result of ice management. The relevant action combinations shall be established based on available ice and metocean statistics, *operational measures such as ice management and operational limits of the installation (e.g. disconnection system capacity with respect to both action and action effect).*

Mooring lines should be routed so as to avoid direct exposure to ice actions in the splash zone and below, depending on the design ice interaction scenarios.

Ice features caught by the mooring lines can result in additional ice actions on the mooring system. Anchor fairleads shall be positioned to minimize such effects or localized ice management may be adopted.

Additional actions on the mooring system arising from these scenarios shall be included in the system design.

Propulsion and dynamic positioning systems shall be designed to withstand ice actions for ULS (intact and redundancy check system conditions) and for the relevant FLS. For ALS, the design shall be such that the complete failure of the system is avoided. *As minimum, it shall be ensured that hull is not a weak link in the area where appendages for propulsion and steering are connected.*

### 13.7.3.4 Design modes for disconnection

Potential disconnection modes include

- planned disconnection, which allows ample time for depressurizing and flushing of flowlines and for start-up of production after the floating structure has been reconnected; and
- emergency disconnection, which allows sufficient time only to shut down wells
- *planned disconnection during which events accelerate and result in emergency disconnection.*

### 13.7.3.5 Reconnection

Reconnection shall be carried out in an orderly sequence in the appropriate design situations.

*Reconnection after disconnection should be planned so as to ensure an orderly resumption of operation.*

## 16 Other ice engineering topics

### 16.5 Ice tank modelling

#### 16.5.1 General

Model tests with offshore structures in ice basins can be used in conjunction with other methods of ice/structure interaction analysis for obtaining ice related design values.

Ice model tests are normally performed to measure global ice actions on the structure, to verify theoretical estimates or to investigate basic interaction mechanisms of ice and the structure. Ice model tests can also provide information about ice rubble formation, ice pile-up near the structure, ice jamming and ice clearing around the structure.

An assessment should be made as to whether the problem can be investigated reliably using the proposed ice tank modelling techniques.

Calibration of model results to field data and observations provide added confidence when model results are extended beyond field information. Confirmation that the ice failure processes are modelled correctly should also be performed in any model test programme.

*Ice model tests should also be utilized to quantify under-hull ice transport as well as for evaluation of any blockage and underwater rubbing mechanisms especially for stationary floating installations. Potential ice hazards for mooring lines and risers attached to a floating structure shall be assessed on basis of model tests.*

*To determine the response of a moored floating structure to ice actions, the dynamic properties of the mooring system shall be included to account for possible dynamic amplification.*

#### 16.5.2 Scaling

In ice model tests, the geometrical and mechanical properties of the ice should be scaled in accordance with an appropriate similarity theory as accurately as possible. Attention should be paid to minimize and assess errors due to scale effects. The particular *physical and* mechanical properties of the ice that are most important for the expected ice failure mechanisms and the test objectives should be modelled as accurately as possible. *The most important ice properties should be assessed and documented before performing the ice model tests, including acceptable ranges of variation and order of priorities.* The effect of imperfections in the ice modelling material should be assessed.

The modelling scale should consider:

- the model ice type and its properties;
- the dimensions of ice test tank;
- the dimensions of the model;
- the processes being studied.

#### 16.5.4 Model ice properties

Geometrical and mechanical properties of the model ice (such as ice strength and thickness) should be scaled according to ice properties anticipated at the production site. The adjustment of test data to full scale should take deviations from similarity theory into account if the correction method is properly substantiated. *Modelling of physical and mechanical ice properties should be based on the actual ice-structure interaction scenario investigated.*

## 17 Ice management

### 17.2 Ice management system

#### 17.2.4 Ice management system reliability

Design and operational considerations shall be used to assess the overall reliability of an ice management system. The reliability of an ice management system shall be maintained for all of the anticipated physical environmental and operating conditions over the duration of the project.

*If there is insufficient data to assess the reliability quantitatively, a qualitative risk assessment should be used.*

### 17.4 Ice management planning and operations

#### 17.4.2 Ice events, threat evaluation and decision-making

The ice management plan should contain clear documentation of the ice alert procedures that define ice event (hazard) thresholds, the activation of ice management systems, subsequent decision-making requirements and their timing, and the consequent operational reactions.

Ice alerts requiring active responses should be defined in the context of the ice events and the operations of the installation. Specific provision shall be made for specifying the effectiveness of systems and equipment, time allowances and thresholds precipitating action associated with the systems identified in 17.3.1.

The ice management plan should ensure the proper definition of levels of responsibilities, accountabilities and actions for all parties, as well as the issuance of clearly identifiable alert levels.

*The ice management and ice alerts systems should be operating continuously throughout the year for permanent operations and during the periods of preparation, mobilization, execution and demobilization of time-limited operations. The extent and intensity of the monitoring should be a function of the ice hazard and may vary throughout the year.*

# ANNEX A (INFORMATIVE)

## ADDITIONAL INFORMATION AND GUIDANCE

### A.5 General requirements and conditions

#### A.5.3 Site-specific considerations

##### A.5.3.3 Structural Configuration

Recommendations of RCS rules, ice basin model testing and direct calculations are normally used together.

### A.6 Physical environmental conditions

#### A.6.1 General

##### A.6.1.1 Physical environment requirements

The probability of occurrence of an ice event (for example, iceberg occurrence) is often difficult to assess due to insufficient data and one has to rely on limited information that are explained and documented in the design document.

Changes in storm frequency and magnitude, ice conditions, ocean circulation, air temperatures, permafrost, wave heights and water levels can occur during the design service life of the structure. Consideration for such changes should be included in the design. Site-specific assessments are normally made with regard to potential consequences of the climate variability that may occur during the lifetime of the installation. These can include, but not be limited to:

- change in magnitude and persistence of the metocean and ice conditions
- change in frequency of the iceberg invasion to the area of operations
- representativeness of the data collected within a particular climate cycle.

In most waters with all-year or seasonal sea ice or with ice features of glacial origin, the available data on ice conditions can be scarce. Ice conditions, particularly over the continental shelves, show large intra-annual variations and ice data collection is performed in many different ways and it is often difficult to judge to what extent results from the different measurement campaigns are comparable. It is, therefore, normal practice to require documentation of the data collection process for third parties to be able to judge the validity and representativeness of the data for the application in question.

Given the many different applications of ice and metocean data it is important to have good descriptions of the surveys in case the results are considered for use for other purposes than the original one. Reporting would normally include but not necessary be limited to:

- Description of purpose
- Positions of measurement and position of intended use (may be different due to changing ice conditions)
- Instrumentation; description, resolutions, accuracies (repeatability), ranges, calibration procedures and calibration results
- Experimental set-up
- Placement of record into a long-term climatic perspective
- Processing approaches
- If statistical treatment is included: discussion of limitations of data sets, extrapolation approaches (choice of distribution, curve fitting methods), uncertainties
- If data are to be used for a location different from the survey position; a discussion of the spatial representativeness.



### A.6.5.1.1 Nomenclature and modelling

The WMO sea ice nomenclature [A.6-32] should be used when describing sea ice and icebergs. Statistical modelling from limited site-specific data sets is generally performed by Monte Carlo simulations where theoretical probability distributions are fitted to the data and then randomly sampled; see, for example, References [A.6-33] and [A.6-34].

*It is preferable to establish statistics from site specific field data. If it is impossible to get a sufficient number of potential interactions per year, e.g. because ice is not present at the site every year, data from a nearby region where more data is available can be used, accounting for the fact that ice is not present every year in the final statistics. This is typically from a region that is physically connected to the site in question, e.g. by advection of ice. Use of calibrated and verified numerical ice models can also be used. If using data from a nearby site where ice is more frequent than at the site in question, the final statistics will typically account for the fact that ice is not present every year.*

### A.6.5.2 Ice types

#### A.6.5.2.3 Icebergs

Glaciers and ice caps with access to open water can be found in many regions. As they are formed by snow falling and gradually being compressed into ice over many hundreds of years, they consist of freshwater ice. The extremely large (several tens of million tonnes) ice pieces that calve from a glacier are called icebergs. Smaller pieces are termed bergy bits and growlers. Iceberg sizes are classified according to waterline length as growlers (0 m to 5 m), bergy bits (5 m to 15 m), small (15 m to 60 m), medium (60 m to 120 m), large (120 m to 200 m) and very large (> 200 m). The average density of icebergs is generally in the range 850 kg/m<sup>3</sup> to 910 /m<sup>3</sup> [A.6-47].

Icebergs can survive in the ocean for many years, either floating or grounded. Reference [A.6-32] provides an accepted iceberg shape terminology. Unfortunately, this shape terminology is not really useful for dealing with icebergs in offshore operations. An alternative shape terminology [A.6-23] has been modelled after Reference [A.6-48]. The distinction between tabular and non-tabular icebergs is useful from design and operational perspectives. Some wedge or dome-shaped icebergs can be more difficult to tow.

*If some data on iceberg shapes are available it will be more useful to generate a range of iceberg shapes using Monte Carlo simulation.*

*Many icebergs have underwater protrusions of icebergs. These are difficult to observe from above the sea surface and instrumentation like side scan sonar operated from a vessel or structure can be used.*

### A.6.5.4 Ice movement

#### A.6.5.4.1 Processes

Under the influence of wind and current, ice can be very dynamic. Although ice drift speeds are generally less than 1 m/s, speeds of over 3 m/s have been observed in regions of high tidal currents, such as Cook Inlet, Alaska. Numerous publications are available that describe the factors that influence ice drift speed, i.e. surface and keel drag coefficients, horizontal areas, wind speed, current speed, etc. If actual measured ice drift data are not available, ice drift speed can be estimated by the use of algorithms adopted in computer simulation models, determination of ice feature encounter frequency, speed of ice impact, etc.

An important phenomenon that results from ice dynamics is ice pressure. Ice pressure is common in coastal regions when onshore winds cause ice to build up along a coast or when the wind or current direction changes rapidly. Changes due to tidal currents can be quite important in this respect. In either case, the ice cannot respond by changing its direction and internal stresses within the ice cover build up, causing ice pressure. The effect of ice pressure is to reduce the capability of a vessel to transit through the ice. In extreme cases, it has been known to cause ice floes to penetrate a vessel hull, causing it to sink. Offshore platforms are generally designed to higher local actions than those caused by ice pressure but a check should be performed.

Wind, waves and currents govern the drift of icebergs. Since most of the iceberg mass is under water, icebergs have a lower wind factor than sea ice, implying that the underlying current has a relatively greater effect on iceberg speed and direction [A.6-23].



*For stationary floating structures in ice, particularly ship-shaped, variations in local ice movement, and in particular changes in drift direction, can be important. Changes in drift direction can be caused by wind changes (e.g. passing front), current change (e.g. passing eddy) and forces at geophysical scale (e.g. tides). They can occur at time scales of minutes to days. Observational methods include:*

- Drifting buoys with a satellite positioning system;*
- Tracking vessels that follows ice motion, e.g. when attached to an ice floe from which samples are taken;*
- Coastal and offshore radar systems;*
- Observations of the movement of the ice cover using autonomous reverse Doppler sonars placed on the seabed.*
- Analysis of satellite images*

*The temporal resolution and length of record should be determined by the expected conditions at the site in question. If changes occur on the tidal scale (a few hours) duration of the observations of at least two weeks is commonly applied. If using satellite imagery to obtain drift data, these will in general only give average speeds over several days and require that only limited changes occur in floe shapes in order for pattern recognizing software to be applicable. Verified numerical models can be used to supplement data from observations. Monitoring of under-ice currents, air temperature, and wind speed and direction is typically most efficient when conducted concurrently.*

## A.7 Reliability and limit states design

### A.7.1 Design philosophy

### A.7.2 Limit states design method

#### A.7.2.2 Actions

The concepts of “frequent environmental processes” and “rare environmental events” were introduced in other codes<sup>[A.7-1]</sup> to emphasize the distinction between frequent events (wind, storms, etc.) that have several peak values each year, and rare events such as iceberg collisions that occur only once every several years. The design values for such iceberg collisions can be calculated for annual exceedance probabilities of  $10^{-2}$  and  $10^{-4}$  per year, respectively, for L1 structures.

In this International Standard, the concepts of EL and AL events replace the concepts of “frequent process” and “rare events”. Note that these two sets of concepts are not equivalent.

Both EL and AL events should be calculated for all interaction scenarios, whether they are characterized by frequent environmental processes or rare environmental events. The present approach removes the somewhat arbitrary distinction between the frequencies associated with frequent processes and rare events.

As required in 7.2.2.3 and 7.2.2.4, the  $10^{-2}$  ELIE and  $10^{-4}$  (for L1) or  $10^{-3}$  (for L2) ALIE characteristic action values are calculated for all events; the “rare” value can be close to zero for ELIE, but can dominate ALIE as shown in Figure A.7-1. Conversely, the frequent case can be dominant at the ELIE level. If there are insufficient data to calculate characteristic values, the representative values should be selected by expert judgment. Due account should be made for the differences in the consequences associated with ELIE and ALIE ice actions.

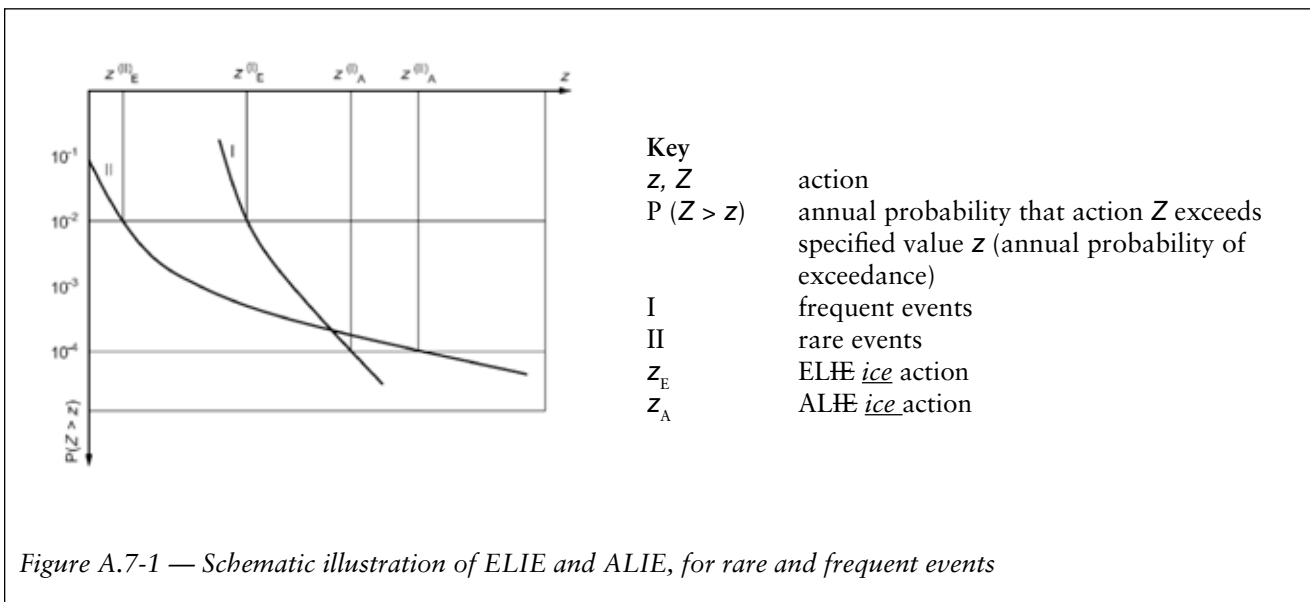


Figure A.7-1 — Schematic illustration of ELIE and ALIE, for rare and frequent events

Earthquakes generally have small or insignificant values at the extreme level.

Potential examples of events for which only ALIE applies include iceberg and ice island impacts. If such events occur with an annual probability greater than  $10^{-4}$  (for L1 structures), the ALIE *ice* action with an annual probability of exceedance of  $10^{-4}$  can be estimated using the approach outlined in 8.2 and A.8.2.

To satisfy target reliabilities less than  $10^{-4}$  in Table A.7-1 (i.e. for L1 structures), ice events with an annual probability of occurrence between  $10^{-4}$  and  $10^{-5}$  should also be considered. It is not possible to calculate a representative action with probability of exceedance of  $10^{-4}$  for an ice event that has a probability or occurrence of less than  $10^{-4}$ . In such cases, the ALIE design can be assessed using probabilistic methods or by considering nominal values of the action based on the ice events. The target can be achieved by the demonstration of adequate structural resistance, through operational procedures as discussed in 8.2.7, or using a combination of both. Similarly, ice events with an annual probability of occurrence between  $10^{-3}$  and  $10^{-4}$  should be considered for L2 structures with respect to the reliability target of  $10^{-4}$ . However, the reliability target for L3 structures is such that the ALIE is not relevant.

#### A.7.2.4 Combinations of actions and partial action factors

The action factors for permanent and variable actions presented in Table 7-4 are based on ISO 19902 for fixed steel structures. For fixed concrete structures and for floating structures, ISO 19903 and ISO 19904-1 present different and sometimes lower values of these action factors. Therefore, if using ISO 19902, ISO 19903 and ISO 19904-1 for the respective structure types, the use of their action factors for permanent and variable, but not for environmental, actions is permitted. The calibration analysis for this International Standard demonstrates that the action factor required for environmental actions for arctic offshore structures is not sensitive to small changes in the gravity action factors.

The action factors are specified to be not less than the values in Table 7-4 (or in the structure-specific International Standards, if used) because larger factors can be used if greater reliability is required. In the case of action factors less than unity in Table 7-4 for overturning, uplift and action reversal, lower action factors can provide greater reliability.

Thermal contraction and gravity combinations are defined in ISO 19900. Moving actions can be considered as variable actions.

An action factor of 1,2 for permanent hydrostatic pressure and for physically limited variable actions can be used because of the very low uncertainty in the maximum values of these actions. An example of a physically limited variable action is the contents of a tank for which the variable weight cannot exceed that determined by the maximum volume of the tank.

Action factors have not been included for the L3 exposure level in Table 7-4. Although their specification is usually at the discretion of the owner and subject to national approval processes, some guidance on general values is provided in Reference [A.7-2].

This International Standard allows a user to perform a calibration of action factors for use in place of the action factors presented in Table 7-4, to the reliability targets presented in Table A.7-1, for all exposure levels. This can be necessary due to particular aspects of the physical environment, of the structure type, of the ice-structure interaction scenarios and of other factors such as ice management if these are an integral part of the system design. A methodology for such a calibration is presented in Reference [A.7-2]. The results of such a calibration can be values of action factors that are less than or are greater than the values in Table 7-4. In such a calibration, due account should be made of the relevant resistance factors, as specified in ISO 19902 and ISO 19903, as well as in other International Standards for offshore structures.

Table A.7-1 – Reliability targets for each limit state action combination

Exposure level	Reliability target expressed as annual failure probability
L1	$1,0 \times 10^{-5}$
L2	$1,0 \times 10^{-4}$
L3	$1,0 \times 10^{-3}$

The targets in Table A.7-1 are for single causes, i.e. for each action combination, and apply to both global effects such as overturning and local effects.

The action factors in this International Standard were calibrated according to Reference [A.7-2]. The calibration accounts for weighted combinations of all action effects over all design equations and action combinations, for different resistance models, for different levels of action effect model uncertainties, for different levels of statistical uncertainty, and for different mean action event occurrence rates. *However, non-linearities that can arise from the response of some floating structures due to flexibility of the moorings or due to possible changes in ice failure mechanisms arising from changes in structure orientation were not included in the calibration.* The methodology involves a weighted optimization process with the objective function minimizing the deviation from L1, L2 and L3 targets, with checks that upper bound failure probability constraints are not violated. For L1 structures, a target annual failure probability of  $10^{-5}$  was applied as per Table A.7-1, and a constraint was applied to ensure that no limit state annual failure probability exceeded  $10^{-4}$ .

The reliability targets in Table A.7-1 take cognizance of both human safety and environmental protection through the exposure levels L1, L2 and L3. If either the safety class is S1 (manned non-evacuated) or the consequence class is C1 (high environmental consequence), the exposure level is L1 and the greatest reliability applies. Similarly, if the safety class is S3 (unmanned) and the consequence class is C3 (low environmental consequence), the exposure level is L3. Other circumstances are covered by the intermediate exposure level, L2. It is emphasized that the targets in Table A.7-1 are for single causes, intended to be the governing one or ones. It should be noted that the reliability targets do not include operational risks such as transportation to and from the installation. Seismic risk is addressed separately, by reference to ISO 19901-2.

For exposure level L1, a manned installation for which evacuation or shutdown is not planned in the face of extreme or abnormal situations for which it is designed, as distinct from being disconnected in the face of situations for which it is not designed, the reliability target can be considered as being approximately the worst case individual risk to life-safety for each person on the installation, as well as significant environmental damage, for one specific limit state or failure cause. Background to the value of the reliability target associated with exposure level L1 is provided in Reference [A.7-3].

Values of reliability targets have been quantified in CAN/CSA S471 for arctic and other offshore structures, Reference [A.7-1], since its publication in 1992. The “annual reliability target level” of  $1 - 10^{-5}$  for CAN/CSA S471 “Safety Class 1”, equivalent to ISO 19906 “exposure level L1”, served as a basis for the  $10^{-5}$  target annual failure probability used for calibrating the L1 action factors in this International Standard. CAN/CSA S471 has been applied successfully in offshore projects subject to ice actions, such as Terra Nova and White Rose on the Grand Banks off Canada’s east coast.

For the lower exposure levels L2 and L3, the annual failure probability target is increased to compensate for the reduced exposure of personnel and to the environment. For exposure level L2, it is reasoned that such exposure can be roughly 10% of that for L1, on the basis that a precautionary evacuation and shutdown is 90% likely to occur without casualties or damage, so that the target annual failure probability can be increased to  $10^{-4}$ . Similarly for L3, a further tenfold reduction in exposure is considered appropriate, giving an annual failure probability target of  $10^{-3}$ . This value for ISO 19906 “exposure level L3” is consistent with the “annual reliability target level” of  $1 - 10^{-3}$  for CAN/CSA S471 “Safety Class 2”.

In view of the track record of successful application of these reliability targets for actual designs, an attempt at greater accuracy has been avoided as an overly precise definition involving smaller subdivisions of orders of magnitude of the probabilities is not considered justifiable. The resulting calibrated action factors are consistent with the other International Standards for offshore structures.

*In application to stationary floating structures, site and structure specific calibration of partial action factors is deemed advisable. Calibration is typically based on action distributions that account for uncertainty in the environmental data, the effect of operational procedures such as ice management and the possibility for disconnection, and all other inherent non-linearities in the system. The uncertainties involved in assessing characteristic ice actions and action effects typically increase when operational procedures like ice management systems are introduced.*

## A.8 Actions and action effects

### A.8.2 Ice actions

#### A.8.2.2 Representative values of ice actions

##### A.8.2.2.6 Characterization of the sea ice cover (new subclause insertion)

*In the absence of identifiable discrete features, the total length of ice interacting with the structure over the course of the year is expressed as*

$$L = C_N v t$$

*where*

*$L$  = the total length of sea ice interacting with the structure*

*$C_N$  = average sea ice concentration*

*$v$  = average drift speed*

*$t$  = duration (noting that the reference period or duration is generally one year)*

*An alternative way of representing the total length of ice is to separate the year into different periods with distinct ice cover characteristics, in which case the annual ice length is the sum for the individual periods “ $i$ ” within the year*

$$L = \sum L_i$$

*or alternatively*

$$L = \sum C_{Ni} v_i t_i$$

*where*

$L_i$  = *incremental length of ice interacting with the structure during period i*

$C_{Ni}$  = *average ice concentration during period i*

$v_i$  = *average drift speed during period i*

$t_i$  = *duration of period i*

*In this case, governing equations (A.8-19) and (A.8-20) should be applied using appropriate probability distributions for ice thickness  $h$  and strength parameter  $C_R$  that differ from those used for an annual reference period.*

*For calculation purposes it is sometimes convenient to consider the ice cover as a sequence of discrete ice features, each with equal length or duration. In such cases, each feature can be defined by parameters, which can include*

- a) *ice thickness*
- b) *drift speed*
- c) *drift direction*
- d) *water level*
- e) *failure mode or process*
- f) *ice pressure or stress (as a maximum value over the feature length)*
- g) *temperature*
- h) *driving forces*
- i) *pack ice pressure*
- j) *amount of rafted or deformed ice*
- k) *ice concentration*

*The feature size (length or duration) for use in the calculation can be chosen arbitrarily or can be defined in relation to a parameter considered significant, for example, the period could be defined by the interpretation period for peak measured pressures, in which case the period can be short (e.g. minutes or hours). The annual maximum ice action is calculated from the maximum value of the action for each of the  $i$  ice periods in equations above according to A.8.2.2.1.*

*The parameters describing Equations (A.8-19) and (A.8-20) in A.8.2.4.3.2 do not directly relate to any specific ice cover length or event duration. Instead, they represent a long and complex event over the entire year and represent the maximum value of a large number of different ice actions relating to sub-events over the year. To apply the approach, the parameters of Eq. (A.8-19) and (A.8-20) should be recalibrated to avoid unnecessary conservatism.*

#### **A.8.2.4.4 Sloping structures**

##### **A.8.2.4.4.1 Description of the failure process**

Offshore structures with a sloping surface can be considered as an alternative to a vertical structure. Level ice interacting with a sloping structure is more likely to fail in a flexural failure mode. Ice actions in such failure modes can be significantly lower than in a crushing failure mode, which is typical for vertical-sided structures. Sloping icebreaking surfaces can also reduce ice actions from ice ridges.

There are several possible types of sloping structures. A conical shape is often the preferred shape for offshore structures due to its symmetrical plan shape. In addition to smooth conical structures with circular waterlines, multi-faceted cones with flat, sloping faces have also been investigated. Ice actions on conical or multi-faceted sloping structures have been extensively investigated theoretically and in numerous small-scale laboratory test programmes. Ice action on sloping structures was also studied during several field programmes including Kemi-1 lighthouse in 1983-86 in the Gulf of Bothnia, two piers of the Confederation Bridge since 1997, jacket production platforms in the Bohai Sea, the Kulluk downward breaking floating caisson in the Beaufort Sea, and an experimental tower at Mombetsu, Japan. These structures experienced a wide variety of first-year ice conditions including level ice, first-year ice ridges and rubble fields. Results and observations from these field

measurement programmes were used as benchmarks for verification of theoretical models<sup>[A.8-13]</sup> and ice design criteria for newly built conical and sloping structures. Alternatively, when the full-scale data are not available, small-scale model test data have been used to verify the validity of theoretical models and design criteria. A side geometry that is formed of two sloping flat surfaces can be used in areas where the ice movement has a dominant direction. Studies have also been done on sloping flat panels to obtain fundamental understanding of the ice actions due to sheet ice. Flat sloping panels can also be used as a part of a structure.

Sloping structures break the oncoming sheet ice by deflecting it either upwards or downwards. The resulting ice action has both a vertical and horizontal component. The horizontal and vertical components of ice action on a downward breaking structure are lower relative to those acting on an upward breaking structure of the same size and slope angle. In the case of a downward breaking structure, the vertical component of the ice action is directed upwards, reducing the effective shear resistance at the structure-seabed interface.

Ice interaction with a sloping surface is a complicated process that includes failure of intact ice, ride-up of broken ice pieces, accumulation of ice rubble on the slope, and subsequent clearing of the rubble accumulation; see Figures A.8-9 and A.8-10.

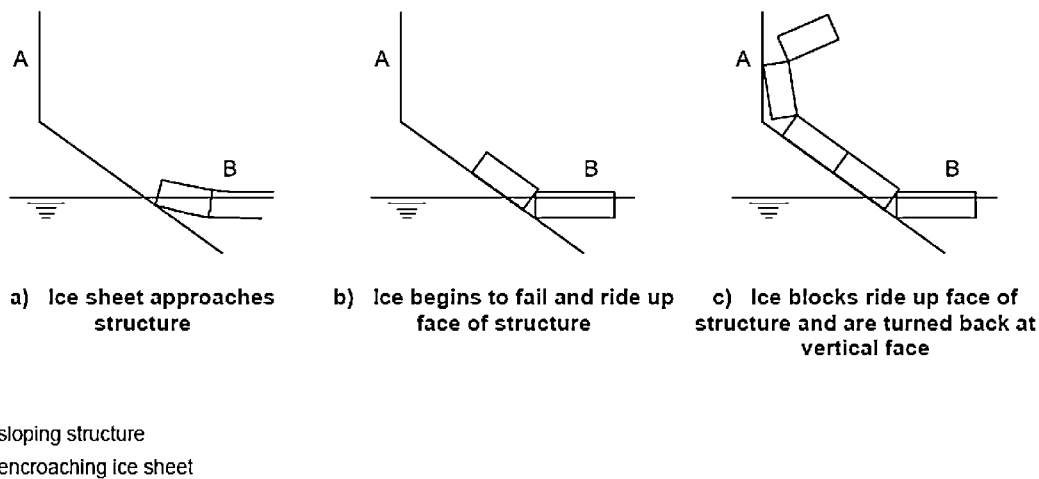


Figure A.8-9 – Processes in the interaction between a sloping structure and sheet ice.

Ice rubble can also accumulate under the ice sheet, further complicating the interaction process. The maximum ice action on a sloping structure is hence a function of several different parameters including bending, compressive and shear strengths of the ice sheet, friction coefficient between structure surface and ice, presence of snow, density of ice, and the height and geometry of ice rubble.

Figure A.8-11 depicts level ice action components for a two-dimensional interaction with an upward breaking structure. The horizontal and vertical components of ice action are as given by Equation (A.8-25):

$$F_H = N \sin \alpha + \mu N \cos \alpha$$

$$F_V = N \cos \alpha - \mu N \sin \alpha \tag{A.8-25}$$

where

$N$  is the component normal to the structure surface;  
 $\alpha$  is the inclination angle of the structure surface from the horizontal, expressed in radians;  
 $\mu$  is the coefficient of kinetic friction between the ice and structure surface (for values, see A.8.2.8.7).

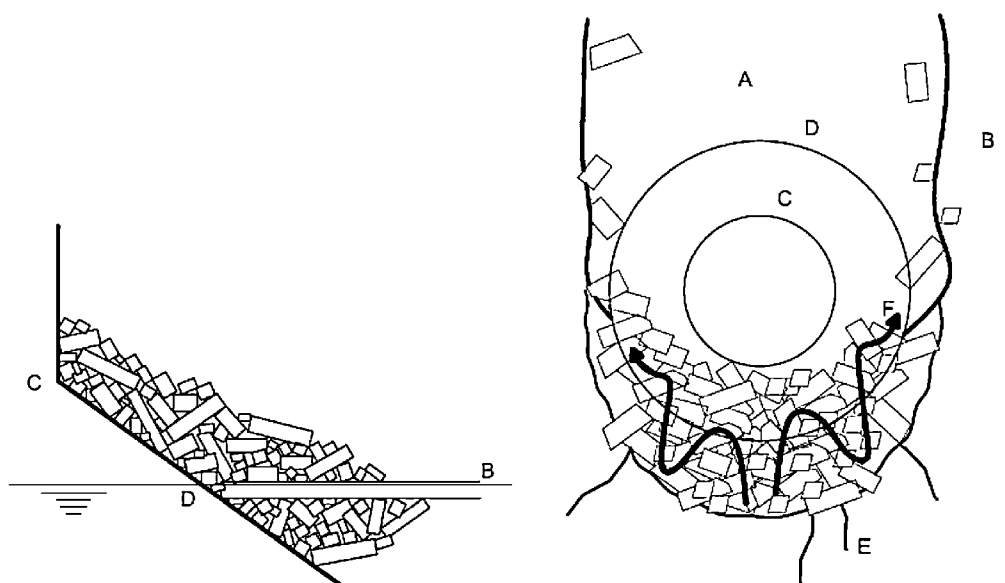


The relationship between the vertical and horizontal components is given by Equation (A.8-26):

$$F_V = \frac{F_H}{\xi} \quad (\text{A.8-26})$$

where  $\xi = \frac{\sin \alpha + \mu \cos \alpha}{\cos \alpha - \mu \sin \alpha}$ .

Theoretical models developed to calculate level ice actions on sloping structures can provide reasonably accurate estimates of ice action, as long as the input data and assumptions are appropriate.



a) Ice rubble pile-up against a sloping structure

b) Ice failure and clearing of rubble around an upward breaking conical structure

**Key**

- A open water in wake of structure
- B encroaching ice sheet
- C top of sloping face of structure
- D waterline of structure
- E cracks forming in encroaching ice sheet
- F clearing of ice rubble blocks around structure

*Figure A.8-10 – Ice-rubble pile-up and clearing around a sloping structure*

A number of methods of determining ice actions on cones and sloping structures have been developed, two of which are described below. The first, as described in A.8.2.4.4.2, is based on the theory of plasticity, and the second, as described in A.8.2.4.4.3, is based on elastic beam bending.

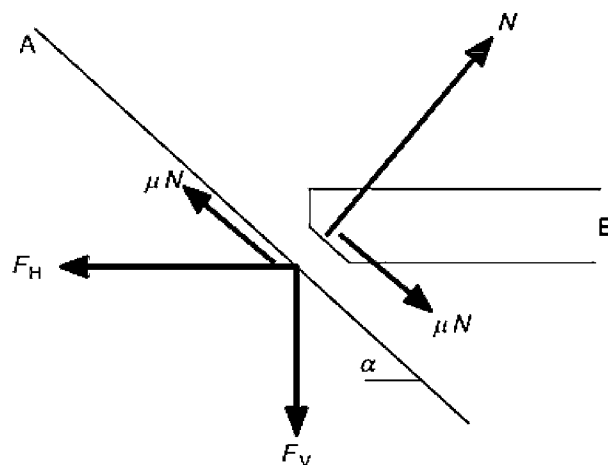
Besides the parameters used in Equations (A.8-25) and (A.8-26), the following parameters are used in the two models, with the various parameters expressed in consistent units:

- $H_B$  is the horizontal action on the cone due to ice breaking;
- $V_B$  is the vertical action on the cone due to ice breaking;
- $H_R$  is the horizontal action on cone due to ride-up;
- $V_R$  is the vertical action on cone due to ride-up;
- $\sigma_f$  is the flexural strength of the ice sheet;
- $h$  is the thickness of the ice sheet;
- $w$  is the waterline diameter of the cone or width of a sloping structure;
- $\rho_i$  is the density of ice, see A.8.2.8.10;
- $\rho_w$  is the density of water;
- $g$  is the acceleration due to gravity;
- $\nu$  is the Poisson ratio for ice, typically equal to 0,3.

The flexural strength depends on the size of the ice specimen that is used to obtain this parameter. Therefore, the values of this parameter should be adopted from field tests where the specimen size is comparable to the design condition (see A.8.2.8.3).

For the case of sheet ice moving against a downward sloping structure, ice bending failure is initiated and the broken ice is pushed down the slope (see Figure A.8-N). The distance moved by the broken ice down the slope is limited by the downward extension of the shaft (if existent) or by the draft of the vessel and will depend on the slope angle, ice-piece size, friction and slope width. Information of ice transport along the underwater part of the hull is important in preventing excessive underwater rubble pile formations, for example, on appendages which will affect the global load on the structure.

Note that for slopes exceeding slope angles of about 60 degrees, the ice load can revert to crushing failure which will be associated with increased ice force levels. Steep slopes are not recommended in the waterline area.



**Key**

- A sloping face of structure
- B encroaching ice sheet
- $N$  normal component of reaction to ice action on structure
- $\mu$  ice-structure friction coefficient
- $\alpha$  slope of structure face from horizontal
- $F_H$  horizontal component of ice action
- $F_V$  vertical component of ice action

Figure A.8-11 – Ice action components on a sloping structure for a two-dimensional condition

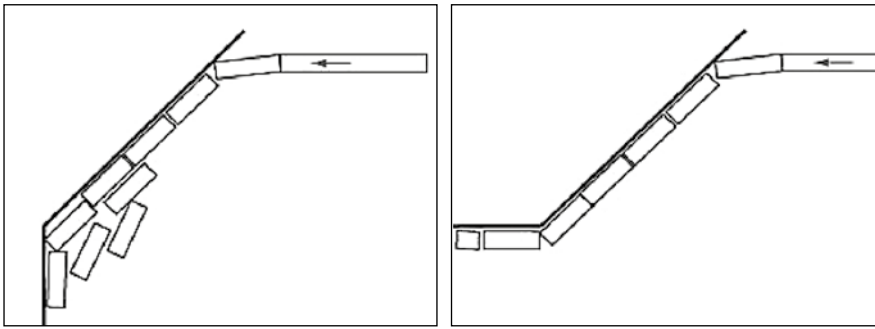


Figure A.8-N1. Ice failure process on downward sloping structures.

#### A.8.2.4.4.4 Effect of ice rubble

It should be noted that the predictions obtained from the two models provided in A.8.2.4.4.2 and in A.8.2.4.4.3 depend significantly on the amount of rubble on the slope. Depending on slope angle and the width of the cone, the volume of ice rubble can vary in different situations. Frictional effects due to snow or the roughness of the ice sheets also influence the height of the rubble pile. The frictional effects can vary in different ice regimes. Field measurements in the Bohai Sea have shown that the clearing process of the ice rubble can be very effective on narrow cones, especially in the absence of snow cover. In such conditions, the horizontal component of the ice action consists mainly of the icebreaking component.

In the model described in A.8.2.4.4.3, the actions are also very sensitive to the angle of repose chosen for the rubble pile. Combined with the rubble height, the angle of repose determines the volume of ice rubble on the slope of the structure. The force to drive the oncoming ice through this rubble pile and up the slope increases rapidly with this volume. This force is then transmitted to the structure and is a component of the total ice action. The choice of angle of repose should be based on experience and observations from actual structures. Model tests can also provide a guide. In general, the angle of repose should not be less than the structure slope angle minus  $10^\circ$ . For very high rubble piles, as can occur on a wide structure, an angle of about  $5^\circ$  less than the slope angle gives a realistic volume of rubble on the slope. It should be recognized that an angle of repose equal to the slope angle ( $\theta = \alpha$ ) implies a single layer of ice riding up the slope. Angles of repose steeper than the slope angle cannot be accounted for in this model because this leads to a negative volume of ice rubble on the slope.

It is recognized that, in nature, an idealized uniform angle of repose for the rubble on the slope does not necessarily occur. In fact, investigators of ice action on the Kemi-1 cone in Finland and the Confederation Bridge in Canada have observed a variety of bilinear, curved or straight rubble slope angles<sup>[A.8-18], [A.8-13]</sup>. The geometry of the rubble formation seems to depend on ice strength, velocity, thickness, friction (snow on top of the ice) as well as on the cone angle and waterline diameter. When using the model described in A.8.2.4.4.3, the selection of the rubble angle of repose should approximate the correct volume of ice rubble that can occur on the slope.

A wide structure, especially with a flat face in shallow water, encourages high rubble heights on the structure because the ice cannot clear around it. In this situation, rubble heights in the 12 m to 20 m height range can occur. In fact, once sufficient rubble has accumulated on and in front of the structure, the ice action required to continue to push oncoming ice through the rubble to the slope of the structure, and then up its slope, becomes so large that the ice failure mode eventually switches to failure of the oncoming ice against the rubble pile in front of the structure. The ice action is then determined using methods valid for ice acting against ice rubble. For wide structures, the ridge building actions described in A.8.2.4.5 can be applied. If the ice rubble in front of the structure is grounded and has time to consolidate, then the crushing equations given in A.8.2.4.3.2 and A.8.2.4.3.3 provide a conservative estimate of global ice pressures. It should also be recognized that if the ice is acting on grounded ice rubble in front of the structure, the actual action transmitted to the structure is reduced by the sliding resistance of the grounded ice rubble. This sliding resistance can be estimated from the footprint of the ice rubble and the cohesive strength of the soil. For a granular soil, the weight of the ice rubble acting on the sea floor multiplied by the tangent of the friction angle of the soil gives a reasonable estimate.

The effect of ice rubble on ship-shaped structures is typically accounted for by applying a friction term along the ship length that adds to the global ice action estimate.

Underwater ice rubble accumulations are typically studied in model tests for detail design of floating structures in ice.

#### A.8.2.4.5 Ice rubble and ridges

##### A.8.2.4.5.1 First-year ridges

First-year ridges and hummock fields are found anywhere where first-year ice forms and is mobile enough to create them. In sea areas where there is only first-year ice, ice ridges are often the governing interaction scenario for design ice actions.

First-year ridges are composed of a sail, a consolidated layer and a keel of lower strength. The keel consists of partly consolidated ice blocks or loose ice blocks with friction only between the blocks. A major part of the consolidated layer is a rafted ice sheet where several thinner sheets of parent ice are refrozen one above the other. The geometrical forms of ice ridges vary in nature. In design, it can be assumed that the cross-section of an ice ridge is symmetric, as illustrated in Figure A.8-12.

The sail height and the level ice thickness are often used as key parameters to define other geometrical shape parameters. For the ridge profile shown in Figure A.8-12, typical relationships are given as  $h_c = 1,6h$ ,  $H_k = 4,5H_s$  and  $\theta_k = 26^\circ$ . The width parameter can vary from  $b_k = 0$  to  $b_k = 5H_s$ . The porosity of the ridge keel depends on the age of the ice ridge and varies in different sea areas. Some key indices of ridge shape are outlined in Reference [A.8-20].

The thickness parameters  $h_c$  and  $H_k$  depend on geographical location. Thicker consolidated layers and keels develop in highly dynamic sea areas due to the rafting process. Therefore, it is suggested that field data be used to specify statistical characteristics of the consolidated layer. Existing field data suggest that the parameters  $h_c$  and  $H_k$  are not correlated with each other. In the absence of field data, it can be assumed in a deterministic analysis that  $h_c$  is 2,0 times the thickness of an ice sheet that has grown in open water under the same conditions as the ice ridge.

The thickness  $h_c$  of the consolidated layer of an ice ridge is locally variable in the vicinity of the structure during an ice action. This can be considered if field data are available to create a probability distribution for the consolidated layer thickness. Using this probability distribution, an average value of the consolidated layer thickness can be determined for each event. The average value can be determined by considering the thickness variability in an area of  $A = w^2$ , where  $w$  is the width of the structure.

If detailed data are not available, the keel porosity can be assumed to have a uniform probability distribution with a lower bound of 0,1 and an upper bound of 0,4.

An accurate, theoretical determination of the actions caused by ice ridges is difficult. An upper bound estimation of the horizontal action caused by a first-year ridge,  $F_R$ , can be obtained as given by Equation (A.8-48):

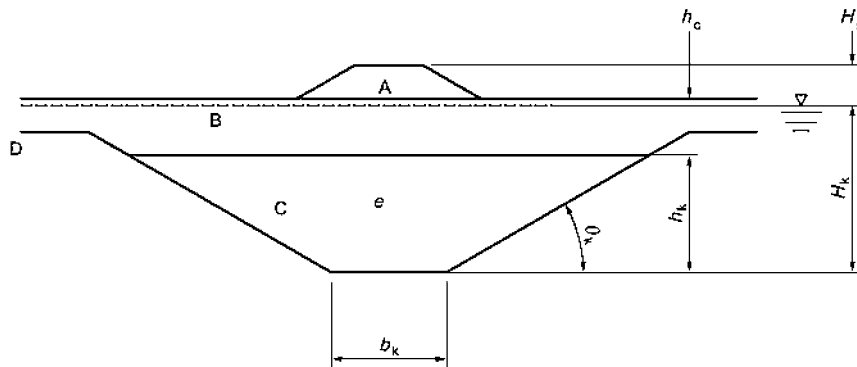
$$F_R = F_c + F_k \quad (\text{A.8-48})$$

where

$F_c$  is the action component due to the consolidated part of the ridge;

$F_k$  is the keel action component.

Since the volume of the sail is small compared to that of the keel, the effects of the ridge sail can be neglected in the case of first-year ridges. The action component,  $F_c$ , can be determined, as an estimate, using instructions given in A.8.2.4.3 and A.8.2.4.3.3 for parameters of the consolidated layer of an ice ridge, or A.8.2.4.4 for sloping structures by substituting  $h_c$  for  $w$ .



**Key**

- A ridge sail
- B ridge consolidated layer
- C ridge keel
- D level ice
- $H_s$  sail height
- $H_k$  keel depth
- $h_c$  consolidated layer thickness
- $h_k$  vertical distance between the base of the consolidated layer and the base of the keel
- $b_k$  width of the base of the keel
- $e$  keel porosity
- $\alpha_k$  keel angle

Figure A.8-12 – Idealized geometry of a first-year ridge

Several models are available for the determination of the unconsolidated keel action component  $F_k$ . Passive failure models are generally used to determine the unconsolidated keel action component acting on vertical or inclined structures. Measurements indicate that the keel cohesion often varies from zero at the base of the keel to a maximum immediately beneath the consolidated layer. Under such conditions, the keel action can be determined for vertical structures (see Reference [A.8-21]), with suitable modification (see Reference [A.8-22]) as given by Equations (A.8-49) and (A.8-50):

$$F_k = \mu_\phi h_k w \left( \frac{h_k \mu_\phi \gamma_e}{2} + 2c \right) \left( 1 + \frac{h_k}{6w} \right) \quad (\text{A.8-49})$$

$$\mu_\phi = \tan \left( 45^\circ + \frac{\phi}{2} \right) \quad (\text{A.8-50})$$

Where

$\mu_\phi$  is the passive pressure coefficient;

$\phi$  is the angle of internal friction;

$c$  is the apparent keel cohesion (an average value over the keel volume should be used);

$w$  is the width of the structure;

$\gamma_e$  is the effective buoyancy, in units consistent with  $c$ .

The effective buoyancy is given by Equation (A.8-51):

$$\gamma_e = (1 - e)(\rho_w - \rho_i)g \quad (\text{A.8-51})$$

where

$e$  is the keel porosity;

$\rho_w$  is the water density;

$\rho_i$  is the ice density.

Guidance for the specification of ridge keel parameters is provided in A.8.2.8.8.

Alternative equations can be derived to obtain the unconsolidated keel action component,  $F_k$ , on a sloping structure. Measurements indicate that the keel cohesion varies from zero at the base of the keel to a maximum immediately beneath the consolidated layer. An average value over the keel depth is appropriate for use in Equation (A.8-49).

The application point for the action of a first-year ridge keel can be assumed to be at one third of the keel depth below the base of the consolidated layer.

To calculate the keel action on a multi-leg structure, the sum of the keel action from each individual leg should be checked against the action on the effective width of the structure and the lower action selected. In addition, the vertical action of ice rubble should be considered if the ice acts against a submerged portion of the structure.

Equations (A.8-49) to (A.8-51) represent a limit stress approach for actions due to ice ridges. Other failure modes, such as the ridge building process, plug shear failure and out-of-plane ridge failure (see A.8.2.4.2), can limit the design action. The plug failure case tends to occur when the ice blocks are loose or when the cohesion is uniformly distributed in the vertical direction. The model described in References [A.8-15] and [A.8-23] can be used in such conditions.

For floating structures with a conical shape (also bow shape) in the water line passive failure of the ice rubble takes account of surcharge. In this case,  $h_k$  in Equation (A.8-49) is substituted by  $h_{eff}$ :

$$h_{eff} = h_k + S \cdot w_e$$

in which the term  $h_{eff}$  refers to the effective keel depth which is a sum of the keel draft,  $h_k$ , and the surcharge,  $S$ , applied over the effective width of the structure,  $w_e$ , at the water depth where surcharge of the keel takes place.

In most of the calculations for realistic ridge widths, a surcharge factor of 0,1 is typically sufficient which would relate to a 10% increase of effective keel draft due to surcharge. Model tests can be consulted in the detail design phase to assess the surcharge on the actual structure. In addition, numerical methods can be used in addition to ice model tests to analyse shape/width and friction effects.



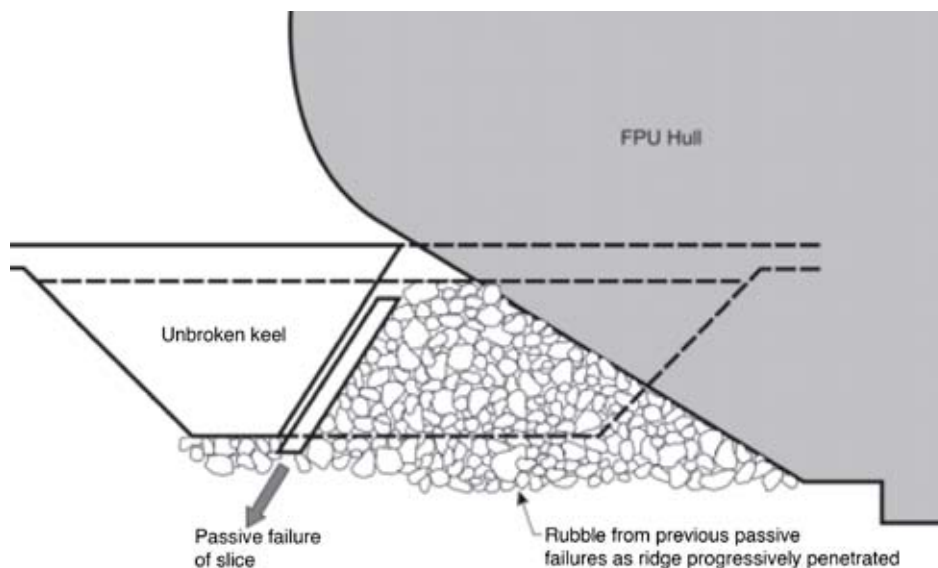


Figure A.8-N2 – Sketch of effective keel depth,  $H_{eff}$ . The  $h_k$  is the depth of the unbroken keel depth, the surcharge  $S$  is the increased depth due to the rubble and  $H_{eff}$  is the total depth of the rubble.

#### A.8.2.8 Physical and mechanical properties of ice

##### A.8.2.8.10 Density

There are several different methods to measure the density of ice. The most common technique is the mass/volume technique by which an ice block is cut from an ice sheet and trimmed to a standard size, which provides the volume,  $V$ . Weighing the sample provides the mass,  $M$ . The ice density is then calculated as given by Equation (A.8-85):

$$\rho_i = M/V \quad (A.8-85)$$

Measurements done by a large number of researchers<sup>[A.8-63]</sup> show that

- the sea ice density ranges between 720 kg/m<sup>3</sup> and 920 kg/m<sup>3</sup>;
- in situ densities are different above and below the waterline;
- above the waterline, the density ranges from 840 kg/m<sup>3</sup> to 910 kg/m<sup>3</sup> for first-year ice and from 720 kg/m<sup>3</sup> to 910 kg/m<sup>3</sup> for multi-year ice;
- below the waterline, the density is more consistent, ranging from 900 kg/m<sup>3</sup> to 920 kg/m<sup>3</sup> for both types of ice.

*Full scale assessment of ice rubble density is challenging. The ice rubble density plays, however, a key role for the actual ice ridge action on the structure. If the sheet ice density, the density of the water, and the rubble porosity is known, the buoyant ice rubble density can be derived from Equation (A.8-51). If applying estimates for the ice density in ice load calculations, the uncertainty regarding density can have a significant impact on the results. Particular care is needed if modelling of density in ice model basins due to deviations between water- and ice rubble density from full scale magnitudes. Numerical methods can be used to assess these sensitivities.*

## A.13 Floating structures

### A.13.4 Actions

There are two types of probabilistic approach for ice actions on stationary floating structures, as follows:

- Probabilistic calculations of ice actions for (linearized) system and specific interaction scenarios (such as head on for ship-shape structure). The operational effect of ice management can be incorporated in such analysis.
- Response based design (RBD), which involves long-term time domain simulations. The operational effect of ice management can be incorporated in such analysis.

### A.13.5 Hull integrity

#### A.13.5.5 Condition monitoring

Table A.13-N – Overview of possible structural monitoring systems

<u>Structural monitoring</u>	<u>Common methodology</u>
<u>Vessel displacements/velocities/accelerations</u>	<u>Gyrocompass</u>
<u>Local ice pressure</u>	<u>Pressure panels</u>
<u>Mooring line tension</u>	<u>Strain gauges / Tension bolts</u>

## A.16 Other ice engineering topics

### A.16.5 Ice tank modelling

#### A.16.5.1 General

Ice tank modelling can be used to investigate various ice-structure interactions and offers the advantage that relatively complex problems (that can be difficult to analyse using other methods) can be studied and visualized at a small scale (i.e. smaller than full scale).

Generally, ice model tests have been used to investigate global ice actions resulting from moving ice, such as the expected ice actions and/or the expected ice interaction modes (e.g. ice failure modes, ice ride-up, the build-up of ice rubble around a structure, ice clearing behaviour around a structure, ice blockage, etc.). Ice model tests have not been used to investigate static ice actions, e.g. resulting from thermal effects. Also, ice model tests have generally not been used to investigate local effects, such as local ice pressures.

The results of the ice model tests can be used for calibration and verification of numerical models that have been developed for investigation of the floating structure/ice interaction. In this case, additional requirements to the ice model tests are typically made (e.g., boundary conditions should be determined during the ice model tests). Clear specification of the objective of the ice basin model tests is useful in order to avoid setting up tests that only give partial answers to the questions raised. The objectives could be one or more of the following, but not be limited to these:

- Determine global ice actions on the structure in fixed configuration
- Determine forces on mooring or requirements to station-keeping
- Determine the ability to ship-shaped floating structures to vane in various ice conditions
- Provide validation data for model calculations or other means of obtaining ice actions
- Qualitatively study the behaviour of the floating structure, e.g. accelerations, offsets etc
- Investigate the effects of managed ice on the floating structure and its station-keeping system
- Investigate ice clearance around the structure and under hull ice transport
- Study different ice breaking hull shapes with the aim to recommend one
- Provide input to evaluate fatigue life under ice actions.
- Provide insight to the ice failure mode

Before embarking on ice basin model tests it is normal to assess the extent to which the questions raised can be reliably investigated by the tests.

Ice tank modelling is a flexible tool that has been applied to many ice-structure interaction cases such as

a) various structure types; the types tested include

- large vertical or multi-faceted caissons,
- upward breaking and downward breaking cones,
- narrow versus wide structures,
- multi-leg structures,
- berms,
- moored versus bottom-founded structures,
- satellite structures placed near a drilling structure to provide ice protection, and access for EER craft or protection for quay areas;

– *ship-shaped turret moored units*

b) Various ice features interacting with a structure, such as

- sheet ice,
- first-year ridges,
- multi-year ridges,
- broken ice, and floe ice conditions.

Table A.16-3 lists common ice processes treated by means of physical modelling and indicates the important variables influencing them. Model reliability depends on the accuracy with which the model replicates those variables. Note that some modelling situations can involve a combination of processes. Consequently, the variables can be grouped differently as shown in Table A.16-3<sup>[A.16-67]</sup>.

Only a limited number of comparisons have been made between model scale and full-scale results for structures, although several correlation studies have been done for icebreaking ships. Ice model tests have been conducted at different scales for fixed icebreaking conical structures. Comparisons are made for the Kulluk (a large downward breaking floating conical structure) between model tests conducted at different ice tanks and field data collected while it was on station in the Beaufort Sea.

A problem of major concern in planning a model test programme is the type of ice. Not all ice problems can be investigated reliably using present-day ice tank modelling techniques. An ice model test programme should be targeted to investigate the specific ice interaction problem of interest. Sometimes, it is preferable to test a simplified, basic problem in the ice tank, and then use these results to assess an overall problem that is more complex.

Table A.16-3 - Ice processes and variables that it is important to model

Ice process	Variables of importance
Ice sheet deflection	Ice flexural strength Modulus of elasticity Loading rate Ice thickness
Ice ridging	Velocity of parent ice sheet Ice thickness of parent ice sheet Ice-ice friction Ice sheet strength (flexural, crushing, shear) Keel depth Sail height Consolidated layer
Ice-structure interaction	Structure stiffness Dynamic characteristics of structure/mooring system Velocity of ice sheet Ice thickness Ice sheet strength (crushing, flexural, shear) Ice-ice and ice-structure friction Mode of breaking (crushing, flexure, shear) Ridge properties and dimensions
Icebreaker modelling	Vessel speed Ice-ice and ice-hull friction Ice thickness Ice sheet strength (crushing, flexural, shear) Ice piece size Piece movement around hull and propeller Mode of breaking (crushing, flexure, shear) Ridge properties and dimensions

Previous investigations of ice ride-up and ridge building are examples where this approach has been used. Initially, simple model tests were done to investigate ice ride-up and ridge building processes. These basic data are part of the information set that is used to address more complex issues such as

- designing islands and structures to avoid ice ride-up problems;
- quantifying pack ice driving actions and developing satellite structures designed to form protective rubble around drilling structures in the Beaufort Sea.

Scaling uncertainties and modelling artefacts are another important issue that should be considered in planning an ice model test programme. These can arise from imperfections in the ice modelling material being used. Some model ices are better able to simulate some types of ice interactions than others.

**A.16.5.2 Scaling**

*The objective of model experiments is to create dynamic similarity between the model and the prototype. If this is achieved, then forces and responses on the model and the full scale are in the correct ratio. This is difficult to achieve for all forces, and so ice modeling has focused on scaling the forces and motions most significant to the problem.*

When model testing is used for ice-structure interactions, appropriate scaling relationships should be selected to represent the mechanisms or processes that dominate the ice actions or action effect to ice actions. In the physical modelling of ice and structure interactions, Froude similarity (the ratio of inertial to gravitational action) and Cauchy similarity (the ratio of inertial to elastic forces) are maintained between the prototype and the model<sup>[A.16-68]</sup>. Considerable effort has been expended on the development of model ice with mechanical properties scaled to prototype ice and with analogous failure behaviour. There can also be rigorous modelling of the structure shape, stiffness, and surface characteristics. As long as the failure modes expected in the prototype are correctly simulated, model tests can provide an important input into the design process. Model ice can provide optimum simulation of ice interactions only over a certain range of scale factors, generally within about 10 to 50. Tests done at scale factors that are too high are likely to produce results that are subject to modelling distortions.

*The scale is typically selected so that it provides the correct modelling with respect to parameters such as*

- *geometry*
- *mass and centres of gravity*
- *hydrodynamic*
- *compliance of the mooring system.*

*If an equivalent model shape is used the following is typically satisfied:*

- *hull displacement, hydrodynamic stiffness and natural periods within specified tolerances*
- *part of the hull structure that interacts with the ice have the same shape as the prototype.*

Scaling is *typically* accomplished by observing the Froude scaling law, as given in Equation (A.16-14), and the Cauchy scaling law, as given in Equation (A.16-15):

$$Fr = \frac{v}{gL} \quad (A.16-14)$$

$$Ca = \frac{v^2 \rho_w}{E} \quad (A.16-15)$$

where

- Fr* is the Froude number, the ratio of inertial to gravitational forces;  
*Ca* is the Cauchy number, the ratio of inertial to elastic forces;  
*v* is the speed, expressed in metres per second;  
*g* is the acceleration of gravity, expressed in metres per second squared;  
*L* is the length dimension, expressed in metres;  
 $\rho_w$  is the density of water, expressed in kilograms per cubic metre;  
*E* is the modulus of elasticity of ice (Young's modulus), expressed in megapascals.

Since inertial and gravitational forces dominate free-surface flow, the Froude number is generally used as the similitude criterion for ice basin modelling. The Cauchy number, then, provides the necessary scaling for material parameters. It is not possible in model tests to simultaneously satisfy the requirements of Reynolds law, which governs viscous effects, with those of Froude/Cauchy scaling. Since viscous effects are relatively small for ice model tests at low speeds, Reynolds law is usually ignored.

In order to satisfy the Froude and Cauchy laws, the various geometrical and physical quantities of the tested objects should be scaled according to Table A.16-4.

*Table A16.4 – Scale relations*

<i>Parameter</i>	<i>Model scale</i>	<i>Full scale</i>
Ice thickness	$h'$	$h = \lambda h'$
Flexural strength of ice	$\sigma_r'$	$\sigma_f = \lambda \sigma_r'$
<i>Crushing strength of ice</i>	$\sigma_c'$	$\sigma_c = \lambda \sigma_c'$
Elastic modulus of ice	$E'$	$E = \lambda E'$
Density of water	$\rho_w'$	$\rho_w = \rho_w'$
Density of ice	$\rho_i'$	$\rho_i = \rho_i'$
Time	$t'$	$t = \lambda^{1/2} t'$
Velocity	$v'$	$v = \lambda^{1/2} v'$
<i>Acceleration</i>	$a'$	$a = a'$
Force	$F'$	$F = \lambda^3 F'$
Friction coefficient	$\mu'$	$\mu = \mu'$

*Note :  $\lambda$  is the geometric scale factor*

*At model scale, it is not always possible to produce all these parameters in the correct ratios. For example, the non-uniform properties of some types of model ice mean that flexural strength and crushing strength are not in the same proportions between model and the full scale. Also flexural strength and elastic modulus may be out of proportion. The emphasis of scaling flexural strength is important when most of the ice failure is in flexure, but less relevant if all the failure is crushing. In such a case, scaling should be based on crushing strength. It is also less important in cases where the ice pieces are pushed out of the way without significant fracture, such as some pack ice and rubble ice conditions. All types of model ice have an optimum scale ratio, where the errors in the proportions of the major force components are the smallest.*

### A.16.5.3 Test methods

#### A.16.5.3.2 Testing technique

In general, two testing options are used in ice model tanks. The first method is to push or pull the model through a stationary ice sheet; the second is to have a moving ice sheet pushed against a fixed or moored model. The selected option should be consistent with the test objectives. Parameters measured and the configuration of the measurement systems should be primarily dictated by the test objectives and the characteristics of the structure and its operational conditions.

*Ice model tests of a stationary (i.e. moored) floating structure call for special considerations in test preparation compared to model tests of fixed structures. Two modes of tests of stationary floating structures are usually considered: 1) fixed model mode; and 2) in moored model mode.*

*In first option a simulation of the mooring system is not required. This test mode is intended to study general mechanisms of the floating structure/ice interaction and to estimate global ice actions on the floating structure in certain fixed position. The results of these tests should not be used for design, only preliminary assessments. All natural frequencies of the model for these tests should be considerably higher than a frequency of the floating structure/ice interaction process. In some cases it can be valuable to perform ice model tests of moored floating structures in semi fixed mode where one or more degrees of freedom (DoF) are restricted. This can typically be the case in early design/feasibility phase when certain DoF's and/or possible dynamic amplification of ice action is of secondary importance or when model tests results are used to calibrate analytical / numerical models and certain DoF's are not accounted for in the calibration.*

*The second option considers modelling the flexibility of the mooring system and the tests should generally consider the following:*

- The model mooring system will be designed in order to represent the prototype mooring line characteristics, including linear and angular displacements of the floating structure model corresponding to full-scale conditions. This can be achieved by modelling a bundle of mooring lines as represented by one equivalent line which is attached to the moored model at the correct fairlead position. The overall mooring layout (e.g. azimuth angle, vertical mooring line angle at fairlead, number of mooring bundles) will generally be maintained.*
- The mass-inertia parameters of the floating are typically simulated. As a rule, during the tests of moored model all kinematical parameters of the model motion (6 DoF) are recorded, as well as the mooring line tensions.*
- Calibration and testing of the mooring system connected to the floating model are usually performed before and after the respective ice test to ensure consistency with specified full scale design values. This can include but not be limited to:
 
  - Pull-out tests to assess the motion characteristics of installed mooring arrangement;*
  - Pitch and roll tests of the moored model to check the installed GM;*
  - Decay tests in all degree of freedom to check the natural periods and damping properties of the moored model;*
  - Check of installed moored model characteristics such as mass, mass centre, and inertial parameters;*
  - Stiffness characteristics of each individual mooring line and the whole system, including total restoring capacity, should be assessed.**

The selected option should be consistent with the test objectives. Parameters measured and the configuration of the measurement systems should be primarily dictated by the test objectives and the characteristics of the structure and its operational conditions.



Tests in various ice basins can give different results and it can be necessary to conduct a benchmark test to get an understanding for how the differences manifest themselves. A simple test structure can be designed for the benchmark test and the test procedures will typically specify at least model scale, dimensions and angles of the test structure, configuration (fixed or floating) and ice conditions.

Hydrodynamic effects associated with the testing techniques can be considered. The objective of ice model testing is often to quantify the global ice action on a structure. If the model is pushed through a stationary ice sheet the measured force also contains a contribution from the hydrodynamic effect, i.e. an equivalent current force, on the structure. Ice action measurements can be corrected for this effect. In case of pushing the model through the stationary ice sheet, hydrodynamic effects are usually evaluated (e.g. by open water run) and its influence on the measured global ice action are assessed and compensated for.

Differences in the dimensions and layout of the ice tank facility can have some influence on the tests. An important factor is the effect of the basin size (length and width) on the number of tests that can be carried out with one ice sheet. The required actual test length depends on the type of test. As an example, for ice rubble formation tests or ice pile-up tests, the model should be able to proceed until a steady state is reached. The other factor that can restrict the test programme is the proximity of the basin walls. For the case when a model is pulled through ice, the level ice sheet can be considered to have infinite extent if the shortest distance from the point of application of any actions to the nearest tank wall is more than three times the characteristic length of the ice sheet.

The choice of testing technique depends strongly on the type of test. In particular, it should be appreciated that when pushing the ice sheet against a model of a fixed or moored structure, unrealistic cracks can often propagate from the model towards the sidewalls of the tank, In addition, the ice sheet can fail along the pushing plate instead of on the model; this happens especially for thin and brittle ice. As well as for the testing technique option, the most practical way to minimize negative consequences of the boundary condition deviation is to conduct tests with an ice sheet sufficiently wide relative to the model width.

In ice modeling, visualizing the failure of the ice and the flow of ice broken ice around the structure is often essential to interpreting the results. Clear underwater video of the experiments is often used to record the experiments (with multiple views above and below the waterline). The time code on the video records will then be synchronized with the force and speed data, so that load events can be identified and visually inspected. Global ice forces acting on the structure can be measured using a variety of techniques.

If the model is simplified such that it is not free floating, then a captive method can be used which measures 3 force components ( $F_x$ ,  $F_y$ ,  $F_z$ ) and 3 moment components ( $M_x$ ,  $M_y$ ,  $M_z$ ).

If a mooring system is used, then mooring tension can be measured in each mooring line. Mooring tension and line angle can be used to resolve the forces into global loads acting on the floating structure.

Local structural loads can also be measured at model scale. This can be either in the form of local structural elements supported multi-component load cells or specialized pressure panels.

In all cases data can be recorded as time histories at a sampling rate sufficiently high to capture peak load events at model scale. Based on this information relationship between the physical processes and quantitative assessments of the measured parameters can be obtained.

#### A.16.5.3.3 Ice conditions

Model tests can be performed in ice conditions such as level ice, rafted ice, a newly broken channel, brash ice (old channel), broken ice, rubble ice fields and ridges. The proper documentation of the tests should include the method by which the ice conditions are simulated. It is recommended to document the ice conditions prior to and after the test by still photographs and video records, preferably from some elevation. The number, time and location of ice thickness and property measurements should also be documented. Visible cracks in the ice extending from the broken channel towards the basin walls or towards open water areas should be included in the report.

The thickness of the model ice should be measured after each level ice test and the number of measurements should be sufficient to adequately evaluate variations in ice thickness along the track of the model through the ice. In cases where test runs are performed close to the sidewalls of the ice tank, measurements should be taken on both sides of the broken channel.

In an old channel or rubble field, the thickness should be measured along two or more lines within the model track. Underwater sonar for scanning the lower surface of model ice and laser profiles for evaluation of ice upper surface or similar remote sensing devices is particularly advantageous for tests with ice rubbles/ridges or brash ice. Such measuring systems allow for the non-destructive acquisition of the ice thickness profiles or a 3D picture before running the test.

Ice ridges and rubble can contribute, in many cases, to the design actions on a structure, and conducting model tests for such conditions is of particular importance. Producing model ridges and rubble in compliance with the requirements of similitude theory is one of the most challenging tasks in ice/structure interaction modelling. The conventional method of creating a first-year ice ridge/rubble is to grow level ice with a thickness equal to the thickness of ice blocks constituting a model ridge/rubble, break this ice sheet into irregular pieces and then collect these pieces into a pile. The resulting pile of ice is normally left exposed for some period of time to negative ambient air temperature in order to create a consolidated layer of the ridge/rubble.

In the course of ice ridge/rubble modelling, particular attention should be paid to modelling the effects of the interaction within the non-consolidated part of the ice feature and to the mechanical properties of its refrozen part. The mechanical properties of the consolidated layer can be evaluated in the same way as for level ice, assuming that both sail and keel are carefully removed. For the measurements of the mechanical properties of the non-consolidated part, pull-up, punch and/or shear tests can be employed.

*Ice ridge interactions with fixed and floating structures are often the main objective for model testing campaigns due to the fact that they are often associated with the design action effects on these installations. Ridge specifications for the model ice ridges are typically characterized by constant geometrical characteristics (the thickness of the consolidated layer, macro-porosity, individual ice block thickness, the keel depth, and keel width) together with the mechanical properties of the consolidated and unconsolidated part. These parameters form part of the model test specifications and are carefully controlled during the ridge preparation and model test. Scaling of both surrounding level ice and ice ridge at the same time appears to be challenging due to the fact that ice properties evolve differently in the level ice and ice ridge, mainly since the flexural strength is achieved by tempering the ice, a time consuming process, which also affects the ice properties of the ridge. Initial ice temperature during ridge creation and evolution of ice temperature during ridge formation is typically monitored and documented. The ice temperature is important in order to control the freeze-bond development in the ridge keel together with the development of the consolidated layer.*

*Model tests in managed ice conditions are often carried out. Managed ice conditions can be achieved by systematically breaking up the parent ice sheet into pieces with a specified edge length or overall dimension. In order to replicate natural managed ice conditions, partial concentrations can be utilized in which the distribution of broken ice size and its concentration scale with the full scale ice conditions. This may also include a typical amount of brash ice. For all managed ice tests the following parameters are typically recorded and assessed:*

- Initial ice floe distribution and initial ice concentration.*
- Evolution of the ice cover during the test.*
- Constraint of external boundaries on the managed ice test.*

#### A.16.5.4 Model ice properties

##### A.16.5.4.1 General

Different model testing facilities use different types of model ice materials. None of the existing model ice materials is absolutely perfect. Thus, ice properties measured for one type of material cannot be directly compared with another material. The geometrical parameters and mechanical properties of the model ice should be determined accurately, regardless of the material composition.

To maintain reliable results, it is recommended to perform property measurements in situ in the tank and, whenever possible, without lifting the samples out of the natural environment. The timing and location of the

measurements are important. The measurements should be done as close as possible to the actual test area and test time. All measurement procedures should be as simple as possible and measure the desired parameter directly. The test procedures and measurements should be performed by qualified personnel and should be clearly documented. The equipment used in all measurements should be calibrated at the ambient temperatures of the ice tank.

Properties of first-year and multi-year ridges are very difficult to control in ice basins. Samples should be taken from parts of the ridge to document both consolidation and other internal properties. The ice conditions adjacent to the ridge should be documented. For instance, broken level ice surrounding a ridge reduces the actions substantially compared to intact level ice.

*Level ice is the basic building block of all ice modeling. The ice is grown to the scaled thickness. Once the growth of the ice sheet is complete, measurements can be made of the ice properties relevant to the problem before and after the experiments. This will likely include ice thickness, ice flexural strength, elastic modulus, ice density, ice crushing strength and ice-structure surface friction coefficient.*

*Pack ice can be created by breaking the level ice sheet into smaller floes. The additional parameters to be included in modeling are the dimensions of the ice floe (in the plane of the water surface) and the average fractional coverage of open water.*

*First year ridges require considerations when planning model tests. Some factors for consideration include: thickness of the parent ice to be used, ice block cohesion within the ridge, consolidation or re-freezing of top layer, adhesion or freezing to adjacent ice sheet, and the final thickness of the surrounding ice sheet.*

*Generally ridges in nature form from relatively thin first-year level ice (<1.5 m) and are made primarily of ice blocks with dimensions 3-5 times the parent ice thickness.*

*If ice ridge actions are crucial for the capacity and performance of the tested structure and the ridge properties are uncertain or cannot be investigated, confidence can be gained by conducting repeated tests with the same ridge specifications.*

*The final ridge profile can be measured underwater and above water. This can be done using an automated measurement device (e.g. sonar) or by direct physical measurement. The final porosity of the ridge can be calculated from the profiled volume and the volume of ice used in its manufacture, as can the ice properties for the consolidated layer and the unconsolidated layer.*

#### A.16.5.4.4 Friction coefficient

*The object of the friction tests is to measure the coefficient of friction between the surface of a structure / ship model and the top surface of the model ice.*

The dynamic friction coefficient is determined through measurements of the tangential action when either a piece of model ice is slid along a plate, painted identically to the model structure, or such a plate slides over a piece of model ice. In the both cases, the ice and the plate should be pressed together by a given normal action. The friction between two ice pieces can be determined using the same testing arrangements. The contact surfaces of the ice and the plate should be moistened, since wet and dry friction coefficients differ significantly. The friction tests should be performed at a speed corresponding to the ice/structure interaction velocity expected in the tests. The friction coefficient,  $\mu$ , is calculated according to Coulomb's friction law as given in Equation (A.16-19):

$$\mu = F_T / F_N \quad (\text{A.16-19})$$

where

$F_T$  is the normal mean measured tangential (friction) load during steady motion  
 $F_N$  is the normal load on the contact surface

Whenever possible, the friction tests are carried out at the same time as the model tests to maintain the same ice strength.

## A.17 Ice management

### A.17.1 General

Floating structures that are deployed in ice-covered waters are often supported by highly capable ice management vessels, with the intended role of modifying the local ice environment, reducing ice actions on the structure and enhancing ice clearance around it. The requirement to identify potentially adverse ice features or situations requiring ice management and then to deal with them in a timely manner increases the range of environmental considerations that are normally associated with fixed structures. Fixed structures can also rely on ice management to ensure access to re-supply and offloading facilities and to clear potential escape routes for EER craft.

The type of ice management systems that is employed can have a significant influence on the design approach taken for any particular offshore system. This depends upon expected level of ice management reliability, for example, the ability to consistently detect potentially adverse ice conditions and, in turn, to manage them successfully before they interact with the structure (e.g. by towing icebergs, clearing grounded ice from EER access points, fragmenting severe sea ice features, etc.).

The major components of an ice management system used for floating facilities in ice-prone regions are illustrated in Figure A.17-1. In the outermost region or observation zone, ice features are detected using a variety of techniques, including aerial surveillance (visual or radar) and satellite-based radar or optical systems. Potentially hazardous features such as icebergs, multi-year and thick ice floes, ridges or rubble fields are tracked and their motion forecast according to the requirements of the structure and its operation.

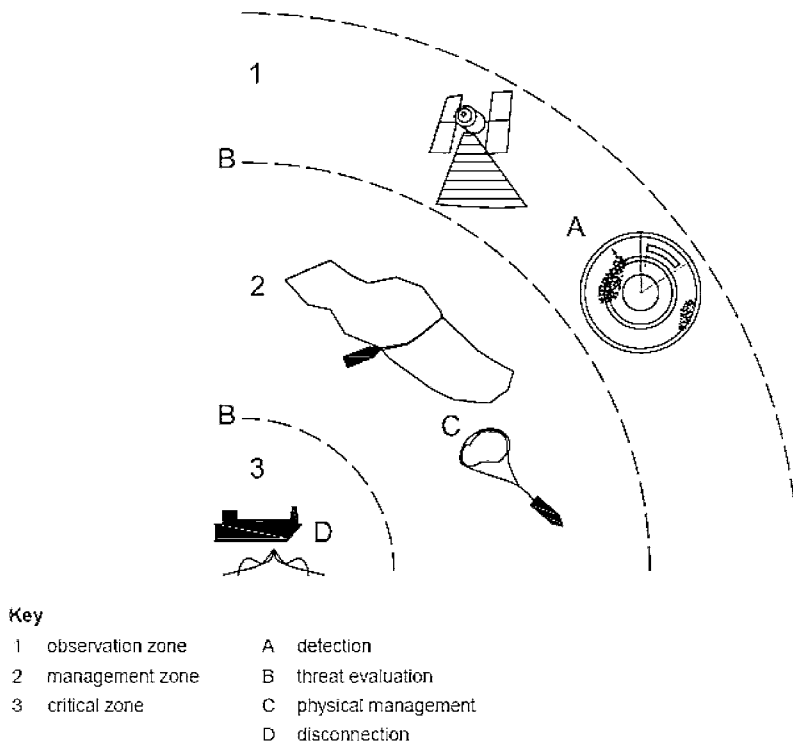


Figure A.17-1 – Typical components of an ice management system

Closer to the structure is the management zone, in which tracking of the features continues, the requirement for physical management is assessed and procedures are implemented. Physical management techniques include deflection by towing icebergs or by applying water cannon to bergy bits and growlers, pushing of large floes, breaking of thicker ice to decrease floe sizes, and breaking up of ridges or rubble fields. This list is by no means exhaustive and all feasible means should be considered. The sizes of the zones vary according to the operational characteristics of the platform and the ice environment. For icebergs off Canada's east coast, the management zone can correspond to drift times on the order of a day, while sea ice management zones seldom extend to drift times of more than a few hours

Each floating structure has one or more critical zones close in corresponding to times required to shut down production, disconnect risers or release some mooring lines prior to full disconnection. These circumstances typically correspond to a series of alert levels with associated drift times estimated for the ice feature to reach the platform. Ice management, detection, tracking and forecasting should continue as long as hazardous features remain within the critical zones.

An ice management strategy for icebergs and many sea ice conditions is illustrated in Figure A.17-2. Detection, tracking and forecasting continue throughout the time when potentially hazardous ice features are present. Once a threat is perceived and the feature is within prescribed time and/or distance limits (generally specified in the ice management plan), ice management resources are deployed. If the threat is averted, detection, tracking and forecasting should continue until it is ensured that the feature can no longer approach the structure. Similarly, production should be suspended and the platform disconnected if the threat persists.

Examples of ice management systems that have been used in ice-covered waters include

- the ice management systems that have supported floating drilling operations in the Beaufort Sea<sup>[A.17-1]</sup>;
- the ice management systems that have supported a flowline installation and extended season oil production operations (through a SALM buoy to an FSO) in the Okhotsk Sea off northeast Sakhalin Island<sup>[A.17-2]</sup>;
- the ice management systems that have supported drilling and production operations on the Grand Banks, and floating drilling operations in the Labrador Sea and off West Greenland<sup>[A.17-3], [A.17-4]</sup>;
- the ice management systems that have supported a range of offshore activities in the Caspian Sea, such as the protection of drilling and production structures against adverse ice events, ice clearance to allow marine access to platforms, and icebreaking to enhance various EER approaches.

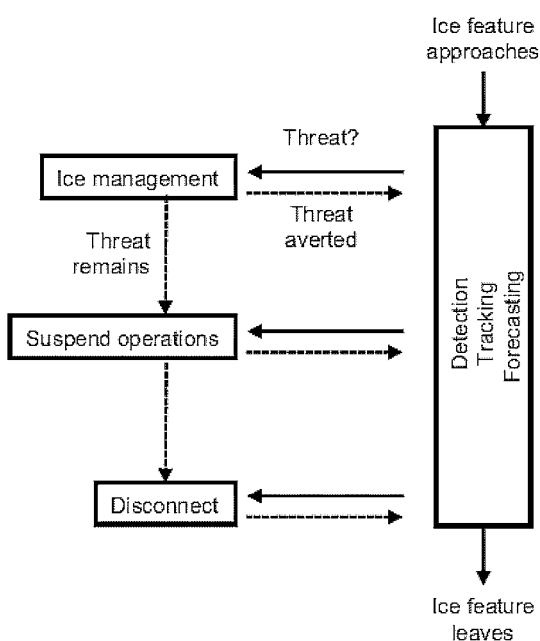


Figure A.17-2 – Typical functions of an ice management system

When these ice management systems were first put into place to support drilling operations on Canada's east coast and in the Beaufort Sea, there was little, if any, related experience in place. As a result, they were configured in a qualitative manner, using judgment, and applied in combination with ice alert and move-off procedures, with the basic objective of reducing downtime levels. At the time, there was insufficient documentation about ice management effectiveness to even attempt to quantitatively assess "system reliability in combination with structural resistance" across a range of ice conditions, ice management techniques and vessel types.

Ice management systems have proven to be quite successful in many situations, with the actual ice related downtime levels providing a feel for their overall reliability. Some representative ice related downtimes are summarized in Table A.17-1.

When planning ice management the following should be considered:

- The occurrence of rafted ice may become more likely, especially when significant ice pressure is experienced.
- The large managed ice pieces tend to rotate as one piece when interacting with the structure, which can lead to interaction with mooring lines or risers for structures with a relatively shallow draft or topside structures with a relatively small airgap.
- The water between managed ice floes can refreeze and this should be considered.

## A.17.2 Ice management system

### A.17.2.1 Overall reliability and design service life

There are presently no recognised approaches for how to assess the reliability of sea ice management operations. This presents a challenge when considering the effect of ice management operations in the limit states design checks and reliability assessments. With respect to iceberg management, the reliability, or at least the probability of interaction between structure and iceberg, can be assessed by the following fault tree analysis in six steps:

- a) Identification of initiating discrete event (icebergs only)
- b) Identification of the safety functions that are designed to deal with the initiating event
- c) Construction of the event tree
- d) Description of the resulting accident sequences
- e) Calculation of probabilities/frequencies for the identified consequences
- f) Compilation and presentation of the results from the analysis

The safety functions can include ice feature detection, forecasting the motion of the feature, support vessels, e.g. towing vessel in case of iceberg or ice breaker in case of sheet ice, and disconnection. Each of these functions has a certain probability failure, for which the available information can be insufficient for a confident estimation.

A typical event tree is illustrated in Figure A.17-N, where failure of the physical ice management is assumed to be caused by a range of factors, like human errors, icebreaker failure, mobilisation failure and forecasting failure.

All probabilities that go into the event (or fault) tree analysis should be documented or, in case of insufficient data, justified through arguments.

During the basic design work for any offshore system that is reliant on ice management, calculations are typically carried out to quantitatively demonstrate that the intended level of success can be achieved. The approach used is to be founded on documented experience wherever possible, and shall reflect the related uncertainties.



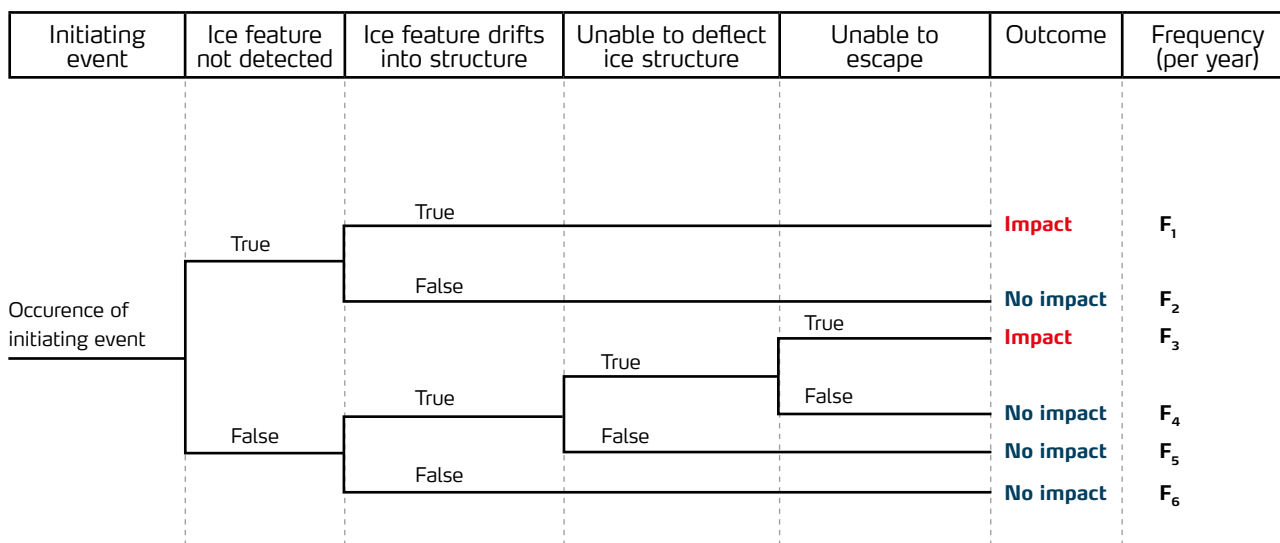


Figure A.17-N - Illustration of an event tree for iceberg-structure collision. Modified from Eik and Gudmestad (2010).

### A.17.2.3 Characterization of ice management performance

Various analytic methods have been, and can be, developed to characterize the performance of any icemanagement system across a range of ice scenarios. However, the actual full-scale field experience that is available to calibrate and verify these methods remains quite limited, particularly for high ice class vessels of novel design in very severe ice conditions.

In this regard, it is important to note that systematic documentation of actual experience is highly recommended to improve future ice management activities. Full-scale demonstration projects can be beneficial, particularly when uncertainties about the effectiveness of ice management systems are both high and very consequential.

Given the current state-of-the-art and a general absence of well documented and quantitative information about ice management effectiveness (particularly for sea ice), it is also recommended that experienced ice management personnel be used to provide judgments on probable ice management effectiveness for the types of quantitative assessments recommended by this International Standard. In this regard, even undocumented input from well experienced operational people is a key factor to recognize, and should be solicited as a key input to any evaluations about ice management approaches and their effectiveness, at least to the extent possible.

*Where ice management is used for reducing the applied ice actions on an offshore installation, the following typically apply:*

- a) *The expected performance of ice detection, tracking and forecasting capabilities and the associated uncertainties are documented so the actual performance of the types of systems or devices used in the ice management is reflected.*
- b) *The overall performance of ice detection and management systems can be characterized in terms of their ability to reduce or alter the frequency and nature of adverse ice events, and reflect the influence of the other ice and physical environmental factors that are associated with these events. Parameters influencing this performance can include:*
  - *ice feature dimensions and drift speed,*
  - *ice feature mechanical properties,*
  - *ice pressure occurrences, pack ice presence around icebergs,*
  - *metocean conditions (e.g. poor visibility, sea state).*

Ice management performance are also considered (and measured) in terms of its ability to extend operations, reduce downtime levels, allow disconnection, facilitate structure move off, and enable safe and efficient reconnection.

In the characterization of ice management, physical ice management are typically separated into iceberg management and sea ice management.

For sea ice management the documentation typically include, but is not necessarily limited to, the following parameters:

- Type of structure, including station keeping system, and operation
- Location
- Weather and oceanic conditions
- Ice conditions, including type or age, thickness, concentration
- Presence and conditions of ridges, rubble, hummocks etc (frequency, sizes, drift speed etc)
- Floe size distribution and drift speed
- Number and characteristics of vessels engaged in ice management
- Ice management organization, strategy and tactics
- Alert procedures
- Weather and ice observation services employed
- Tools for detection of ice
- Personnel involved and their background
- Resulting ice conditions, specified by accomplishments per vessel

### A.17.3.3 Threat evaluation

The purpose of an threat alert system is to define, in a timely manner, any hazards to the platform/well that can cause an interruption to operations or threaten the security of the well or platform, so that appropriate action effect measures can be taken. Hazards can be divided into those caused by ice conditions and those caused by weather and wave conditions.

Zone definition is the first step of the IM process. An example of how ice management zones around a stationary floating structure is typically defined as shown in Figure A.17.1:

- The Observation Zone, where remote sensing (satellite imagery), dedicated helicopter flights and other means will be used to identify potential ice threats.
- The Management Zone or Threat Assessment Zone, where the extent to which the identified ice features may pose a threat is assessed, physical management evaluated and, if needed, initiated.
- The Critical Zone, where preparations are made for disconnection and, if needed, initiated.

Sizes of the different zones are computed for different drift speeds.

An alert system typically includes a sequential list of alert status colour codes assigned to the zones. This provides the means to determine and communicate the degree of alarm corresponding to observed ice hazards and their forecasted drift. The Ice Alert Colour will be determined by considering the specific type of ice hazard as well as the associated Hazard Arrival Time. As a typical example for the structure, the following Ice Alert Colours represent the following conditions during operations:

- Green represents normal operations, no specific action is required.
- Yellow represents an early warning. An ice threat has been identified within the “general surveillance zone”.
- Orange indicates that an ice threat has entered the physical management zone. Ice breaking and iceberg towing become a priority. The structure is prepares to initiate a Planned Disconnection.
- Red indicates a requirement to initiate the Planned Disconnection Procedure. This typically includes stopping field production and starting depressurization in order to prepare for disconnection. Forecasted ice and weather conditions are such that ice hazard actions can be predicted to exceed operational limits. Final release of the structure may be delayed until 15 minutes before the forecast impact.

- Black indicates a need for final disconnection of the structure. Ice hazard is about to enter the exclusion zone with possible imminent impact.

The ice alert criteria or hazards are based on the predefined operational limits of the floating structure and its mooring .

The ice alert colour (IAC) valid at any time are typically displayed in all facilities and vessels in the field. Any change to the IAC are typically communicated to onshore operations and logistics centers

The ice alert status, and changes to it, can cause a variety of very specific, integrated and well-defined response actions. These can range from an increased frequency of ice observations, to the provision of more icebreaker support on site, to higher levels of communication between the floater and icebreakers about ice management strategies and their effectiveness.

Responsibility for the implementation of the ice alert system are defined along with the roles, accountabilities and lines of communication and are a key part of the alert system.

## **A.17.4 Ice management planning and operations**

### **A.17.4.1 Scope of ice management plan**

To get a more detailed understanding of the scope for an ice management plan, reference can be made to documentation that has been submitted as part of the approval process for various offshore activities, along with various regulatory guidelines. Several examples include

- National Energy Board (NEB) Requirements for Physical Environmental Data Acquisition for Drilling and Production Operations on Canadian Frontier Lands;
- the Kulluk Drilling Program Approval Submission from 1991 (located in the National Energy Board library in Calgary, Canada);
- the Terra Nova Field Development Project material (located in the Canada-Newfoundland & Labrador Offshore Petroleum Board (C-NLOPB) library in St John's, Canada);
- the White Rose Field Development Project material (located in the C-NLOPB library in St John's, Canada).

HSE requirements are important when developing the scope of an ice management plan. Conducting ice management operations involves a number of activities which are beyond the general routine work for offshore personnel. The risks in all such activities are typically managed by proper risk assessments prior to start of the work. Typical activities that can involve some risk for personnel injuries and material damage are:

- Frequent deployment and recovery of ice and iceberg drift buoys
- Vessels operating close to each other
- Transfer of personnel between vessels
- Iceberg towing (risk for towline ruptures and wear on machinery, tow line faults, work on deck in high seas)
- Helicopter or air recognisance operations in remote regions and potentially in unfavourable weather conditions

# ANNEX B (INFORMATIVE) REGIONAL INFORMATION

## B.16 Barents Sea

### B.16.1 Description of region

The Barents Sea is a marginal sea bordering on the Arctic Ocean in the north, the Greenland and the Norwegian Seas in the west, the Kara Sea in the east and the coast of the Kola Peninsula in the south (see Figure B.16-1).

The Barents Sea has its greatest depths, up to 600 m, in the central part and a vast shelf with depths of less than 100 m predominating in the southeast and near the coast of the Svalbard Archipelago. For the purposes of this International Standard, the Barents Sea is divided into the *eight regions* shown in Figure B.16-1. This division takes into account the general physical-geographical features of the Barents Sea (seabed relief, atmospheric processes, system of currents, ice edge position, etc.).

The major morphometric characteristics of the Barents Sea are as follows:

- area: 1 424 000 km<sup>2</sup>;
- water volume: 316 000 km<sup>3</sup>;
- average depth: 222 m;
- deepest depth: 600 m;

The hydrometeorological stations used to determine data are as follows:

- a) western region: representative station, Bear Island;
- b) northeastern region: Nagurskoye and Malye Karmakuly stations;
- c) southeastern region: Varandey station.



Figure B.16-1 Boundaries and regions of the Barents Sea. Regions with approximately uniform ice conditions: I) Spitsbergen; II) Norwegian; III) Franz Josef Land; IV) Kara; V) Novozemelsky; VI) Kola; VII) Pechora; VIII) White Sea. NOTE: Regions I and II are referred to as Western region, Regions III, IV and V as Northeastern region and Regions VI and VII as Southeastern Regions in Tables B.16-2 to B.16-4.

## B.16.2 Barents Sea technical information

### B.16.2.3 Sea ice and icebergs

An important distinguishing feature of the Barents Sea ice regime is that its surface area is never completely ice covered. During the period of the greatest ice cover, March to April, sea ice usually covers only 55 % to 60 % of the surface area, with open water occupying the remainder.

The ice cover can be a combination of multi-year ice up to about 3 m thick, first-year ice generally less than 1,5 m thick and icebergs. Multi-year ice spreads in a narrow zone along the eastern shores of the Svalbard Archipelago and Franz Josef Land, predominantly in spring, but it is not the prevailing ice type. In general, for the entire Barents Sea during the period of the maximum ice cover development, the fraction of multi-year ice averages 10 %, while the fraction of young ice is around 15 %.

The Barents Sea ice cover contains icebergs from the glaciers of Svalbard, Franz Josef Land and Novaya Zemlya. Icebergs drift from these glaciers under the influence of the prevailing winds and ocean currents. Entrained in the general ice drift, icebergs can move large distances during their life span. Information on icebergs and their drift is provided in References [B.16-1] to [B.16-4].

Landfast ice is established annually along most continental and island shores of the Barents Sea. The largest width and stability of landfast ice is noted in bays and inlets of the southern sea area and also among the islands of Franz Josef Land and Svalbard.

In the wintertime, strong ice pressure often occurs at sea and forms conglomerations such as hummocks, ridges and stamukhi. Stamukhi are generated in coastal areas in water depths up to 20 m. The maximum sail height for these features ranges from 3 m to 5 m and keel depths from 15 m to 20 m<sup>[B.16-5]</sup>. The greatest intensity of ridging is observed in the northwestern and southeastern sea areas due to the onshore drift of the ice.

*It is important to note that the ice conditions vary significantly between the eight regions. Region II is generally ice free; regions I, III, IV, VII and VIII usually have ice every winter; whereas regions V and VI are in-between. If other data is unavailable the following distributions can be used to describe the ice conditions for regions I, IV and V [from OGP, 2010] to supplement Table B.16-4:*

#### Icebergs:

Parameter	Data Source	Description
Areal density (per 1000 km <sup>2</sup> )	Site specific data	0.05
Waterline length (m)	Site specific data	Combination of two distributions
Significant wave height (m)	Site specific data	Rayleigh, $\mu = 1.76$ m and $\sigma = 0.99$ m
Mass (tonnes)	Loset and Carstens (1996)	$M = 1.49L^{2.57} \exp(\epsilon)$ , where $\epsilon = N(0,0.43)$
Draft (m)	C-CORE (2006)	$D = 3.14L^{0.68} \exp(\epsilon)$ , where $\epsilon = N(0,0.25)$
Width (m)	C-CORE (2006)	$D = 3.09 \times L^{0.490} \times W^{0.215}$ , with $R^2 = 0.661$
Drift speed (m/s)	Site specific data	Gamma, $\mu = 0.25$ m/s and $\sigma = 0.20$ m/s

*First year ridge conditions*

Parameter	Source	Description
Season length (weeks)	NIC archived ice charts	Exponential distribution with a mean of 5.6 weeks (39.2 days) corresponding to concentrations greater than 8/10ths
Ice concentration	NIC archived ice charts	9/10ths (corresponding to definition of season length)
Level ice thickness (m)	Derived from NIC archived ice charts	Exponential distribution with mean 0.56 m, standard deviation 0.26 m, shift 0.3 and upper cut-off 1.5 m.
Keel draft (m)	Derived from plot in Naumov et al. (2007)	Gamma distribution with mean 4.8 and standard deviation 2.3.
Consolidated layer thickness (m)	-	Model as random factor times times level ice thickness where factor is a triangular distribution from a probability of 1 at 1 m to a probability of 0 at 1.9 m.
Keel angle (°)	Wadhams (2000)	Fixed value of 33°
Keel length (m)	Derived from plot in Naumov et al. (2007)	Gamma distribution with mean 36.3 m and standard deviation 19.2 m
Ridge frequency	Zubakin et al. (2004)	5.1 per km
Instantaneous drift speed (m/s)	Zubakin et al. (2004) -	0.2 m/s (assumed same value as for icebergs)







**RN03**  
Risk Management  
of Major Hazards  
Related to Offshore  
Activities in Arctic Areas





# RN03: RISK MANAGEMENT OF MAJOR HAZARDS RELATED TO OFFSHORE ACTIVITIES IN ARCTIC AREAS

## 1. INTRODUCTION

The purpose of the Barents 2020 project for Phase 1-3 has been to recommend HSE standards for common Norwegian - Russian application in the Barents Sea, for safeguarding people, environment and asset values in connection with oil and gas activities, including sea transportation of oil and gas. The underlying assumption is that petroleum operations in the Barents Sea shall be at least as safe as those in the North Sea.

Phase 1 of the project lasted from October 2007 to October 2008. The results of phase 1 were documented in 5 "Position Papers". The position papers provided the basis for further work in phase 2, lasting from November 2008 to March 2009, resulting in the special topics prioritised for further study in expert working groups in phase 3. The scope of the working group RN03 for phase 3 was to identify need for change, if any, in existing *offshore oil and gas standards related to risk management of major hazards for operations in the Barents Sea*.

The result of the work after completion of phase 3 working groups was:

- Common agreed references to recognised international standards which may be used in the Barents Sea;
- Harmonised comments to standards and practices which need to be revised due to Barents Sea challenges;
- Proposals for revisions and amendments to key industry standards;
- Suggestions for any amendments to national and international regulations to allow for the application of industry standards proposed by the working groups; and
- Identification of research and development needs in areas where current knowledge is insufficient.

The phase 4 projects of Barents 2020 address recommendations from the phase 3 report, and in this phase the project has shifted focus from

functional standards to detailed industry guidelines. However, for RN03 the scope defined by the Barents 2020 steering committee has been to prepare and deliver two seminars on risk assessment and risk management. Our group has hence not in this phase had a task to work with updates or amendments to standards or guidelines.

This report presents the contents and results from the risk management seminar which was held in Moscow 12.12.2011.

The risk assessment seminar was held in Moscow 07.12.2010, and the material from the seminar was made available as a download from Internet.

Focus for this phase has continued to be on the Barents Sea, but pan arctic in scope, e.g. ice loads on floaters, risk assessment and risk management in cold climate, EER in cold climate, working environment and human factors, ice management, and emissions and discharges from ships and offshore units.

Phase 4 has involved international operators and OGP to capture the best arctic competence.

Project results may be freely used by operators, regulators, standardisation organisations, a. o.

## 2. SCOPE OF WORK FOR RN03 IN PHASE 4

The scope of work for RN03 in Phase 4 has been:

**Task 1** – Outline and plan two risk management seminars

**Task 2** – Prepare and carry out risk assessment seminar in arctic conditions/ workshop with focus on:

- experience exchange
- comparative analysis of efficiency of methods and software
- required databases to increase safety of offshore operations
- practical application of risk assessment in the design process for offshore activities

**Task 3** – Prepare and carry out risk management seminar with emphasis on concrete cases typical for offshore installations in the Barents Sea.

- Objective is to convey best international practice for risk management and risk assessment to be efficiently used for exploration, planning and development of oil and gas fields in the Barents Sea and other Arctic areas
- Emphasis on concrete cases typical for installations in the Barents Sea.
- Cases reflecting both the usage of risk management and risk assessment in the development process.
- Learnings from actual recent accidental events (e.g. Gulf of Mexico) will be used to illustrate the risk management process 100 participants, target group is Russian authorities, oil and gas company managers, designers

**Task 4** – Proceedings/Position paper to document the contents of the seminar and the discussions that take place.

The rationale for the risk management seminar is that technical excellence in risk assessment is not sufficient to ensure that risks are properly managed. There is a need to implement the full risk management cycle to follow up and manage identified risk, Figure 1 Risk Management cycle.

The intention of the seminar has been to anchor the understanding of the importance of risk management, and what risk management is. This objective was targeted through practical examples from industry and authorities, to give the complete picture on "how and why" to do risk management.



Figure 1. Risk Management cycle

### 3. EXPERT MEMBERS OF RN03, PHASE 4

DNV, responsible for project management, has appointed coordinators for all expert working groups. The coordinator plans, facilitates and leads the Russian-Norwegian expert working groups through the workshops to the final presentation of results. The Russian side nominated the Russian coordinator and experts, and the Sponsors nominated the international experts. The companies and institutions in the groups represent leading organisations within the maritime and offshore petroleum industries in Norway and Russia, and bring the required competence to the groups to assess the selected safety critical topics. The coordinators and participating experts were:

Expert	Company
Børre Paaske (Norw. Coordinator)	DNV
Odd Thomassen (observer)	Norwegian Petroleum Safety Authority
Øyvinn Hålle	Statoil/SDag
Lars Tronstad	Statoil
Erik Bjørnbom	Eni Norge AS
Jerome Frindel	TOTAL
Inger Elise Bjørkedal	DNV
Jo Hulbækdal	DNV
Valery Lesnykh (Russ. Coordinator)	NIIGAZ Economica
Denis Gordienko	EMERKOM
Valery Nekrasov	EMERKOM
Dimitry Kazakovtsev	Rosneft
Mikhail Lisanov	Centre for Industrial Safety
Mikhail Yaroshevich	Giprospetsgaz
Sergey Sidorov	Rosneft
Andrey Petrulovich	Gazprom Dobycha Shelf
Vladimir Safonov	Gazprom VNIIGAZ

### 4. PREVIOUS WORK OF RN03

The scope of the RN03 working group in the previous phases has been to identify need for change, if any, in existing offshore oil and gas standards related to risk management of major hazards for operations in the Barents Sea. Risk management of major hazards is here understood as controlling the risks related to major hazards through developing safe designs and how the risk assessment techniques is a tool in this process. The group have considered standards for the technical safety barriers that shall prevent and mitigate major hazards, and the risk assessment tools used to define requirements to barriers and to measure the risk level reflecting the functionality and performance of the safety barriers. The results from Phase 3 is presented in the Barents 2020 Final report, ref. /1/

A major hazard is here understood as an incident that may cause multiple fatalities, and/or which has a potential to escalate and threaten the integrity of an installation if it is not controlled. The work has been limited to major hazards related to the topside and main process systems, and loss of well control. This implies that loss of containment of well/process hydrocarbons and ignitions of such releases has been the focus for the work.

The area of offshore safety and risk management has many interfaces to other engineering disciplines, and includes aspects within many engineering areas. It has therefore been necessary to select some areas for prioritization, since the mandate for the work has been *review of a limited number of key recognised standards*.

The following issues have been prioritized:

- Standards for functionality and performance of technical safety barriers in arctic conditions, see Figure 2:
  - Containment of hydrocarbons in order to prevent and mitigate uncontrolled releases
  - Ignition source control
  - Fire and explosion risk management
  - Prevention of loss of well integrity and blow outs
- Standards for safety risk assessment of major hazards for topside facilities on offshore drilling, production and storage units in the Barents Sea, all with the aim to prevent **occurrence** and **escalation** of incidents.



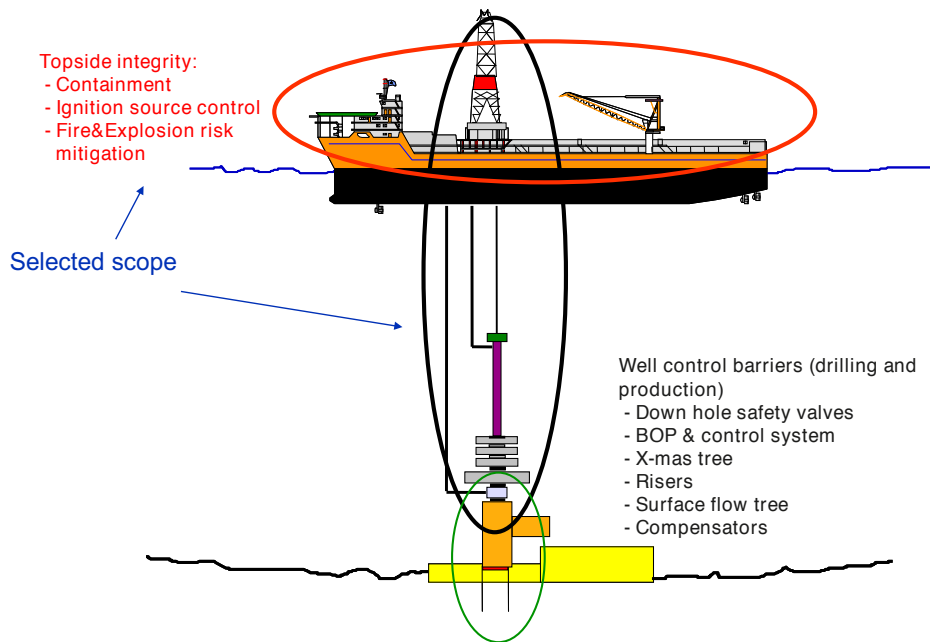


Figure 2. Technical safety barriers and standards for risk assessment of major hazards.

Special attention has been paid to the challenge enclosing/ sheltering (winterisation) of hazardous areas due to cold climate, and the effect this may have with respect to ventilation, ignition probability and explosion pressures. In these areas the group have produced and co-ordinated comments and suggestions for change to standards relating to use of electrical and non-electrical equipment in explosive atmospheres and ventilation of offshore installations.

Risk is understood as the combination of the probability of an event and its consequences. The term “risk” is generally used only when there is at least the possibility of *negative* consequences, ref. /2/.

Risk management is the process of:

- Identifying risk factors
- Assessing and describing the risk factors
- Prioritizing risk contributors
- Evaluating the risk against risk tolerance criteria
- Implementing measures to control the risks in the areas that give the highest benefit.

The generic process for risk management is given in ISO 3100 “Guidelines on principles and implementation for Risk Management”.

#### 4.1. Recommended Key HSE Standards

The working group agreed to assess the applicability of technical standards applied in the North Sea, for application in the Barents Sea. The main reason for this decision has been that the standards to be

applied in the Barents Sea must represent a set of best practice standards that have been applied successfully in an area that is comparable to the Barents Sea.

The recommended standards represent the standards applied and developed within the fields of risk management and technical safety in the North Sea, based on more than 30 years experience from offshore activities. The standardisation regime in the North Sea also reflects the principles of risk management.

The North Sea also represents an area that in many ways can be compared to the Barents Sea, but still with differences with respect to specific arctic conditions. The implications of these differences are the subject of this project.

There are important challenges with respect to the interface between the proposed standards, and national legislation and national standards. Solving the challenges that this interface represents has not been within the scope of the project, but rather to agree on a common set of prioritized standards which the group members see as a starting point to develop a coherent safety regime in the Barents Sea based on internationally accepted standards.

A total of 27 standards were in Phase 3 through an initial review within this framework:

- ISO: 13
- IEC: 5
- IMO:1
- API: 7
- NORSOK: 4

Based on these 27 standards, a set of 14 standards were selected as prioritized and recommended standards, to be included in the basis list of standards for offshore activities in the Barents Sea. The recommended standards are shown in Figure 3.

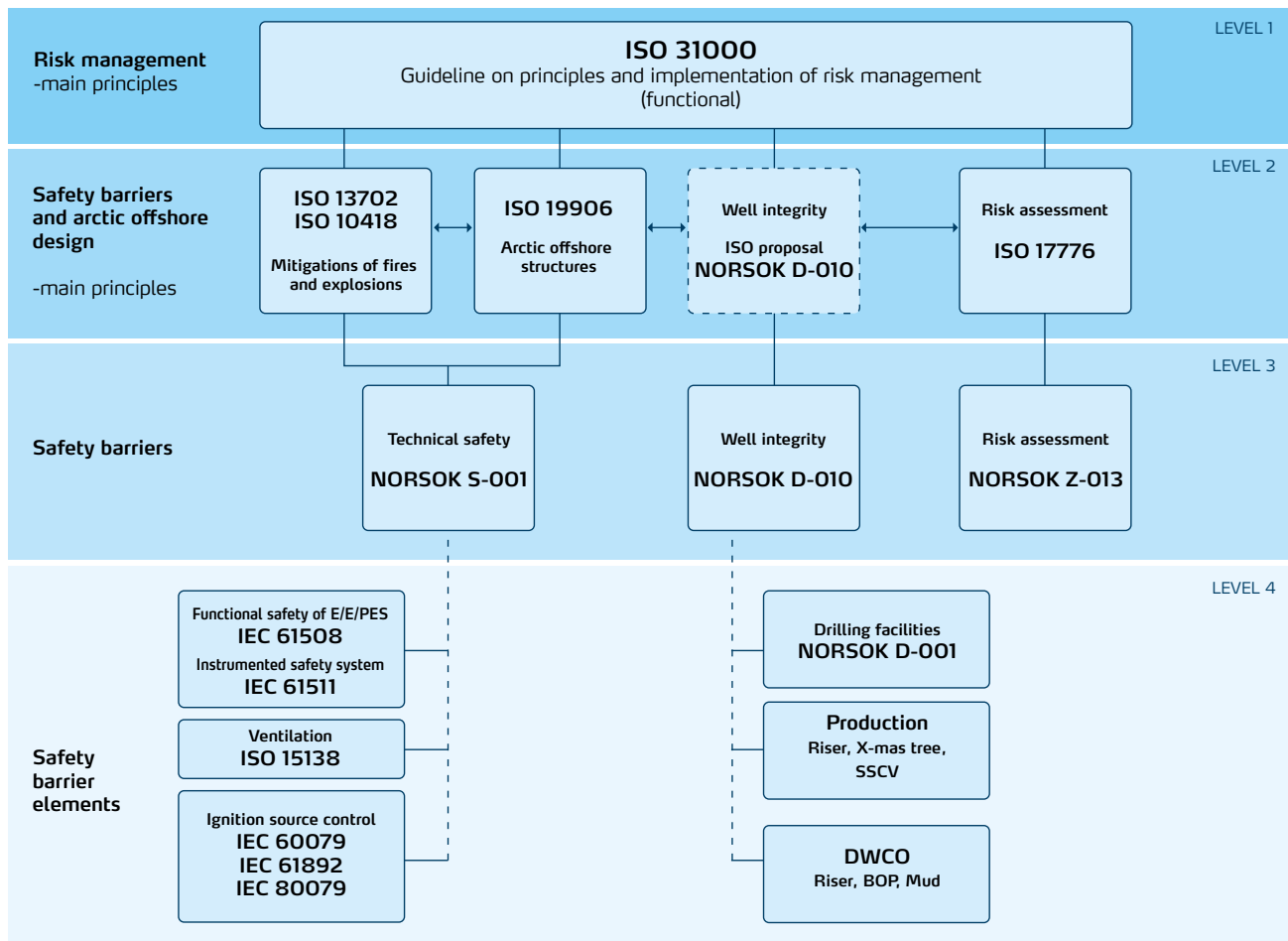


Figure 3. Recommended Key HSE Standards

The group produced detailed comments and recommended changes to the proposed key standards, and these are presented in the Final report from Phase 3, ref. /1/.

The standards and updates which were proposed represent the recommendation from the Russian and Norwegian Industry for a set of harmonised technical standards that will contribute to an acceptable safety level for offshore activities in the Barents Sea. Some of the international standards are already harmonised in Norway and Russia, and in addition some international and Norwegian standards have been proposed as basis for further harmonisation.

International and Norwegian standards considered by the Group do not contradict the basic provisions of the similar Russian documents and can

be used as informational and reference documents for risk analysis and offshore design as well as for development of special regulations, safety rules and oil & gas industry standards. During the work it has come clear that there will be a need for further work and clarifications to ensure the interface with Russian legislation and national standards. There will inevitably be issues resulting from this work which need to be considered further by the appropriate authorities. To accelerate this process and get experience from application of the standards as soon as possible, it is possible to make use of the proposed standards as corporate standards or as project specific standards.

## 5. DELIVERABLES FOR RN03, PHASE 4

### 5.1. Risk Assessment seminar

The risk assessment seminar was held in Moscow 07.12.2010, and the material from the seminar was made available as a download from Internet.

The seminar and the work from Phase 3 was presented in an article by Mikhail Lisanov et. al.: “Russian and international approaches to risk analysis for offshore facilities”.

The article was published in the Russian publication «Occupational safety in industry». The article was 70% based on Phase 3 work from RN03, and 30% on B2020 Risk Assessment seminar in December 2010.

In addition input from Phase 3 of RN03, has been provided to the new GOST R standard on Risk Assessment.

### 5.2. Risk Management seminar

This report documents the risk management seminar “Risk Management of major hazards for Offshore Activities in the Barents Sea”, which was held in Moscow 12.12.2011. The report presents the background and context of the seminar, findings from seminar discussions, observations and the seminar presentations.

## 6. CONTENTS OF RISK MANAGEMENT SEMINAR

To meet the objective of the seminar three main sessions was defined, with a total of 8 speakers:

### Session 1: Interfaces between Risk Management and Regulatory regimes in the Barents Sea

- Norwegian Petroleum Safety Authority (NOR)
- EMERKOM (RU)
- Centre For Industrial Safety (RU)

### Session 2: Risk Management Cases from Russian and Norwegian offshore/arctic oil and gas industry

- ExxonMobile Development Company
  - Sakhalin 1; international risk management approach in Russian context
- Total Exploration and Development
  - application of risk acceptance criteria
- Statoil – monitoring safety barriers during operations
- Eni Norge – Goliat Barents Sea development

### Session 3: Learning from Case Studies

- DNV; Learnings from Macondo blowout

### Reception at VNIIGAZ sponsored by Rosneft

Sections 6.1, 6.2 and 3.3 present the speakers’ own summary of the presentations which were given at the seminar. The full presentations are included in Appendix 1.

### 6.1. Session 1: Interfaces between Risk Management and Regulatory regimes in the Barents Sea

#### Norwegian Petroleum Safety Authority (Odd Thomassen, Principal Engineer, Process Integrity): *Safety Barrier Management*

The presentation gave some insight into risk management through management of safety barriers in a Norwegian risk based and functional based regulatory regime, in the total lifecycle.

The main objective with barrier management is to establish and maintain safety barriers so that they at any time can handle the risks involved by preventing that incident happens and/or reduce loss and mitigates the consequences if the incident occurs.

Management of safety barriers includes the management processes, systems and measures to be in place to ensure necessary risk reduction and comply to the requirements set to safe design and operation.

Risk management, as per ISO 31000 std. assumes the use of risk assessments, suitable for the purpose to support decisions to be taken that directly or

indirectly man influence the risk, positive or negative.

The presentation gave a description of a model for management of barriers based on the ISO 31000 principles and process that could be used in the risk management.

Risk management/barrier management will have the basis in certain situations or conditions, Context, and that a risk picture is established for the given situations and the specified conditions.

The risk picture will be the basis for treatment of the risks and the product of the entire process, a Strategy (as per ISO 13702) must be described to ensure the full understanding of the need for and role of safety barriers. The outcome should also be the Performance standards specifying the performance requirements for the different Technical, Organisational and Operational barriers and barrier elements, in terms of Functionality (capacity/efficiency), Integrity (reliability, availability, and Vulnerability) (robustness, load resistance be efficient for the situation considered).

The presentation focused also on the need for Monitoring and review of all the elements and products involved in the barrier management process. The monitoring and review processes should encompass all aspects of the risk management process for the purposes of detecting changes in the external and internal context including changes to the risk itself which can require revision of risk treatments and priorities; validate that the risk control and treatment measures are effective in both design and operation. Finally the presentation illustrated typical technical, organizational and operational barrier elements and that these may be interconnected and dependent in a way that they need to be considered in combination to ensure an effective barrier and pointed on the supervision activities necessary both in design, fabrication, commissioning and operation.

**Centre for Industrial Safety (Mikhail Lisanov, Director of Risk Analysis Center STC: “Industrial Safety” CJSC): Russian and international approaches to risk analysis for offshore facilities**

Based on the analysis of practice of accidents Quantitative Risk Assessment (QRA) at the oil/gas facilities of Sakhalin and Shtokman Continental Shelf development, and the status of the Russian normative methodical base in the field of industrial safety the following conclusions can be made:

1. In Russia the necessity of performing quantitative risk analysis is established in the number of legal documents in the field of industrial and fire safety, by technical regulation as well as in the normative legal documents of Rostekhnadzor and EMERCOM of Russia.

More detailed results of accident risk assessment are specified in the Industrial Safety Declarations (analogue of “Safety Report”) developed in accordance with Rostekhnadzor requirements and risk-fire - EMERCOM.

2. Russian normative methodical base on risk analysis with regards to general approaches and methodology reflected in the documents of Rostekhnadzor, EMERCOM of Russia and GOST R, is, as a whole, harmonized with the International one.
3. The differences are related to:
  1. use of individual methods, criteria of damage, for example, based on consequences of explosions of fuel-air mixture clouds (RD 03-409-01 and methods TNO-Multi-Energy);
  2. assumptions used in practice (e.g. in the International practice the scenarios with complete destruction of LNG tanks is not calculated);
  3. lack in Russia of
    - normative methods of explosion loads calculations in the enclosed areas (e.g., at the platforms) considering the probability of their occurrence (the explosion pressure in the enclosed areas during their categorization is calculated more simply per SP 12.13130.2009);
    - data bases on equipment reliability, incidents and accident rate for offshore objects of the continental shelf of Russia;
    - requirements and practices on conducting methods of qualitative analyses of hazards HAZID/HAZOP – effective for analysis of technological hazards and supplementing QRA;
4. Development of risk acceptance criteria
  - Use of the results of the project «Barents -2020» for improving the Russian normative base in the field of industrial safety on the basis of the list of the reviewed standards ISO IEC, NORSOK considering the requirements of the Russian normative documents PB 08-623-03, PB 08-623-03, RD 03-418-01, RD-03-14-2005, etc.
5. Work in the expert group proposed to be within risk analysis for other offshore objects (subsea production complexes, offshore pipelines, risers).

- Exchange of data on reliability and accident rate at the offshore objects in the Northern sea and at the Russian objects in the northern latitude and shelves of the Sakhalin island.
- Performance of the comparative analysis of the Russian and International methods and computer software (TOXI+, FLACS, SAFETI ...) on risk assessment with the objective of development of standards and special technical conditions (STU) on designing oil and gas objects of Barents sea fields.

#### Main forms of the further cooperation :

1. Seminars, master-classes on risk assessment with the review of specific projects in the Northern or Barents sea (based on the example of Shtokman gas and condensate complex).
2. Preparation of joint publications about the results of work on the project «Barents -2020» in the journal «Occupational safety in industry» and other Russian publications.
3. Joint participation of the Russian and Norwegian specialists of Group N03 in realization of the SDAG project similar to Sakhalin-1 and Sakhalin-2 projects, etc. (risk analysis, expertise, verification of software on risk assessment...).

#### EMERCOM (Denis Gordienko):

##### *Fire Risk and Technical Regulations for Fire Safety in Industrial Facilities.*

##### **Fire Risk Acceptance Criteria**

Both approaches (prescriptive and alternative) are used in Russia at present. The alternative approach is based on Quantitative Fire risk assessment. The Fire risk is one of the key message of the Federal Law of July 22, 2008 N 123-FZ “Technical Regulations for Fire Safety Requirements”.

Fire risk is used both at design stage (fire risk calculation is a part of design documentation) and at commission stage (fire risk calculation is a part of fire safety declaration).

Fire risk calculation for industrial facilities is based on “Method for fire risk assessment values determination in industrial facilities” with all the set requirements.

Criteria of maximum allowable fire risk have been fixed in the Federal Law of July 22, 2008 N 123-FZ «Technical Regulation on Fire Safety requirements”:

- - Individual fire risk for buildings, constructions and structures shall not exceed one millionth per annum ( $10^{-6}$  year<sup>-1</sup>);

- As to industrial facilities for which it is not possible to ensure an individual fire risk magnitude equal to one millionth per annum ( $10^{-6}$  year<sup>-1</sup>) due to specific technology process carried therein, increase of an individual fire risk up to one-ten-thousandth per annum ( $10^{-4}$  year<sup>-1</sup>) is permissible. At that, activities on personnel fire training and on employees social security to compensate their work under increased risk shall be provided;
- Individual fire risk for people remaining in residential area being in close proximity to the facility that may occur due to fire hazards thereat shall not exceed one millionth per annum ( $10^{-8}$  year<sup>-1</sup>).

Social fire risk for people remaining in residential area being in close proximity to the facility that may occur due to fire hazards thereat shall not exceed one-ten-millionth per annum ( $10^{-7}$  year<sup>-1</sup>).

*The above said criteria are in compliance with the most practices of the developed countries in total.*

## 6.2. Session 2: Risk Management Cases from Russian and Norwegian offshore/arctic oil and gas industry

### EXXON MOBIL Development Company (Daniel E. Egging, Sakhalin-1 Safety, Security, Health & Environment Manager):

Risk Management of an international project in Russia; application of International risk management standards and Russian regulations and standards.

The Sakhalin-1 Project continues to be a world-class development opportunity, one of the largest single foreign direct investments in Russia, and an excellent example of how advanced technological solutions and front-end execution planning can be applied in harsh arctic/sub-arctic environments. The successful completion of the project to date required thorough evaluation of the business, technical and execution risks, the use of innovative technologies, application of state-of-the-art management processes, close interaction with multiple regulatory organizations, and the highest levels of environmental and safety protection. While some specific challenges addressed by the Sakhalin-1 Project were unique to Russia, many challenges and associated solutions developed by the project team are applicable to many projects in frontier regions, particularly those with limited existing infrastructure.

**TOTAL Exploration & Production (Jerome Frindel, Safety Engineer): *Technological risk assessment & risk acceptance criteria***

Total presented the approach that the Exploration & Production branch (as well as the Total Group) adopted during the development phase to manage technological risks, noting that within the organisation:

- Technological risks related to EP's operated facilities are associated with the use or processing of toxic, flammable or explosive characteristics of substances.
- Identifying, assessing and managing risks associated with these substances are integral part of Total's continuous efforts to improve safety and sustainable development targets.
- The systematic processes of identifying hazards associated with Total's operations, assessment and management of these risks at all phases of development are known as Technological Risk Assessment.
- The management of risks involves at reducing the risks for both onsite and offsite facilities to a level As Low As Reasonably Practicable (ALARP).

The technical risk assessment implemented by Total EP includes features commonly seen within most risk management systems:

- Hazard identification
- Preliminary risk assessment
- Detailed and quantified risk assessment
- Risk assessment and ALARP demonstration
- Priority based program of actions and a register of major risk

The organisation adopted a scenario based risk assessment, in part due to the belief that it provided an excellent tool for risk communication and the identification of mitigation measures.

As with all risk assessment approaches, risk levels need to be determined which trigger certain decisions. The risk acceptance criteria in force in Total EP were presented and discussed

**STATOIL (Lars Tronstad, Leading Advisor Operational Safety) : *Monitoring and follow up of "safety barriers" as risk management in operational phase***

**Introduction**

There are several internal and external (regulatory) requirements to follow up and maintenance of safety barriers in the oil & gas industry. It is expected that

the operator shall establish strategies for handling risks, and provide effective safety barriers in order to prevent accidents.

For good barrier management, it shall be known:

- Which function the different barriers shall maintain
- Which performance requirements have been placed on the technical, operational or organisational elements that are necessary to ensure that the individual barrier is effective
- Which barriers are non-functioning or weakened, and the effect on the risk level
- How to implement necessary compensating measures to restore or compensate for missing or weakened barriers

In the following an overview of important issues for follow up safety barriers in the operational phase is given.

**Follow up programs**

There is a clear need to establish barriers on several levels. It is important to have safety barriers that take care of both human-, organisational- and technical issues. Performance standards for the different types of barriers needs to be established, and the condition of the barriers should be known at any time.

**Technical safety condition**

Monitoring and follow up of the performance standards for technical safety systems and barrier functions should as a minimum address:

- Functionality, integrity and vulnerability.
- Maintenance of documentation.
- Maintaining and developing knowledge and competence on the systems.
- Compliance with internal and authority requirements through systematic follow-up.

A verification scheme should comprise:

- Verification in the terms of a periodic review of the safety condition at the plant and mapping of conditions that do not comply with the company's Performance Requirements.
- Follow-up of safety systems and barriers.
- Visualization and follow-up of safety indicators.



**Operational safety condition**

A review and monitoring program for operational safety condition must cover the human- and organisational aspects, like; work practice, competence, procedures, communication, workload etc.

A proactive and systematic method to reveal non-compliance with best work practices in different levels in the organisation should be implemented. Observations and findings will form a basis for developing risk reducing measures by the operating unit. The focus is on work practices that could affect the risk for major accidents.

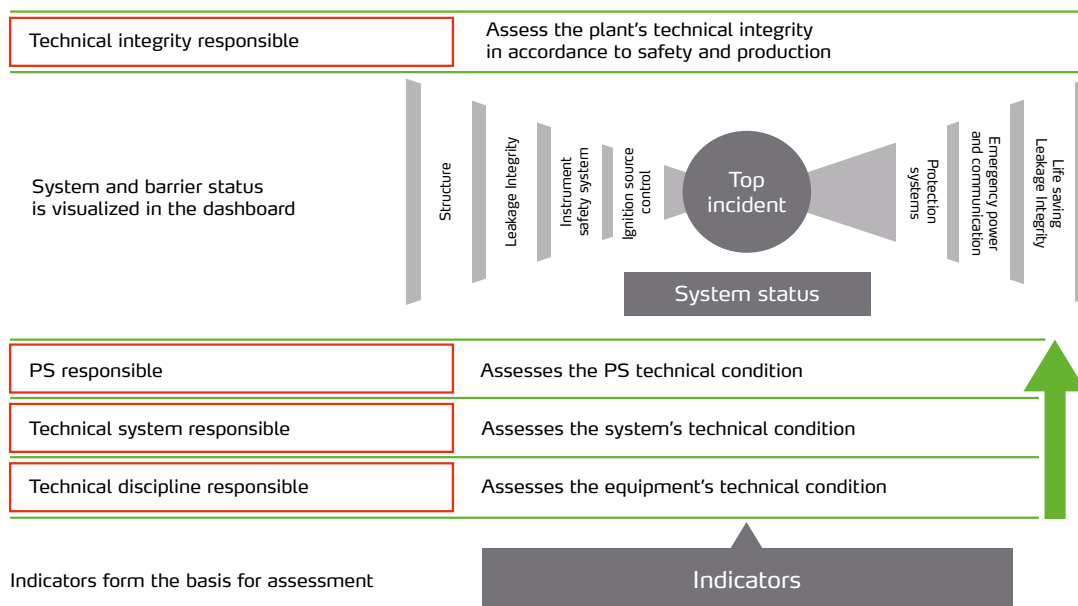
**Continuous monitoring of technical integrity**

Statoil has developed a monitoring program that gives an “online” overview of the status of the safety barriers on a plant. The Technical Integrity Management Program (TIMP) shall ensure a consistent and systematic manner in which to regularly compile and visualise the technical condition of equipment, systems, barriers (performance standards), and the overall technical integrity of the plant.

The status of the technical integrity form the basis for prioritizing and implementing risk reducing measures in cases where there are weaknesses identified. TIMP provides an overview of the technical integrity at the plant by means of:

- identifying, documenting, visualising and assessing the risks related to technical integrity
- identifying adverse trends/development in order to prevent unacceptable risk due to degradation of integrity
- use of common methods for risk assessment to as far as possible ensure a consistent way of identifying risk level
- Presenting gaps in the plant’s integrity so that these can be taken into account in the daily planning (priority) of activities at the plant.
- sharing relevant experiences (the learning/knowledge that is acquired) from across the plants

The technical integrity is assessed in terms of effect on both safety and production. Responsible persons are appointed for all relevant indicators for the plant, and data are collected automatically from different sources in order to make the assessment process easier (sources are for example; backlog on safety critical equipment, performance test data, dispensations, etc. for the relevant equipment). The Performance Standard (PS) responsible is responsible that the function and condition of the performance



*The TIMP work process is based on the this model*

standards are met and documented in accordance with regulations and internal requirements.

The purpose of the TIMP work process is to ensure that the technical integrity of the plant is ensured at all times. As such, status of all indicators shall be registered and assessed with respect to risk and risk reducing measures, with the aim of taking action before an accident occur.

### Conclusions

- Performance Standards for safety barriers needs to be established on several levels, and include human-, organisational- and technical safety barriers.
- The status of the safety barriers needs to be known at all times, and risk reducing measures implemented where weaknesses are revealed.
- TIMP is a tool developed in order to give an “online” status of safety barriers, and is a tool for barrier assessment and risk reducing measures in operation.
- The method is useful and identifies:
  - Status of safety barriers.
  - Areas for improvement/compensating measures.
  - Trends (as indicators).
  - Improved competence and understanding of risks and barriers
  - Comparison between installations.
- Performance is **monitored** at the highest level, giving focus on compliance.
- Safety barriers will be under control and improved, and consequently reduce the risk for **major accidents**.

**Eni Norge AS (Erik Bjørnbom, Environmental Team Leder): *Environmental risk and oil spill contingency analysis – risk based approach***

### Environmental risk and oil spill contingency analysis – risk based approach

The Goliat field in the Barents Sea is currently being developed and will be the first offshore oil field in the Barents Sea. The development consists of a geostationary FPSO, 8 sub-sea templates (22 wells) and an electrical power supply from shore. The produced water will be re-injected and the oil will be exported by the use of shuttle tankers. The production will commence during the last quarter of 2013. Eni Norge is operator and Statoil ASA is the only license partner. The area has high political

focus, especially on oil spill preparedness, and strict environmental requirements.

The development was sanctioned by the Norwegian Storting by “St.prp. nr. 64 (2008-2009) Development and operation of the Goliat field”, which also highlighted oil spill preparedness.

The Petroleum Safety Authority Norway (PSA) is responsible for developing and enforcing regulations which govern safety and working environment in the petroleum activities on the Norwegian continental shelf and associated land facilities states in their regulations:

*“The responsible party shall carry out risk analyses that provide a balanced and most comprehensive possible picture of the risk associated with the activities. The analyses shall be appropriate as regards providing support for decisions related to the upcoming operation or phase. Risk analyses shall be carried out to identify and assess contributions to major accident and environmental risk, as well as ascertain the effects various operations and modifications will have on major accident and environmental risk.”*

The oil spill preparedness requirements will be solution will be set by The Norwegian Climate and Pollution Agency based on the operators risk assessments and proposed oil spill preparedness solution, as part of a discharge permit, which is required before drilling or production can be conducted.

Eni Norge is currently implementing the Goliat oil spill preparedness for the production drilling, based on conducted environmental risk and oil spill contingency analysis (including oil drift modeling). Important inputs to these studies are blow out potential and well release frequencies, oil weathering data, natural recourse data and meteorological data. The analyses are based on Norwegian industry standards developed by OLF.

Eni Norge’s aim for the Goliat oil spill preparedness is that it shall be robust, effective and well adapted to local conditions.

### 6.3. Session 3: Learning from Cases studies

**DNV (Inger Elise Bjørkedal, Senior engineer operational safety): *Learnings from the Macondo blowout (GoM)***

Learning from accidents is an important part of managing risk. During the history we have had accidents which have changed the way we design offshore installations, and how we work with safety. Maybe the most important accident in this regard is Piper Alpha in 1988. This was a game changer in light of how we on British and Norwegian

continental shelf include risk evaluations in design and operation of offshore installations. Now we have the Macondo accident. The question we raise; what can we learn?

In the Report to the President it is stated; “One of the key responsibilities of government is to regulate – to direct the behavior of individuals and institutions according to rules<sup>1</sup>”. There exist different regulatory regimes; prescriptive and performance based. However, no regulations or authority scheme is occasional. Historical, cultural and legal traditions have influenced on how regulatory regime is and will be designed.

Regulatory oversight alone is however, not sufficient to ensure adequate safety. The oil and gas industry will need to take its own steps to increase safety throughout the industry, including self-policing mechanisms that supplement governmental enforcement<sup>2</sup>.

From 2004 to 2009, fatalities in the offshore industry where more than four times higher per person-hour worked in US water than in European water. Even though many of the same companies worked in both areas, this reinforce the view that the problem is not an inherent trait of the business itself, but rather depends on the different cultures and regulatory systems under which members of the industry operates<sup>3</sup>.

The Chief Council’s report concluded that “Better management would have identified the risks at Macondo and prevented the technical failures that lead to the blowout”<sup>4</sup>. The most risky industry can be made safer, given the right incentives and disciplined system, sustained by committed leadership and effective training.

## 7. OBSERVATIONS FROM THE SEMINAR

### 7.1. Prescriptive and performance based regulations and standards

The implication of prescriptive versus performance based regime, and the role of the supervising authority in such a regime and function of “self-supervision” brought up several questions from the participants during the seminar. It is therefore relevant to include a short discussion on prescriptive and performance based regulatory regimes.

Development of a regulative regime is necessarily a function of political, juridical and cultural factors in a society, and as such regulations is not something that can be isolated as a “plug and play” option. The approach will always reflect the overarching patterns for how authorities and industry share roles and responsibilities to ensure safe operations. A prescriptive set of regulations and standards reflects a given cultural and political context, while a performance based regime is developed in a different context.

<b>Prescriptive</b>	Prevent accidents by identifying specific technical requirements that the <b>operator must comply with</b> . The Authorities control the operator’s activity inter alia through approvals and inspections.
<b>Performance based</b>	Make the <b>operator regulate own activity</b> when it comes to safety, health and environment (SHE)

A prescriptive regime points to accepted solutions that by experience and available knowledge are considered safe. These solutions represent what is perceived as a reasonable balance between risk mitigation (risk reduction) and costs related to investment and operation. The results from the prescriptive regime can in this perspective be viewed to represent a more certain way to reach a safety level which meets the expectations from the authorities.

A performance based regime is designed to describe the level or function which shall be met with respect to safety. It will be the operator’s responsibility to select the solutions that meets these objectives and requirements in each specific case. This ensures a clear responsibility for the operators to find the solutions, and by this to build the necessary competence about technology, operations and risk understanding. The responsibility for developing new knowledge and improved solutions is transferred to the operators. The main intention for a performance based regime is to make the industry fully responsible for their activities, combined with sanctioning means from the authorities, ref.

1 Page 234, “Deep Water; The Gulf Oil disaster and the Future of Offshore Drilling”, Report to the President, National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling, January 2011

2 Ref “Deep Water; The Gulf Oil disaster and the Future of Offshore Drilling”, Report to the President, National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling, January 2011, section 8

3 As above

4 Page 225, “Macondo; The Gulf Oil Disaster”, Chief Council’s Report 2011, National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling.

/4/. The authorities will have a range of means to sanctioning companies that does not comply with their regulations.

The task of the authorities in the performance based regime is to design and develop the regulations, and to supervise that the operators have work processes and management systems that ensure that the objectives of the regulations are met. The operators will have a relatively high degree of freedom to develop their own solutions, as long as they can demonstrate that they manage risk associated with their activity, and objectives and functional requirements in the regulations are complied with, ref. /4/.

Both a detailed, prescriptive regime and a performance based regime will have their strong and weak points. Figure 4 lists some of the challenges and pre-requisites with respect to performance based and prescriptive safety regimes.

Performance based
<ul style="list-style-type: none"> <li>▪ Dependent on dialogue and trust between the authority and the industry</li> </ul>
<ul style="list-style-type: none"> <li>▪ The companies themselves need to aim for a good safety culture</li> </ul>
<ul style="list-style-type: none"> <li>▪ Tripartite cooperation, cooperation and involvement</li> </ul>
<ul style="list-style-type: none"> <li>▪ Transparency/openness regard to reporting of failures and non-conformities.</li> </ul>
<ul style="list-style-type: none"> <li>▪ Require high degree of knowledge and competence.</li> </ul>
Prescriptive
<ul style="list-style-type: none"> <li>▪ Can be behind with regard to technological and social development.</li> </ul>
<ul style="list-style-type: none"> <li>▪ Require comprehensive and detailed inspection</li> </ul>
<ul style="list-style-type: none"> <li>▪ Reduction of operator's responsibility to evaluate and manage risk</li> </ul>
<ul style="list-style-type: none"> <li>▪ Dependent on of the industries own will to give access and share information</li> </ul>

Figure 4 Challenges with regards to regulatory regimes

The key HSE standards recommended by RN03 in Phase 3 of the project are essentially functional standards aimed at reaching a given performance level, ref. /1/. The prioritized standards are those that give functional requirements for risk management, risk assessment, mitigation of fires and explosions by technical safety barriers and well integrity. The basis for selection has been their successful application in the North Sea, where the standards are aligned with performance based regulatory regimes.

The regulations for safety in the Norwegian petroleum industry are mainly performance based. A performance based system can be challenging to develop, as the performance levels and outcomes

are not as readily measurable as the requirements in a prescriptive regime. To give examples of how the functional requirements of the regulations can be met, the regulations in many cases refer to standards. This implies that by meeting the requirements in the standard which is referred to, one will also comply with the regulations. At the same time the regulations opens up for other solutions, as long as the chosen solution can be proven to be equally good or better than the one included in the standard. The standards referred to in the regulations are hence assessed by the Norwegian Petroleum Safety Authority to communicate a sufficiently high ambition with respect to safety and working environment, ref. /4/.

The past decades there has been a trend among safety authorities to develop their regulations and supervising activities in the direction of a performance based regime. The main reason has been to encourage a more active approach of the industry themselves with respect to managing and reducing risk and improving safety, not relying on detailed guidance on requirements and solutions from the authorities. The learning has been that detailed guidance from the authorities in several cases has proven to create a more passive and less pro-active attitude among the operators, waiting for the authorities to arrive on inspection to identify deviations and explain how to improve and resolve.

In such situations the responsibility of operator – which sits closest to the operations and has the actual ability to identify and manage risks – with respect to managing own risks can become unclear and may be perceived as partly shared with the authority. A fundamental challenge with a detailed prescriptive regime is that complete follow-up of requirements is hard to accomplish, since this will require frequent and detailed inspection from the authorities, ref. /4/.

In a performance based system the regulators need to collect information about the industry's safety performance through a set of fixed reporting mechanisms on a wide range of performance indicators. To achieve this, the industry has to have a mature safety culture, where there is a transparency with respect to reporting of failures and deviations, both internally and towards the authorities. The reporting of failures is necessary to ensure learning within each company, to share experiences across the whole industry and to give the authorities the necessary oversight to target their supervision activities and development of regulations.

The Presidential report following the Macondo blowout in the Gulf of Mexico underlined that “(even) in industries with strong self-policing, government (supervising authorities. ed. comment) also needs to be strongly present, providing oversight and/or additional regulatory control—responsibilities that cannot be abdicated if public safety, health, and

welfare are to be protected”, (Deep water – Report to the President, report p. 234).

Most regulative regimes will hence have some characteristics of both a performance based and prescriptive system. A performance based system which refers to specific industry standards that can be applied to meet the required performance level is often referred to as a hybrid system.

## 7.2. Risk tolerance criteria, ALARP process and cost-benefit assessments

Criteria for risk acceptability or risk tolerance are a central part of the risk management process. The risk tolerance criteria defines the risk levels or ranges, often in quantitative terms, which are unacceptable and acceptable with respect to exposure of personnel, environment etc.

There are different approaches for formulating such criteria (quantitative, qualitative, what kind of parameters to measure etc.); and also who has the responsibility to define the criteria. In the petroleum industry it is both seen that criteria are set by the operators themselves, but also some places by the authorities. By including in the regulations a requirement that the operators shall establish a risk acceptance criteria, but not giving the specific criteria, one can attain a dynamic process where each operator wants to appear as best in class – or at least be as good as the others, and by that a continuous process to increase the safety ambitions of the industry. This also makes it possible for the authority to confront the operators with their safety ambitions, relative to other operators. On the opposite side criteria defined by each operator may lead to a conserving process, where the industry as a whole is reluctant to take the responsibility for improvement, afraid of costs that may incur from raising safety ambitions in the industry. In any sense it will be the task of the authority to supervise the application of the risk tolerance criteria, to ensure that the regulations are complied with and risks are managed.

The risk tolerance criteria is a central part of the risk based approach to safety, but needs to be linked with a process to reduce the risk to a level which is As Low As Reasonably Practicable. This implies that risk reduction shall continue, even when the risk acceptance criteria is complied with, until the benefit from further risk reduction is outweighed by any costs/disadvantages. In this process is also included the use of cost-benefit assessments, as an analytical process of estimating the costs and benefits of specific risk reducing measures. The ALARP process with assessments of benefit from risk reducing measures implies that the responsible party will need to compare the implied costs of a statistically saved life and other relevant benefits such as expected increased

production, secured brand/reputations (ICAF = cost of measure/ number of saved lives), with the actual willingness to pay for these benefits (i.e risk reduction). The willingness to pay for the risk reduction is not a constant and objective factor, but is influenced by the risk perception in the industry, the risk management policy of the operator, societal risk perception, expectations from non-governmental organizations etc.

Through company internal and public processes all these stakeholders play a necessary part of the process to achieve a knowledge based risk management process, that applies the ALARP-process in a holistic way.

## 7.3. Approaches for adaption of ISO31000 into Safety Barrier Management

The main objective with barrier management is to establish and maintain safety barriers so that they at any time can handle the hazards involved by preventing that incident happens and/or reduce loss and mitigates the consequences if the incident occurs. The use of safety barriers to manager fire and explosion hazards is reflected in ISO 13702 – Control and mitigation of fires and explosions on offshore production facilities. The Norwegian Petroleum Safety Authority have requirements for safety barrier management in their regulations, reference is given to §5 of the Activity Regulation.

Management of safety barriers includes the management processes, systems and measures to be in place to ensure necessary risk reduction and comply to the requirements set to safe design and operation.

For good barrier management, it shall be known:

- Which function the different barriers shall maintain
- Which performance requirements have been placed on the technical, operational or organisational elements that are necessary to ensure that the individual barrier is effective
- Monitoring - which barriers are non-functioning or weakened, and the effect on the risk level
- How to implement necessary compensating measures to restore or compensate for missing or weakened barriers

Risk management, as per ISO 31000 std. assumes the use of risk assessments, suitable for the purpose to support decisions to be taken that directly or indirectly can influence the risk, positive or negative. Norwegian Petroleum Safety Authority have



described a model for management of barriers based on the ISO 31000 principles, and this is presented in Appendix A. A practical application of the principles is presented in the presentation from Statoil on *Monitoring and follow up of "safety barriers" as risk management in operational phase, ref. Appendix A.*

The phases 1-3 for Barents 2020 have mainly focused on the principles that should be included in HSE standards to design inherently safe offshore installations for operations in the Barents Sea. The two presentations presented above extended focus to include safe operations, and to implement continuous risk management through the different phases of planning, development, construction and commissioning, operation and decommissioning.

## 8. PROPOSAL FOR FURTHER WORK, OUTSIDE SCOPE OF BARENTS 2020

Based on the work in the RN03 expert group, covering the work from all four phases, and the observations from the risk management seminar the following topics are suggested for further work:

- Perform a gap-assessment of Risk tolerability criteria, implementation of risk based approach and ALARP-principle, cost benefit assessments for Russian and international best practice
- Experience exchange and agree on approaches for assessing efficiency of safety barriers, based on ISO31000.
- Address the challenges (arctic risk picture) identified in Phase 1&2, and how these now can be managed with the use of the deliverables from Barents 2020.
- Exchange of data on reliability and accident rate for offshore objects in the Northern sea and Russian objects in the northern latitude, and shelves of the Sakhalin island.
- Qualify and possibly compile databases to establish failure frequencies and losses for use in risk assessments of arctic offshore activities.
- Update the Barents 2020 gap analysis from 2009 of RU legislation and standards vs. international standards, based on 2011 status in RU (Russian normative documents PB 08-623-03, PB 08-623-03, RD 03-418-01, RD-03-14-2005, etc)

- Experience exchange and agree on detailed modelling of gas dispersion under natural and forced ventilation
- Fires and explosions in confined/enclosed areas
- Develop a framework for risk Assessment and risk communication as a decision support to the management;
  - who are the decision makers ?
  - what type of information do they need, transfer of technical knowledge to decision makers ?
  - how do you convey required information to the decision makers.
  - Use of economic figures to strengthen the message compared to using "un-named" risk figures.
- Based on the work in Barents2020 develop a Risk Assessment "book of knowledge" for arctic areas

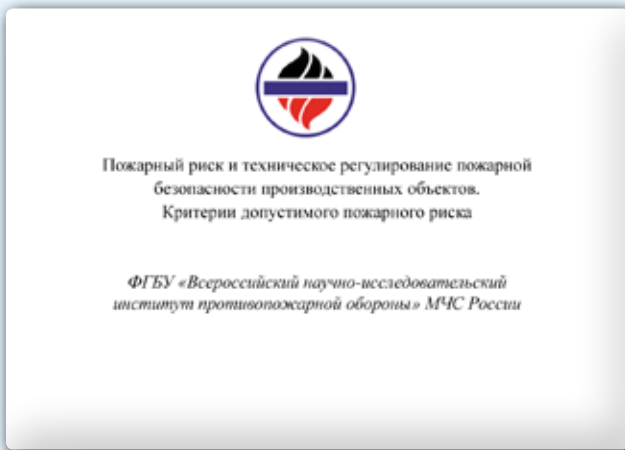
## 9. REFERENCES

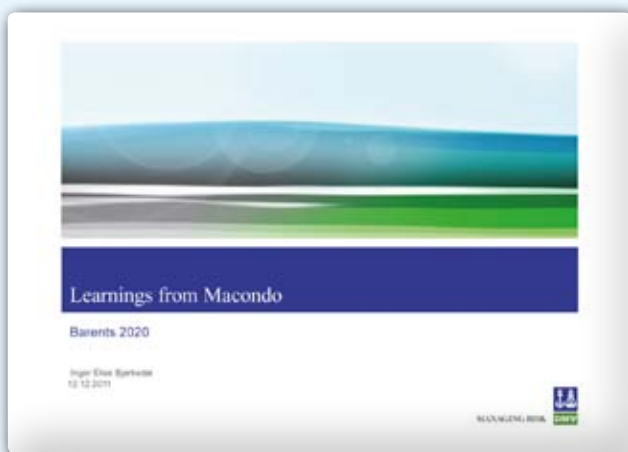
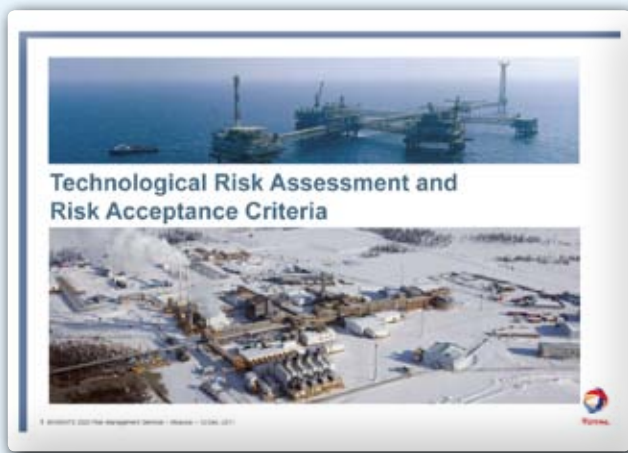
/1/	Barents 2020 - Assessment of international standards for safe exploration, production and transportation of oil and gas in the Barents Sea, Final Report, 2010
/2/	ISO/IEC Guide 73:2002 – Risk Management Vocabulary, Guidelines for use in standards
/3/	Safety Baseline Offshore – Harmonisation of HSE standards in the Barents Sea, DNV report 2008-0694, rev.01
/4/	Deepwater Horizon-ulykken, vurderinger og anbefalinger for norsk petroleumsvirksomhet, Petrolumstilsynet, 2011.



# APPENDIX 1. PRESENTATIONS FROM RISK MANAGEMENT SEMINAR, MOSCOW, 12.12.2011

The presentations can be downloaded from: <http://www.dnv.com/>











**RN04**  
Escape, Evacuation  
and Rescue of People



# RN04: ESCAPE, EVACUATION AND RESCUE OF PEOPLE

## EXECUTIVE SUMMARY

The primary objective of Work Group 4 (RN04), as established by the Steering Committee for the Barents2020 Project, has been to make an assessment of the need for change in existing maritime and offshore oil and gas standards for escape, evacuation and rescue (EER) operations in the Barents Sea, and to propose changes to the standards where necessary, including standards for related equipment.

RN04 has assessed the most relevant Norwegian, Russian and International standards which are assumed applicable to the Barents Sea maritime and offshore industry. In addition to relying on experience in Arctic regions RN04 took into account operational experience in subarctic conditions such as those for offshore Sakhalin Island and the northern Caspian Sea. The assessment included a review of key recognized standards which currently contribute to the definition of the safety level for people, the environment and investments within the topics reviewed by RN04. Key standards are those which cover the main EER risks more directly related to offshore fixed and floating facilities, than for commercial and passenger ships. (The same principles as are recommended herein for fixed and floating facilities should apply equally to ships). Reference standards largely serve as support for recommendations for change explained in this report.

The offshore emergency response system includes many components – EER being just one. To fully appreciate the inter-relationships between EER system hardware and software components, it will be necessary for projects to first determine coarse Performance Standards for each of the other emergency response (ER) elements including Medevac, Oil Spill Response, Command and Control, ER Communications, etc. The Barents 2020 project does not address the much wider ER system, as was the case also in ISO19906.

RN04 concluded that ISO19906 (Petroleum and natural gas industries – Arctic offshore structures), published in December 2010, is the only international standard which deals with Arctic EER issues and should therefore be used as a common basis for review, comments and subsequent recommendations. It was recognized and agreed that the relevant sections of ISO19906 (Chapter 18 and Appendix A18), provide appropriate normative requirements and informative guidance for EER operations in general Arctic conditions.

It was realised that the best way to address the findings of the group would be to propose a separate addendum or guidance document to ISO19906 specifically for the Barents Sea, and this became the primary focus of the work during Phase 4. While progress is being made in Arctic EER standards and guidelines, especially in research and development of new concepts, there is still no single secondary evacuation system available that can provide year-round availability under all Arctic conditions.

Further assessment by RN04 identified the importance of developing performance standards for all EER system components. The scope of work for RN04 during Phase 4 was then expanded to also include guidance on preparing Performance Standards for secondary evacuation methods and emergency response vessels. This expands the guidance given in ISO19906 Appendix A18. This report also explains how Performance Standards can be utilised to align performance-based international standards with national rules and regulations.



## 1. INTRODUCTION

### 1.1. Membership of RN04

At the start of the Barents 2020 project, both the Russian and Norwegian sponsors nominated their respective experts. The Project Steering Committee then considered and approved these nominations adding experts from other countries as well. The experts of the companies and institutions in the

groups represent leading organisations within the maritime and offshore petroleum industries, and bring the required competence to the groups to assess the selected safety-critical topics.

The membership of RN04 changed during the course of four years. The participating experts in the concluding stages were as follows:

#### Russian Experts

Name	Organisation	Expertise
Sergey Kovalev	Gazprom VNIIGAZ	Russian Coordinator, / Arctic Oil and Gas Safety
Albert Shigabutdinov	Central Marine Research & Design Institute	Arctic Marine Systems
Vladimir Shlyachkov	Krylov Shipbuilding Research Institute	Arctic Marine Systems
Anatoly Suvalov	State Rescue and Diving Research Institute	Arctic HSE / EER
Evgeny Taranukha	State Rescue and Diving Research Institute	Arctic HSE / EER
Petr Yaroshuk	Giprospetsgaz	Arctic Oil and Gas Safety
Sergey Myagkov	Gazprom Dobycha Shelf	Arctic HSE / EER
Dmitry Melekhov	Design Centre for Oil & Gas Equipment	Oil and Gas Safety

#### Norwegian Experts

Name	Organisation	Expertise
Leif Nesheim	DNV	RN04 Coordinator
Rune Bråthen	Statoil	Emergency Response
Terje Ø Hatlen	Transocean	Arctic Marine Systems
Sigurd Jacobsen	Petroleum Safety Authority	Regulatory Compliance & Emergency Response
Johan Vedeler	DNV	Arctic Marine Systems

#### International Experts

Name	Organisation	Expertise
Gus Cammaert	DNV	Arctic Marine Systems (and former RN04 Coordinator)
Stephen Knight	Shtokman Development AG	Arctic HSE / EER
Frédéric Turlan	Total	Arctic Safety/HSE Engineering

## 1.2. Target Audience

The target audience is primarily as follows:

### National and international standardisation organisations

This report is for use by standardisation organisations and committees for their consideration and input for possible future updating of industry standards.

### Regulatory organisations

This report is intended to be used by regulatory bodies and authorities in Norway and Russia who are involved in the review and acceptance or approval of projects for oil and gas development in the Barents Sea. It is expected that the report will provide useful information for authorities regarding best available industry practice related to the reported topics and how existing rules and regulations can be satisfied wherever practicable by following a common performance-based approach to ensure offshore risks are reduced to ALARP levels.

### Operators, contractors and manufacturers

This report will hopefully be used by operators, contractors and manufacturers in Norway and Russia and internationally for projects related to petroleum exploration, production and transportation in the Barents Sea.

## 1.3. Use of Document in Barents Sea Projects

This document has been developed in order to provide guidance to operators on issues related to EER for the Barents Sea. It contains important issues that need full consideration when performing activities in the cold climate conditions of the Barents Sea.

This document, together with the referenced documents, can be used as the basis for the development of Performance Standards that lead to Project Specific Technical Specifications, where both can be used to develop EER Philosophy and Strategy, Emergency Preparedness Analysis, Emergency Preparedness Plans and EER Equipment Specifications. In its current form and content, the document contains necessary information and guidance to create project-specific Performance Standards for the design of EER equipment. However, it is not the aim of this document to provide explicit details for the manufacture of such equipment. As referred to in Section 1.6, standards for and suitable equipment for EER in all Arctic and sub-arctic conditions are simply not available, and due to such extreme variances in ice conditions it is not reasonable to expect them to be. This is clearly a focus area for further research and development.

## 1.4. EER Terms and Definitions

The intention of RN04 is to use established definitions as stated in ISO19906 and ISO15544 and to supplement them where found necessary.

In case of discrepancy between the English and Russian translations, the English definitions as described in this report will prevail; however, it must be recognised that the terms used, such as escape, evacuation, emergency etc., translate differently in both languages, as seen in Table 2.

Table 2 - Examples of Terminology Differences:

English	Russian
Escape	Evacuation
Evacuation	Evacuation (escape from installation)
Rescue	Rescue
Emergency = the situation leading up to the incident including escalation	Emergency = the situation after the incident involving escalation

Note that there are also many differences in terminology used for emergency response. The work of Barents 2020 does not address these differences.

In the next table, please note that wording in italics means the definition has been extracted from sources *other* than ISO19906 or ISO15544.

Table 3 - EER Terms and Definitions:

Terms and Definitions	Source and Comments
<b>Abandonment</b> Act of personnel onboard leaving an installation in an emergency.	Section 2 of ISO15544
<b>Accidental situation</b> Exceptional condition of use or exposure for the structure (note: exceptional conditions include fire, explosion, impact or local failure.	Section 3 of ISO19906
<b>Consequence category</b> Classification system for identifying the environmental, economic and indirect personnel safety consequences of failure of a platform.	Section 3 of ISO19906
<b>Duty holder</b> Individual, legal entity or organization holding legal title to the equipment or process and accountable for the safety and welfare of all associated personnel (note: the duty holder is also referred to as "owner.")	Section A.18.1.2 of ISO19906
<b>Embarkation area</b> Place from which personnel leave the installation during evacuation.	Section 2 of ISO15544
<b>Emergency</b> Hazardous event which cannot be handled by normal measures and requires immediate action to limit its extent, duration or consequences.	Section 2 of ISO15544
<b>Emergency command centre</b> Location from which the person in overall charge coordinates ER activities.	Section 2 of ISO15544
<b>Emergency response (ER)</b> Action taken by personnel on or off the installation to control or mitigate a hazardous event or initiate and execute abandonment.	Section 2 of ISO15544
<b>Emergency response arrangement</b> Plant and equipment provided for use under emergency conditions.	Section 2 of ISO15544
<b>Emergency response measure</b> Anything provided to facilitate the management of an emergency. (note: this is a generic term which includes emergency response arrangements, as well as the planning, procedural and organizational aspects of managing emergencies.	Section 2 of ISO15544
<b>Emergency response team</b> Group of personnel who have designated responsibilities in an emergency for the safety of the installation, the safety of others or for environmental protection	Section 2 of ISO15544
<b>Emergency Response Vessel (ERV)</b> <i>Vessel capable of performing emergency response support duties in accordance with the performance standards established for mitigating the effects of major accident hazards on the facility and protection of its personnel and the environment.</i>	Definition added by RN04
<b>Emergency station</b> Place to which emergency response personnel go to undertake their emergency duties.	Section 2 of ISO15544
<b>Escalation</b> Increase in the consequences of a hazardous event.	Section 2 of ISO15544
<b>Escape</b> Act of personnel moving away from a hazardous event to a place on the installation where its effects are reduced or removed.	Section 3 of ISO19906
<b>Escape route</b> Normally available and unobstructed route from all locations where personnel can be present on the installation to the temporary refuge or alternative protected muster point.	Section A.18.1.2 of ISO19906
<b>Evacuation</b> Planned precautionary and emergency method of moving personnel from the installation (muster station or TR) to a safe distance beyond the immediate or potential hazard zone.	Section 3 of ISO19906
<b>Evacuation route</b> Escape route which leads from the muster area to the place(s) used for primary or secondary evacuation from the installation.	Section 2 of ISO15544
<b>Hazard</b> Set of conditions in the operation of a product or system with the potential for initiating an accident sequence that can lead to injury, environmental and/or property damage or any combination.	Section A.18.1.2 of ISO19906
<b>Hazard zone</b> Largest possible area within which personnel safety is at risk due to the installation hazard.	Section A.18.1.2 of ISO19906
<b>Major accident</b> An event with potential for multiple personnel casualties, significant environmental damage, installation failure, or any combination of these consequences.	Section A.18.1.2 of ISO19906
<b>Muster</b> Movement of people to a designated area so that the person in overall charge can account for all people and thereby facilitate subsequent emergency response actions.	Section 2 of ISO15544

Terms and Definitions	Source and Comments
<p><b>Muster area</b> Designated area to which personnel report when required to do so, in an emergency.</p>	Section 2 of ISO15544
<p><b>Offshore Installation Manager (OIM)</b> Person responsible for the installation, and all operations on and around a structure.</p>	Section 3 of ISO19906
<p><b>Owner</b> Individual or organization responsible for the design, construction, commissioning, and operation of the structure.</p>	Section 3 of ISO19906
<p><b>Performance-based standard</b> Standard that defines in qualitative and quantitative terms the specification of the requirements of safety critical systems and their elements</p>	Section A.18.1.2 of ISO19906
<p><b>Place of safety</b> Area outside the hazard zone in which personnel safety is no longer at risk due to the installation hazard.</p>	Section 3 of ISO19906
<p><b>Precautionary evacuation</b> Controlled means of removing personnel from the installation prior to an uncontrolled or escalating incident that can otherwise dictate an emergency evacuation.</p>	Section A.18.1.2 of ISO19906
<p><b>Preferred means of evacuation</b> The first choice available method selected to evacuate personnel based on being lowest risk, familiarity, frequency of use, availability, and suitability for prevailing conditions – normally the method used to transfer personnel to and from the offshore location.</p>	Section A.18.1.2 of ISO19906
<p><b>Primary means of evacuation</b> Method of evacuation that can be carried out in a controlled manner under the direction of the person in charge and the preferred means of evacuation of the installation in an emergency.</p>	Section A.18.1.2 of ISO19906
<p><b>Recovery</b> Transfer of evacuees to a rescue vessel, helicopter, etc.</p>	Section 3 of ISO19906
<p><b>Rescue</b> Process by which persons entering the sea or reaching the ice surface, directly or in an evacuation craft, are subsequently retrieved to a place where medical assistance is typically available.</p>	Section 3 of ISO19906
<p><b>Risk</b> Combination of the probability that a specified undesirable event will occur combined with the severity of the consequences of that event</p>	Section A.18.1.2 of ISO19906
<p><b>Secondary means of evacuation</b> Controlled means of removing personnel from the installation, which can be carried out independently of external support.</p>	Section A.18.1.2 of ISO19906
<p><b>Survival craft</b> Generic name for a marine craft that is used by installation personnel to evacuate to the sea or ice and provides evacuees with protection from the incident and the environment.</p>	Section A.18.1.2 of ISO19906
<p><b>Survival suit</b> Protective suit made of materials which reduce body heat loss of a person wearing it in cold water</p>	Section 2 of ISO15544
<p><b>Temporary Refuge (TR)</b> Place provided on the installation where personnel can take refuge for a specified period while investigations, emergency response and evacuation preparations are undertaken.</p>	Section 3 of ISO19906
<p><b>Tertiary means of evacuation</b> Method of leaving the installation that relies heavily on individual's own actions, is used when the primary and secondary methods are not available, and has an inherently higher risk.</p>	Section A.18.1.2 of ISO19906

## 1.5. Abbreviated Terms

Table 4 - List of Abbreviations:

<b>AARI</b>	Arctic and Antarctic Research Institute
<b>ALARP</b>	As Low As Reasonably Practicable
<b>CAPEX</b>	Capital Expenditure
<b>CAPP</b>	Canadian Association for Petroleum Producers
<b>CBA</b>	Cost Benefit Analysis
<b>DNV</b>	Det Norske Veritas
<b>EER</b>	Escape, Evacuation and Rescue
<b>ER</b>	Emergency Response
<b>ERV</b>	Emergency Response Vessel
<b>FARSI</b>	Functionality, Availability, Reliability, Survivability, Interdependency
<b>HAZER</b>	HAZard IDentification for Emergency Response
<b>HAZEER</b>	HAZard IDentification for Escape, Evacuation & Rescue
<b>HAZID</b>	Hazard Identification
<b>HSE</b>	Health, Safety and the Environment
<b>IMO</b>	International Maritime Organization
<b>ISO</b>	International Organisation for Standardization
<b>MAH</b>	Major Accident Hazards
<b>MOB</b>	Man OverBoard
<b>MOPO</b>	Manual of Permitted Operations
<b>OGP</b>	International Association of Oil and gas Producers
<b>OIM</b>	Offshore Installation Manager
<b>PDCM</b>	Prevent, Detect, Control and Mitigate
<b>PMS</b>	Project Management System
<b>PPE</b>	Personal Protective Equipment
<b>PS</b>	Performance Standard
<b>QRA</b>	Quantitative Risk Analysis
<b>RF</b>	Russian Federation
<b>RN</b>	Russian-Norwegian group of experts (in this project)
<b>SAR</b>	Search and Rescue
<b>SCE</b>	Safety Critical Elements
<b>SIMOPS</b>	Simultaneous Operations
<b>SOLAS</b>	International Convention - Safety of Life at Sea
<b>TDC</b>	Transport Development Centre (Canada)
<b>TEMPSC</b>	Totally Enclosed Motor Propelled Survival Craft
<b>TR</b>	Temporary Refuge
<b>WMO</b>	World Meteorological Organization

## 1.6. Review of Relevant Standards

RN04 chose to review the Barents Sea specific EER system requirements based on ISO19906 and standards such as ISO15544, Norsok Z-013 and Norsok S-001.

None of the listed standards address all of the EER risks that are relevant for the Barents Sea. It is recommended that the process for developing performance standards in Section 2.1 should be used as a guide. A summary of each of the standards reviewed is provided in Table 5 below, together with the limitations of each standard. Only ISO19906 is written specifically to cover Arctic operations. The other standards are however valuable references where relevant.

The RN04 report is intended to be handed over to ISO for consideration when updating the standard or to be included as an addendum to ISO19906. The report does not have official international status but it is hoped that national regulators will refer to the document as a complement to existing standards and guidelines.

Table 5 - List of Key Standards, Main Contents and RN04 Remarks:

Summary	RN04 Remarks
<b>ISO19906:2010 Petroleum and natural gas industries – Arctic offshore structures (Chapter 18 and Appendix A18)</b>	
This standard is the main reference to principles for design for cold climate offshore structures. It specifies requirements and provides guidance for the design, construction, transportation, installation, and decommissioning of offshore structures, related to the activities of the petroleum and natural gas industries, in Arctic and cold regions environments.	The standard does not apply to specialized equipment or vessels associated with Arctic and cold regions offshore operations unless necessary for the structure to sustain the actions imposed by the installation and operation of EER equipment.
<b>ISO15544:2010 Petroleum and natural gas industries – Offshore production installations – Requirements and guidelines for emergency response</b>	
This standard describes objectives, functional requirements and guidelines for emergency response (ER) measures on installations used for the development of offshore hydrocarbon resources. It is applicable to fixed offshore structures or floating production, storage and off-take systems.	The standard does not follow latest best practice and does not align with ISO19906, which it needs to do. However, the two standards are complementary and it is therefore a relevant document that should be referred to as part of step 4 of the performance standard process.
<b>ISO31000:2009 Risk management – Principles and guidelines</b>	
ISO31000 is the new series of ISO standards that define principles of risk management. The standard provides the basis for a common approach to risk management. The principles in this standard are embedded in NORSOK Z-013.	The risk analysis approach described in ISO31000 should be applied to establishing EER system designs in the Barents Sea.
<b>ISO17776:2000 Petroleum and natural gas industries -- Offshore production installations -- Guidelines on tools and techniques for hazard identification and risk assessment</b>	
Guidelines for hazard identification and risk assessment. This standard provides descriptions of specific tools and techniques. The standard is particularly useful for hazard identification and provides check lists. The principles in this standard are embedded in NORSOK Z-013.	The risk analysis approach described in ISO17776 should be applied to establishing EER system designs in the Barents Sea.
<b>NORSOK Z-013:2010 Risk and emergency preparedness analysis</b>	
This standard presents requirements to planning, execution and use of risk assessments and emergency preparedness assessment, with an emphasis on providing insight into the process and concise definitions. This standard covers analysis of risk and emergency preparedness associated with exploration, drilling, exploitation, production and transport of petroleum resources as well as all installations and vessels that take part in the activity.	The standard is generic and can be used for the Barents Sea; however it does not identify the governing metocean conditions. The standard should be aligned with ISO19906 on guidance for risk assessment of EER system in Arctic climates. This standard provides a systematic approach to risk and emergency preparedness analysis. ISO31000 and ISO17776 are normative references in Norsok Z-013, which are agreed apply to Barents Sea EER system risk management process.
<b>NORSOK S-001:2008 Technical safety</b>	
This is an industry standard for Technical Safety which, together with ISO13702, defines the required standard for implementation of technologies and emergency preparedness to establish and maintain an adequate level of safety for personnel, environment and material assets. This standard describes requirements for individual safety barriers and systems, and represents or prescribes generic performance requirements standards for these barriers and systems.	The requirements of the standard can be applicable to EER systems in the Barents Sea; however it should be evaluated by following the performance standards process proposed here.



Guidance for Barents Sea/ Arctic specific EER processes, requirements and solutions are illustrated in Table 6 below.

Table 6 - Guidance for Barents Sea / Arctic Specific EER Processes):

Standard/Guideline  Topic	Existing standards and guidelines						RN04 report
	ISO 19906	ISO 15544	Norsok Z-013	S-001	ISO 31000	ISO 17776	
EER philosophy	X	X	X		x	x	X
EER strategy	X	X	X		x	x	X
Environment	X		X		x	x	X
Hazard and risk analysis	X		X		X	X	X
Continuous assessment	X				x	x	X
EER system design	X		X	X	x	x	X
Emergency response organization	X				x	x	X
Competency assurance	X	X			x	x	X
Communications and alarms	X	X		X	x	x	X
Personal protective equipment	X			X	x	x	X
Man overboard recovery	X			X	x	x	X
Escape design	X			X	x	x	X
Evacuation design	X			X	x	x	X
Rescue design	X			X	x	x	X
Maintenance of EER equipment		X			x	x	
Medical emergency response		X			x	x	
Arctic evacuation methods					x	x	X
Emergency response vessels					x	x	X

Note: x (lower case X in gray) indicates that hazard and risk analysis techniques as guided by ISO31000 and ISO17776 apply to all topics listed.

Additional information of guidance to operators and regulators can be found in the following documents:

Table 7 - List of Reference EER Standards

Standard	Title
NORSOK C-001	Living Quarters Area.
NMD Reg. No. 853	Evacuation and Rescue Means on Mobile Offshore Units.
OLF/NR No. 002	Guidelines for Safety and Emergency Training.
OLF/NR No. 064*	Guidelines for Area Emergency Preparedness.
OLF/NR No. 066	Recommended guidelines for helicopter flights to petroleum installations.
IMO, SOLAS	International Convention for the Safety of Life at Sea.
IMO, Resolution A.1024(26)	Guidelines for ships operating in Arctic ice-covered waters (ratified internationally on December 2, 2009).
IMO, MODU Code	Amendments to the MODU Code (consolidated text of the draft revised MODU Code), 2008, (DE 52/5).
OLF/NR No. 094*	Guidelines for Survival Suits.
OLF/NR No. 096*	Guidelines Man Overboard.
DNV Rules	Rules for Classification of Ships, Newbuildings, Part 5, Chapter 7: Tugs, supply vessels and other offshore/harbor vessels.
DNV Rules	Rules for Classification of Ships, Newbuildings, Part 1, Chapter 1.
IMO, MSC.1/Circ.1206	Measures to prevent accidents with lifeboats.
IMO, SAR-79	International convention of Search and Rescue 1979.
PB 08-623-03	Safety Rules for Exploration and Development of offshore Oil and Gas fields.
Russian Maritime Register of Shipping rules	Rules for classification, construction and equipment of mobile offshore drilling units and fixed offshore platforms, 2010 Rules for classification, construction and equipment of floating offshore oil and gas production unit, 2011.
TDC (Canada) - Canadian PBS	Canadian offshore petroleum installations escape, evacuation and rescue performance-based standards.
SP 1.13130.2009**	The systems of fire protection. Evacuation ways and exits.
SP 2.13130.2009**	Systems of fire protection. Fire-resistance security of protecting units.
SP 3.13130.2009**	Systems of fire protection. System of annunciation and management of human evacuation for fires. Requirements of fire safety.
SP 4.13130.2009**	Systems of fire protection. Restriction of fire spread at object of defense. Requirements for special layout and structural design considerations.
SP 5.13130.2009**	Systems of fire protection. Automatic fire-extinguishing and alarm systems. Design, regulations and rules.
SP 6.13130.2009**	Systems of fire protection. Electrical equipment. Requirements of fire safety.
SP 7.13130.2009**	Heating, ventilation and conditioning. Fire requirements.
SP 12.13130.2009**	Determination of categories of rooms, buildings and external installations on explosion and fire hazard.

\* Only available in Norwegian

\*\* Only available in Russian

### 1.7. Risk Identification for the Barents Sea

In the Barents Sea, as well as in other ice-covered regions of the world, a wide range of ice and weather conditions and structure-dependent factors can be seen at any particular point in time. Because of this, safe EER approaches must be capable of accommodating a full spectrum of ice or open water situations, which are often complicated by many other environmental and logistical factors. The major EER risks which were identified by the RN04 Work Group include the following:

- Traditional EER methods may not be appropriate for most of the year;
- The full range of ice conditions, including icebergs and sea ice, combined with cold weather, wind and other weather conditions which may be encountered;
- The logistics systems that may be available to support any required evacuation from the structure or vessel, including the presence of emergency response vessels;
- The long distances from the potential emergency site to the support bases and other facilities;
- The shortage of duly equipped support vessels that may be called on for assistance, with regards to their maneuvering and station-keeping abilities in ice;
- The accumulation of ice on external surfaces and its effect on equipment operation;
- The limited amount of time that is available to react to a particular emergency situation;
- The effect of cold temperatures on human physiology and psychology, equipment, materials and supplies;
- The lack of experienced personnel and training facilities for the specific evacuation systems which have been proposed for the Barents Sea;
- The effect of the polar night, with extended periods of darkness, on personnel activities in Arctic conditions;
- Difficulties caused by communication due to magnetic conditions and high latitude, lack of satellite coverage and language differences; and
- The possible lack of qualified medical support.

The EER risks are closely related to the installation's type, function, location in the Barents Sea and distance from rescue bases and resources. Hence the EER risks are, and should be, an integral part of the overall risk assessment for the installation itself.

### 1.8. Environmental Description of the Barents Sea

As has been recommended by other panels of the Barents2020 project, it is recommended also here that the following changes are proposed to the section in ISO19906 describing the Barents Sea:

The Barents Sea is a marginal sea bordering on the Arctic Ocean in the north, the Greenland and the Norwegian Seas in the west, the Kara Sea in the east and the coast of the Kola Peninsula in the south (see Figure 1).

The Barents Sea has its greatest depths, up to 600 m, in the central part and a vast shelf with depths of less than 100 m predominating in the southeast and near the coast of the Svalbard Archipelago. Rather than the original description of Barents Sea zones in ISO19906, it is proposed that reference should now be made to the eight regions shown in the figure, as described in a report by AARI. This division takes into account the general physical-geographical features of the Barents Sea (seabed relief, atmospheric processes, system of currents, ice edge position, etc.). Regions I and II are referred to as the Western region, Regions III, IV and V as the North-eastern region and Regions VI and VII as the South-eastern Region in Tables B.16-2 to B.16-4 of ISO19906.



Figure 1 - Boundaries and regions of the Barents Sea (source AARI).

(Regions are based on areas with approximately uniform ice conditions: I) Spitsbergen; II) Norwegian; III) Franz Josef Land; IV) Kara; V) Novozemelsky; VI) Kola; VII) Pechora; VIII) White Sea.

The major morphometric characteristics of the Barents Sea are as follows:

- area: 1,424,000 km<sup>2</sup>
- water volume: 316,000 km<sup>3</sup>
- average depth: 222 m
- deepest depth: 600 m

An important distinguishing feature of the Barents Sea ice regime is that its surface area is never completely ice covered. During the period of the greatest ice cover, March to April, sea ice usually covers only 55 % to 60 % of the surface area, with open water occupying the remainder. The ice cover can be a combination of multi-year ice up to about 3 m thick, first-year ice generally less than 1.5 m thick and icebergs.

Multi-year ice spreads in a narrow zone along the eastern shores of the Svalbard Archipelago and Franz Josef Land, predominantly in spring, but this is not the prevailing ice type. In general, for the entire Barents Sea during the period of the maximum ice cover development, the fraction of multi-year ice averages 10 %, while the fraction of young ice is around 15 %.

The Barents Sea ice cover contains icebergs from the glaciers of Svalbard, Franz Josef Land and Novaya Zemlya. Icebergs drift from these glaciers under the influence of the prevailing winds and ocean currents. Entrained in the general ice drift, icebergs can move large distances during their life span.

Landfast ice is established annually along most continental and island shores of the Barents Sea. The largest width and stability of landfast ice is noted in bays and inlets of the southern sea area and also among the islands of Franz Josef Land and Svalbard. In the wintertime, strong ice pressure often occurs at sea and forms conglomerations such as hummocks, ridges and stamukhi.

Stamukhi are generated in coastal areas in water depths up to 20 m. The maximum sail height for these features ranges from 3 m to 5 m and keel depths from 15 m to 20 m. The greatest intensity of ridging is observed in the north-western and south-eastern sea areas due to the onshore drift of the ice.

It is important to note that the ice conditions vary significantly between the eight regions. Region II is generally ice free; regions I, III, IV, VII and VIII usually have ice every winter; whereas regions V and VI are in between.

## 2. GUIDANCE ON CREATING PERFORMANCE STANDARDS

### 2.1. Creating and Using Performance Standards for Arctic EER Systems

This section describes at high level how performance standards are created and used within a project management system to deliver the lowest risk Arctic EER system solution. It does not attempt to duplicate well established risk management practices but concentrates more on the main steps that need to be considered as an integral part of design development. If implemented correctly the process should deliver a fully auditable decision trail leading to the approval required against existing national rules and regulations. This guidance follows the principles laid down in ISO31000, ISO17776 and ISO19906.

The core element of the diagram below is extracted from ISO17776. It shows how the development of performance standards fit within the risk management process.

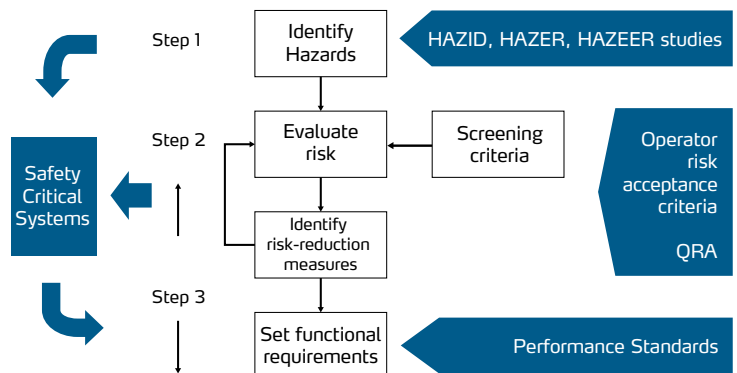


Figure 2 - The ISO17776 risk management process

The steps involved are expanded in Figure 3 with a suggested sequence of the main activities. The simplified diagram shows the main steps to establishing the initial performance standards (using evacuation as the example) through risk analyses to selecting the lowest-risk evacuation method.

Understanding and managing the correct sequence of activities as part of the PMS and involving national authorities at key stages are vital if the lowest risks during operations are to be achieved.

Accepting that many activities need to be performed in parallel is also important. Missing one activity or not dealing with it correctly at the right time can lead to schedule delays and increased costs to rectify errors, or worse, the operating facility will inherit unnecessary risks that cannot be reduced later by modifying procedures.

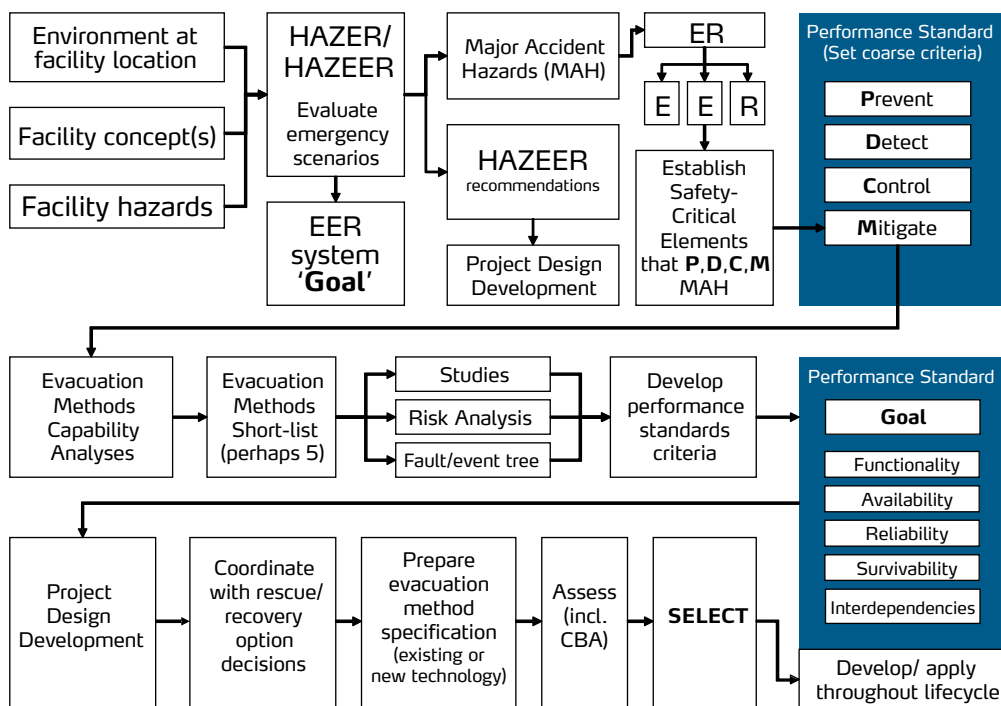


Figure 3 - The process of establishing/using performance standards.

The components of the generic activity sequence – taking Secondary Evacuation as the example, are explained below:

- Environment– understand and appreciate the changing natural environment and its influences on the evacuation system, including consideration of sea states, ice build-up, ice thickness and pressures of converging floes, wind directions, polar darkness, etc., and many other characteristics of the environment during the periods when any MAH could occur and lead to emergency evacuation;
- Facility concept(s) – the different facility layout options should be evaluated together with the process of establishing evacuation system performance standards and the evacuation method options, from which the lowest risk evacuation method and optimum facility layout will be selected. Neither one can be selected independent of the other;
- Facility hazards – hazard consequences (qualitative and/or quantitative) associated with each facility concept need to be understood. Hydrocarbon gas, explosion and fire will all influence the positioning and type of evacuation methods that can be considered;
- HAZEER – Conduct a qualitative structured hazard identification study that focuses on the Escape, Evacuation & Rescue components of the Emergency Response System. This should be attended by key project experts from the various involved disciplines and external specialists if needed. The study methodology should follow this sequence;
  1. Identify the EER system goal.
  2. Establish MAHs – record the warnings (alarms), accident events and consequence scenarios that relate to the need to evacuate the facility, either prior to the ‘top event’ as a precaution (reducing personnel exposure to risk) or under emergency conditions during the accident event.
  3. Assess the evacuation steps involved – i.e. Muster, leave the TR, embark Evacuation method, deploy, launch into water/ ice, transit away from the facility unassisted, etc.
  4. Identify the SCEs that Prevent, Detect, Control & Mitigate the evacuation-related hazards, thus ensuring no casualties are incurred during the evacuation process.
- Coordinate recommendations and their interfaces with design development;

- Engineers involved then develop the coarse Functionality, Availability, Reliability, Survivability criteria for each SCE and Interdependencies (FARSI) with other SCEs that resulted from the HAZEER study, for inclusion in respective Performance Standards (noting that no decision should have been taken at this stage as to what the evacuation solution should be). It is the process that will determine it;
- Perform a semi-quantitative evacuation method capability assessment based on the coarse FARSI criteria to arrive at a short list of evacuation method options that could be suitable for some or all evacuation conditions/ hazards and sea/ice environments;
- Conduct detailed studies and analyse risks in conjunction with facility design development and operations availability targets to add quantitative criteria to the Performance Standards to arrive at perhaps two or three most viable evacuation method options;
- Continue to develop the Performance Standards criteria, refining the criteria based on study results and event tree analyses through all project stages;
- Coordinate all aspects of evacuation process and equipment interfaces with ERV & SAR support services etc. associated with rescue and recovery of evacuees;
- Finalise the evacuation method specification (using PS criteria) to select an evacuation method that either already satisfies or can be adapted or developed to satisfy all performance standard criteria within the project schedule. Delaying the decision-making process should be no excuse for selecting a solution that increases risks to evacuees;

- Maintain the performance standards throughout the operating life of the facility, taking account of changes as they may occur, to ensure the integrity of the whole evacuation (EER) system is maintained;

It should be noted that failure of any EER system component during operations to satisfy these criteria can lead to production cut-back or shutdown of facilities to reduce or remove threats that could otherwise lead to incidents requiring evacuation. If the integrity of the EER system is compromised, production availability can be significantly reduced. If an evacuation solution cannot be found or developed that satisfies the criteria, the entire project may not be viable

Recognising that national rules and regulations exist that may be relevant is important, however literal adherence to rules and regulations should not dictate the EER selection process. Compliance with all relevant and appropriate (to the specific application) rules and regulations can however be achieved and demonstrated by correctly following the performance standards sequence, as explained below and in the example given for an Arctic TEMPSC.

The sequence of establishing Performance Standard criteria, through to demonstrating compliance with relevant or deviation from non-optimum clauses in national rules, regulations and other codes and standards, has to work from left to right.

The 4-step process, shown very simply in Figure 4, can help to deliver a transparent and auditable decision trail that aims to satisfy regulations, codes and standards that are relevant in delivering lowest risk solutions – with the reasons documented in the references as to why some may require deviations (this process can reduce risks and supports the approval process)

1. SYSTEM GOAL: Explain in few words the purpose/objective of the system		
2. CRITERIA	3. PROJECT COMPLIANCE	4. REGULATORY/ CODES COMPLIANCE
Insert qualitative criterion, adding quantitative measures when studied/ Established (state sources)	Involved disciplines explain how the criterion has been implemented in design/operations (state project)	Involved disciplines then explain how by satisfying the performance-based criterion, the rules/ regs. have/ have not been met (state specific clauses)

Figure 4 - Performance standards template and process



Prescriptive requirements such as IMO SOLAS, Class rules, etc. will need to be reviewed, assessed and applied where their adoption does not compromise the level of safety otherwise achieved by complying with the Performance Standards. The same applies to national rules and regulations as explained in Section 1.2 above. This means that by taking a performance-based approach each project/ location must first establish the specific of that location, rather than rely on any prescriptive requirement to arrive at a design or operational solution. For example, in many parts of the Barents Sea it is not practical to only consider using conventional lifeboats (TEMPSC) as a reliable means of secondary evacuation, due to extent and dynamics of Barents Sea ice cover, whereas in other parts of the Barents Sea such a solution may be proven to deliver the lowest risk at the lowest cost.

Figure 5 shows how projects should approach national rules and regulations in relation to satisfying or exceeding the project risk acceptance level.

Over the past 10 years or more, research has shown that where sea ice is present, no single secondary evacuation method is currently available for year-round (24/7) operations. The challenge that designers face is therefore to establish the performance requirements (or performance standards) for the evacuation method at that location and in the range of sea environments expected, rather than to assume the facility only needs to comply with prescriptive (IMO, Class, Authority, etc.) requirements. If this were the case then risks would most certainly increase if ice were present at the particular offshore facility during an emergency requiring evacuation.

For the reasons given above, personnel should never ‘presume’ to select a solution to be correct, and then defend it, based on a perception of its capability before first working through the performance-based steps described here. The performance-based approach will naturally lead to appropriately determining functional and other requirements that the solution must fulfil. Not the other way around.

In this section, the performance standard criteria apply to an Arctic lifeboat or TEMPSC as they are more typically termed. Other evacuation methods exist for use in limited Arctic conditions or are in development (those that hover, are amphibious, or are of designed mass and thrust to break ice) that may deliver lower risk solutions depending on the facility type, prevailing hazards around and from the facility itself.

In the event that a TEMPSC is concluded as one of the shortlisted evacuation options, the performance standards guide provided below can be used, however, it will need to be reviewed and developed in much greater detail so as to be appropriate and relevant for the particular facility and location. The criteria given in the example have been established using ISO-based hazard identification processes and risk assessments conducted for several Arctic offshore facilities.

While there will be many similarities with Barents Sea environments, it should never be assumed that the criteria given below are relevant or appropriate for all Barents Sea facility types and locations. For good reasons it will become obvious that the criteria developed will be more onerous than the prescriptive requirements stated in SOLAS for conventional TEMPSC.

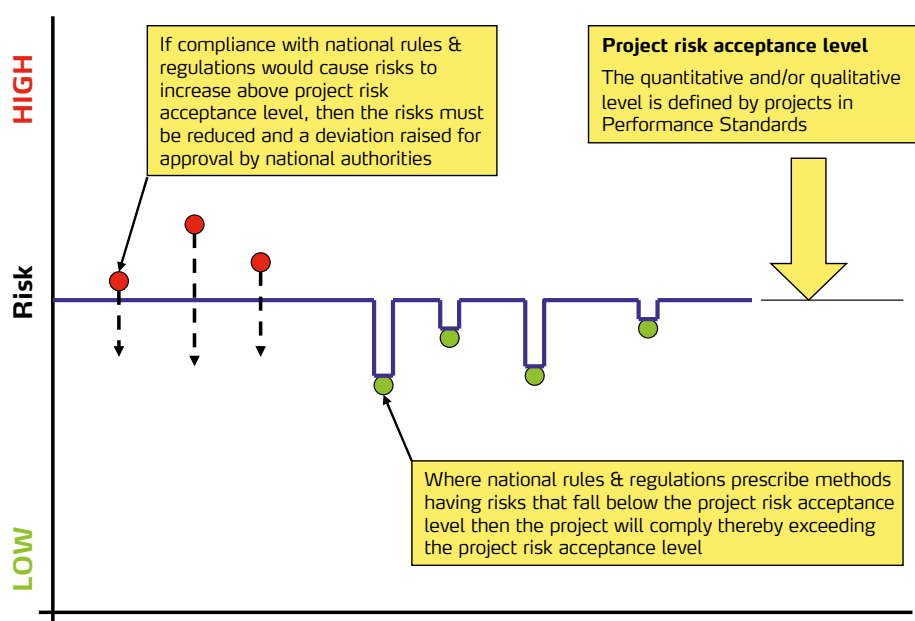


Figure 5 – The relationship between national rules and regulations and project risk acceptance

## 2.2. Performance Standards for Evacuation Methods

This section provides a template for projects to use to develop performance standards for the secondary means of evacuation. It starts the process off by providing several criteria that should be common to the secondary evacuation means for any offshore Arctic facility. Guidance is also provided on what should be stated in each section of the Performance

Standard including the last column which is dedicated to aligning international practices, codes, etc. with national rules and regulations that together are used to demonstrate risks during emergency response are managed to ALARP levels.

Table 8 - Performance standards for secondary means of evacuation:

This 'simplified' performance standard is provided as an EXAMPLE ONLY to show how the alignment between national rules & regulations and international standards can be achieved.

The criteria are provided as sample criterion for what in real terms would be a much larger project document.

Safety Critical System		Evacuation Systems - Secondary Means of Evacuation	
<b>System GOAL</b>		A secondary evacuation system shall be available on the facility during periods when an evacuation scenario is plausible with capacity for the maximum number of personnel on the facility, be deployed and transit unassisted in prevailing environments to beyond the hazard zone where evacuees can survive until rescued/ recovered and taken to a Place of Safety, without incurring casualties.	
Item	Criteria	Project Compliance	Regulatory/ Codes Compliance
<b>Functionality (F)</b>			
F1	Evacuation routes leading from the TR to all Arctic TEMPSC shall be as short as possible and protect evacuees from exposure to prevailing hazards  Ref: HAZEER Study, doc't no. XXXXX	The Arctic-TEMPSC are stowed in a winterized 'enclosure' immediately adjacent to the Temporary Refuge. The location is shielded from process related accident events that may occur. Evacuees are protected from all prevailing hazards when embarking the Arctic TEMPSC, being protected by the 'enclosure'.  Ref: Fire and explosion risk analyses WWW Escape, evacuation and rescue analysis XXXX Layout drawings YYYY etc Arctic TEMPSC enclosure specification ZZZZ Etc.	The following regulations/ clauses which apply to evacuation routes on offshore petroleum facilities have been satisfied as demonstrated in the referenced project compliance document: <i>Regulation aaa/ Clause bbb</i> <i>GOST Nos. bbb &amp; ccc</i> <i>Etc.</i>  The following regulation/ clause has not been satisfied because compliance would increase risks: <i>refer to deviation ddd.</i>
F2	Evacuee linear space requirement (shoulder widths) shall not be less than 57.5 cm and restraints shall take account of Arctic PPE, the distribution of evacuee mass and acceleration forces during deployment and transit under the range of sea/ ice conditions. Arctic TEMPSC capacity should be based on an evacuee minimum weight of 95 kg.  Ref: ISO/DIS19906 Ch. 18,  Brooks, C. et al, "Research Studies to Investigate the Impact of Immersion Suit Use in an Emergency Situation" Technical Report to Transport Canada, November 2004  Canadian Delegation IMO Info paper 2005	<i>Insert a statement (similar to that shown in F1 above)</i>	<i>Insert a statement (similar to that shown in F1 above)</i>

F3	Arctic TEMPSC Coxswain shall have visibility of the sea surface during deployment from the seated position to select the lowest risk launch point into the sea/ ice and to navigate thereafter between ice floes  Ref: HAZEER Study, doc't no. XXXXX	<i>Insert a statement (similar to that shown in F1 above)</i>	<i>Insert a statement (similar to that shown in F1 above)</i>
F4	The strength of the Arctic TEMPSC hull shall be sufficient to prevent failure caused by collision with another IS-TEMPSC, with a vessel or the offshore facility during deployment and with ice and ice interaction during transit.  Ref:ISO/DIS19906 Ch. 18	<i>Insert a statement (similar to that shown in F1 above)</i>	<i>Insert a statement (similar to that shown in F1 above)</i>
F5	All internal and external components of the Arctic TEMPSC shall be designed/ specified to operate in low temperatures, ice and snow. Ref:ISO/DIS19906 Ch. 18  Ref: Project research results ZZZZ	<i>Insert a statement (similar to that shown in F1 above)</i>	<i>Insert a statement (similar to that shown in F1 above)</i>

**Availability (A)**

A1	Arctic TEMSPC shall have sufficient (additional) survival PPE, provisions such as food and water stored on-board to ensure evacuee survival in case of delayed rescue and recovery.  Ref: ISO/DIS 19906 Ch. 18  Project research results ZZZZ	<i>Insert a statement (similar to that shown in F1 above)</i>	<i>Insert a statement (similar to that shown in F1 above)</i>
A2	Secondary evacuation system shall be available for use in year-round sea/ ice environments for at least 94% of the time at sea  Ref: Project research results ZZZZ	<i>Insert a statement (similar to that shown in F1 above)</i>	<i>Insert a statement (similar to that shown in F1 above)</i>
A3	In case Arctic TEMPSC fails inside the hazard zone it shall have incorporated in the design or carry on-board the necessary equipment to facilitate rescue by Emergency Rescue Vessel  Ref: Project research results ZZZZ	<i>Insert a statement (similar to that shown in F1 above)</i>	<i>Insert a statement (similar to that shown in F1 above)</i>

**Reliability (R)**

R1	Winterization measures for the Arctic TEMPSC and its equipment (e.g. access doors, hatches, winches, hinges, lashes, gaskets, brake wires, sheaves) shall be assured and have contingencies.  Ref: ISO19906	<i>Insert a statement (similar to that shown in F1 above)</i>	<i>Insert a statement (similar to that shown in F1 above)</i>
R2	The selected Arctic TEMPSC transit route away from the facility shall be based on event scenario at the time and shall direct Coxswain to a reliable safe location where the rescue/ recovery platform is located or where it will arrive.  Ref: HAZEER Study, doc't no. XXXXX Project research results ZZZZ	<i>Insert a statement (similar to that shown in F1 above)</i>	<i>Insert a statement (similar to that shown in F1 above)</i>

<b>Survivability (S)</b>			
S1	Arctic TEMPSC and stowage arrangements shall survive accident events  Ref: HAZEER Study, doc't no. XXXXX	<i>Insert a statement (similar to that shown in F1 above)</i>	<i>Insert a statement (similar to that shown in F1 above)</i>
S4	Arctic TEMPSC shall survive all environmental and installation hazards while transiting through the sea/ice within the hazard zone, e.g. pool fires etc.  Ref: HAZEER Study, doc't no. XXXXX	<i>Insert a statement (similar to that shown in F1 above)</i>	<i>Insert a statement (similar to that shown in F1 above)</i>
S6	The bow of the IS-TEMPSC shall maintain integrity (survive), being capable of resisting a direct or glancing impact load as a result of striking an ice floe at full speed.  Ref: Project research results ZZZZ	<i>Insert a statement (similar to that shown in F1 above)</i>	<i>Insert a statement (similar to that shown in F1 above)</i>

<b>Interdependencies (I)</b>	
I1	Emergency response vessel (performance standards no. xxxxxx)
I2	Emergency communications (performance standards no. xxxxxx)
I3	Ice management for emergency evacuation (performance standards no. xxxxxx)
I4	Medevac (performance standards no. xxxxxx)
I5	Ice management (performance standards no. xxxxxx)

### 2.3. Performance Standards for Emergency Response Vessels

This section provides a template for projects to use to develop performance standards for the Emergency Response Vessel. It starts the process off by providing several criteria that should be common to ERVs at any offshore Arctic facility. Guidance is also provided

on what should be stated in each section of the Performance Standard including the last column which is dedicated to aligning international practices, codes, etc. with national rules and regulations that together are used to demonstrate risks during emergency response have been managed to ALARP.

Table 9 - Performance Standard for Emergency Response Vessel:

This 'simplified' performance standard is provided as an EXAMPLE ONLY to show how the alignment between national rules and regulations and international standards can be achieved.

The criteria are provided as sample criterion for what in real terms would be a much larger project document.

Safety Critical System		Emergency Response Vessel	
<b>System GOAL</b>		The ERV shall be capable of performing all emergency response support duties relevant to the assessed needs of the offshore facility, its personnel and the environment	
Item	Criteria	Project Compliance	Regulatory/ Codes Compliance
<b>Functionality (F)</b>			
F1	The ERV shall be capable of monitoring and tracking evacuation methods (craft), life rafts and personnel in the water  Ref: HAZEER Study, doc't no. XXXXX	The ERV is equipped with navigational tracking equipment, plot boards etc. in order to diligently track multiple targets (i.e. evacuation craft, life rafts, personnel and/or equipment in the sea).  Ref: analyses XXXX Protective structure specification ZZZZ	The following regulations/ clauses which apply to ERV on offshore petroleum facilities have been satisfied as demonstrated in the referenced project compliance document: <i>Regulation aaa/ Clause bbb Class rule. bbb &amp; ccc</i>  The following regulation/ clause has not been satisfied because compliance would increase risks: <i>ccc - refer to deviation</i>
F2	The ERV shall be equipped in such a way that the vessel can operate as the offshore (on-scene) command centre in an emergency involving evacuation of the facility personnel.  Ref: HAZEER Study, doc't no. XXXXX	<i>Insert a statement (similar to that shown in F1 above)</i>	<i>Insert a statement (similar to that shown in F1 above)</i>
F3	The ERV shall be capable of providing a managed ice environment suitable for evacuation methods to transit beyond the facility hazard zone  Ref: HAZEER Study, doc't no. XXXXX	<i>Insert a statement (similar to that shown in F1 above)</i>	<i>Insert a statement (similar to that shown in F1 above)</i>
F4	Sustain and medically treat rescued personnel until they are disembarked ashore  Ref: ISO19906 Ch. 18	<i>Insert a statement (similar to that shown in F1 above)</i>	<i>Insert a statement (similar to that shown in F1 above)</i>

<b>Availability (A)</b>			
A1	The ERV location shall always ensure it is able to transit and respond to the specific emergency within the pre-determined maximum time period relating to the emergency  Project research results ZZZZ	<i>Insert a statement (similar to that shown in F1 above)</i>	<i>Insert a statement (similar to that shown in F1 above)</i>
A3	..... <i>Insert other qualitative and/or quantitative criteria when established early in the project and as developed thereafter to be consistent with the as-operated facility requirements</i>  Ref: Project research results ZZZZ	<i>Insert a statement (similar to that shown in F1 above)</i>	<i>Insert a statement (similar to that shown in F1 above)</i>

<b>Reliability (R)</b>			
R1	The ERV shall be proven to be capable to function under all local environmental and installation hazards to satisfy the facility expectations in relation to the Emergency Response Plan  Ref: HAZEER Study, doc't no. XXXXX	<i>Insert a statement (similar to that shown in F1 above)</i>	<i>Insert a statement (similar to that shown in F1 above)</i>
R2	The ERV shall be provided with redundant means with contingency procedures to carry out its emergency tasks  Ref: ISO19906 Ch. 18	<i>Insert a statement (similar to that shown in F1 above)</i>	<i>Insert a statement (similar to that shown in F1 above)</i>  Ref: IMO MSC/48 (66) - the LSA Code - 4.4.6.2
R3	..... <i>Insert other qualitative and/or quantitative criteria when established early in the project and as developed thereafter to be consistent with the as-operated facility requirements</i>  Ref: Project research results ZZZZ	<i>Insert a statement (similar to that shown in F1 above)</i>	<i>Insert a statement (similar to that shown in F1 above)</i>

<b>Survivability (S)</b>			
S1	The ERV shall be located or self-protected so as not to be impaired/ malfunction due to facility accident hazard or sea/ice environments  Ref: HAZEER Study, doc't no. XXXXX	<i>Insert a statement (similar to that shown in F1 above)</i>	<i>Insert a statement (similar to that shown in F1 above)</i>
S3	..... <i>Insert other qualitative and/or quantitative criteria when established early in the project and as developed thereafter to be consistent with the as-operated facility requirements</i>  Ref: Project research results ZZZZ	<i>Insert a statement (similar to that shown in F1 above)</i>	<i>Insert a statement (similar to that shown in F1 above)</i>

<b>Interdependencies (I)</b>	
I1	Arctic evacuation method (performance standards no. xxxxxx)
I2	Emergency communications (performance standards no. xxxxxx)
I3	Ice management for emergency evacuation (performance standards no. xxxxxx)
I4	Medevac (performance standards no. xxxxxx)
I5	Ice management (performance standards no. xxxxxx)



## 2.4. Alignment with National Authorities

The purpose of this section is to present a simplified overview of a process that could be adopted to align the use of existing and developing national rules and regulations with the application of international best practice and standards.

Essentially where international best practice has adopted a performance-based approach, existing rules and regulations are often found to be prescriptive, as was the case with the UK regulatory Statutory Instruments prior to the Piper Alpha disaster in 1986. The Lord Cullen enquiry concluded a number of recommendations that are being adopted worldwide by International Standards.

The challenge projects face is to demonstrate how existing rules can be satisfied, in part or whole, while adopting lowest risk goal-setting objectives using performance standards that demonstrate risks are being or have been reduced to below those laid down by prescriptive rules and regulations. For example, understanding how a project can satisfy all national rules and regulations where inter-relationships and hierarchy is confusing, because they either fall under Government, Ministries and Authorities or under regional municipality and regional divisions of national authorities, would be most challenging at the start of a project.

Appreciating the differences and similarities between national rules and regulations and international standards (ISO) is fundamental to establishing and agreeing the process that leads to the necessary approvals. Not all clauses in rules and regulations are relevant for every offshore project at its specific location, and so a gap analysis approach is first necessary to establish the most likely requirements ahead of establishing Performance Standards and those that are not likely to be relevant. A seamless process is necessary, one that is understood, supported and accepted by national authorities, one that includes the need to take a performance-based approach, fully evaluating the specific risks and then demonstrating compliance with *relevant* rules and regulations.

Both the Authorities and Operators should be aligned in the principle of achieving designs and operations that have reduced risks to people, environment and assets to ALARP, and in so doing, satisfy relevant national rules and regulations.

Demonstrating compliance with international best practice for Escape, Evacuation and Rescue systems therefore relies on correctly identifying the parts of the facility and its operations that require transparent demonstrations that risks have been evaluated and reduced to ALARP. The setting of facility Performance Standards, i.e. those parts that are safety critical by definition with respect to preventing, detecting, controlling and mitigating Major Accident Hazards, are the key, as has been proven over many years internationally. Merging the expectation of rules and regulations compliance with the performance standards approach can both be satisfied by providing a logical 4 step process. RN04 concluded that these sequence steps can provide successful and timely approvals, while delivering an auditable project decision trail that reduces risks during Escape, Evacuation & Rescue. It should be adopted also for many other systems determined to be safety-critical and even processes that are not, such as production availability / flow assurance.

### 3. GUIDANCE FOR ARCTIC EVACUATION METHODS

This section is intended to offer some initial guidance only, as to the elements within the overall design and operational considerations of an offshore Secondary Evacuation Method. Tertiary or additional means of evacuation should be provided and should follow the same evaluation process to select the most appropriate methods, however, this is not covered by this report.

Many of the subjects discussed here will be established as necessary criteria in project-specific Performance Standards developed for the location and facility type in the Barents Sea. The bench mark and therefore start point for establishing what may be acceptable for an evacuation method deployed in the Barents Sea, is to be able to operate at the same safety level (or higher) as expected by the maritime and offshore industry for the North Sea, accepting that Barents Sea distances to shore may be greater.

No specific type of evacuation method is intended to be recommended here, but that whatever method is eventually selected, its Performance Standards will need to consider most if not all aspects included in this section. To comply with the ALARP principle and thereby prepare an ALARP justification for a selected evacuation method, it will be necessary to consider radically different methods. Assessing the very different methods that fly, float, crawl or move under the water/ice surface should be considered. Even for a conventional self-righting lifeboat there will be a variety of solutions for satisfying location-specific performance criteria.

Other systems, typically used for escape to sea/ ice (tertiary means) such as life rafts, chutes, descent devices or stairways are not considered here, but the selection process will need to follow the same performance-based principles as explained in Chapter 2.

Governing bodies/ approval authorities firstly need to appreciate that it is unlikely that any one type of evacuation system can be considered to deliver the lowest evacuation risks for all facilities wherever they may be located in the Barents Sea. Whether the facility is located in deep or shallow water, in open water or ice environments will influence the selection process, as will the type of facility, whether a fixed or floating structure.

The objectives of both Operator and Authorities should align, in that the selected primary and secondary evacuation means shall not incur casualties in the process. The risks involved shall be demonstrated to be As Low As Reasonably Practicable (ALARP).

There are many offshore Arctic facilities in operation, having applied a performance-based

approach to assessing risks that lead to establishing lowest-risk emergency evacuation solutions. All solutions, whether in operation or under development, are very different due to the various environments, facility designs and related hazards. Examples include 450-tonne H<sub>2</sub>S tolerant Ice Breaking Emergency Evacuation Vessels (IBEEV), amphibious ARKTOS for climbing over ice and through water, specially adapted lifeboats such as TEMPASC and Air Cushion Vehicles, even airboats and sub-surface systems. Because the solutions can vary in principle and design the term Evacuation Method is used.

Developing location and facility-specific Evacuation Performance Standards is therefore the key to establishing lowest risk solution(s), in conjunction with production availability requirements, satisfying relevant and appropriate national regulations. Refer to Section 2.1 for guidance on developing performance standards.

Regardless of location and facility type, there are several principles that will be common to all evacuation methods for operations in Arctic seas.

These include:

- To stow and winterize the method(s) so they are protected from accident hazards to be available in extreme low temperature conditions when needed – ideally adjoining or very close to the Temporary Refuge;
- To embark personnel, while protected from prevailing hazards in a quick and orderly fashion;
- To deploy the evacuation methods(s) from the stowed position without damage during descent;
- To launch the method(s) with minimum risk into open water or ice conditions while maintaining the integrity and operability of the evacuation method and without harm to evacuees;
- To navigate unassisted through all possible sea states, ice and polar darkness conditions, to beyond the hazard zone; and
- To sustain evacuees until rescued and/ or recovered to an Emergency Response Vessel or by other means.

These principles apply during all reasonably foreseeable conditions, while a major accident event could occur on the facility and for the period of time needed until evacuees are rescued without incurring casualties during any stage of the evacuation process.

The main environmental parameters and safety risks are discussed in this report, in Sections 1.7 and 1.8. Facility type and Arctic environment variances will have an effect on the Escape, Evacuation & Rescue (EER) systems that are required, which ultimately can influence the design of the facility to a great extent. The location in the Barents Sea will determine if and when ice may be present, the type of ice, the distance to the nearest shore base, the weather, wave, wind and temperature conditions, etc. These factors create constraints or can offer counter-intuitive opportunities that will affect the requirements for the evacuation method.

Fixed installations will be able to more easily establish location variables and apply them to the design, while floating moveable structures will have to take into account many sea and ice variables and design their systems accordingly. Deviating from conventional prescriptive IMO or Class rules should be expected, regardless of facility type. Transport units (i.e. tankers) may have the most difficult task as their evacuation methods would have to serve all Arctic and non-Arctic waters. It should be kept in mind that conventional SOLAS craft would not be effective in Arctic or even sub-Arctic waters, whether of the more simple twin-fall davit launched type, or the free-fall type. This would require significant rethinking of the principles, the craft and its stowage and launch arrangements.

### 3.1. General Considerations

As the evacuation method is just one component within the total Emergency Response system and its subordinate EER system, its design requirements cannot be fully defined before the total system has been assessed in conjunction with all involved. Agreeing the principles of the whole ER system enables the boundaries and interfaces of the EER system to be defined. This sets the scene for developing the performance standards that lead to establishing the optimum specification of the evacuation method.

Studies and group activities are necessary to collect coordinate and disseminate reliable metocean data, facility layout arrangement options (during concept selection) and facility hazard analyses to coordinate the range of conditions and options that serve to establish the Secondary Evacuation Method Performance Standards criteria.

The EER system is the last stage in preventing, controlling and mitigating risks. As a mitigation system it has to be assumed that all other risk reducing measures have failed and that the system components must function as intended, be reliable to operate when called upon, available when needed and for the period of time necessary to function and survive all threats, where the failure of any part

could result in loss of lives.

ISO19906 should be consulted before starting the process above, with special emphasis on the following requirement as provided in Sections 7, 18 and A.18:

“The structure and its components shall be designed so that they function with adequate reliability for all physical environmental, accidental and operational actions and conditions to which the structure can be subjected during all phases of the design service life, including construction, transportation, installation and removal. The required reliability depends on the exposure level, which is determined by the life-safety category and the environmental and economic consequence category of the structure or component.”

One conceivable conclusion is that multiple evacuation methods or systems would be necessary in order to ensure safe year-round operations and mitigate risks during all emergency evacuation scenarios. In such a case it is vital to have well-thought through procedures and fail safe systems to ensure the correct evacuation method or rescue system is selected for the prevailing accident event and environment scenario. A manual of permitted operations (MOPO) typically defines the range of operating envelopes, planned SIMOPS periods or other facility activities together with the corresponding safeguards, such as selecting the correct evacuation method and following the correct procedures.

Given the diversity of metocean, environmental and physical conditions that will be present at the facility location and in the Barents Sea area, it is evident that applying all existing prescriptive requirements in Codes, Standards, Regulations, etc. will not deliver the necessary level of safety during EER.

For each field and/ or location a non-prescriptive, goal-setting approach has to be taken. To avoid late changes with incumbent cost and schedule delays to reduce risk it is important that such an approach is adopted from the earliest stage of a project and then implemented properly. If implemented too late, the pressure will be to accept unnecessarily high residual risks which would then be carried through into operations where only small adjustments may be possible. The design of the EER system, the facility and logistics marine and aviation platforms must be developed together to achieve cost-efficient solutions.

The evacuation methods are only a small part of the installations safety systems. During the period that an evacuation method is used, the assumption is that a major accident has already occurred and is endangering the offshore personnel to such an extent that evacuation risks are less than remaining on the installation. The prerequisite is then to move all personnel to a relatively safe distance away from the

installation and to sustain them there until it is safe to return or they can be rescued.

In order to ascertain the exact requirements to be used in the design of the evacuation method(s) and its/ their system, the designers will need to conduct HAZard IDentification (HAZID) and HAZard IDentification for Escape, Evacuation & Rescue (HAZEER) studies together with risk and emergency preparedness analyses. These studies must take into account location, meteorological and oceanic conditions, their effect on people and facility hazards that people may be subjected to.

### 3.1.1. Location on the Installation

Similar to all emergency equipment the evacuation method must be located at suitably protected location(s), ready for use at all times. The location will be selected based on the results of HAZID and HAZEER studies. Access to the muster and embarkation areas shall be adequately addressed, ideally directly linked to the Temporary Refuge to protect personnel from harsh weather, low temperature and prevailing facility major accident hazards.

### 3.1.2. Winterisation

The evacuation system components on the installation should be winterised to ensure their availability when needed. Passive winterisation methods are recommended. It is necessary to monitor the conditions and availability with predefined actions to be taken in case winterisation fails. Backup systems and procedures need to be considered.

The evacuation method and its engine should be kept heated while stowed on the facility, to start reliably when needed. This may be achieved in a number of ways including heating the enclosure in which the evacuation methods are stowed.

Services from the facility to the evacuation method to maintain their functionality while stowed should have quick or auto-disconnections.

### 3.1.3. Davit Hoisting and Deployment Equipment

Use of simple and proven twin-fall davit systems that include latest release hook technology could be considered, however the craft would need to meet many other criteria. Taking into account the results of research and testing of davit-launched craft would be necessary, since prescriptive rules may in some cases drive project decisions towards less reliable methods.

Use of free-fall deployment systems would need to be considered carefully. To date there are no free-fall evacuation systems known to be available for deploying into ice. Even with very small ice concentrations it will be hazardous to utilise the free-fall system. If initially considered as the lowest

risk method, the system would need to include a well proven and technically qualified alternative means of deployment, perhaps by davit-launching in order to maintain the crafts integrity and personnel safety during deployment. Launching into or onto ice with waves present and disconnecting safely are aspects that should receive very special attention.

## 3.2. Design Considerations

There are many different methods that should be considered, however this section should be used as an aide memoire during HAZID studies, for example. Not all considerations are included in this section.

The survival craft must be capable of being deployed from a facility, launched and transit unassisted to beyond the hazard zone, there to survive until recovered by an ERV in prevailing metocean conditions.

Care must be taken when considering the choice of evacuation method and its systems taking into account environmental effects on personnel.

### 3.2.1. Hull

The craft shall be able to self-right in the concentrations of ice that can be present. Special attention should therefore be given to the design of the superstructure, canopy and deluge system that may impede self-righting when in contact with ice floes. Strengthening of the hull will be required to resist impacts with ice during transit, whether direct or glancing impact.

The structural integrity of the craft should tolerate actions it may experience, such as:

- High seas
- Ice accretion
- Impacts with the facility during or after launch
- Interaction with ice floes and ice bergs

The hull form must be constructed in such a way that if the craft is trapped between ice floes the forces will not impair the integrity of the craft. Its design might follow the “Fram principle”, to be raised, projected forwards or backwards by the converging ice.

In areas without ice, free fall lifeboats may prove to be the lowest risk method. In such cases the DNV Offshore Standard Design of Free Fall Lifeboats would be a useful reference with additional measures to suit the location of the facility.

### Materials

Materials used in the hull and other areas should be suitable for operation in the environment that prevails at the location. The performance standard sequence should be followed (refer to Figure. 2 in Section 2.1) based on location-specific hull integrity and strength requirements.

### Exterior

The exterior of the evacuation method should consider preventing ice accretion that otherwise might affect its self-righting moment or integrity. It is not considered feasible to remove ice manually after deployment. Care should be taken when designing the craft's entry points and embarkation areas so that able bodied and stretchered personnel can quickly enter the craft.

### Fire Protection System

The fire protection systems fitted must be able to function for the determined time and for the most severe conditions as determined during the HAZID evaluation. It is perceived that this can be a challenge in the scenario where the survival craft is deployed into ice.

### Maneuvering

A forward conning/ coxswain position to navigate through ice floes during darkness/ polar night conditions should be considered. Appropriate floodlights should be considered to provide 180 degrees of visibility around the bow of the craft.

### 3.2.2. Equipment

All equipment to be stored onboard must be securely fastened in suitable lockers. The equipment shall be able to survive capsizing without breaking loose or injuring people within the craft.

### Navigation and Searching Equipment

A satellite system (GPS, GLONASS, or equivalent) and beacons are recommended to be fitted to the evacuation method, where the type and specifications have been coordinated/ agreed with regional search and rescue services as determined by project HAZEER studies.

The evacuation method needs to navigate in darkness and avoid obstructions such as ice floes, therefore suitable lights should be considered that provide maximum visibility for the coxswain. Adjustable search light may also be considered with directional movement, controllable from the helm position.

The helm windows should be fitted with suitable means to prevent obscuring the coxswain's visibility. The windows should be fitted with an efficient means of clearing melted ice, freezing rain, snow, mist and spray from outside and accumulated condensation from the inside. A mechanical means to clear moisture from the outside face of a window should have operating mechanisms protected from freezing or the accumulation of ice that would impair effective operation.

### Communication Equipment

In addition to equipment for communication with helicopters and ERVs, satellite communication equipment should be considered where conventional equipment is unable to reach shore bases.

### Weapons

Deterrent means for protection against wildlife if relevant to the location, should be considered to be available on the evacuation method with appropriate security and safety devices fitted.

### Food and Water Supplies

Based on the results of a performance standards process, food and water supplies should be provided for the time until rescue can be undertaken. The daily energy content of the food supply should be in accordance with recommendations for Arctic conditions.

### Life Saving Protection

The requirement for and quantities of personal and group survival kits should be considered based on the findings of the performance standard process. There should also be provisions for changing wet clothing and protection against the effects of low temperatures.

### Medical Supplies

Medical supplies should be stored on board each evacuation craft which shall be determined based on the performance standards process.

### 3.2.3. Interior

#### Hatches

Consideration should be given to personnel access hatches for embarking evacuees, injured personnel on stretchers, rescuing people from the sea or ice, disembarking and other being internally shielded in order to protect onboard evacuees from exposure to adverse prevailing conditions. The design of the evacuation method hatches should prevent ingress of seawater while the hatch is open. The hatches must be able to operate with the potential for heavy icing around the hatch seals.

#### Insulation

The insulation must be such that a sustainable internal environment for evacuees can be maintained for the maximum period until rescued (avoiding heat loss, overheating and condensation).

#### Furniture

Consideration should be given to the bulkiness of personnel wearing survival suits when designing seating. The ergonomic design of seats should take



into consideration that personnel may be required to sit and stay on board for a long period of time.

### Sanitary

Consideration should be given to providing sanitation, which will directly relate to the maximum amount of time evacuees are expected to remain in the evacuation method.

### Ventilation

Ventilation systems will need to provide sufficient air for the operation of machinery, air conditioning and heating for internal climate control purposes. Methods used to open and close ventilation inlets and outlets should be designed and located to protect them from ice or snow accumulation that could interfere with their operation.

#### 3.2.4. Machinery

The installed propulsive power should be sufficient to ensure that the evacuation method can navigate without risk of damaging engine and propulsion systems under all foreseeable ice and metocean conditions.

Piping and intake systems associated with the machinery essential to the propulsion system should be designed such as not to be affected by ice blockage.

The engine should be designed for propulsion and generation of electrical power, sufficient for both operations.

### Heating

General heating requirements need to be considered which can be provided from the engine. The interior climate needs special consideration. With a well design heating system the water stored on board for consumption should not be too cold or freeze. A method for heating water should nevertheless be considered.

### Exhaust

The temperature of exhaust gases shall not ignite released hydrocarbon gases on the facility. Below waterline exhausts should be considered in conjunction with cooling as part of the exhaust system. Personnel shall be protected from contact with hot surfaces.

Where closing apparatus for exhaust outlets is included in design, they should be designed and located to protect them from ice or snow accumulation that could interfere with the effective closure and operation of such systems.

### Fuel

Fuel capacity shall be in accordance with performance standards and determined based on

transit and survival requirements according to maximum time for rescue.

### Electrical systems

Equipment that is safety-critical for the evacuation method should each have a battery backup with charger fed from the engine.

### Batteries

Batteries should be stored in separate water tight storage lockers suitable for the surrounding conditions.

The battery capacity should have endurance not less than the time taken for deployment, transit and survival outside the hazard zone until rescue. A sufficient and demonstrable contingency should be available until needing to be recharged.

### Lighting

It should be taken into consideration that the lighting onboard is evaluated based on the psychological wellbeing of the evacuees in addition to applicable rules and regulations.

### Strobe Light

The decision on whether the evacuation method should be fitted with a continuous light or strobe type (or both) will need to be coordinated with search and rescue services. Strobe lights should automatically turn on upon deployment of the evacuation method with an alternative switching method in case it is deployed onto the ice surface, preventing the water activated switch to operate.

## 3.3. Sustainability and Retrieval

The survival craft will need means to sustain and keep the crew in a healthy condition for the maximum time necessary to organise rescue operations taking into consideration that weather, darkness and remoteness may greatly hamper any search and rescue operation. In almost all cases it is expected that the Emergency Rescue Vessel will be in close proximity.

For areas where ice may occur, retrieving the evacuation method during rescue from areas of high ice concentration or perhaps from the surface of an ice floe should be possible in conjunction with Emergency Response Vessel facilities and capabilities.

## 3.4. Qualification and Testing

Concepts for new evacuation methods should be qualified according to an accepted process, such as DNV-RP-A203 or similar.

The evacuation method, including equipment and materials used will be required to be tested to demonstrate it satisfies all applicable performance standards.



### 3.5. Training

Training in harsh offshore environment is unlikely due to the incurred risks. Therefore a robust alternative maintenance and coxswain training program will be required where the evacuation method can be used perhaps under better controlled conditions.

Consideration should be given to use of simulators onshore and even PC-based systems offshore to give the coxswain continuous access to simulated launch, deployment and transit environments.

## 4. GUIDANCE FOR EMERGENCY RESPONSE VESSEL

This section is meant to provide guidance for basic conceptual design for an Arctic Emergency Response Vessel. It is not meant to be a technical specification on how to design or operate such a system, but rather guidance for the industry when designing these systems. There might be a variety of solutions for the design of such a Vessel for a specific installation, so this section will cover only functional requirements.

An Arctic Emergency Response Vessel will likely be assigned other tasks and functions that are necessary to fulfil its obligation as a rescue vessel. This section will not cover requirements needed for the fulfilment of such other tasks as it will be assigned when not engaged in purely rescue operations. It is conceivable that a number of requirements will overlap. On the other hand these other tasks may influence the EER operation on how it is designed and should therefore be considered when the EER principles and evaluations are established.

General maritime systems will not be covered here as these will be the same in any ship.

There are today numerous emergency response and rescue vessels in operation in connection with offshore installations, and the knowhow and technology refined in the operation of these vessels should be used as a basis in the process of Arctic offshore exploration and production. The environmental conditions differ from other parts of the world and it will be these requirements that should govern the type of solutions in design, arrangement and operation of these vessels.

### 4.1. Design Considerations

The Emergency Response Vessel is considered to be the last link in the escape, evacuation and rescue system. The overall EER system should be evaluated first in order to determine the specific requirements for the ERV. The results should identify key design requirements for the design of an ERV suitable for the given location or locations within the set operation area. The study should also consider what other operational tasks the vessel is to perform, as this may lead to design requirements for other systems farther up the chain of EER systems.

As an example, if the ERV is to cover other installations or be part of the ice monitoring or ice management tasks, it may have impact on the response time for the vessel to be in position to rescue personnel and retrieve survival craft, and thereby prolong the time the survival craft will need to sustain personnel after deployment.

An ERV's main tasks in an escape, evacuation and rescue situation will be to:

- Monitor and track personnel in the water, life rafts and survival craft;
- Assist survival craft, life rafts and personnel to navigate away from danger;
- Positioning the ERV for the rescue operation;
- Rescue (bringing personnel and/or equipment onboard);
- Search and rescue of unaccounted for personnel or craft;
- Sustain and medically treat rescued personnel until they can disembark in controlled and safer location (i.e. shore base);
- Perform fire fighting and to deluge hydrocarbon fires around or on the installation.

In order to ascertain the exact requirements to be used in the design of the ERV and its tasks, the designers should carry out HAZEER studies and risk analysis where endurance and capabilities of the system will be derived from the results of such analysis, i.e. following the process described in section 3, Guidance for Creating Performance Standards.

#### 4.1.1. General Considerations

The ERV should comply with guidelines such as IMO *Guidelines for Ships Operating in Arctic Ice-Covered Waters*, DNV Rules *Ships for Navigation in Ice* or similar, in addition to international, national and flag state rules and regulations.

A number of factors influence the vessel's size which is partly determined by the number of personnel on the offshore facility. The ERV should be able to accommodate a full installation crew, leaving other support vessels to tasks of containing the situation on the installation.

The ERV's sea keeping capabilities should be designed taking into account that the vessel moves in such a way that it limits crew fatigue due to the environmental conditions. In an EER situation it is vital that the operating crew is fully alert and can diligently deal with the crisis at hand.

#### Maneuvering

The ERV must have the ability to navigate and position itself in order to fulfil its intended tasks. Dynamic positioning and icebreaking capability should be considered.

#### EER Systems

All systems must be designed to work under the full range metocean conditions which may be encountered.

#### Command Centre

It is conceived that the ERV will be in on scene command of a search and rescue operation and therefore should have a dedicated command centre connected to its communication and navigation centres.

#### Navigation

In addition to the ERV's normal navigation equipment as required by the above mentioned rules, regulations and guidelines, the ERV should be equipped with navigational tracking equipment, plot boards etc. in order to diligently track multiple targets (i.e. survival craft, life rafts, personnel and/or equipment in the sea. This will further require that the ERV has up to date weather, current, ice floe monitoring information and can incorporate these into its tracking instrumentation. These systems should also be able to predict drift paths in order to assist the ERV in most likely search areas. As this vessel will be taking lead in a search and rescue situation, it should have the ability to command and track other vessels in the search and rescue party in order to conduct the most efficient search patterns.

#### Communication

The communication system should be equipped in such a way that the ERV can operate as the command centre in an emergency situation. This may require equipment for communication with helicopters, aircraft, other vessels, lifeboats and shore bases. Satellite communication equipment should be considered where conventional equipment is unable to reach shore bases.

#### Searching

The ERV should be equipped with searchlights suitable to visually highlight and direct multiple craft in the water. Night vision or infrared search technologies should be installed to search for and track evacuees.

#### Rescue

Rescue in this context is considered as getting the evacuees onboard. This could be anything from a single person in the water to all evacuees onboard a life raft or survival craft.

The ERV must be designed and equipped to very expediently pick up personnel from the water or ice (as time in this case is crucial). Side ports or recesses in the ERV's side at waterline level or a crane with a personnel transfer basket are means that should be considered in addition to traditional MOB boats.

In harsh Arctic conditions, it is recommended to retrieve the survival craft's evacuees with minimum exposure to adverse conditions by taking the survival craft on board and then disembark the evacuees. A

conceivable method of this could be by means of a slipway in the stern of the ERV. However, secondary means of retrieving evacuees will have to be in place as well, such as side ports or recesses in the side of the ERV or cranes with personnel transfer baskets.

#### 4.1.2. Other Systems

##### Medical facilities

The ERV should be equipped with a hospital and medical facilities to a degree that is needed. Bearing in mind the location of the installation, its distance from shore base and the time it takes for the vessel to transit or other means are in place for transport of injured personnel (i.e. helicopter).

##### Fire Fighting

The ERV's fire fighting capability should primarily be designed for protecting evacuees, and secondary for other tasks. Care must be taken that such equipment must be winterised and able to operate in the prevailing conditions.

#### 4.2. Training

Due to the environment, full scale training session may induce greater risks to personnel than is advisable. Therefore operators should consider a simulator centre for training in search, rescue and management of conceivable situations.

## 5. COMMENTARY ON ISO19906 CHAPTER 18 AND APPENDIX A18

### 5.1. Overview of ISO Approach and Content of Standard

The EER provisions of ISO19906 are based on applying a systems approach intended to promote the successful escape from the incident, subsequent evacuation from the installation (when the incident cannot be controlled) and ultimate rescue of installation personnel. It is clear that these EER provisions should be used as part of a continuous improvement process for managing risks and the safety of personnel working offshore in Arctic and cold region environments.

The EER systems of the ISO standard are performance based, which means that verifiable attributes or benchmarks that provide qualitative levels or quantitative measures of performance are to be achieved. The key characteristic of a performance-based standard is its focus on what is to be achieved rather than on how this should be done.

The performance target is to be the development of an EER system that incurs no additional casualties (i.e. a serious life-threatening injury or fatality resulting from an incident, including cases when emergency medical help cannot be provided) when prescribed EER systems and technical means are implemented. The performance target is developed in the context of a design health, safety and environment (HSE) case together with the relevant emergency preparedness plans.

The provisions of this document should be used by stakeholders, including designers and owners. It is clearly recognized that the emergency evacuation of personnel from offshore structures and vessels is of critical importance in the event of a major onboard problem. In addition to the issue of specific evacuation systems and their capabilities, the question of safe evacuation also involves the procedures and training that are necessary for personnel to systematically respond in emergency situations, and a clear understanding of the range of environmental situations that may be encountered. However, while progress is being made in HSE standards and guidelines, similar progress has not been made in the development of suitable evacuation systems and equipment in order to deal with different emergency situations in both ice and open water conditions.

The Work Group recognized and agreed that the relevant sections (Chapter 18, Appendix A.18) of ISO19906 provide appropriate general and functional guidance for EER operations in Arctic conditions. However, the standard does not provide

adequate EER recommendations for the Barents Sea. It was realized, therefore, that the best way to address the findings of RN04 would be to propose a separate addendum or guidance document to ISO19906 for the Barents Sea.

## 5.2. General

It should be noted that the left-hand column in the tables below indicates the original ISO numbering for Sections 18 and A.18; the middle column is a summary of the original ISO19906 provisions (Normative and Informative sections are grouped

together); and the right-hand column gives the comments by RN04 to date. The right-hand column indicates whether the input of the reviewers was a “comment”, “suggested addition”, or “requested clarification” (or some other input). Where no comments were made the summary table has been omitted.

*(Note: only excerpts of the original ISO19906 provisions are included here. Direct quotations from ISO are shown in italic font)*

ISO reference	Current ISO Text	Applicable to Barents Sea region
<b>18.1</b>	<b>General (normative)</b>	
	<i>The escape, evacuation and rescue (EER) provisions of this International Standard are intended to promote the successful escape from the incident, subsequent evacuation from the installation (emergency evacuation of precautionary), and the ultimate rescue of installation personnel. The EER provisions should be used as part of a continuous improvement process for managing risks and the safety of personnel working offshore in arctic and cold regions.</i>	The terms “survival and recovery” should be added in order to emphasize that the rescue stage consists of survival and recovery.
<b>A.18.1</b>	<b>ANNEX A (informative) General</b>	
<b>A.18.1.1</b>	<b>Performance standard (informative)</b>	
		The escape, evacuation and rescue (EER) system should be designed such that there are no additional casualties beyond those that arise during the initial incident; The EER system shall be part of the health, safety and environment (HSE) case.
<b>A.18.1.2</b>	<b>EER terms</b>	
		Qualitative and quantitative terms shall mean “qualitative levels and quantitative measures of performance”. The term system and/or its elements shall be used. The preferred priority of evacuation methods (1, 2, etc.) should be specific and stated clearly. Example 1. Normal crew change / travel methods 2. Bridge (if relevant) 3. Crane lift to standby vessel / emergency response vessel or supply / anchor handling or other service vessel. 4. Lifeboats 5. Life rafts / chute systems. 6. Escape ladders to surface

### 5.3. Escape, Evacuation and Rescue Philosophy

ISO reference	Current ISO Text	Applicable to Barents Sea region
A.18.2.2	<b>EER governing principles (informative)</b>	
	<b>A.18.2.2.1 Statement of principles and breakdown of components.</b> The first governing principle is that the system for managing EER shall be designed and implemented using a systematic approach, the 3 main components being hardware integrity, personnel competence and EER procedures and controls.	No comments
	<b>A.18.2.2.2 Hardware Integrity</b> The hardware components should be adequately designed in compliance with EER system performance standards and maintained to meet the expected environmental, operational and emergency conditions.	No comments
	<b>A.18.2.2.3 Personnel Competence</b> Requirements should be defined up-front to allow for timely EER safety training, and for the development and assessment of critical roles and responsibilities of the EER chain of command.	Relevant training shall be governed by performance goals.
	<b>A.18.2.2.4 Procedures and controls.</b> EER procedures and controls should be timely developed to complement the hardware integrity and personnel competence components. It is important to appreciate that all three of these components should be applied to each part of the EER triangle well in advance of the beginning of each distinct project phase, including simultaneous operations.	The second part of text in A.18.2.2.4 should be a separate section because it contains three main parts and governing principals. The first part of text describes the third part of the system only.

### 5.4. EER Strategy

No comments

### 5.5. Environment

No comments

### 5.6. Hazard and Risk Analysis

No comments

### 5.7. Continuous Assessment

No comments

### 5.8. EER System Design

ISO reference	Current ISO Text	Applicable to Barents Sea region
18.7	<b>EER system design (normative)</b>	
	<p><i>The EER system shall ensure that, in the event of a potential or actual emergency, installation personnel are protected and can be moved to a place of safety. The EER system design shall be fully integrated within the overall emergency response system, complying with the governing principles described in 18.2.2.</i></p>	<p>During tests, the worst credible environmental conditions should be reproduced (e.g. ice thickness, swell...) as far as practicable.</p> <p>The evacuation system shall be provided with enough power to reach a safe location based on ALARP demonstration.</p> <p>The EER systems shall take into account the specific requirements regarding and health of personnel for operations in extremely cold environments, especially considering additional layers of clothes.</p> <p>Lifesaving appliances shall be specifically designed for freezing environments.</p> <p>The operator should know the expected capabilities of the means of evacuation in the range of physical environment conditions that can be expected to occur in the operating area, taking into account the location and arrangement of the evacuation stations.</p> <p>Knowledge of the performance capabilities of the selected means of evacuation, including launching and clearing, should be incorporated into operational planning, including emergency response plans, recognizing residual risks that exceed any of the limits of the means of evacuation.</p> <p>This is site and installation specific: the operator should recognize how risk increases as weather conditions deteriorate and to reduce risk to ALARP levels.</p>

### 5.9. Emergency Response Organisation

ISO reference	Current ISO Text	Applicable to Barents Sea region
18.8	<b>Emergency response organisation (normative)</b>	
	<p><i>The installation emergency response organization shall be documented and summarized (e.g. in a station bill), and posted at strategic locations throughout the installation.</i></p>	<p>Statement of 2. line and 3. line emergency response organizations, and information of need for external assistance in an emergency situation shall be included.</p>

### 5.10. Competency Assurance

ISO reference	Current ISO Text	Applicable to Barents Sea region
18.9	<b>Competency assurance (normative)</b>	
	<p><i>The operator shall ensure that all personnel on board the installation are adequately familiar with the operator's safety management system, including the emergency escape, evacuation and rescue response plans and hardware systems, and that they are adequately trained and competent in accordance with their safety related responsibilities and duties.</i></p>	<p>On a regular basis key personnel shall be trained onshore in a safe and controlled environment.</p> <p>Key personnel defined to be lifeboat coxswain/ commander, lifeboat crew, FRC crew, fire and rescue team members</p> <p>Clear distinction must be made between <u>training</u> and <u>drill</u>.</p> <p>Training; is to achieve and to improve skills and knowledge.</p> <p>Drill; is to demonstrate and verify the skill and knowledge</p>



## 5.11. Communication and Alarms

ISO reference	Current ISO Text	Applicable to Barents Sea region
18.10	<b>Communications and alarms (normative)</b>	
	<i>The communication system shall operate under all emergency scenarios taking into account geography, distance and environment (within the operational network offshore, onshore, standby vessel support, on the platform).</i>	Alarm beacons and PAGA appliances locations shall be chosen according to the worst environmental conditions (very limited visibility and impossibility to hear anything). Emergency Response Vessel (Multi- Purpose Rescue & Standby Vessel) capabilities and role shall be clearly defined.

## 5.12. Personal Protective Equipment

ISO reference	Current ISO Text	Applicable to Barents Sea region
18.11	<b>Personal protective equipment (normative)</b>	
	<i>The need for and numbers, types and storage locations of personal protective devices shall be determined in the EER analysis.</i>	PPE shall be designed so that personnel can reach a safe location without being injured (able to withstand extreme environmental conditions) More detailed advice shall be given, especially towards extreme low temperatures

## 5.13. Man Overboard Recovery

ISO reference	Current ISO Text	Applicable to Barents Sea region
18.12	<b>Man overboard recovery (normative)</b>	
	<i>The installation shall have a means to recover a man overboard including injured personnel under anticipated incident and physical environmental conditions.</i>	It should be considered if this requirement, for operation and practical reasons, should be solved by the emergency response Vessel.

## 5.14. Escape Design

ISO reference	Current ISO Text	Applicable to Barents Sea region
18.13.2	<b>Escape routes (normative)</b>	
	<i>Escape route(s) shall be designed to ensure that all personnel can safely move from any part of the installation to the TR or muster station under credible incident, physical environmental and operational conditions.</i>	The escape route should not allow people flow coming from opposite directions - personnel movement to temporary refugee or muster points shall be in one direction only. Surface icing and potential snow accumulation shall be taken into account. The size of primary escape routes shall not be smaller than that required by International Standards. Escape routes shall also be sheltered from heat radiation from the drill floor area, mud processing areas and other similar areas in case of fire, explosion and/or blowout.
A18.13.2	<b>Escape routes (normative)</b>	
		The design of escape routes shall ensure the movement of all personnel from any part of the installation to the TR or muster station is one direction only.
18.13.3	<b>Temporary refuge (normative)</b>	
	<i>The TR shall protect personnel from any incident and physical environmental effects for a time sufficient to allow control of the emergency or until a decision is made to abandon the installation. It is not necessary that a TR be useable under all incident scenarios, provided contingency plans are in place to ensure the safety of personnel</i>	The TR shall be able to be inhabited by the installation personnel for a sustained period of time as identified through risk and emergency preparedness analysis. The TR shall be useable under all incident scenarios.

### 5.15. Evacuation Design

ISO reference	Current ISO Text	Applicable to Barents Sea region
<b>18.14</b>	<b>Evacuation design (normative)</b>	
<b>18.14.1</b>	<b>Evacuation - general (normative)</b>	
	<p><i>Personnel moving from the TR or muster station to the primary embarkation areas shall be protected from the installation hazards and environment.</i></p> <p><i>The methods of evacuation (whether installation or non-installation based) shall be assessed in the EER analysis according to the number, location, orientation and means used.</i></p> <p><i>The design and selection of evacuation method(s) shall include a risk assessment of the lowest probability of incurring casualties, taking into account the range of credible physical environmental conditions during emergency, precautionary and scenario drill evacuations.</i></p>	Requirements for primary, secondary and tertiary methods should be specified, describe and included.
<b>18.14.2</b>	<b>Evacuation method design (normative)</b>	
	<p><i>Each independent method (type) of evacuation shall accommodate the full complement of personnel on-board (POB) the installation, including visitors, under any emergency scenario requiring evacuation.</i></p> <p><i>The evacuation system shall have a provision onboard for retrieval of personnel, including injured personnel from the sea or ice.</i></p>	<p>Spare systems shall be provided depending on the facilities layout (possibility for personnel to be trapped away from the main muster area) and maintenance.</p> <p>Deployment over solid ice shall be considered when it is a credible case.</p> <p>A installation, design and area specific analyses should be conducted in order to demonstrate ability to escape from hazards. The analysis shall demonstrate possible escape distance and duration based in design, risk assessment and ALARP.</p>
<b>A.18.14.2</b>	<b>Evacuation method design (informative)</b>	
		Evacuation systems, shall be designed such that evacuees can survive in the prevailing physical and environmental conditions until such time as they can be rescued by the rescue system. Due consideration shall be given to requirements for medical supplies, food, water, temperature control, fuel and toilet facilities.

### 5.16. Rescue Design

ISO reference	Current ISO Text	Applicable to Barents Sea region
<b>18.15</b>	<b>Rescue Design (normative)</b>	
	<p>The design integrity of the rescue system shall ensure that evacuees are recovered from the sea, the ice, or from evacuation systems, onto a rescue platform in the prevailing physical environmental conditions.</p> <p><i>Rescue systems shall be designed to ensure that evacuees can be rescued in the event that they do not clear the hazard zone.</i></p>	<p>Communication with the rescue systems shall always be available.</p> <p>The dimensioning of the rescue system should be based on information of the system's availability and effectiveness.</p>

## 6. REFERENCES

*It should be noted that only references to standards and norms are provided here. Technical references (limited to published papers) related to evacuation methods and emergency response vessels are provided in the Appendices which follow.*

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## APPENDIX A. EVACUATION METHODS

This section of the report presents a number of examples of Arctic evacuation methods that have either been implemented or are currently under development. The RN04 work group has gathered information from different sources to describe in a general way the different methods included here. All information should be checked for accuracy at the time it is needed. RN04 acknowledges that there may be other systems being conceptualized and developed, details of which were not available to RN04 at the time of issuing this report. It will be the responsibility of the owner, operator or design contractors to investigate thoroughly all options that may be available or can be developed, proven and certified for use within the respective project schedule, that can satisfy the Performance Standards criteria determined for the project.

Each of the methods discussed in this Appendix have capabilities in open and/or ice-covered waters; however, they all have certain operational limitations. Years of research and the establishment of location-specific performance standards have in most cases preceded and influenced the designs. This process is of utmost importance when developing and selecting an evacuation method (or more than one method) for any facility.

The examples of evacuation methods presented here have been divided into two groups:

- Evacuation methods already in operation at one or more specific Arctic or sub-Arctic location, including
  - ARKTOS amphibious evacuation craft, and
  - Ice Breaking Emergency Evacuation Vessel (IBEEV).
  
- New concepts under development for specific Arctic conditions, such as
  - Boat-In-A-Box Davit,
  - Hovercraft,
  - AST/TIT800 Archimedean Screw Vessel,
  - Seascape Life Rescue Craft,
  - Totally Enclosed Motor Propelled Arctic Survival Craft (TEMPASC),
  - Ice Strengthened Lifeboat (ISL),
  - Polar Haven Lifeboat, and the
  - Ganymede Dropped Container.

## A.1 Evacuation Methods in Operation

### ARKTOS Amphibious Evacuation Craft

The ARKTOS Evacuation Craft is an amphibious craft designed for evacuation and rescue functions. The craft consists of a pair of reinforced hulls, designed to withstand crushing forces from ice floe formations, permanently linked together by a hydraulically powered articulating arm. This arm is necessary to enable the front and rear units to operate at independent angles so they can transit a variety of irregular features on land, at sea or on ice. On solid surfaces, the craft moves on tracks while propulsion jets supply the thrust in open water.

ARKTOS has proven ability to climb from water onto ice floes and maneuver through most ice-rubble fields and to handle limited-angle steep slopes on hard or soft surfaces. ARKTOS has been used for crew evacuation for several offshore developments consisting of gravel islands in the Beaufort Sea located well within the land-fast ice area and the northeast Caspian Sea, and are typically parked near the edge of the islands. Should an evacuation be necessary the craft can be driven away from the island over the ice.

The manufacturers state that a conceptual design has been developed for a 75-person ARKTOS suitable for operation beyond the shear zone. This includes the effect on performance in ice of increased craft track width, extended track carriages, increased water jet thrust, self-righting capability, improved vertical ice step climbing capability, hydrostatic drives for improved track performance, fire resistant hull and track material, and davit launching from a production platform onto ice, mixtures of broken and water, or open water.



*Figure A1 - ARKTOS evacuation craft undergoing pilot training in the US Beaufort Sea (source: ARKTOS Development Ltd.)*

### Ice Breaking Emergency Evacuation Vessel (IBEEV)

The Ice Breaking Emergency Evacuation Vessel (IBEEV) is a vessel specifically designed for the Kashagan field in the northeast Caspian Sea, Kazakhstan. It has DNV notation X1A1 ICE1B DAT(-30°C). The Kashagan D Island houses a fleet of IBEEVs docked alongside that provide a means of evacuation for all personnel on the island in case of an emergency. The IBEEV has an extremely shallow draft for Caspian Sea operations and is capable of breaking ice by moving in either direction via twin helm positions. It protects evacuees from the lethal effects of toxic gas (H<sub>2</sub>S) and can operate in gas, fire or explosion conditions. Evacuees enter the vessels through evacuation tunnels linking each vessel to the facility. Evacuees enter air locks on the IBEEV which will be purged using stored air from cylinders before proceeding into three hermetically sealed evacuee compartments. The IBEEV has the capacity to evacuate 340 persons in extra wide seats, and has a medical suite and toilets onboard.

The IBEEV has proven Caspian sea-keeping abilities and is capable of operating in extremely low temperatures as well as in first year ice up to 0.6 m thick. Due to the shallow waters in which it operates, the IBEEV cannot function like an ordinary icebreaker which cuts through the ice. Instead the bow of the IBEEV crushes the ice in front of the vessel; the vessel's powerful engines allow the vessel to make its way through the ice while those inside can breathe via self-contained air supplies or oxygen candles if needed.





Figure A2 - An IBEEV near Kashagan D-Island in the Caspian Sea  
(source: [travel.webshots.com/album](http://travel.webshots.com/album))

## A.2 Evacuation Concepts under Development

### Boat-In-A-Box Davit

The Boat-In-A-Box davit is part of the “Nadiro Arctic System”, together with a disc-brake winch system and the “Drop-In-Ball” hook system.

The Boat-in-a-Box davit is a system developed for operation in extreme environments. The Arctic survival craft and all ancillary equipment, except the davit arms, are stowed inside a container, which protects it from toxic fumes, smoke and other hazards, as well as ambient environmental conditions. While the container itself is reinforced to handle ice accretion, it excludes the potential for ice accretion on the craft, and deterioration by sunlight and corrosion. Furthermore, insulating material can be incorporated for protection against extreme temperatures. The container comprises a de-humidification system and heating appliances. Hydraulic oil and cylinders are certified for low temperatures and material selection is based on extreme design temperatures.

Upon embarkation, one must open the doors on the container and survival craft then board. Upon deployment, the davit arms move the container from the stowed position to the launch position, so the davit mechanism deploys the survival craft as well as its protective stowage arrangements, i.e. the container, outside the facility’s perimeter, providing a controlled launching and recovery environment. Stabilizing mechanisms inside the container are meant to prevent survival craft motion making it unable to move and damage the survival craft canopy or container interior.



Figure A3 - A Boat-In-A-Box installation, in launched and stowed positions  
(source: Barr et al)



## Hovercraft

Hovercraft have been used in many applications, including very cold climates, and are capable of rapidly moving large numbers of people over large distances. They can transit many open, partially ice-covered or fully ice-covered waters. Since they are moving *over* the ice, there is little interaction.

D.F. Dickins Associates concluded that “there is no fundamental technical limitation or operating constraint preventing hovercraft from serving year-round in a Canadian Arctic environment, as long as the design and specifications are drawn up with specific attention to the expected marine and ice operating environments”. Subsequently, Shell and Griffon Hoverwork have been working on concept designs and an engineering feasibility study concerning the modification of existing hovercraft designs such that they are capable of conducting year round operations in the Beaufort Sea and in the Chukchi Sea. This includes application as a platform-based evacuation craft.

After a review on cold weather hovercraft operations several concepts were developed, using as many proven components as practical. Requirements for the concept designs included the capability to operate in extreme cold conditions (-40°C) and the ability to cross ice ridges of significant height. One of the main issues studied was launch and obstacle clearance as the craft moves beyond the hazard zone.

It was realised that existing craft would require extensive modifications, particularly to the skirt, in order to increase the cushion clearance for operations over rough ice and potentially high sea states. This in turn required the craft to be increased in width to maintain stable operation. The study concluded that a derivative of the Griffon Hoverwork BHT150 model could be modified to provide a feasible solution.



Figure A4 - Griffon BHT 150  
(source: Griffon Hoverwork)

## TIT-800 Archimedean Screw Tractor (AST)

Archimedean Screw Tractors (ASTs) are amphibious craft, propelled by a pair of rotating screw-shaped pontoons. Various concepts have been developed and tested by the US military during the 1960s, mainly for applications in mud and swamp conditions. In the 1970s and the 1980s, Mitsui produced a number of ice-capable AST prototypes to address a range of needs, including platform evacuation in ice-covered waters, which have been demonstrated to work quite well within or on ice covers, although the technology was far from mature.

KOMtech is currently working with Norwegian researchers in developing the TIT-800, a survival craft suitable for use in Arctic environments. The vehicle comprises a hull for accommodating people and a pair of rotatable propulsion screws connected to the hull for propelling the vehicle on water, ice, snow and land. Generally the vehicle should be able to transit from ice to water and vice versa. Furthermore, it must be stable under all operating conditions.

The propulsion screws comprise a cylindrical shaft with helical blades. A crawler mechanism is fitted at the bow to enable the lifeboat to climb from water to ice or land. There is also a transport mechanism under the lifeboat to provide extra traction over loose snow or ice. Two uprighters are connected to the roof of the lifeboat for self-

righting in water in case it is overturned. The vehicle further comprises a closed heating system configured to draw heat away from one or more engines of the vehicle and to circulate the heat around the hull for de-icing purposes.

The vehicle has been tested using a 1/7 scale model. The next phase will involve industry to find acceptance of the concept and advance its development to prototype.



Figure A5 - A 1/7 scale model of the TIT-800  
(source: Offshore Marine)

### Seascope Life Rescue Craft

Seascope 2000 was a research & development project carried out as a multi-national joint industry and government project (JIP) involving regulators from several jurisdictions and a consortium of major operators. It received funding to test the facility consisting of the following components:

- Life Rescue Craft
- Deployment Arm
- Hydraulic Fall Arrestor
- Support Structure.

The original Seascope system was designed to use a pivoting and articulating steel arm arrangement, combined with winches, to deploy a craft into the sea. The arm is located at some point above sea level to avoid being damaged by ice interacting with the facility. The craft itself is yoke-mounted at the end of the arm and can float free of the yoke when it is waterborne. The system would have been capable of deploying the craft quite some distance away from the facility, as far as 20 to 30 m, thus decreasing the risk of being propelled towards the facility and avoiding the ice-structure interaction zone, as well as any grounded rubble around the facility.

It is reported that the Seascope Craft has undergone the full scale SOLAS fire test.



Figure A6 - Seascope deployment system and rescue craft  
(source: Gardin-Haag BV)

### Totally Enclosed Motor Propelled Arctic Survival Craft (TEMPASC)

The Totally Enclosed Motor Propelled Arctic Survival Craft (TEMPASC) is an enhanced survival craft for operating in Arctic ice-covered waters. It has an ice strengthened hull that can withstand up to 100 tonnes ice crushing load and is equipped with a twin fall launching system, a single point lifting arrangement, a towing arrangement, and a bow thruster for assisting in navigating between ice floes. Extra wide seating is provided for Arctic PPE. The steering (helm) canopy is located at the bow of the craft to improve the coxswain's field of vision when maneuvering between ice floes and debris. This helm arrangement combined with the addition of 4 permanently installed, recessed, wide beam flood lights should improve navigation in ice environments at night and during polar darkness.

The TEMPASC is to be suspended from fixed beam-type davits, entailing less moving parts, with a shock

absorbing system and placed inside single or multiple protected and interconnected embarkation areas that can be linked directly to the temporary refuge (TR). The craft are therefore winterized in combined walkway and embarkation enclosures to maximise craft availability and reduce personnel risks after leaving the TR. The enclosures are heated and have slight positive pressure to prevent ingress of hazardous gases, cold ambient temperatures, green water, spray ice and snow.

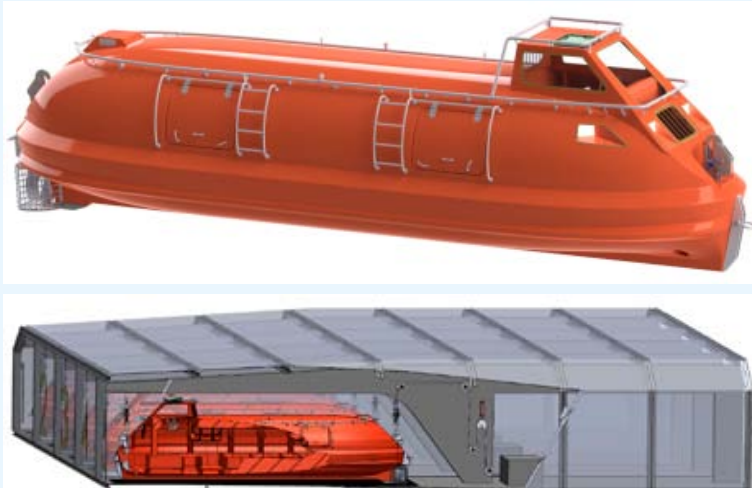


Figure A8 - The TEMPASC and an example of a multiple craft enclosure  
(source: Oceanwide Safety at Sea)

### Ice Strengthened Lifeboat (ISL)

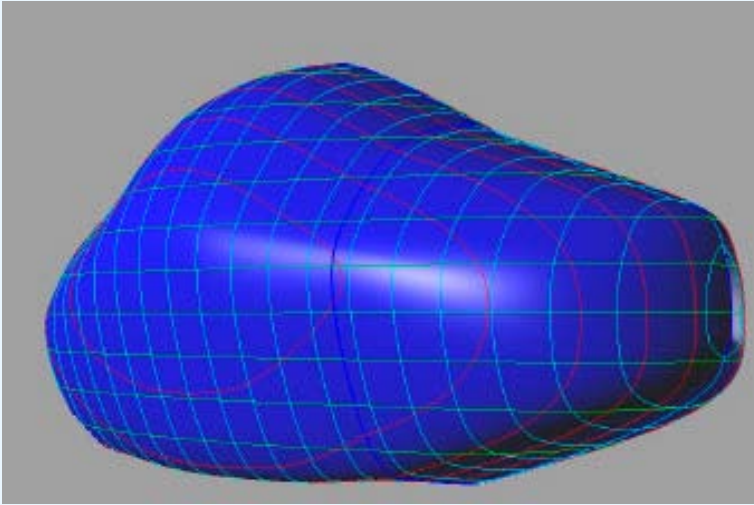
The Ice Strengthened Lifeboat is a practical design of an ice capable TEMPSC that has been developed in a Joint Industry Project and has reached the prototype design stage. The ISL is designed to mitigate the risk of damage or loss due to crushing by ice, during evacuation from offshore installations or vessels in ice covered waters.

The ISL design combines an ice-strengthened composite shell that resists the ice loads with novel hull shape features that help escape from converging, high freeboard ice floes, by enabling the craft to “pop up (or back and forth)” when pinched between two ice features (i.e., the “Fram” principle). The ISL’s shape was designed according to the following features:

- an appreciable side slope;
- small waterline angles;
- no parallel middle body; and
- high side slope freeboard.

The ISL prototype design can accommodate 67 people. It has a 10 m long hull, made of fibreglass composite materials, and can withstand ice crushing and lifting loads up to 100 tonnes. The concept incorporates many outfitting components not found on typical TEMPSCs to enhance the comfort and safety of evacuees under cold weather conditions. The ISL design concept also addresses the potential of the vessel being stranded on an ice floe.

Between 2002 and 2008 a performance based design was developed for an ice capable Totally Enclosed Motor Propelled Survival Craft (TEMPSC) for use as an evacuation craft in Arctic areas. Several international operators provided key criteria that were incorporated into a design philosophy and translated into a design specification and design drawings by Robert Allan Ltd *et al.* The design evolved on the requirements of operators with differing ice environments. With this work concluded, the project has now reached the stage where construction of a prototype ISL is ready to commence. The design combines novel hull shape features that helps escape from converging, high freeboard ice floes with an ice-strengthened composite shell that resists the ice loads and many other performance-based requirements.



*Figure A9 - The unique hull shape of the ISL  
(source: Robert Allan Ltd)*

### **Polar Haven Lifeboat**

Mad Rock Marine Solutions' Polar Haven Lifeboat is a lifeboat specifically designed to operate in harsh environments and ice-covered waters. It is claimed to have good maneuvering capabilities and a forward-placed coxswain cabin, providing a 360° view so obstacles such as ice and debris can be seen and avoided.

Features include roll reduction, ice protection for the propeller and a forward placed "ice knife" to prevent the hull from grounding on top of the ice while transiting ice floes. It has been model scale tested and is awaiting full scale build and testing.



*Figure A10 - Concept drawing of the Polar Haven Lifeboat  
(source: Mad Rock Solutions Inc.)*

### Ganymede Dropped Container

This method does not constitute a secondary means of evacuation for use on offshore facilities; however, it may be of interest as an external support response capsule.

The Ganymede concept was developed by the V.M. Myasishchev Experimental Aircraft Design Bureau and consists of a container-cabin designed for fast and safe deployment by parachute for rescue, medical and other teams, as well as response equipment from aircraft in remote areas where accidents or natural disasters may occur. The basic concept may have potential for modification as a rapidly-deployed EER method for offshore platforms; however, the occupant capacity is very limited.

The container has been designed to land safely on virtually any underlying surface such as forests, building ruins, mountain slopes, swamps and water. A parachute system is intended to decrease the vertical landing speed down to 6.5 m/s and the air damper perforated container provides uniform damping speed to zero without re-jump, which allows medical or other specialists to be dropped from the air to any location without prior parachute training.

The Design Bureau developed the controls for the container landing through a system of parachutes and jet engines, thereby enhancing the accuracy of landing and operational capabilities. The container is capable of landing in automatic mode. The Ganymede container is meant to be used in conjunction with the UPGS-500 cargo airplane.

The container is capable of carrying 5 people and 300 kg of cargo, or 1000 kg of cargo only. The range of air speeds during which the container can be deployed from an airplane is 320 to 400 km/h and the range of altitudes from which it can be deployed is 400 to 8000 m. The accuracy of the landing is claimed to be approximately 80 m.



Figure A11 – Ganymede container-cabin concept for rapid deployment EER response  
(source: Central Marine Research and Design Institute)



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## APPENDIX B EMERGENCY RESPONSE VESSELS

An Arctic Emergency Response Vessel will most certainly be assigned tasks and functions other than those to fulfil its obligation as a rescue vessel. This section presents a number of Arctic Emergency Response Vessels that have been developed, are under development, or under consideration. RN04 acknowledges that there may be other vessel designs of interest details of which were not available to the panel at the time of issuing this report.

### B.1 Russian Multipurpose Rescue and Salvage Vessels

#### Multipurpose Rescue and Salvage Vessel (MRSV)

In the context of Russian governmental decisions and the Russian federal program “Development of the Transport System of Russia for 2010-2015”, a total of 4 multipurpose rescue and salvage vessels are under construction, capable of carrying out search and rescue and emergency response operations, ship-repair, towage and diving work in Arctic seas. The vessels will all be classed as KM Icebreaker AUT2 FF2 Salvage Ship by the Russian Maritime Register of Shipping (RMRS) and will feature propulsion power of 7 MW.



*Figure B1 – Multipurpose rescue and salvage vessel for Arctic areas  
(source: Central Marine Research and Design Institute)*

#### Shallow Water Ice Management Standby and Support Vessel (SWIMMS)

The M/V “Tulpar” is a shallow water icebreaking offshore support vessel. The vessel is especially designed and constructed to meet the requirements for standby support work, ice breaking and barge towage, in the shallow waters of the North Caspian Sea. The M/V “Tulpar” has the capacity for a crew of 20 and 120 rescued persons.

The vessel is designed for a wide range of offshore operations such as:

- Providing offshore supply services for production platforms and drilling platforms;
- Towing of production platforms and drilling platforms, barges etc.;
- Icebreaking: in excess of 0.6 m thick ahead, ice milling of sheet ice up to 1.0 m thick, and clearing ice rubble many meters deep astern;
- Fire fighting of external fires; and
- Rescue functions complying with regulations UKOOA 120-Group B.

The vessel has systems to contain sewage onboard with zero dumping. The ship has been designed with a push bow and low noise and vibration levels throughout.



Figure B2 – MV Tulpar  
(source: Schottel)

Operational details include:

- Delivered by: Ulstein Verft AS, Norway
- Owner: BUE Marine Ltd., Scotland
- Designed by: BMT Shipdesign Ltd., United Kingdom
- Chartered by: Agip KCO

### Ice Breaking Supply Vessel (IBSV)

The Antarcticaborg IBSV also sails the Caspian Sea and is equipped to carry dry cargo, fresh water, fuel oil, liquid mud, cement and barite. Furthermore, the vessel is equipped to remove sewage and waste water from rigs.

Fire fighting, rescue and pollution control capabilities are installed and the vessel is fitted with towing and anchor handling equipment. The vessel is propelled with two electric azimuthing azipod units, making the vessels suitable for ice management and navigation through waters covered with ice up to 90 cm thick and in shallow waters with a depth of 2.5 to 3.0 m.

The vessel meets the requirements of SOLAS, MARPOL, the Russian Maritime Register of Shipping, and Bureau Veritas.



Figure B3 - The Antarcticaborg  
(source: Wagenborg)

### Icebreaking Supply and Standby Vessel Fesco Sakhalin

The ISSV Fesco Sakhalin, delivered in May 2005, is operating in the Sakhalin area of the Sea of Okhotsk. The operating conditions in the Sakhalin area include temperatures down to -40 deg C and difficult ice conditions with ice ridges up to 20 m deep and solid ice exceeding 1.5 m in thickness.

The current ship design is a result of long term research and development activities by AARC. This activity started in 1989 with research on the operational conditions offshore Sakhalin and has continued in form of different research and development tasks for the potential operators and oil companies in the area and in co-operation with several Russian organizations. The vessel design is based on the “double-acting” concept for icebreakers. The vessel has a length of 100 m and a deadweight of 4.000 dwt. The shaft power is 13 MW and the ship is fitted with azimuthing electric propulsion.



Figure B4 – The Fesco Sakhalin  
(source: Aker Arctic).

## B.2 Norwegian Multipurpose Emergency Response Vessels

### Multipurpose and Standby Vessel for the Goliat Development

The construction of a state-of-the-art safety and standby vessel will be a major milestone towards reaching the objective of a robust and effective oil spill preparedness system on the Goliat field off the coast of Finnmark, Norway. The winterized vessel will be mobilized at the field location at all times and will be designed and equipped to operate under the full range of Barents Sea conditions.

The ship differs from other standby ships because it can accommodate daughter crafts or rescue boats directly on board through a special stern arrangement, even under difficult weather conditions, with waves of up to 10 m. The vessel has the Ulstein X-bow® that, among other advantages, allows higher transit speed in rough weather, reduces fuel consumption, decreases spray, and reduces vibration levels. The ERV has a diesel electric propulsion system.

The ship will be able to take on board 370 accident victims, and it will also be able to operate as a tow and salvage vessel. The standby / rescue vessel is 80 m long and 17 m wide. It can operate at speeds of over 16 knots in calm weather, and is furnished for a crew of 40 people.



Figure B5 – Emergency Response Vessel for the Goliat Development  
(source: ulsteingroup.com)

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**RN05**  
Working Environment  
– Barents Sea





# RN05: WORKING ENVIRONMENT – BARENTS SEA

## 1. INTRODUCTION

### 1.1. Focus and scope of Work Group 5

The focus of the Barents 2020 Work Group 5 was Working Environment and Human Factors. The objective of the group was to ensure the optimal health, safety, performance and decision-making of people working on vessels and installations in the Barents Sea. The work group focused on how to mitigate risk to health, accidents and human work capacity due to Arctic environmental conditions in the Barents Sea, including:

- Physical environment and safety of workers in cold climate
- Risk of accidents from accumulations of ice and snow
- Impairment of physical tasks and work efficiency
- Fatigue and impairment of complex mental tasks, cognition and decision-making
- First aid and medical provision

The combined effects of environmental factors in the far north and the difficult and potentially harmful working conditions should be the subject of scientific justification analyses. These analyses should include occupational safety, hygiene, and rehabilitation for the prevention of occupational diseases and injuries.

The cold Arctic climate imposes a special role on the importance of the protection measures in the workplace personnel of industrial facilities that should be priority in companies working there. These activities should be aimed at the preservation of health, health workers, to reduce lost work time and, consequently, to increase productivity and efficiency.

Figure 1 shows the groups of occupational risks to which workers may be exposed while working on offshore facilities, including those located in the Arctic. Occupational risks are classified into three groups: effects of physical factors of industrial environment; danger (harm) connected to special kinds of work (characteristic for certain trades); and potential danger of adverse factors from emergency situations at an offshore facility. Potential harmful effects of these occupational risk factors are increased at Arctic sites due to the extreme conditions of cold, polar night, etc.

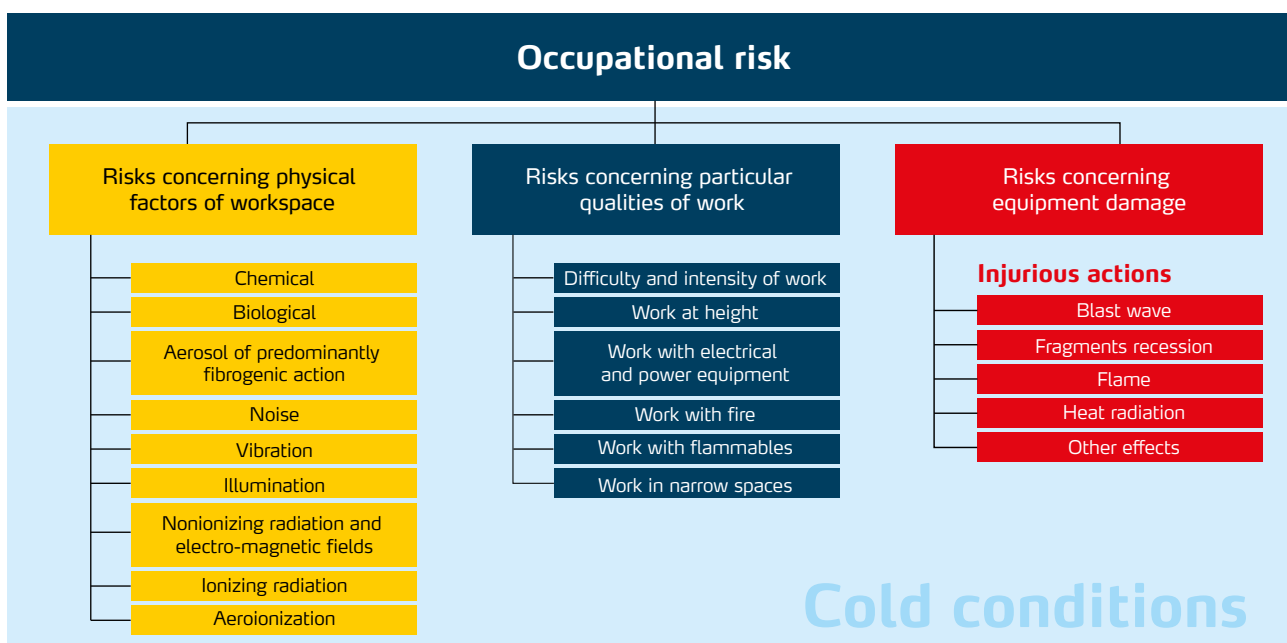


Figure 1. Structure of occupational risk

Most of the measures to ensure normal working conditions should be used as fundamental design considerations at the design stage of the facility:

- the use of safety equipment,
- the use of sound technologies,
- local conditions in the design (physical-geographical, social, and other factors),
- estimate the number of personnel required for production management and operation of equipment for sound work and rest,
- equipment, jobs and sanitary facilities.

Appropriate operational measures and administrative routines are also necessary to minimize occupational exposure, and include

- personnel,
- medical examination
- professional expertise and training of safety rules
- providing clothing and PPE
- proper nutrition;
- current health care;
- rehabilitation and leave regimes

Complex technical and organizational measures taking into account the features of placing objects in the cold Arctic climate and working conditions was the subject of discussion at the working group 5 meetings.

The experience gained in the operation of existing facilities in the polar latitudes in Norway and Russia shows that for normal working conditions for designing objects transport enterprises, the levels and characteristics of most of the physical factors of the labor process to a number of professions in the design of workplace organization, perhaps even lead would lead to acceptable levels.

Comprehensive inventory and assessment of the degree of exposure to harmful physical factors of the labor process, specific to the Arctic conditions will help to eliminate or minimize the effects of risk of injury, as manifest and latent.

Barents 2020 Group 5 prepared the enclosed proposal for an international standard on Working Environment for Arctic Offshore Operations to fill a gap in the current ISO profile, which lacks a working

environment standard for offshore operations. It draws principally on the respected Norwegian Shelf standard for Working Environment, NORSOK S-002. The proposal builds on aspects of the NORSOK S-002 philosophy, principally the use of risk assessments and its emphasis on design solutions to minimizing working environment risks. To this, the proposal adds the specific aspects of working environment risks related to the Arctic offshore environment found in the Barents Sea.

## 1.2. Working group members

This proposal was developed by the members of Barents 2020 Group 5, which consisted of the following individuals during Phase 4 of the project:

Name	Affiliation
Sawhill, Steven	DNV
Terekhov, Dr. Alexei Leonidovich	Gazprom VNIIGAZ
Afansieva, Prof. Dr. Rallema Fedorova	Russian Academy of Medical Sciences
Borovikov, Pavel Andreevich	Gazprom
Drobakha, Marina	Gazprom VNIIGAZ
Ervik, Liv Åshild Landstad	Shtokman Development AG
Grazhdankin, Aleksandr Ivanovich	Scientific and Technical Research Centre of Industrial Security
Haugan, Arne	Statoil
Heber, Hilde	Norwegian Petroleum Safety Authority / BG Group
Ivanov, Aleksandr Nikolaevich	Giprospeitsgaz
Lebedeva, Elena Olegovna	RTIST GO University
Mordovin, Lt. Col. Igor Stanislavovich	State Research Institute 40, Ministry of Defence
Øvrum, Arild	University Hospital of the North / Statoil
Razletova, Anna Borisovna	Krylov Research Institute
Shapovalov, Alexander	Schlumberger
Sokolov, Mikhail Olegovich	Central Marine Design & Research Institute (CNIIIMF)
Terebnev, Aleksandr Vladimirovich	Gazprom VNIIGAZ
Tkachuk, Mikhail Vasilevich	Gazprom Mining Shelf
Tonda, Henri	Total
Tufto, Pål	Eni Norge

## 2. REFERENCES

### 2.1. Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 511, *Protective gloves against cold*

ISM Code, *International Management Code for the Safe Operation of Ships and for Pollution Prevention* (incorporated as Chapter IX of SOLAS)

ISO 5349-1, *Mechanical vibration — Measurement of human exposure to hand-transmitted vibration — Part 1: General requirements*

ISO 5349-2, *Mechanical vibration — Measurement of human exposure to hand-transmitted vibration — Part 2: Practical guidance for measurement at the workplace*

ISO 9886:2004, *Ergonomics — Evaluation of thermal strain by physiological measurements*

ISO 11079, *Ergonomics of the thermal environment — Determination and interpretation of cold stress when using required clothing insulation (IREQ) and local cooling effects*

ISO 12894, *Ergonomics of the thermal environment — Medical supervision of individuals exposed to extreme hot or cold environments*

ISO 13731, *Ergonomics of the thermal environment — Vocabulary and symbols*

ISO 15265, *Ergonomics of the thermal environment — Risk assessment strategy for the prevention of stress or discomfort in thermal working conditions*

ISO 15544, *Petroleum and natural gas industries — Offshore production installations — Requirements and guidelines for emergency response*

ISO 15743, *Ergonomics of the thermal environment — Cold workplaces — Risk assessment and management*

ISO 17899, *Ships and marine technology — Marine electric window wipers*

ISO 19900, *Petroleum and natural gas industries — General requirements for offshore structures*

ISO 19901-1, *Petroleum and natural gas industries — Specific requirements for offshore structures — Part 1: Metocean design and operating considerations*

ISO 19906, *Petroleum and natural gas industries — Arctic offshore structures*

NORSOK C-004, *Helicopter deck on offshore installations*

NORSOK E-001, *Electrical systems*

NORSOK R-CR-002, *Lifting equipment*

NORSOK S-001, *Technical safety*

NORSOK S-002, *Working environment*

RD 2.2.2006-05, *Guidelines on hygienic assessment of working environment and labour process — Criteria and classification of labour conditions*

RD 31.81.01-87, *Rules for safety of seagoing ships [construction]*

RD 31.81.10-91, *Rules for safety of seagoing ships [operations]*

RD 31.87.02-95, *Instruction on labour safety training for personnel on seagoing ships*

### 2.2. Informative references

DNV, *Rules for the classification of ships, Chapter 5, Part 6, Winterization*

OGP 343, *Managing health for field operations in oil & gas activities*

OGP 398, *Health aspects of work in extreme climates: a guide for oil and gas industry managers and supervisors*

Russian Maritime Register of Shipping, *Rules for the classification and construction of sea-going ships, Vol. 3*

### 3. TERMS AND DEFINITIONS

**Company** — The owner or any person, such as the manager or charterer, who has assumed responsibility for operating a ship, mobile offshore drilling unit or offshore installation in the Barents Sea.

### 4. SYMBOLS AND ABBREVIATED ITEMS

#### 4.1. Symbols

$T_{wc}$  Wind chill temperature

#### 4.2. Abbreviated terms

<b>AARI</b>	Arctic and Antarctic Research Institute, St. Petersburg, Russia
<b>EER</b>	Escape, Evacuation and Rescue
<b>HAV</b>	Hand/Arm Vibration
<b>IREQ</b>	required clothing insulation for the preservation of body heat balance at defined levels of physiological strain
<b>ISM Code</b>	International Safety Management Code (long title: International Management Code for the Safe Operation of Ships and for Pollution Prevention, SOLAS Chapter IX)
<b>OGP</b>	Oil and Gas Producers Association
<b>OHS</b>	Occupational Health and Safety
<b>PPE</b>	Personal Protective Equipment
<b>SAD</b>	seasonal affective disorder
<b>SAR</b>	search and rescue
<b>SHE</b>	Safety, Health and Environment
<b>SOLAS</b>	International Convention for the Safety of Life at Sea
<b>WCI</b>	Wind Chill Index

### 5. WORKING ENVIRONMENT DESIGN AND TECHNICAL SOLUTIONS

#### 5.1. Working environment design philosophy

**Guidelines** – Arctic environmental conditions will have a strong influence on the working environment and technical safety of offshore operations in the Barents Sea. Design requirements need to be considered in order to ensure that offshore units meet the facility integrity and operability requirements under these conditions.

The general design philosophy shall be that technical safety and working environment quality on facilities in the Barents Sea shall be maintained at the same level as for other facilities not exposed to Arctic environmental conditions. To meet the working environment challenges of the Arctic environment, specific requirements are set to system and equipment design, construction and operations that will influence the overall safety level.

All systems, equipment and areas of a facility where the Arctic environment may impair safety, functionality or operability need to be evaluated with respect to working environment. A systematic process for evaluation and selection of solutions is required to ensure the risk level is as low as reasonably practicable. The evaluation process should be risk-reduction driven.

Preference shall be given to selecting permanent, technical solutions rather than temporary, operational or procedural solutions. It is important to select solutions that increase safety and working environment quality without introducing adverse side effects.

The main objective is to provide adequate protection for personnel to ensure their health, safety, performance and decision-making under the expected Arctic environmental conditions.

The main principle to provide such protection is to enclose or shield working areas from the elements. Areas that are not fully or partially protected and where snow and ice may accumulate should be provided with anti-icing or de-icing arrangements, as appropriate.

#### 5.2. Working environment design basis

##### 5.2.1. Environmental and cold climate preconditions

**Proposed standard** – The Company is responsible for selecting appropriate physical environmental design parameters and operating conditions. Physical environmental parameters shall be determined in accordance with ISO 19901-1 and the further requirements of ISO 19906. General guidelines on metocean information are given in ISO 19900. The



Company shall take regulatory requirements into account, where they exist. These requirements can include a minimum duration of site-specific data (according to country regulations), the type of data and a definition of extreme design parameters.

The Company shall conduct a realistic assessment of the physical environmental parameters affecting the proposed offshore structure or operation. This assessment shall be used in preparing the facility’s design and operation with respect to working environment.

**Guidelines** – Fundamental to the risk management strategy is the philosophy of assessing the expected environmental conditions at the specific geographic location an installation will be placed or an operation will be conducted. This approach has the advantage of tailoring risk management efforts.

Defining generalized environmental climate zones, however, can be an efficient means of promoting certain risk management efforts, such as for the design and provision of cold weather clothing.

In the Barents Sea, environmental conditions vary substantially from north to south and east to west. Regional information found in Annex B.16 of ISO 19906 does not adequately differentiate the environmental conditions for the Barents Sea, particularly the lack of discrimination regarding the presence of sea ice from north to south. Climate zones defined by the Arctic and Antarctic Research Institute (AARI) of St. Petersburg, shown in Figure 2, provide a better basis for harmonizing cold risk assessment and management for work in the Barents Sea (Mironov, 1996).



The sub-areas as designated by AARI are:

- |                       |                 |
|-----------------------|-----------------|
| I. Spitsbergen        | V. Novozemelsky |
| II. Norwegian         | VI. Kola        |
| III. Franz Josef Land | VII. Pechora    |
| IV. NE Barents Sea    | VIII. White Sea |

Sub-area II is generally ice free.  
 Sub-areas I, III, IV, VII and VIII usually have ice every winter.  
 Sub-areas V and VI are in-between.

Figure 2 – Borders and sub-areas of the Barents Sea (Source: AARI)

### 5.2.2. Psychosocial preconditions

Reference is made to NORSOK S-002, Clause 4.3.5.

**Proposed standard** – As input to detailed engineering, the Company shall perform a systematic analysis of the preconditions for a safe, efficient and health-promoting interaction between the worker and the environment. The purpose is to analyse organisation, manning, and workplace design in order to identify potential problem areas related to psychosocial working environment in particular. (NORSOK S-002, Clause 4.3.5.0-1)

For various positions on the installation, the analysis should, as a minimum, include an evaluation of the psychological job demands and the preconditions for social interaction, support and control at work. The analysis should also consider the preconditions for restitution while off-duty at the installation. (NORSOK S-002, Clause 4.3.5.0-2)

The analysis shall also include an evaluation of the psychological effects of additional stressors found in the Arctic offshore environment, including cold, prolonged periods of darkness (polar winter) and light (polar summer), remoteness, isolation, etc.

**Guidelines** – HSE personnel conducting these analyses should have knowledge about working conditions in the cold climate.

### 5.2.3. Arrangements and frequency/means of access

Reference is made to NORSOK S-002, Clause 4.3.6.

**Proposed standard** – The requirements to access for operation and maintenance of equipment shall be defined and documented as input to engineering and design. The following method is recommended, and the results shall be documented:

- Identify all equipment needing access by area and system and tag number.
- Determine access frequency (daily, weekly, monthly, quarterly, semi-annually, annually, or less frequently), whether there is need for emergency access, and whether access can be deferred under adverse weather conditions, including extreme low temperature, high wind chill, and heavy icing.
- Designate zones for different types of work, indicating those zones requiring frequent access.
- Decide arrangements and means of access, minimizing outside work wherever practicable.



### 5.3. Working environment analyses

#### 5.3.1. Job hazard/risk of occupational injuries

Reference is made to NORSOK S-002, Clause 4.4.3.

**Proposed standard** – A coarse Job Hazard Analysis shall be carried out for each work area on the installation. The analysis shall include the elements defined in NORSOK S-002, Clause 4.4.3.0-2.

A detailed Job Hazard Analysis shall be carried out for each critical workplace involving tasks with a high risk of accidents. Minor accident risks should also be covered. Criteria for the selection of workplaces for the analyses shall include the elements defined in NORSOK S002, Clause 4.4.3.0-6.

Both the coarse and detailed Job Hazard Analyses referred to above shall include the additional potential job hazards/risk of occupational injury stemming from exposure to Arctic environmental factors. These include exposure to cold air and surfaces, icing and falling ice, wind and precipitation, snow drift, darkness and brightness, glare from low-angle sunlight, etc.

Arctic installations may be designed with enclosed, semi-enclosed or sheltered topsides to protect operators and operations from the cold weather. The possible indirect effects of reduced ventilation on increased vapor, particle or gas exposure and explosion risk should be considered in the Job Hazard Analysis and explosion risk analyses for such areas.

**Guidelines** – HSE personnel conducting these analyses should have knowledge about working conditions in the cold climate.

#### 5.3.2. Hazardous chemicals

Reference is made to NORSOK S-002, Clause 4.4.6.0-1.

**Proposed standard** – During project development, a Chemical Health Risk Assessment shall be performed to identify, evaluate and control chemical health risks to an acceptable level.

The analysis shall consider the operational need for using substitute chemicals suited to Arctic environmental conditions, and the potential health risks to humans of using these substitute chemicals. Arctic installations may have more enclosed, semi-enclosed or sheltered working areas to protect workers from the cold. The possible effects of reduced ventilation on increased vapour, particle or gas exposure and chemical health risks shall be assessed.

#### 5.3.3. Cold and wind chill exposure

##### Wind chill index

**Guidelines** – ISO 11079 represents the current international standard for calculating wind chill and classifying risk exposure to cold. It supersedes previous methods in the ISO system.

**Proposed standard** – The formulas and methods contained in ISO 11079 shall be used for calculating the Wind Chill Index and classifying cold exposure risk for offshore operations in the Barents Sea.

##### Outdoor operations/cold stress analyses

Reference is made to NORSOK S-002, Clause 4.4.9.

**Proposed standard** – Outdoor operations/cold stress analyses shall be carried out for open work areas and semi-open work areas, in order to identify and remedy potential problem areas due to overall exposure to temperature, wind, icing and precipitation, including investigation of the weather protection necessary to comply with WCI and other functional requirements identified in the analysis.

The analyses shall be performed early in design/layout development, and shall be updated when design changes are made that will affect workers' exposure to cold stress.

The Company shall ensure the following:

- Workplaces in open and semi-open areas where there is frequent work with duration of 10 minutes or more are identified.
- The analysis includes WCI calculations for the identified workplaces, in combination with explosion load calculations. When calculating the WCI, verified meteorological data (combined wind and temperature) for the past five years or more should be used.
- The formula in ISO 11079:2007 Annex D shall be used to calculate the wind chill temperature ( $T_{wc}$ ).
- Simulations shall be made for the seven coldest months of the year, for the following wind chill temperature ( $T_{wc}$ ) ranges:
  - less than -10°C
  - -10°C to -24°C (wind chill risk class 1)
  - -25°C to -34°C (wind chill risk class 2)
  - -35°C to -59°C (wind chill risk class 3)
  - -60°C and higher (wind chill risk class 4)
- The acceptability of the exposure to high wind chill temperatures is determined, taking

into account the type of work, activity level and duration of stay in exposed areas, and assuming normal winter work clothing.

- Where necessary, measures to avoid exposed workplaces or reduce the exposure to wind and/or precipitation are evaluated, e.g. redesign or relocation of equipment, windbreaks, etc. Design and layout measures that are feasible with respect to both technical safety and working environment shall be identified for implementation in the design.

**Guidelines** – HSE personnel conducting these analyses should have knowledge about working conditions in the cold climate.

## 6. WORKING ENVIRONMENT DESIGN REQUIREMENTS

### 6.1. Arrangements

#### 6.1.1. Work areas and access ways

*Reference is made to NORSOK S-002, Clause 5.1.2.*

**Proposed standard** – All work areas shall have a layout that provides for safe and easy access for operation, inspection, readings and maintenance (NORSOK S-002, Clause 5.1.2.0-1). The layout design shall take Arctic environmental conditions into account by minimizing exposure to spray, wind, cold and the accumulation of ice and snow. This should be done by enclosing or shielding work areas and access ways from the elements wherever practicable.

#### 6.1.2. Falling ice

**Proposed standard** – The layout design shall minimize the danger to personnel from falling ice that may accumulate on structures (such as cranes and derricks). This may be done by arranging work areas away from structures likely to accumulate ice, installing anti-icing systems on structures to prevent ice accumulation, or protecting work areas with roofing that can withstand the impact from falling ice.

#### 6.1.3. Anti-slip systems

**Proposed standard** – Slippery floor surfaces shall be avoided in work areas and access ways. Non-slip systems shall be installed in exposed stairways and stepladders, including the uppermost step at deck/platform level. (NORSOK S002, Clause 5.1.2.0-19 and 20)

#### 6.1.4. Anti-icing and de-icing

**Proposed standard** – Work area surfaces and access ways subject to snow, ice or frost accretion shall be provided with anti-icing or de-icing arrangements as follows. As a minimum, anti-icing arrangements should be provided to

- Escape routes
- Escape exits, including doors
- Emergency muster locations
- Access ways to lifeboats, life rafts, rescue boats and their associated launching and embarkation systems
- Stairways and their railings, where stairways comprise part of an escape route

- Decks, access ways, stairways and stairway railings that are exposed to snow, ice or frost accretion and required for frequent daily use.
- Drainage systems, including scuppers, drains and down-piping on all decks and access ways exposed to snow, ice or frost accretion.
- Helicopter deck for offshore facilities (Ref. NORSOK C-004, Helicopter deck on offshore installations, Clause 17 on sub-zero conditions; and NORSOK S-001, Technical Safety, Clause 20.4.9 on helideck fire fighting system)
- Helicopter deck for ships, if it is classified as a primary element of the vessel's escape, evacuation and rescue (EER) plan, or if the ship has primary EER or SAR support duties for an offshore installation.

Anti-icing arrangements (generally by means of heating or cover) shall have sufficient capacity to keep the area or equipment free of ice, snow or frost down to the facility's minimum design operating temperature, accounting for heat loss by applying a scaling factor related to a specified design wind speed.

De-icing arrangements shall be provided to

- Decks, access ways, gangways, stairways and stairway railings exposed to snow, ice or frost accretion that are not in frequent daily use
- Railings
- Helicopter deck for ships, if not classified as a primary element of the vessel's EER plan, and if the ship does not have EER or SAR support duties.

De-icing arrangements shall be sufficient to remove ice, snow or frost accumulations within a reasonable period of time (normally 4 to 6 hours), under the icing conditions specified in the working environment design basis (see 5.2.1).

In arrangements with electric heating cables or heating pipes with fluids or steam as a heating medium, special attention shall be paid to the heat transfer from the cables or piping to the structure to be heated. The spacing of cables or pipes shall be appropriate for efficient heating. The fastening of cables or pipes shall be such that the heat will be readily dissipated to the structure.

In arrangements applying heating by fluids in pipes, additional capacity of steam plants or thermal oil heaters must be calculated.

Heat tracing should be of the self-limiting type (Ref. NORSOK E-001, Clause 6.10.2).

### 6.1.5. Safety showers and eye wash stations

*Proposed standard* – Safety showers and eye wash stations shall be protected from freezing. They shall be located such that users are protected from exposure to freezing temperatures.

The locations of safety showers and eye wash stations shall be identified through an evaluation considering the chemicals handled, spillage that may occur, and risk for burns or exposure to personnel, and also considering protection of both the shower or eye wash station and the user from exposure to freezing temperature. Reference is made to NORSOK S-001 for Technical safety, Clause 22.4.2.2.

Where safety showers and eye wash stations will be located in areas subject to freezing temperatures, they shall be located in a heated enclosure and water lines to the showers/stations shall be trace heated with thermostatically controlled, low voltage electric heating systems (Ref. ISO 19906 for Arctic offshore structures, Clause 15.2.9.5).

## 6.2. Ergonomics

### 6.2.1. Prevention of musculoskeletal injuries

*Reference is made to NORSOK S-002, Clause 5.2.1.1.*

*Proposed standard* – Workplaces shall be designed such that the personnel are not exposed to excessive workloads with risks of musculoskeletal injury. The design shall prevent additional musculoskeletal stress caused by exposure to low temperature and other aspects of the Arctic physical environment.

### 6.2.2. Human-machine interfaces/human factors

*Reference is made to NORSOK S-002, Clause 5.2.2 and 5.8.0-6.*

*Proposed standard* – The design of displays and controls shall take into account the expected polar environmental conditions, including cold, ice, snow, wind, darkness and low-angle sunlight. It should be possible to operate outdoor controls and displays while wearing insulated gloves and other personal protective equipment required for working in a cold and potentially icy environment. The design shall ensure displays may be comfortably read during conditions of polar winter and low-angle sunlight.

### 6.2.3. Reduced motion due to clothing and cold

*Proposed standard* – Physical motion may be reduced and restricted in cold temperatures due to cold weather clothing and muscular stiffness. Precise movements may be difficult. The likelihood of reduced motion and manoeuvrability due to cold shall be taken into account during design.

### 6.3. Noise and vibration

#### 6.3.1. Noise and vibration analyses for Arctic operations

Reference is made to NORSOK S-002, Clause 4.4.7.

**Proposed standard** – During concept definition and optimisation/front-end engineering design, the activity shall ensure that major noise and vibration sources are identified (NORSOK S-002, Clause 4.4.7.0-2 and 3). On installations that are planned for use in the Barents Sea, noise and vibration caused by external Arctic environmental conditions, such as the interaction of sea ice on the installation, and by icebreaking and ice management activities, shall be considered in the concept definition and optimisation/front-end engineering design.

During engineering, the activity shall ensure that significant noise and vibration sources are identified and their influences evaluated (NORSOK S-002, Clause 4.4.7.0-9 and 10). On installations that are planned for use in the Barents Sea, noise and vibration caused by external Arctic environmental conditions, such as the interaction of sea ice on the installation, and by icebreaking and ice management activities, shall be considered in the evaluation.

Evaluations should take into account the combined effects of noise and vibration on a person over a 24 hour period.

#### 6.3.2. Additional health risks from hand/arm vibration in cold

Exposure to hand–arm vibration (HAV), particularly from handheld tools, is a risk factor related to peripheral vascular disease and Raynaud’s disease (white finger). Cold environment is known as a co-factor increasing the risk for developing disease. Exposure is particularly relevant during maintenance periods. Even if most maintenance is performed in the summer, Arctic summer climate conditions are still defined as a cold working environment (that is, temperatures below +10°C).

**Proposed standard** – Hand/arm vibrations shall meet the requirements stated in ISO 5349 (all parts).

Use of hand–arm vibration tools should be kept to a minimum when working in a cold climate.

Vibration requirements should be established for tools used in cold.

Workers shall be monitored routinely for signs of disease related to hand arm vibration.

### 6.4. Visibility

#### 6.4.1. Operator cabin windows

Reference is made to ISO 17899 for marine electric window wipers and NORSOK R-CR-002 for lifting equipment.

**Proposed standard** – Operator cabins on an offshore installation shall be provided with suitable windows equipped with wind-shield wipers, wind-shield spray nozzles and a window heating/defrosting system, as appropriate, to ensure a clear view of the relevant working area in all expected climatic operating conditions. These include crane, drilling, offloading, helicopter deck and other operator cabins.

Offshore operator cabins shall fitted with means to defrost the windows. The window heating and defrosting system shall be dimensioned to prevent icing of the windows down to the minimum design operating temperature, accounting for heat loss by applying a scaling factor related to a specified design wind speed.

Offshore operator cabins exposed to rain and snow shall be fitted with window wipers compliant with ISO 17899, giving particular attention to the provision for de-icing. The window wipers and window washing system shall be protected from freezing down to the minimum design operating temperature, accounting for heat loss by applying a scaling factor related to a specified design wind speed.

### 6.5. Illumination

#### 6.5.1. Illumination studies

Reference is made to NORSOK S-002, Clause 4.4.8.

**Proposed standard** – During engineering, quality of illumination should be analysed for both internal and external working and living spaces. The illumination should be analysed for various weather conditions and consider the unique seasonal illumination requirements during the prolonged periods of darkness (polar winter) and light (polar summer), as well as the effects of low-angle sunlight. Special attention should be given to the illumination of the outdoor areas, as several operations and tasks that are usually conducted during normal daytime working hours will take place in darkness during winter days.

#### 6.5.2. Preventing glare

Reference is made to NORSOK S-002, Clause 5.6.0-10.

**Proposed standard** – Provision shall be made to avoid direct glare from sunshine, from artificial light sources and from reflecting surfaces. Special consideration shall be given to the prolonged periods in the Barents Sea when the sun is low on the horizon

and the problems this causes by both direct glare and reflected glare from the sea or ice surface.

### 6.5.3. Special lighting

The reduced level of sunlight in autumn and winter can disrupt the body's circadian rhythm, serotonin levels and melatonin levels. These changes have been linked to Seasonal Affective Disorder (SAD), a type of depression that occurs most commonly in autumn and winter, particularly in high latitudes. Phototherapy (light therapy) is a proven treatment for SAD.

*Proposed standard* – Facilities in the Barents Sea should be provided with special lighting designed to assist in preventing or mitigating the effects of Seasonal Affective Disorder during the polar autumn and winter.

## 7. PREVENTION AND MANAGEMENT OF HEALTH PROBLEMS

### 7.1. Cold risk management

#### 7.1.1. General

Arctic offshore operations expose workers to cold, windy and wet conditions. Working in a cold environment can cause several adverse effects on human performance and health: thermal discomfort, increased strain, decreased performance and cold-related diseases and injuries. Cold can also interfere with several other factors in the workplace, modifying or aggravating the risk of common hazards and increasing the risk of cold-associated injuries.

Due to the negative impact of cold on human health and performance, as well as on work productivity, quality and safety, a comprehensive strategy of risk assessment and management practices and methods is needed for offshore work in cold environments such as the Barents Sea.

#### 7.1.2. Cold and wind chill exposure limits

*Reference is made to NORSOK S-002, Clause 5.8.*

*Proposed standard* – On installations that are planned for use in areas with Arctic climate, outdoor operations shall be identified and reduced to a minimum.

Frequently manned areas shall be sheltered without exceeding the allowable explosion risks. If the requirements are in conflict with explosion or wind load limits, it is acceptable to compensate with adequate enclosure of other areas that are also part of the operator's working environment, such as utility areas.

The percentage of time that the individual employee is exposed to a WCI ( $T_{wc}$ ) of  $-10^{\circ}\text{C}$  or colder shall be reduced insofar as reasonably practicable for workplaces where there is frequent work with a duration of 10 minutes or more.

In the event of a WCI of  $-10^{\circ}\text{C}$  or colder, operational measures shall be implemented to limit cold exposure and prevent harmful effects of wind chill. These include

- Setting wind chill limits for normal work, planned maintenance and emergency work
- cold risk assessments (7.1.3);
- limiting cold exposure through appropriate shift schedules and work/warm-up routines (7.1.5);

- appropriate cold weather clothing and personal protective equipment (7.1.4);
- providing local work area wind shielding, heating or shelter; and
- proper supervision of personnel while working in cold conditions (7.3.1).

**Guideline** – In setting wind chill exposure limits, the following guidance is suggested:

Wind chill	Wind chill risk class	Recommended limits
less than -10°C	0	Normal work; emergency work; planned maintenance
-10°C to -24°C	1	Uncomfortably cold Normal work (reduced work periods); emergency work
-25°C to -34°C	2	Very cold, risk of skin freezing Normal work (reduced work periods); emergency work
-35°C to -59°C	3	Bitterly cold, exposed skin may freeze in 10 min Emergency work only
-60°C and higher	4	Extremely cold, exposed skin may freeze in 2 min Emergency work only

**7.1.3. Cold risk assessment**

ISO 15743 presents a strategy and practical tools for assessing and managing cold risk in the workplace. It supports good occupational health and safety and is applicable to offshore work in the Barents Sea, with the exception of work performed underwater. It includes

- models and methods for cold risk assessment and management,
- a checklist for identifying cold-related problems at work,
- a model, method and questionnaire intended for use by occupational health care professionals in identifying those individuals with symptoms that increase their cold sensitivity and, with the aid of such identification, offering optimal guidance and instructions for individual cold protection, and
- guidelines on how to apply thermal standards and other validated scientific methods when assessing cold-related risks.

Cold risk assessment in the workplace follows the principles of risk assessment presented in ISO 15265 and generally accepted principles of risk assessment. It consists of three stages, shown in Figure 3.

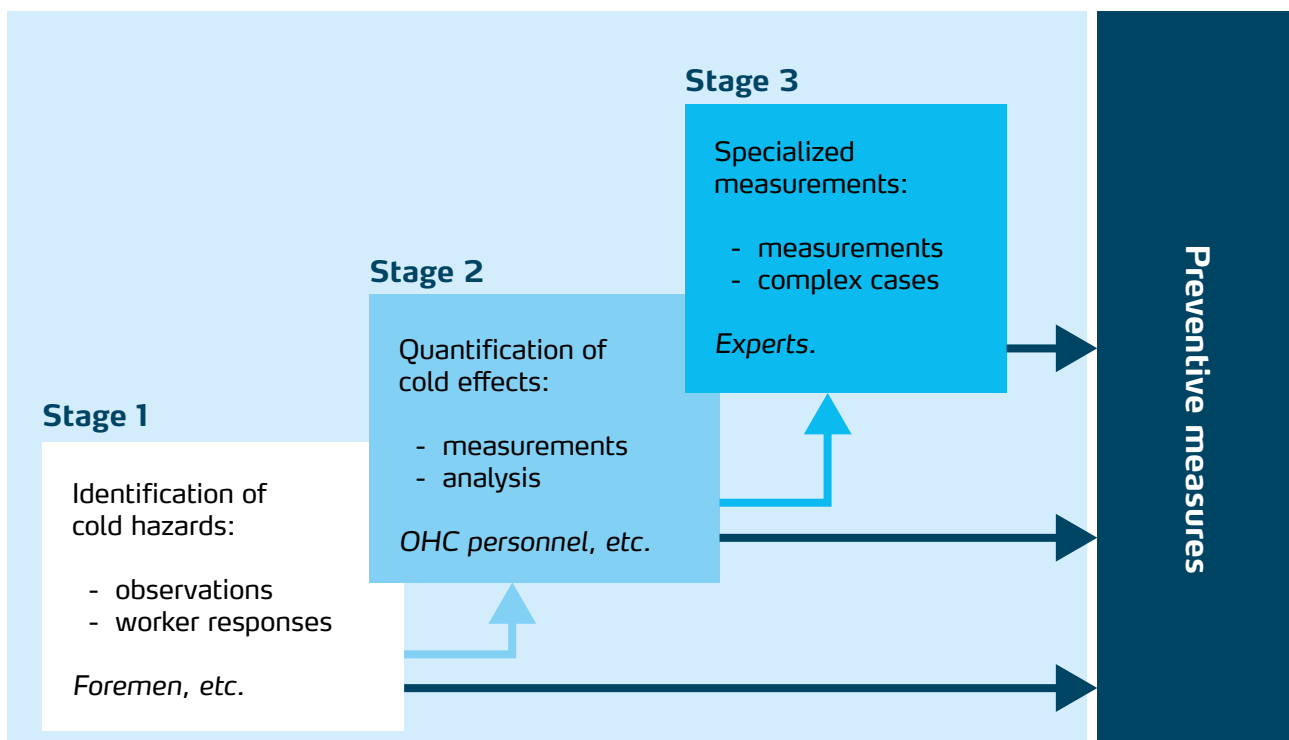


Figure 3. Model for cold risk assessment in the workplace



**Proposed standard** – The Company is primarily responsible for the operational assessment and management of potential cold-related risks to health and safety in the workplace. The cold risk management model and practices presented in ISO 15743 should be fully integrated into the OHS management system and practices of the Company, in order to ensure the implementation and continuance of the activities. This kind of system may be established according to, for example, the OHSAS 18001 occupational health and safety management system specification, which is compatible with the ISO 9001 quality management and ISO 14001 environmental management systems. For ships, this activity should be incorporated into the mandatory Safety Management System required by the ISM Code (SOLAS Chap. IX).

#### 7.1.4. Clothing and personal protection equipment

##### Cold weather clothing

*Reference is made to ISO 11079 Annex F and OGP 398.*

Proper clothing in cold climates is an essential factor for ensuring personnel health, safety, comfort and work performance. Working in the cold implies varying climatic conditions and activity levels and thus varying requirements for protection. The Company shall ensure that all personnel working outside are correctly dressed for the weather conditions and the job to be undertaken.

A multi-layered clothing system is ideal, with each layer serving a specific purpose.

- Inner layer (underwear): moisture absorption and transport
- Middle layer (shirt, sweater): insulation and moisture transport
- Outer layer (wind breaker, Arctic clothing, rain gear): protection against the external environment and moisture transport.

In addition, protective clothing must include appropriate head, face and neck protection; hand protection; and foot protection.

**Proposed standard** – Outdoor operations in cold climate shall be identified and reduced to a minimum. Where outdoor operations must be undertaken, cold climate clothing and personnel protection equipment (PPE) shall be provided and used. The Arctic climate zones defined in Section 5.2.1 should be used in selecting clothing and PPE suitable for the specific geographic location of the installation or operation.

Clothing and PPE must be appropriate to the working environment, the climatic conditions at any particular time, and the specific tasks to be undertaken. Clothing shall be provided to best match the comfort of the worker while facilitating completion of the work tasks. ISO 11079 Annex F can be used to determine the appropriate clothing insulation value (IREQ) needed to protect workers for given climatic factors and work intensity level (See 7.1.5, below).

The need for external waterproof materials and for UV protection should be evaluated and provided for as appropriate.

If work cannot be routinely completed using appropriate cold climate clothing and PPE to preserve health and safety, then other measures such as active heating systems or locality enclosure (either temporary or permanent) shall be provided.

##### Extremity protection

Even at thermo-neutral conditions, the extremities, the hands in particular, may suffer unwanted cooling. This depends to a large extent on the local climatic conditions, local protection and heat input by blood circulation. The latter factor is much dependent on the overall thermal balance. If the heat balance is negative, as for example when protective clothing does not match IREQ, extremity blood flow is reduced due to vasoconstriction. This may reduce heat input to very low levels. Extremities, in particular fingers and toes, will gradually cool down and reach unacceptably low temperatures. Extremity cooling is prevented or reduced by putting on adequate protection, e.g. insulated hand and footwear.

**Proposed standard** – Personnel shall be provided with insulated gloves and anti-slip footwear suitable for protecting the wearer under the relevant environmental conditions (cold, wind and water) as well as the type of work to be performed.

Anti-slip footwear shall be designed to provide stable footing on snow- and ice-covered surfaces. Anti-slip footwear shall be non-static and non-sparking so as not to present an explosion risk.

**Guidelines** – EN 511 specifies the characteristics for protective gloves against cold transmitted by convection or conduction to a temperature of -50°C. This information may be used in selecting suitable cold weather gloves. Test methods for determination of thermal insulation of hand-wear shall be in accordance with EN 511. Required insulation for various wear conditions are also given in EN 511.

##### Respiratory protection

Inhalation of air at low temperatures cools the membranes of the airway walls and can be harmful

to the tissues. Cooling is more pronounced when the ventilated air volume is high (e.g. at high physical activity). Recommendations for lowest temperatures of inspired air are given in ISO 11079 Annex B.

**Guidelines** – At ambient temperatures below  $-15^{\circ}\text{C}$ , respiratory protection is recommended for high activity levels (with increased ventilation volume). At ambient temperatures below  $-30^{\circ}\text{C}$ , respiratory protection is strongly recommended. (Ref. ISO 11079 Annex B.3).

When choosing respiratory protection, consideration shall be given to selecting respiratory protection that fits properly in combination with other cold weather clothing and PPE that are to be worn.

#### 7.1.5. Work, warm-up and rehabilitation regimes

Reference is made to ISO 11079 Annex F and OGP 398.

Sensible work scheduling and warm-up breaks are essential for work in cold climate, not only for preventing ill health but also for increasing productivity. In exposed work sites and low ambient temperatures, thermal clothing alone may not be sufficient to maintain body temperature at a comfortable and efficient level. Extra time will need to be allowed for completing tasks and for re-warming. Shift patterns and work/warm-up schedules should be planned taking these additional time needs into account.

**Proposed standard** – Operators shall develop and implement a work, warm-up and rehabilitation regime for outdoor work in cold climate. The regime shall define the type of work that is allowed under different wind chill conditions, the length of time that workers may work outdoors, the types of clothing and personal protective equipment that shall be used, personnel monitoring and surveillance, and any other special conditions that shall apply.

Work regimes should be planned for outdoor work under the following different conditions:

- Normal work periods
- Shorter work periods
- Emergency work in extreme wind chill conditions

For work under extreme cold conditions, the operator shall develop and implement appropriate procedures to:

- Assess the risk before permitting work to be undertaken; and

- Require workers to obtain a Permit for Cold Work before commencing work under extreme cold conditions. The Permit shall prescribe precautions and assign responsibilities to ensure the workers' safety.

**Guidelines** – ISO 11079 provides procedures for the practical determination of required clothing insulation for the preservation of body heat balance at defined levels of physiological strain, as well as the duration of limited exposure. Duration of limited exposure to cold is defined as the recommended maximum time of exposure with available or selected clothing.

A link to a computer program is provided in ISO 11079 Annex F:

[http://wwwold.eat.lth.se/Forskning/Termisk/Termisk\\_HP/Klimatfiler/IREQ2002alfa.htm](http://wwwold.eat.lth.se/Forskning/Termisk/Termisk_HP/Klimatfiler/IREQ2002alfa.htm)

This program calculates the appropriate clothing insulation required under different environmental conditions (e.g., temperature, wind speed, humidity), the duration of limited exposure to cold, and the required recovery time after exposure. This program provides a practical tool for supervisors in planning work, warm-up and rehabilitation regimes and determining the appropriate clothing requirements to ensure worker health and safety. An example is shown in figure 4.

**CALCULATION OF REQUIRED INSULATION, IREQ AND DURATION LIMITED EXPOSURE, DLE**

116 M (W/m<sup>2</sup>), Metabolic energy production (58 to 290 W/m<sup>2</sup>)  
 0 W (W/m<sup>2</sup>), Rate of mechanical work, (normally 0)  
 -20 Ta (C), Ambient air temperature (< +10 C)  
 -20 Tr (C), Mean radiant temperature (often close to ambient air temperature)  
 8 p (l/m<sup>2</sup>s), Air permeability (low < 5, medium 50, high > 100 l/m<sup>2</sup>s)  
 0.3 w (m/s), Walking speed (or calculated work created air movements)  
 6.0 v (m/s), Relative air velocity (0.4 to 18 m/s)  
 50 rh (%), Relative humidity  
 3.0 Icl (clo), AVAILABLE basic clothing insulation (1 clo = 0.155 W/m<sup>2</sup>K)

Calculate IREQ Interpret IREQ

**IREQ & Dlim RESULTS (minimal to neutral)**

Insulation Required, IREQ 3.1 to 3.4 (clo)

REQUIRED basic clothing insulation (ISO 9920), Icl 4.8 to 5.4 (clo)

Duration limited exposure, DLE 0.7 to 0.6 (hours)

CALCULATION READY!

**CALCULATION OF REQUIRED RECOVERY TIME, RT**

90 M (W/m<sup>2</sup>), Metabolic energy production, (normally lower!)  
 0 W (W/m<sup>2</sup>), Rate of mechanical work, (normally 0)  
 25 Ta (C), Ambient air temperature, (normally warmer!)  
 25 Tr (C), Mean radiant temperature, (normally warmer!)  
 8 p (l/m<sup>2</sup>s), Air permeability  
 0.2 w (m/s), Walking speed (normally lower)  
 0.4 v (m/s), Relative air velocity (normally lower!)  
 20 rh (%), Relative humidity  
 1.5 Icl (clo), AVAILABLE basic clothing insulation, (normally lower!)

Calculate RT Interpret RT

**RT RESULTS (neutral)**

Required recovery time 0.9 (hours)

CALCULATION READY!

Figure 4.

## 7.2. Fitness for work in an Arctic offshore environment

### 7.2.1. Cold-related health assessment

ISO 15743 and ISO 12894 provide relevant guidance for conducting a health assessment of individuals for working in cold environments such as the Barents Sea. The cold-related health assessment they outline is a three-stage medical screening conducted by occupational health professionals. Each stage involves identification of cold-related health risks both in the workplace as well as assessing the health of individuals.

**Stage 1** consists of a health check (see Annex D of ISO 15743). The method used is a medically-based questionnaire whose purpose is to identify potential individuals having cold-related diseases or cold-related personal working limitations. The factors to be identified are, for example, cold sensitivity, cold urticaria, respiratory symptoms, cardiovascular symptoms, peripheral circulatory disturbances, symptoms related to white fingers, musculoskeletal symptoms, and the effect of cold on performance and the occurrence of local cold injuries. As a result of stage 1 of the assessment, those individuals with no personal need for any further analysis with regards to cold are identified.

**Stage 2** consists of an interview and a clinical investigation of persons suspected of having a cold-related individual health problem. The content of the interview and clinical investigation is dependent on the results of the preliminary questionnaire and is symptom- or disease-specific. If cold-related diseases or working limitation are recognized, an additional risk evaluation in the workplace (Annex B of ISO 15743) might be needed.

**Stage 3:** if there are still some open questions on the individual's health status or other cold consequences, a more detailed analysis in a hospital expert unit or a provocation laboratory might be needed. When evaluating health aspects, it is important also to utilize the information obtained from the workplace risk assessment, e.g. the risk check at stage 1 and possibly more quantitative information from stages 2 and 3.

As a result of the assessment, the occupational health professionals recommend whether an individual should be accepted or rejected for work in a cold environment. Those accepted should receive particular advice, training and information in order to ensure their optimal health and performance in cold work.

**Proposed standard** – The Company is primarily responsible for assessing the fitness of individuals for offshore work in the cold environment of the Barents Sea. The Company should adopt the cold-related health assessment process outlined in ISO 15743 and ISO 12894 to identify any possible medical predisposition to harm from exposure to cold. The assessment shall inform Company decisions on accepting or rejecting an individual for offshore work in the cold environment of the Barents Sea.

These International Standards are intended to assist those with responsibility for such exposures to reach appropriate decisions regarding the suitability of individuals for work in cold environments. The International Standards should be read and used in the context of other relevant legislation, regulation and guidance.

### 7.2.2. Other aspects relevant in assessing fitness for work

People face many stressors from the physical and psychosocial environment of high latitudes. Extreme cold is only one component of the total physiological stress imposed by work in an Arctic offshore environment. Other relevant stressors include prolonged periods of darkness (polar winter) and light (polar summer), remoteness, isolation, noise, vibration, and ship or platform motion in a seaway (pitch, roll, heave, etc.).

Experience from polar expeditions indicates that people commonly undergo psychological changes resulting from exposure to long periods of isolation and the extreme physical environment. The most common symptoms include disturbed sleep, impaired cognitive ability, negative affect, and interpersonal tension and conflict. Experience shows that preventing pathogenic psychological outcomes is best accomplished by psychological and psychiatric screening procedures to select out unsuitable candidates. The screening process typically consists of structured interviews by psychiatrists or clinical psychologists, standardized psychometric instruments such as the Minnesota Multiphasic Personality Inventory, and reviews of medical and employment records. Other preventive measures include providing crew members access to psychological support and by training crew members in personal coping strategies, teamwork and leadership (Palinkas & Suedfeld, 2008).

**Proposed standard** – The Company is primarily responsible for assessing the fitness of individuals for offshore work in the polar environment of the Barents Sea. In addition to assessing cold-related health fitness (7.2.1), the Company shall screen potential candidates for other contra-indications for offshore work in an Arctic environment; psychological as well as physical aspects of fitness should be considered. The health fitness assessment should be conducted by a doctor with knowledge of the particular environmental conditions and requirements of the job (IPIECA & OGP, 2008).

The assessment shall inform Company decisions on accepting or rejecting an individual for offshore work in the Barents Sea. In all cases it is essential that an individual risk assessment is undertaken to avoid needlessly excluding someone from work for which they are qualified. This Standard is intended to assist those with responsibility for such exposures to reach appropriate decisions regarding the suitability of individuals for work in an Arctic offshore environment. The Standard should be read and used in the context of other relevant legislation, regulation and guidance.

## 7.3. Health and stress management

### 7.3.1. Cold work supervision and monitoring

**Guidelines** – Extreme environments can only be tolerated for limited periods of time before a risk of ill health results. Control measures are necessary to ensure the safety of those exposed, one of which is the provision of appropriate medical supervision prior to and during exposures.

ISO 12894 provides guidance for the medical supervision of individuals exposed to extreme cold environments.

### 7.3.2. Health and stress management regimes

Workers in an Arctic offshore environment will be exposed to multiple stressors, including cold, snow and ice, lengthy periods of darkness (polar winter) and light (polar summer), remoteness, motion, work responsibilities, etc. the combination of these stressors can lead to fatigue and impair complex mental tasks, cognition and decision-making. Operators should establish health and stress monitoring regimes to ensure their personnel are coping with these stressors in a healthy manner.

## 7.4. First aid and medical provision

### 7.4.1. Medical support assessment

*Reference is made to OGP 343 and ISO 15544 (Clause 13).*

Arctic offshore operations are likely to require a greater degree of self-sufficiency given their distance from shore-side medical facilities and the potential for delays in evacuating personnel for medical attention. The installation's health management philosophy must take into account the constraints of operations in an Arctic environment and how to meet normal health and medical support requirements given these constraints. The health management philosophy comprises pre-mobilisation health fitness screening (7.2), regular health fitness screening (7.3), and the provision of adequate medical support. Adequate medical support relies on having the following:

- company-approved medical professionals in strategic locations;
- effective access to outside specialists/telemedicine to advise on difficult medical cases, treatment and actions to be taken;
- adequate on-site facilities to provide first aid, emergent and interim care;
- effective transport systems and management for evacuation of sick or injured personnel; and

- effective communications with relevant authorities or service providers to expedite the latter.

**Proposed standard** – The Company shall perform a systematic analysis of the preconditions for providing adequate first aid, emergent and interim medical care. The analysis shall consider the intended geographic location of the installation or operation, its proximity to shore-side medical facilities and other area or external resources, the conditions for medical evacuation from the facility, and the potential for extended delays in evacuation due to adverse Arctic weather conditions. The assessment shall be used in determining the provision of adequate medical care in the workplace design (medical facilities), staffing (doctors, nurses, paramedics), supply (medicines, medical equipment and supplies), communications (telemedicine), and organization of the installation or operation. The evaluation shall take into account relevant legislation, regulation and guidance.

The medical support assessment should include the functional requirements and guidelines for emergency medical response contained in ISO 15544 (Clause 13)<sup>1</sup>, and should be used to inform the development of the installation's emergency response strategy (Clause 4).

#### 7.4.2. On-board medical facilities

**Proposed standard** – The offshore installation shall have facilities for providing the appropriate level of first aid, emergent and interim medical care, as identified in the medical support assessment and the emergency response strategy. The medical facility provision and design shall comply with relevant legislation and regulation.

First aid medical kits shall be located at strategic points around the facility. Medical kits shall be located with due regard to their exposure to cold, as pressurized medical gases may exhibit differing physical properties, and there is the potential for fluids to get cold (such as intravenous drips) or to freeze.

## 8. TRAINING AND COMPETENCE

*Reference is made to OGP 398.*

All personnel working offshore in the Barents Sea should be trained in the special aspects of working in an Arctic environment. This training should address an individual's own health and safety as well as that of their co-workers.

**Proposed standard** – All individuals on an offshore installation in the Barents Sea shall receive appropriate training on cold weather health, safety and stress management. The following subjects shall be included, as a minimum:

- The basics of body temperature and heat exchange, including wind chill
- Effects of cold on movement, performance and judgment
- Cold climate operations and safety, including company procedures for approving work outdoors in cold
- Hazards related to sunlight, carbon monoxide poisoning and alcohol in cold weather
- Preventive practices
- Clothing requirements, including how to properly wear and use cold climate clothing and personal protective equipment
- The importance of proper nutrition
- Recognition of hypothermia, cold-related symptoms and cold-stress effects
- First aid procedures for cold-related injuries, illness, or concern of adverse effects of the cold
- The potential for other illness to affect tolerance to cold
- Acclimatization
- Health, fatigue and stress management in an Arctic environment

Initial training should take place prior to an individual's arrival at the installation or operation in the Barents Sea. Refresher training should be conducted at suitable intervals.

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3. Psychological effects of polar expeditions. Palinkas, Lawrence A. and Suedfeld, Peter. 12 January 2008, Lancet, Vol. 371, pp. 153-163.
4. NORSOK. Technical safety. S-001.

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- 1 ISO 15544 provides the following guidance regarding emergency medical response:

### 13.1 Objectives

- To provide medical facilities on the installation capable of treating sick and injured people until more specialized help can be arranged.
- To arrange suitable specialist medical treatment for sick and injured people who cannot be adequately treated on the installation.

### 13.2 Functional requirements

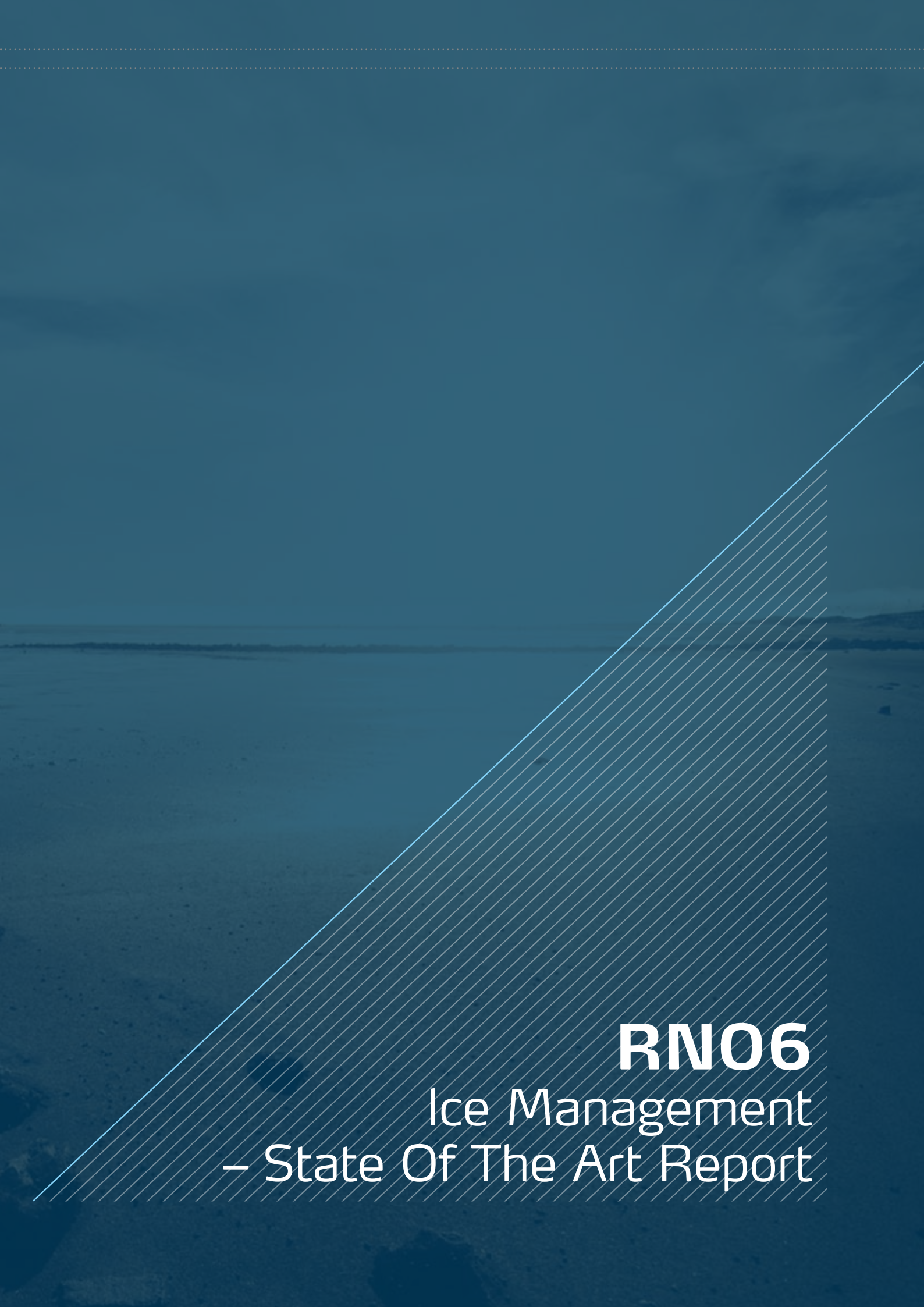
- Arrangements for emergency medical treatment shall consider
  - injuries to personnel as a result of major accidental events;
  - illness of personnel on board, e.g. heart attack;
  - transportation and evacuation of sick and injured people;
  - injuries to personnel as a result of minor accident;
  - other medical situations which may impair the operational integrity of the installation, e.g. food poisoning.
- Controlled drugs and medicines shall be stored in a secure place accessible only to those who are trained to administer such materials.

### 13.3 Guidelines

- All regularly manned installations should have a place where a suitably qualified person can supervise injured or sick people.
- The designated place on the installation for sick and injured people should be readily accessible to people carrying a stretcher, and should have easy access to the places on the installation used for evacuation.
- Medical emergencies that should be considered, particularly if the operating environment means that external assistance may not be readily available, include food poisoning and epidemics.
- The level of medical facilities and trained personnel provided should be in line with the requirements identified in the ERS.







**RN06**  
Ice Management  
– State Of The Art Report





# RN06: ICE MANAGEMENT – STATE OF THE ART REPORT

## EXECUTIVE SUMMARY

This report is the result of the work of Group RN06 – Ice Management - of Phase 4 of Russian-Norwegian Project Barents 2020, the objective of which is to recommend common standards and guidelines for safe offshore design and operations in the Barents Sea. RN06 dealt with “Ice Management”. The work of RN06 has been coordinated with the work of Working Group RN02 “Design of stationary floating units against ice loads in the Barents”. RN02 suggested changes to ISO 19906:2010(E). The suggestions included the following revised definition of Ice Management, which is also adopted by RN06:

*“ice management is the sum of all activities where the objective is to reduce or avoid actions from any kind of ice features.”*

**Note: Ice management includes, but is not limited to:**

- Detection, tracking and forecasting
- Physical management, such as ice breaking and iceberg towing
- Threat evaluation and alerting”

The Scope of Work for RN06 was to prepare a state-of-the-art report on Ice Management (IM). The report summarizes the approach to ice management in four regions where projects have used IM, namely the Beaufort Sea, where Kulluk and Canmar drill ships operated in seasonal ice cover in the 1980’s, the Grand Banks, offshore Sakhalin and at the North Pole (ACEX project). The planned IM activities for the Shtokman Field are described following the descriptions of the mentioned IM activities. The report also summarizes the results from a HAZID workshop held to identify hazards connected to IM activities.

## Main findings

- ISO 19906:2010(E) is currently the only document where IM is addressed, and suggestions for improvements are proposed by RN02
- IM (when relevant) should be considered and planned at all development stages: from feasibility studies to implementation into operations
- Role and function of IM should be clearly defined in the project and operations

- The recognition of the importance of IM team does not come across clearly in studies of earlier IM systems and activities, nor in ISO 19906:2010(E)
- Integration of the IM team into the Organization over the lifetime of a project is important
- The HAZID identified several risks that are related to human behaviour or error
- There is a need for continuous training and education of all personnel that will be or are involved in IM.

## Recommendations

- The operator’s role and involvement in IM throughout the project development and implementation should be highlighted in relevant standards and guidelines
- Projects should establish a core team of people who know and understand all aspects of IM and whom should be involved in all project phases
- For seasonal or new operations a period of time should be allowed for training and team consolidation before any critical operations start. The training should include use of field specific simulators and in-field exercises.
- Due to limited documented IM experience available today, future IM operations should be fully recorded and made publicly available

## Acknowledgements

Working Group RN06 of the Barents 2020 project gratefully acknowledges the contributions from Shell on the ice management experience from Sakhalin 2, the Vityaz Production Complex; from C-CORE on the experiences for the Grand banks and from Shtokman Development AG on the plans on IM for the Shtokman Field.

## 1. INTRODUCTION

### 1.1. Objective

The objectives of the State of the Art (SoA) report are to

1. briefly describe the Ice Management (IM) systems having been operational to date as well as the IM system and philosophy planned for the Shtokman Phase 1
2. give input to what elements and components of different IM systems have proved to work well and where improvements can be made
3. based on the experience gathered through the projects, recommend further action that will contribute to the implementation of IM systems that ensure safe operations, increased operability, extended season operation and keeping ice actions at level below design values, which themselves can be reduced by IM.
3. Detection and surveillance, tracking and monitoring of ice features. Satellite, airborne, radar, vessel, underwater instrumentation, etc.
4. Institution responsible for forecasts, forecast model, whether or not updated by data, update frequency, verification procedure.
5. Physical Ice Management (PIM). Types, number and sizes of vessels, means of removing icebergs, ice breaking patterns, etc.
6. Procedures for threat evaluation and start of PIM.
7. Procedures for disconnection, where relevant.
8. Organisation, responsibilities and implemented procedures.
9. Training. Onshore personnel, ice management crew, offshore personnel.
10. Ice load monitoring, if any, and effects of IM.
11. Monitoring, characterisation and reporting performance of IM. What aspects of IM were monitored and reported, how the performance was reported.
12. Any other aspect of IM.

### 1.2. Scope and content

A brief summary of the IM systems that have been implemented is provided for each of the following projects/regions:

- Kulluk / Canmar drill ships
- Grand Banks
- Sakhalin 2
- ACEX (Arctic Coring EXpedition)

The final section summarizes how the Shtokman Phase 1 Project has combined the accumulated experience with own developments in their operating philosophy and relevant IM specifications and plans.

Summaries for the five projects were supplied by members of Working Group RN06, who were given the following scope for the contributions: Each summary shall contain the following topics whenever relevant:

1. Description of the structure for which IM was implemented. Fixed or floating, station keeping system and whether disconnect able or not for floating structures (in case of disconnect able structure a brief description of the disconnection system and capability is wanted), drilling or production, size and other information relevant for IM.
2. Ice environment: Icebergs, pack ice, ice season, annual or rare occurrence.

In addition, the following is given for each operation:

- Brief assessment of what worked well and what did not work so well, from the first planning of IM to the structure left the site
- Brief descriptions of any further developments of IM that may have been initiated as follow-up the point above

### 1.3. Expert Working Group

Members of the Working Group RN06 were:

Experts	Company
Dmitry A. Onishchenko (Russ. Coordinator)	Gazprom VNIIGAZ LLC
Igor Bardin	Lukoil – Volgogradnimpimorneft
Oleg A. Gasnikov	GNINGI (State Research Navigation Hydrographic Institute)
Yuri P. Gudoshnikov	AARI (Arctic and Antarctic Research Institute)
Mikhail Kuznetsov	Rosneft – Sakhalinnipimorneft
Anna Kvasnyak	JSC Gazprom CKBN Engineering
Vladimir Legostaev	Giprospetsgaz, JSC (Gazprom JSC)
Pavel Liferov	Shtokman Development AG
Mikhail Naumov	Gazprom VNIIGAZ LLC
Aleksander Zimin	KSRI (Krylov Shipbuilding Research Institute)
Bård E. Bjørnsen	Ship Manoeuvring Simulator Centre
Edmond Coche	Total
Claire Channelliere	Total
Kenneth J. Eik	Statoil
Alex Iyerusalimskiy	ConocoPhillips Company
Karl Hamberg	Aker Arctic
Ian Reed	Shell
Jarkko Toivola	Finnish Transport Agency (formerly with Nesteoil)
Morten Mejlænder-Larsen (Norw. Coordinator)	DNV

### 1.4. Background and work process

During the first three phases of Barents 2020 the work carried out in Working Group RN06 included risk evaluation of the different phases of loading/unloading and ship transportation of hydrocarbons. The work concluded that present rules, regulations and standards relevant for the shipping activity were sufficient to ensure the same safety level in the Barents Sea as in the North Sea despite the additional challenges in the former. The procedures and standards applied in the North Sea for the loading/unloading operations were also found to cover the main identified concerns. Adaption and modification of the loading/unloading equipment to the Barents Sea conditions, Winterization, and updates of the procedures were found to be sufficient to take care of the additional Barents Sea challenges.

One part of the operation related to loading/unloading and transportation which is different in ice covered waters from open water areas is the use of ice breakers to break up the ice. This is defined as physical ice management and the purpose is to

reduce the impact loads from the ice acting on a tanker and on an offshore structure or loading buoy situated in ice.

One conclusion from the Phase 3 of the Barents 2020 Project was that there is a lack of formal procedures related to competence training of crew for physical ice management. The recommendations from the work included

- Prepare proposals for functional description for IM as input to IMO and ISO standards with regard to requirements to minimum content for IM manual.
- Propose for IMO a training standard for training institutions for IM (Quality standards for training centres)

It was decided by the Barents 2020 project to focus on Ice management in the last phase of this project and a Working Group, RN06, was established to this end. The objective of RN-06 for Phase 4 was originally to identify relevant parameters and define practical criteria for a successful Ice Management operation, in order to ensure that actual ice loads for the offshore installations and vessels in question are kept within acceptable limits. In addition, establish operational procedures and propose updates of relevant standards, e.g. ISO 19906. The aim is to make the IM operation more safe and optimal from an economical and environmental point of view.

The work process in this group in this phase included a kick off meeting with presentations and experience transfer, a second workshop identifying the different aspects of the ice management operation, a HAZID workshop identifying the main risks and finally a meeting discussing and ranking the different risks. As a result of these activities and after discussions and coordination with Working Group RN02, which worked on the design of floating structures in ice, it was decided that limiting the scope of work to a state-of-the art review would be the best way to prepare for the recommendations described above.

This report describes the state-of-art of ice management operation as manifested by the experience from several operations that involved ice management. The report includes the results from the HAZID workshop carried out by working group 6 in Barents 2020 project phase 4.

### 1.5. Deliverables

The deliverable from the activity of Working Group RN06 within Barents 2020 Project is this report on state-of-the-art for Ice Management.



## 2. ICE MANAGEMENT

### 2.1. Introduction

According to ISO 19906:2010(E) the definition of Ice Management is

*“active processes used to alter the ice environment with the intent of reducing the frequency, severity or uncertainty of ice actions”.*

However, this definition corresponds to what is reported in several places in the literature as “physical ice management”. It indicates that activities such as ice detection, tracking and forecasting are not part of ice management operations. It is also unclear whether disconnect/connect operations are included in the definition.

It is recommended to distinguish in terms and definitions between “Physical Ice Management” and “Ice Management Activities”. It could also be distinguished between “Decision Support Actions” and “Physical IM Actions”. Therefore, the Barents 2020 Working Group RN02 has proposed to expand the definition of Ice Management in ISO 19906:2010 to read

“ice management is the sum of all activities where the objective is to reduce or avoid actions from any kind of ice features.

Note: Ice management includes, but is not limited to:

- Detection, tracking and forecasting
- Physical management, such as ice breaking and iceberg towing
- Threat evaluation and alerting

Ice management is most commonly used to support floating systems in both sea ice and glacial ice environments and can significantly influence the design philosophy that is adopted for them. It can also be used to mitigate the risk of deep draught ice features interacting with sea floor facilities. In certain cases, ice management can be used as a means of modifying ice actions on fixed structures, although this approach is not common. It is also a relevant consideration in terms of supporting other in-ice activities, such as EER systems and tanker offloading operations.

Ice detection, tracking and forecasting should be capable of identifying, tracking and predicting the drift of all kinds of potentially hazardous ice features or ice situations. The devices, data collection and data integration systems used for ice detection will include a suite of platforms that should provide adequate and demonstrable ice detection capability

for the expected ranges of environmental conditions; provide sufficient information to detect, characterize and track the potential threat of ice features or situations; and take into consideration the risks of the potential ice hazards, their probabilities of becoming a threat, and the appropriate operation specific reaction times.

Threat evaluation means identifying potentially adverse ice scenarios that can lead to the exceedance of pre-defined design or operating parameters (such as offsets, mooring line tensions or ice resistance capabilities). It should, amongst other activities, consider the information provided by the ice detection system; forecast and characterize movements of and changes to ice threats; evaluate their expected time of arrival and potential impacts to the installation for the various operations; and identify circumstances when active physical ice management activities are required, as well as the appropriate forms of them.

Physical ice management includes resources in form of qualified personnel and appropriate vessels. The resources should provide a demonstrated and adequate level of effectiveness and they should operate at an efficiency level that is consistent with the reliability requirements of the overall ice management system. Furthermore, they should be available on a fit-for-service basis, when required and be designed to operate under the anticipated range of physical environmental conditions.

The next four sections of this chapter summarize the way IM was conducted in four regions and the experiences gained from drilling and production activities in water with seasonal and all-year ice-cover. The regions are the Beaufort Sea where Kulluk and Canmar drill ships operated in seasonal ice cover in the 1980’s, the Grand Banks, offshore Sakhalin and at the North Pole (ACEX project). The topics listed above are addressed, as well as organizational matters and competence and training of personnel for IM. Note that disconnection routines are included in these four sections. Disconnection is, however, NOT deemed part of IM and is included here for completeness.

The fifth section of this chapter summarizes how the experience from earlier IM activities as well as new developments is being implemented for the Shtokman Field operating philosophy and relevant IM specifications and plans.

## 2.2. Kulluk Platform and Canmar Drillships

The operations were carried out from 1970's to late 80's. The activity was only seasonal during spring, summer and fall season in the Beaufort Sea.

The information given below is mainly based on two reports by Wright et al<sup>1,2</sup>.

### The Kulluk Structure

The Kulluk is a floating structure with deck and waterline diameters of 81 m and 70 m respectively. The operating draft is 11.5 m with a displacement of 28 000 tons. The hull is circular and downward sloping with an outward flare near the bottom. The structure was equipped with a radially symmetric mooring system comprised of twelve 3.5 inch wire lines. All lines were equipped with remote anchor releases (RAR's) to permit quick disconnections. The mooring system was equipped with underwater fairleads. The structure was designed to withstand 1.2m of unbroken level ice. Due to varying pretensions and sometimes fewer mooring lines, the overall mooring capacity was typically in the range of 400-500 tons in drilling mode and 800-1000 tons in survival mode, compared to the design values of 750 tons and more than 1000 tons, respectively.

### The Canmar Drill Ship Structure

Canmar's drill ships (Baltic Class 1A Super) had displacements of about 15 000 tons and with overall dimensions of 100m\*20m\*9m. The vessels were equipped with an eight point mooring system comprised of 2 ¾" wire lines (four bow and four aft) that came off the deck and through the waterline (except Explorer 4 which had underwater fairleads). The mooring lines were equipped with RAR's for quick disconnection. The mooring system could resist global ice forces of about 100 tons with acceptable vessel offsets and tensions in the individual lines. Once moored the drill ships were aligned in a fixed direction and could not weather vane in response to changing ice drift directions.

### Ice Environment

Regular occurrence of pack ice consisting of both first-year and multi-year ice with embedded multiyear ridges. Each part of the season (spring/summer/fall) represented different ice conditions resulting in different ice management strategies depending on season/time of year.

### Detection and Surveillance

Regional ice information was obtained by satellite imagery and periodic airborne radar (SAR or SLAR). Ice information was also exchanged from other locations by other operators. Local information included visual observations from onboard observers on the Kulluk, support ice breakers and occasional from helicopter/plane. Speed estimates were based on sequential fixes from marine radar. Drift buoys were at times placed on the ice.

### Forecast

Ice drift forecast models, which included basic onboard models coupled with wind forecasts and "nowcasts" in combination with persistent tracking, were utilized.

### Physical Ice Management

- The ice management around the drill ships was typically carried out by one or two CAC4 supply vessels and at times the Robert Lemeur (CAC3) and the more powered Kigoriak (CAC2) icebreakers. Four vessels were available in the ice management process for the Kulluk structure. Terry Fox and Klavik had a length of 88m and 17 300kw, while Ikaluk and Miscaroo had a length of 78,8m and 11 110kw. Usually only two or three vessels were utilized and the approaches used were:
  - Picket boat approach – The larger of the icebreakers was stationed far off the installation breaking all the major ice features. The smaller vessel was stationed closer to the installation, picking out the ice features requiring further breaking. This approach was used in thick rough pack ice.
  - High speed approach – in high concentrations of thin first year ice the "the high speed approach" was utilized. The intent of the approach was to fragment large swaths of pack ice in front of the Kulluk in an efficient manner.
  - Ice clearance – this technique was used to clear any ice fragments or rubble that had accumulated in front of the installation. Close icebreaker passes of a circular nature within tens of meters from the installation were efficient, as was propeller wash together with "back and forth" movement close to the installation's port and starboard sides.

### Procedures for Threat Evaluation

Threat evaluation was carried out by an onboard ice advisor. The ice load monitoring system was

1 Wright, B. (2000) Full Scale Experience with Kulluk Stationkeeping Operations in Pack Ice (With Reference to Grand Banks Developments). PERD/CHC Report 25-44.  
 2 Wright, B. (1999) Evaluation of Full Scale Data for Moored Vessel Stationkeeping in Pack Ice (With Reference to Grand Banks Development). PERD/CHC Report 2-200

part of the threat evaluation system and operated continuously. Hazards were divided into two types (ice conditions and weather & wave conditions) and both hazard severity and the time available before its arrival determined the appropriate set of responses. The system included a set of alert status color codes that would trigger a range of response actions. The ice alert criteria or hazards were based on the performance limits of the Kulluk and its mooring lines.

#### **Procedures for disconnection**

The securing procedure for a safe disconnection depended on the well condition and the procedure accommodated time for securing the well and disconnect in an orderly manner. Typically, the secure-time was in the order of 4-6 hours. The ice alert status (or change in status) prompted integrated and well defined response actions.

#### **Organization, Responsibilities and Procedures**

The overall control of the ice management operation was from the Kulluk's control room. The Marine Superintendent (Kulluk's Captain, reported to the Kulluk's Offshore Installation Manager, OIM) was responsible and had the final decision making authority for ice management strategies and priorities, communicating and obtaining feedback from the icebreakers and assessing this information as key input to the ice alert system.

The icebreaker captains were responsible for implementation and execution of the physical IM, own operation and direct communication with Kulluk and the other ice breakers. The communication included recommendations and concerns regarding the physical IM. Typically, the most senior master took a lead role in this regard. The Ice Advisor was responsible for providing information, assessments and recommendations about ice conditions, hazards, strategies, performance, alert levels and so forth. In many cases the Ice Advisor carried out most of the Marine Superintendent's ice management duties.

#### **Training**

The Masters and Mates who operated the icebreaking support vessels benefited from a good understanding of how the entire Kulluk system worked together. To meet this need, ongoing education and training was an important factor. Based on the data gathered it is clear that there was a relationship between the experience of the icebreaker Masters and the effectiveness of their operation.

#### **Ice Load Monitoring**

Individual line tension was measured and the global load was calculated based on these values. Offsets were measured by an acoustic biaxial tilt-meter on

the riser bed (it did not work in ice probably due to the noise generated by the ice). The information was recorded on chart and magnetic tape, the latter with a frequency of 1 – 4 Hz, and communicated through real-time screen displays with a refreshment rate of 1 second.

#### **Performance of Ice Management**

Performance of the IM system was assessed based on, among others, the obtained reduction in ice loads and the downtime of Kulluk operations. Some conclusions from Kulluk are:

- Well managed level ice resulted in peak ice load levels up to about 20% of those of unmanaged ice.
- If the ice is not totally cleared around the vessel, load levels were still about half of those represented by the unmanaged ice.
- The amount of ice related downtime was low, despite the fact that Kulluk often operated in severe pack ice. During situations with pressure in the ice, turning of the icebreakers became increasingly difficult. This in combination with the need to manage the ice in close proximity of the installation during pressure situations forced the Kulluk to move off in a few cases.

The drill ships performance capabilities were established on the basis of the in-ice operating experience. Their station keeping capability was limited by the strength of their mooring system and the fact that they could not orient their bow into the direction of the expected ice action (inability to weather vane in response to short term changes in ice drift direction).

#### **Experience, learnings and recommendations from the Kulluk Ice Management operations**

The reports from the IM vessels of not only ice conditions but also their manageability were of key importance. However the support vessel personnel's assessment of hazards and time frames was not always consistent and the personnel's subjective opinion influenced the assessment. Some key experiences include:

- Ice input that lacks reliability and is not timely was potentially misleading and of little value.
- Poor visibility and darkness was an important factor in slowing icebreaking activities.
- The use of two icebreakers more than halved the time used to break single ice features.

- Unbroken ice features, like large first year ridges, can rapidly cause very high load levels.

Accumulated data suggests a higher level of reliability in keeping load levels down as the number of vessels increase and the “harder to handle” ice events in general resulted in lower load levels due to the increased resources allocated for mitigating the effects.

The highest load events recorded came as a result of “errors in judgement”.

The Kulluk experience resulted in recommendations for future work, with particular emphasis on IM for Grand Banks developments.

#### **Experience, learnings and recommendations from the Canmar Drill Ships Ice Management operations**

The Canmar drill ships were fairly conventional drill ships which maintained location with relatively weak mooring systems in a wide range of ice conditions, within tight offset tolerances and with reasonable levels of station keeping efficiency. The IM support had a very significant effect in providing the drill ships with the ability to station keep in the ice. Some other main experiences include:

- Ice monitoring, ice management and ice alert procedures were developed to enhance the safety and efficiency of drill ship operations in ice, and were quite successful in this regard.
- The fact that the drill ships had essentially no capability to break ice on their own had little impact on their station keeping performance since the ice management support vessels carried out all the ice breaking that was required.
- The orientation of the vessels was fixed and relatively low forces were experienced when broken ice moved against their bow or stern but higher ice force levels were experienced when ice moved along their long-sides and did not clear.
- The relatively weak drillship mooring lines were generally not capable of resisting the forces caused by high concentrations of thick moving ice or the impact from significant sized floes (hundreds of meters)
- The fact that the drillship mooring lines came off the deck and through the waterline was often a problem because ice tended to get stuck, impeding ice clearance and increasing line tensions.
- Ice clearance around the drill ships and their mooring lines was of great importance to keep the mooring loads low. Onboard bubblers enhanced ice clearance around the vessels during late season drilling.
- Damage to the drill ships due to high local ice loads was never experienced in managed first or multi-year ice condition, even though the vessels were only strengthened to Baltic Class 1A Super.

Some of the experience from the drill ship operations and their use of IM was used to improve the systems developed for Kulluk.

### **2.3. The Grand Banks**

#### **Facilities**

IM operations are currently ongoing within the Jean d’Arc Basin on the Grand Banks offshore Newfoundland and Labrador, Canada. Operations are conducted specifically for any one of the installations present: 1 GBS (Hibernia), 2 FPSO’s (Terra Nova and Sea Rose) and multiple MODU’s (eg. GSF Grand Bank) used for in-field development. Both FPSO’s are designed with disconnectable turret systems to mitigate the risk of an iceberg impact and the MODU’s are typically of the moored variety.

#### **Ice Environment**

The ice environment on the Grand Banks consists of both icebergs and sea ice. Icebergs are typically present on an annual basis and occur predominantly between the months of March and June, although iceberg sightings have been recorded in each month of the year. On average, 500 icebergs cross south of 48°N annually but these numbers are highly variable and can vary from zero to over 2200 . Not all of these icebergs will make it on to the Grand Bank or require any management. A review of the PERD iceberg management database reveals that, on average, 48 iceberg tows were conducted annually between the years 1999 and 2009, suggesting that about 10% of the icebergs drifting south of 48°N will require some form of management. During this period, the maximum number of iceberg tows performed in a single season was 144 in the year 2000.

Pack ice occurs off the Newfoundland and Labrador coast annually between December and June with March coinciding with the period of maximum extent. The return period of pack ice in the vicinity of the Grand Banks installations is between 1 in 4 years and 1 in 3 years. When pack ice is present, it is generally loose coverage (at most 4 - 6 tenths), and mostly classified as thin first year ice (30 cm – 1 m) in ice cakes (<20 m dia.) and small floes (20 – 100 m diameter).

### Management Approach

Ice management regions are defined to ensure the effective execution of ice management plans and to ensure safe operations. Monitoring operations are initiated approximately 100 nmi from the facility. Three zones referred to by Environmental Service Providers include Regional Zone (resource planning), Confirmation Zone (accurate positions and assessment of the physical characteristics of the icebergs) and Tracking Zone (detailed iceberg tracks recorded). The Tracking Zone is of most significance to the immediate operations of a facility or facilities in the region. Within the Tracking Zone are ice management zones that are facility specific and include the Observation Zone, Control Zone, Alert Zone, and Exclusion Zone as illustrated in Figure 1 and discussed in detail in Table 1. Depending on the Facility (drilling, FPSO, etc.), and the time required to suspend operations and move off location (T-Time) the size of these zones may vary.

Where practical, operators conducting production and/or exploration operations on the Grand Banks also participate in a coordinated ice management strategy. The purpose of this cooperation is to:

- Reduce duplication of effort;
- Ensure that all ice management operations are made with consideration for all operating fields; and
- Maximize the effective use of resources including not only physical ice management (PIM) activities but reconnaissance activities as well.

Within this context it is important to note that each operation maintains ultimate control over its own IM requirements within its control zone. Within this system, strategic IM activities, such as managing ice outside of any specific facilities IM zone, are coordinated from the Ice Coordination Facility whereas tactical IM is coordinated by the facility requiring the IM. Consideration for preferred ice drift direction is taken into account when planning tows. This usually means that icebergs managed upstream of the facilities are towed further to the east and released in the vicinity of the Flemish Pass (200 m contour) where they will continue to drift south.

Observation Zone	Iceberg monitoring via satellite detection, aerial and ship reconnaissance Iceberg characteristics estimated or measured Iceberg forecasting via drift prediction models Initial threat assessment Sometimes referred to as the tracking zone
Control Zone	Iceberg monitoring via ship or facility based radar Iceberg forecasting via drift prediction models Threat assessment Physical management of threatening icebergs
Alert Zone	Size varies depending on facility operational "T"-Time Operations will suspend to reduce "T"-Time and corresponding size of the zone if an iceberg is approaching the boundary. Size based on time to suspend operations (i.e. suspend drilling, pull anchors, suspend production, disconnection) and drift speed of the iceberg
Exclusion Zone	Zone into which no icebergs can enter and represents the minimal time available for the facility to leave location. This is typically the lesser of one hour or one nautical mile.

Table 1. Ice management zones near a facility

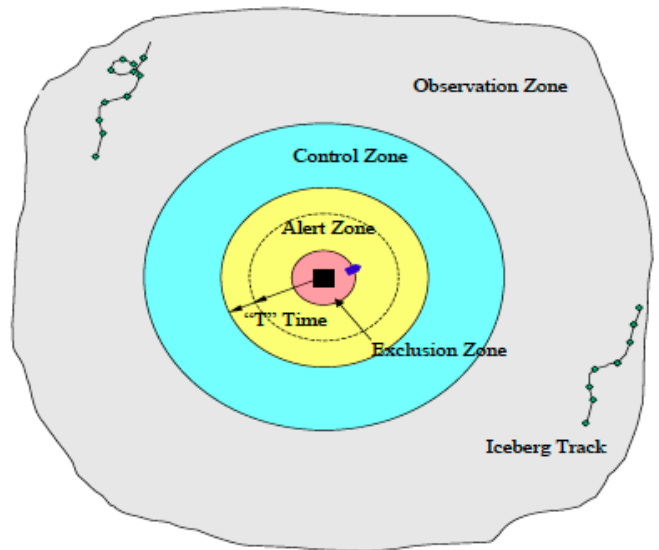


Figure 1. Illustration of ice management zones around a facility



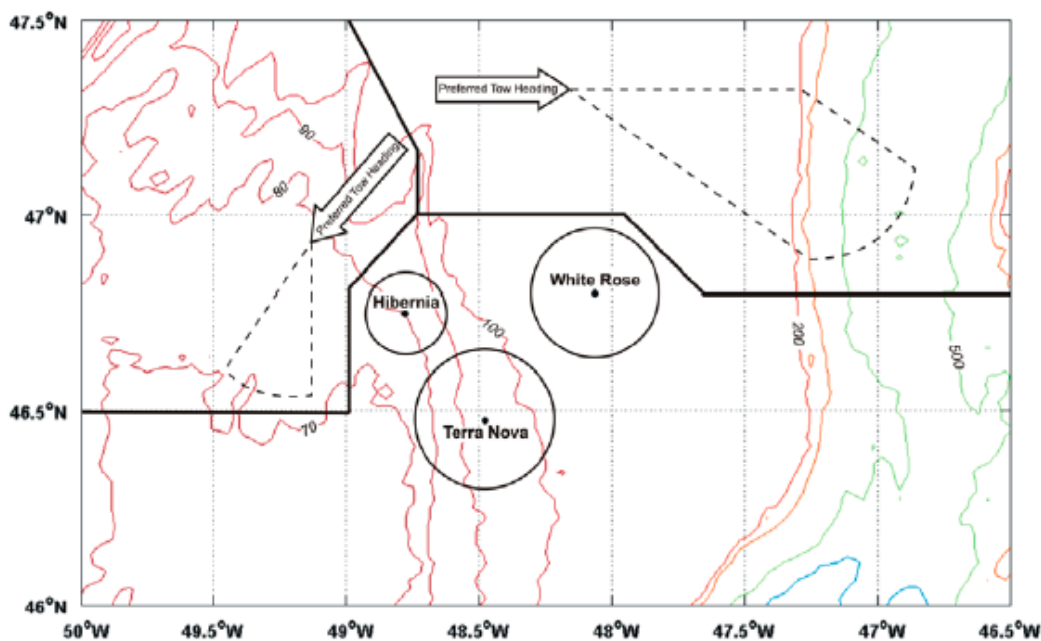


Figure 2. Coordinated Grand Banks Ice Management Zone. Circles around facilities represent nominal IM control zones.

### Detection and surveillance

Radar-based systems are used as the primary surveillance tool for iceberg detection. These include marine radar installations on all facilities (GBS, FPSO, MODU) and supply/support vessels, aerial based systems on reconnaissance aircraft and satellite radar. These systems are supplemented with visual sightings when conditions permit.

Iceberg surveillance is conducted within two “zones”: strategic and tactical. The strategic zone consists of the region north and northwest of the Grand Banks extending as far as the Labrador coast. The need for strategic detection is imperative for establishing a state of readiness for the initial arrival of icebergs as well as maintaining the appropriate level of resources during the ice season. Strategic surveillance is conducted with satellite based radar, aerial reconnaissance and vessels of opportunity that may be transiting through the region. Precise iceberg locations are not necessarily required in the strategic zone as much as the need for positive identification.

The tactical zone will typically extend up to 100 nm from the installation. Once ice has been detected within the tactical zone, the tracking phase will commence. Monitoring and tracking will require the ice position to be updated at a period commensurate with its threat. It is preferred to have updated positions at a minimum frequency of every 3 hours. An iceberg deemed to be a high threat will have its position updated more frequently. A constant knowledge of the prevailing and forecast

environmental conditions is maintained along with the current status of the offshore facilities operations.

Position updates will be obtained either from the offshore facilities radar or from the ice support vessel(s). Calculations of the drift made good (DMG) and the closest point of approach to the facility along with the amount of time available before the ice will cross the outer boundary of any ice exclusion zone. Monitoring data forms the basic information from which a threat assessment can be made. Icebergs predicted to intercept the facility’s alert zone will be flagged for physical management. In the case of multiple targets – priority will be assigned based on threat to facility (i.e. ice deemed to exceed the design tolerances of the facility in question). The parameters considered when assessing threat to installation are:

- Iceberg Size. The size of an iceberg will affect its ability to be towed. There are challenges when towing all sizes of icebergs. Larger icebergs cannot be towed with a high velocity or be deflected by large angles. Smaller icebergs have a tendency to roll under tow and, since their surfaces tend to be smoother, the tow line often slips off and for such the iceberg net is typically used. The iceberg size impacts the probability of tow success as well as the physics of iceberg towing.
- Iceberg Speed Relative to Structure. The projection of the speed of an iceberg in the

direction of a facility measures how fast the iceberg is moving directly towards the structure. Given the distance of the iceberg to the facility, an estimate of the minimum time to impact of the iceberg can be found. The shorter the minimum time to impact, the greater the risk imposed.

- **Proximity to Structure.** The closer the iceberg is to an offshore structure, the greater the risk. When the relative speed of an iceberg is calculated, the minimum time to impact is determined.
- **Heading relative to Structure.** If an iceberg's heading indicates that it is predicted to come close to a facility, then that iceberg has a higher risk. In this way, not only the current proximity, but also the predicted proximity contributes to the risk metric.
- **Probability of Tow Success.** Not all tows that are attempted are successful in deflecting an iceberg from danger. The tow line can slip over or under an iceberg, or the iceberg can roll resulting in a loss of tow. The probability that a tow will be successful is based on the iceberg size and the sea state and has been compiled from field data.
- **Facility T-Time.** Each facility will require a different amount of time to suspend operations and evacuate or move in the case of extreme iceberg threat. The size of a facility's alert zone is estimated using the facility's T-time and each iceberg's relative velocity to the facility.
- **Deviation Angle to Reach Structure.** The greater the angular difference between the current heading and heading to a facility, the lower the probability of impact.

### Physical Ice Management (PIM) Techniques

The number of dedicated IM vessels will vary annually depending on the severity of the ice season. Typically 3 to 4 vessels are assigned exclusive IM duty that includes physical management and surveillance sweeps. In severe years, more than 10 vessels have been tasked with IM duties.

Historically, the most predominant technique used for managing icebergs has been the use of a single floating tow line. The basic procedure involves attaching one end of the tow line to the vessel's steel towing hawser. The other end of the tow line is paid out over the stern of the vessel as it approaches the iceberg. The vessel circles the iceberg until it retrieves the other end of the tow line. The end of the line is attached to the steel towing hawser, steel tow cable is

paid out, and towing is initiated (Figure 3).

More recently, an iceberg net was developed to improve the efficiency of towing smaller, more rounded icebergs and unstable icebergs (Figure 4). In these cases the single tow line would have a tendency to slip over the iceberg resulting in a loss of tow. In most cases, the iceberg net is now deployed as the primary tool for iceberg management. Deployment is conducted in much the same manner as the single tow line.

Other methods of deflection are implemented when smaller ice masses such as bergy bits or growlers approach a facility and their drift path can be accurately predicted. Propeller washing is one technique that is used against ice features in close proximity to a facility. This technique involves the vessel repeatedly backing up to the small ice feature and accelerating away. The backwards thrust of the water from the propellers moves the ice in the desired direction. The propeller wash technique is commonly used for untowable growlers located relatively near the installation that need to be moved short distances (less than 1 nautical mile). Bow mounted water cannons have also been used to manage small ice masses.

### Organisation and responsibilities

The duties and responsibilities of the ice management team are a clearly defined aspect of IM activities. The Offshore Installation Manager (OIM), the Ice Advisor and the Masters of the standby support vessels are the key personnel involved in strategic iceberg management. For drilling activities, the Drilling Supervisor is also central to the ice management activities. This component of the iceberg management system is critical as decisions to suspend operations and possible disconnection have serious consequences.

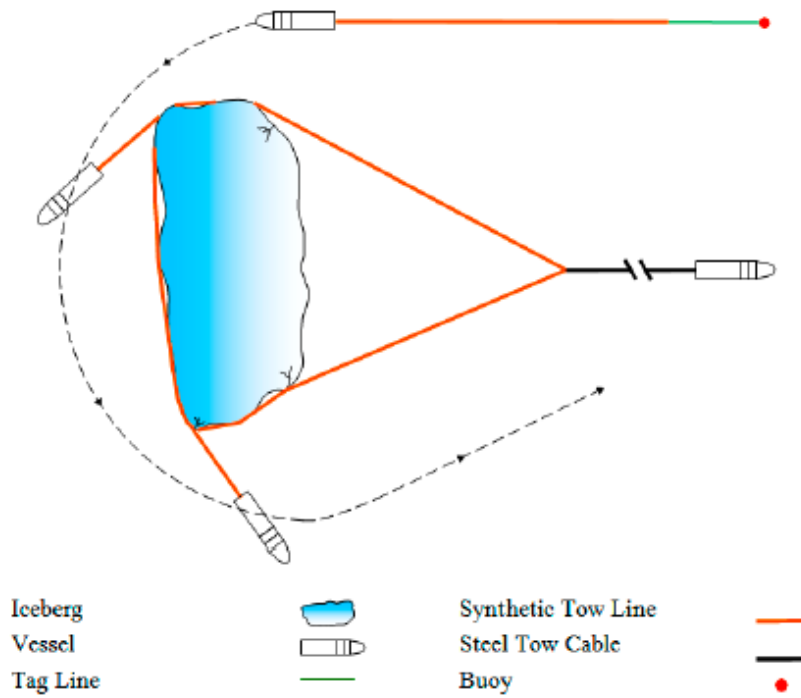


Figure 3. Illustration of single vessel synthetic line towing

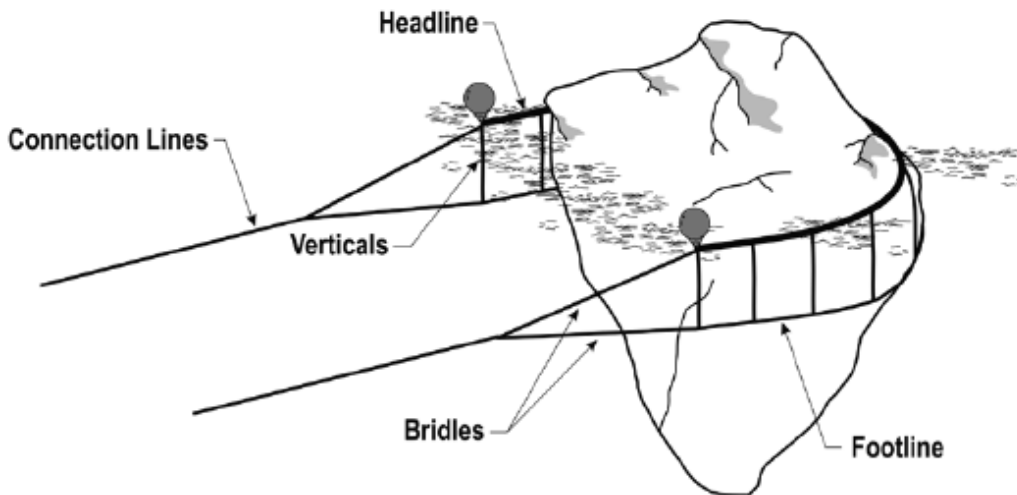


Figure 4. Net towing configuration

### Ice Advisor

The Ice Advisor monitors the actual and forecasted ice & metocean conditions. If there is a threat, they determine the severity in terms of iceberg size and drift. The Ice Advisor determines Arrival Time based on existing and forecasted weather and ice conditions. With a T-Time estimate from the OIM the ice advisor recommends to the OIM the appropriate Hazard Response. In consultation with the Master of the standby support vessel, they may recommend an iceberg management plan.

### Offshore Installation Manager (OIM)

The OIM is responsible for the final decision on the iceberg management strategy. The OIM will be responsible for determining the T-Time, i.e. the time required to safely suspend operations. For drilling activities, this would reference time to suspend drilling operations, secure the well and possibly move off location. For production, this would reference time to shut-in production, flush lines, and for a floater, possibly disconnect. To generalize, the T-Time will be referenced as time to “shut-in operations.” When making final decisions on iceberg management, the OIM will consider the ice advisor’s estimate of time available before a hazardous iceberg approaches, the time required to suspend operations, and the time required to safely disconnect the facility should the need arise. The OIM will use conservative estimates of these time requirements in order to ensure that all necessary steps can be completed with appropriate margins for safety. The OIM will announce any change in iceberg management status over the public address system and inform any standby and arriving vessels of changes to the Alert status on the platform.

### Drilling Supervisor

For drilling vessels and activities, the Drilling Supervisor plays a key role, since he is responsible for advising the team on the state of drilling activities and subsequent T-Time. Also, he must be informed of iceberg threats and times associated with estimated iceberg arrival at the facility since these influence decisions to suspend drilling operations to reduce T-Time. He works directly with the OIM and Ice Advisor and keeps them up to date on state of drilling and T-Time.

### Standby Support Vessel Captain(s)

The Master(s) of the standby support vessels(s) will develop and implement iceberg management plans as required and in consultation with the ice advisor. In the unforeseen event that a floating drilling or production facility is required to disconnect and leave the site, the senior on-site Master would normally assume command as the facility is maneuvered through the ice to safety.

### IM Performance

The PERD IM database, see below, (PAL, 2010) tracks all attempted tows and classifies success. Information for all tows and attempted tows are recorded by the facility ice advisor during the course of the ice season. These data are then entered into the database to provide a permanent record of all IM activities. Additional fields included in the event record are iceberg size, vessel, method, applied tow force and sea state. If tow was not successful, reasons are presented. The overall success rate for all attempted iceberg tows is 86% based on the data presented in PAL (2010)

The PERD Grand Banks Iceberg Sighting Database (formerly known as the PERD Iceberg Population Database) was initiated in 1998 to assimilate all of the information on the annual iceberg population on the Canadian East Coast. It is updated each year with new data from the previous ice season.

## 2.4. Vityaz Production Complex Offshore Sakhalin Island

### The Vityaz Structure

During the period that ice management was taking place there was one structure permanently sited, namely the bottom founded steel caisson platform, Molikpaq. The Molikpaq had started off life as a drill rig in the Beaufort Sea in the 70’s and was brought over to Sakhalin where a spacer was fitted to allow the platform to sit at the correct water depth (@30m). The Molikpaq is an oil producing platform sitting 9 nautical miles off the coast on the North East Coast of Sakhalin. It delivered its oil via a 2km subsea pipeline to a Single Anchor Leg Mooring (SALM) buoy which was attached to the seabed via a swivel joint which allowed the SALM to be laid down on the seabed in a ‘glory hole’ during the winter months when there was full ice cover. During the summer months a Floating Storage Offtake (FSO) tanker, ‘Okha’ was connected to the SALM to receive the export oil from the Molikpaq. Trading tankers then came at weekly intervals to offload from the stern of the FSO.

Ice management was applied at the start and end of the summer season to

- a) try and raise the SALM as early as possible in the remnants of the winter ice so as to be able to recommence production and
- b) to lower the SALM to the seabed as late as possible in the season so as to maximize the production window.

In order to ensure safety of operations, if the SALM was to be raised or lowered in ice, then it was done with the full support of an ice management team. The team consisted of 9 ice specialists reporting to an Ice Team Manager. The Ice Team Manager reported in to the Marine Manager and through him to the Offshore Installation Manager (OIM) and the Operations Manager.

### Ice Environment

In the North East of Sakhalin Island the ice starts to form towards the end of November. The earliest and latest dates of first ice formation vary from 10th November to 9th December. New ice formation begins near shore on the cooled sea water when the water temperature reaches  $-1.7^{\circ}\text{C}$  (water salinity 32.3 ppt). Grease ice and nilas forms first followed by pancake, and eventually sheet ice as the pancakes freeze together. Ice spreads off shore by westerly and northwesterly winds and occupies 9 nautical miles along shore area reaching Vityaz Complex location within 5 to 6 days. The ice thickness grows up to 5-7 cm when the ice reaches Vityaz Complex location. Ice reaching Vityaz Complex continues to drift offshore. The ice spreading stops at 5-15 nm to the east from Vityaz Complex, because the ice comes to the warmer offshore sea water. This ice situation is stable during December. Local ice formation comes through a polynya where Vityaz Complex is located and reaches 20-25 cm thick behind Vityaz Complex at the eastern ice edge of local ice massif. Such ice conditions would allow oil production and loading to continue up to the end of December. As the ice generally gets blown offshore by the northwesterly winds in the winter, a polynya of thin ice forms near shore in the early winter and this condition can persist until late winter when the winds become more omni-directional. Ice more than 30 cm thick forms rapidly along the northwest coast of the Sea of Okhotsk and in the Shantar Islands. This ice is transferred by northwest winds of a winter monsoon to the Molikpaq site by mid to late December, forcing the operations to halt for the winter. During winter, hummocked drift pack ice with sails up to 6 m and corresponding keel heights can cover most of the Sea of Okhotsk or just down the East Coast of Sakhalin Island.

By late April or early May the ice starts to melt and break up, and generally by the beginning of June, just a strip of ice remains down the east coast of the island. At this time of year, offshore winds can move all the ice offshore from the Molikpaq, but the ice can return with onshore winds. In other years easterly winds can keep the ice packed along the shore. Thick ice (about 120cm) and pressure ridges can also come down from the north and pass over the site. In some years, southerly winds can drive

the ice 60 to 100km to the north in late May, and then the ice can rapidly return in early June at speeds of up to 2.5 knots as a result of a strong southerly current, which develops following the break out of the Amur River.

The Amur River freezes over in the winter and is ‘plugged’ by ice until the spring. When this plug melts there are large volumes of fresh water and fresh water ice released in a short space of time which proceed around the top of the island and flow on a southerly course close to the coast of the island to the Vityaz field area of operations in the form of an ‘ice river’. The thickness of ice coming from the north is typically 0.9-1.5 meter and maximum floe size can reach 10 km.

### Detection and Surveillance

Ice was detected with a variety of means. The primary means was by the use of Terra-Modis (MODerate-resolution Imaging Spectroradiometer) images with a backup of Radarsat images in periods when there was cloud or fog. This provided the global picture of the ice distribution around Sakhalin Island and in Sakhalin Bay. Secondary measures used were an ice breaker vessel which was used for scouting to the North of the site and around into Sakhalin Bay. Regular helicopter reconnaissance were flown (every 2-3 days) and occasional fixed wing flights were made to assess a wider picture in the absence of good satellite images. Local visual and radar ice observations were carried out from the ice breaking vessels on site and local ice drift patterns were measured and recorded from the fixed Molikpaq platform using the marine radar.

### Forecast

A twice daily weather forecast was provided by a commercial weather forecasting company. These forecasts provided the winds, gusts, cloud cover, air temperature, wind wave and swell for every 6 hours for the first 3 days then every 24 hours for the next 4 days, plus an analysis map showing the current surface pressure situation. At critical times, the Ice Observers contacted the weather service meteorologist to discuss the forecast and to get further insights into the confidence and reliability of the forecast.

Web based weather sites were reviewed daily to see how these forecasts compare to the “official forecast” mentioned above. Weather sites from the Marine Pacific Centre, Korean Meteorological Association (KMA), Japanese Meteorological Association (JMA), etc, were reviewed for wind and temperature and the JMA ice maps were reviewed for ice cover and water temperature.

Ice drift forecasting was required because the time to stop the FSO loading operation and lower



the SALM to the seabed was about 36 hours. Hence the IM management team had to ensure that no hazardous ice arrived at the SALM site within this time. Short time forecasts of 3 to 10 hours were also required to support SALM raising operations in the spring.

The forecast model was calibrated by comparing the ice drift measured from radar, for the 24 hours before the forecast date and time, to the calculated ice drift. Ice drift was also obtained by comparing the locations of the same floes in Terra MODIS satellite images obtained over two or three consecutive days. Terra Modis images were received daily when the visibility was good.

### Physical Ice Management

Physical ice management was provided primarily with three vessels. There was a dedicated ice breaker which was used as a scouting vessel to the North of the island to warn of approaching dangerous ice. When the SALM raising or lowering operation was imminent, the scouting icebreaker would come closer to the site to assist with the ice breaking. A primary ice breaking vessel was situated 1-3 miles from the SALM area and broke ice on the drift line as reported hourly by the team on the Molikpaq platform to a size that could be handled by the primary protection vessel. An azimuthing ice breaking supply vessel was situated a few hundred meters ahead of the SALM on the drift line and provided a flushing operation using her thrusters angled out in opposing directions and operating at high power levels to clear an area of water wider than the SALM and FSO from ice.

### Procedures for Threat Evaluation

The threat of dangerous ice was evaluated by the ice management team. Firstly they evaluated the dangerous ice that was around to the North of the site, up to the Northern most point of the Island, and then assessed the likelihood and the timings for it coming to site. If it was likely to drift outside of the SALM area then it was only monitored for changes in drift. The operation for raising or lowering the SALM and keeping the FSO connected to the buoy was evaluated and ‘T’ times were developed which were the times required to remove the assets to a place of safety (i.e. lower the SALM back to the seabed and take the FSO to an area with ice that would not damage her hull.) The Ice Management Team then issued daily ice alerts which advised the ‘T’ time available, the dangerous ice in the area and the likelihood of it impacting the site.

### Procedures for disconnection

The FSO and export tanker could disconnect quickly from the site as Camlock flanges were fitted on the end of the export hose from the FSO to the export

tanker and the hose was mounted on a reel on the aft end of the FSO for faster recovery. The FSO could rapidly disconnect from the SALM as there was a quick disconnect coupler fitted and the SALM hose could be lowered quickly and buoyed off. There were remote operated bow mooring hooks which could release the FSO from the SALM and the vessel could move off within minutes if necessary although a more controlled disconnect was preferred.

The SALM took longer to lower to the seabed and was a complicated procedure which relied on the tide flowing in the correct direction so as to avoid damaging the bottom swivel bearing which had to be laid down in a 40 degree segment only. Around 18 hours as a minimum was required for a controlled laydown so the preference was to defend the SALM if possible with the ice breakers. The weak point of the SALM was the export hose which exited the SALM around 2.5 – 4m below the sea surface (depending on tide) which could be crushed and damaged by any ice passing through with a deep enough keel.

### Organization, Responsibilities and Procedures

The Ice Team consisted of 9 individuals with many years of operational ice experience. The Ice Team leader, the Ice Management Director (IMD) worked on the FSO and reported in to the Marine Manager and he presented a consolidated view from the ice team in order to present the management team with only one position to avoid confusion. Two ship masters with experience in ice management assisted the captain on the ice breaker and on one of the support boats. Their job was to review the ice situation at all times and advise the ships’ captains and the IMD where appropriate. One ice observer was placed on the ice breaker, to develop ice maps of the ice around and at some distance from the Molikpaq. Three Ice Observers worked on the Molikpaq to collect ice drift data using marine radar and as a central data collection team. One Ice Observer remained nearby shore base and heliport, to conduct helicopter ice reconnaissance’s when requested. The satellite image provider also provided analysis of ice drift further away from the site when requested and where there were identifiable ice features. All vessels and personnel were in constant communication via internet, marine radio, and telephone.

### Training

The ice team members were all experienced ice scientists before coming to site. There was an ice management manual developed which had the methodology described for all of the processes used. The ice team was assembled a couple of weeks before the operations were due to commence and therefore had time to review this manual, sort out

the IT interconnectivity and data storage and filing protocols.

### Ice Load Monitoring

Ice load monitoring equipment was fitted to the bow area of the FSO Okha and in the hull of the Molikpaq platform. However the equipment proved to be unreliable and so did not provide much data that was used for the active ice management process.

### Performance of Ice Management

The ice management system used provided increased uptime for the facility of somewhere between 10 and 20 days at the beginning and end of each summer production season. The weak link in the system was a requirement when lowering the SALM that a small boat be used in the water for the holdback of the hose as the SALM was lowered. Using a larger vessel could have parted the breakaway coupling. Without this restriction caused by design, it is possible that at the end of the season production could have continued for a significantly extended period.

### Experience, learning's and recommendations from the Vityaz Ice Management operation

The main experience that derived from the Sakhalin Vityaz ice management was the realization that no two seasons are the same and that ice movements and behavioral patterns are largely unpredictable. Local knowledge of the area is important as there are local phenomena which can be anticipated (i.e. in the Sakhalin case the 'ice river' flowing around the island as a result of the Amur river break up in the spring.) Good understanding of the risks to the production system is required to ensure that the ice team is able to know what ice is and is not acceptable to be present on site.

## 2.5. Arctic Coring Expedition (ACEX) 2004

### The ACEX drilling expedition

The first scientific drilling expedition to the central Arctic Ocean was completed in the late summer of 2004. The expedition recovered sediment cores deeper than 400 meters below the seafloor in water depths of about 1300 meters on the Lomonosov Ridge, 250 kilometres from the North Pole. The drilling was carried out by the drillship Vidar Viking (LOA 83 m, Beam 18 m, Power 18,000 bhp).

### Ice Environment

Concentrations of 9-10/10 with 2-4 meter of both first year and multiyear ice were present in the area. Most of the ice consisted of kilometre-large floes with intrusion of ridges. Drift speeds approaching half a knot were recorded.

### Detection and Surveillance

Detection and surveillance was conducted utilizing RADARSAT images, helicopter reconnaissance, visual observations and ice-based monitoring equipment (for drift speeds). The ice-based monitoring system consisted of radar reflectors placed on selected floes by helicopter. The position of these reflectors were tracked in real-time by radars onboard the vessels.

### Forecast

The ice management program used RADARSAT images to provide an overview of conditions in addition to helicopter reconnaissance for mapping local ice features. Using the ice-based monitoring equipment to follow ice movements in real-time combined with weather observations from the onboard weather observations team the ice management team was able to forecast the ice conditions.

### Physical Ice Management

The physical ice management was carried out by the Russian nuclear icebreaker, Sovetskiy Soyuz (LOA 150 m, Beam 29 m, Power 75,000 bhp) and the diesel-electric icebreaker Oden (LOA 109 m, Beam 31 m, Power: 24,500 bhp). The Sovetskiy Soyuz conducted the first attack on oncoming heavy floes, whereas Oden was the last defence in protecting the drilling operation against the oncoming ice. The nuclear icebreaker operated at a distance far enough (about 500 meter- 1 kilometre) upstream in the oncoming sea ice drift so that there would be enough time to trip the drill pipe and move the drill ship away from any unbreakable oncoming floes. The Oden protected the Vidar Viking by breaking the already managed floes into even smaller pieces, of typically about 10 meters to allow the Vidar Viking to stay positioned for the drilling operation.

Vidar Viking was kept on station by manual control. This typically resulted in the vessel moved towards the broken ice upstream of the drill site location of about 20 meters, and then slowly drifting with the ice downstream to about 20 meters downstream of the drill site. Due to this technique prediction of ice drift direction was the highest priority for the ice management team.

### Procedures for Threat Evaluation

The ice management defence strategies were continuously updated with information from a full-time ice and weather forecast team onboard the Oden and Sovetskiy Soyuz. The three ships coordinated their efforts through a central Fleet Manager, at times on a minute to minute basis.

### Ice Load Monitoring

The vessel was kept on station by the manually driven thrusters with the bow continuously maneuvering to head into the direction of the oncoming ice. Load could be roughly monitored by assessing the thrust required to manoeuvre the vessel.

### Performance of Ice Management

Planners predicted that the fleet could maintain the drillship's station for up to 2 full days. It turned out that the station-keeping ability was stretched to more than 9 consecutive days.

### Experience, learnings and recommendations from the ACEX Ice Management operation

Learnings from the ACEX project regarding IM include:

- Dynamic Positioning (DP) is not possible in heavy ice
- Long periods of manual station keeping is not beneficial for the operation
- Operational experience regarding required movement of vessel facing ice-drift is essential
- It is important to have total integration of both drilling and ice management system
- Difficult conditions arose when wind speed/ice drift speed stopped and the ice would start to rotate due to the Coriolis effect.
- Prop-wash from icebreaker effects positioning

## 2.6. Shtokman Gas Condensate Field, Phase 1

### SGCF Phase 1

Note 1: at the moment of writing the present section, the SGCF Phase 1 Project is at pre-FID stage (pre-sanction). FID stands for Final Investment Decision.

Note 2: the present section has been writing by SDAG and remains the courtesy of SDAG

The SHTOKMAN Gas Field is located 610 km from Murmansk in the Barents Sea. The area is a harsh Arctic environment. The water depth at location is around 340 m and the reservoir is 2000 m below the mudline. The field reserves are estimated to be 3700GSm<sup>3</sup>. The field will be developed in three phases, the expected production of each phase being around 70 million Sm<sup>3</sup> per day. Shtokman Development AG (SDAG) owned by GAZPROM, TOTAL and STATOIL will develop and operate the First Phase of the Shtokman gas and condensate field.

The offshore facilities of Phase 1 consist mainly of the following:

- Subsea Production System (SPS).
- Umbilicals, Flowlines and Risers (UFR).
- Ice resistant and disconnectable Floating Production Unit (FPU).
- Trunklines to shore.

Drilling is planned to commence approximately two years before the FPU arrival on site. Logistics will provide support in terms of ice-class vessels and aerial means. From the ice management point of view, there stages are distinguished:

- Installation (approximately from early May to late September over 3 years)
- Drilling (year around for approximately 3 years)
- FPU Operation (year around for 50 years).

Ice and Iceberg Management (IIM) Philosophy for the Installation Stage is as follows:

- No installations activities will be performed when sea ice is forecasted to enter the area of offshore operations
- Detection of glacial ice and appropriate operational measures (threat assessment, alerting, suspension of operations, disconnection and move off) will be performed. Since the probability of iceberg occurrence in the area of offshore operations during the installation stage is very low, physical iceberg management is not planned.

The objectives of IIM during this stage are to:

- Ensure safety of the offshore operations from sea ice and iceberg threats
- Optimize mobilization timing of marine spread.

Specific tasks of IIM during this stage are to:

- Forecast potential delay in the beginning of the installation season due to the presence of sea ice
- Monitor and warn about sea ice edge location with respect to the area of offshore operations
- Detected icebergs in the area of offshore operations.

Ice Management Philosophy for Drilling Stage is as follows:

- Suspend drilling operations when significant sea ice is forecasted and move off the location. For ice-reinforced semi-submersible rig with the riser protection included, the ice coverage exceeding 2/10<sup>th</sup> with ice strips / ice floes exceeding 250 m is deemed “significant sea ice”. Ice strips or isolated ice floes less than 250 m will be broken up using available ice-class vessels in pieces small enough that they pose no threat.
- In order to minimize iceberg related downtime, it is deemed necessary to perform physical iceberg management, in particular since the resources (anchor handlers) will be available on site anyway.

The objectives of IIM during this stage are to:

- Ensure drilling rig safety from ice and iceberg threats
- Minimize ice and iceberg related downtime
- Minimize/avoid Emergency Disconnections.

Specific tasks of IIM during this stage are to:

- Carry out sea ice surveillance (detection, tracking & forecasting), using drilling rig(s) as part of the detection network
- Carry out physical iceberg management
- Break isolated ice patches / floes (intentionally not called as physical sea ice management)
- Alert drilling rig of ice & iceberg hazards arrival in sufficient time to safely suspend wells, disconnect and move off.

Ice Management Philosophy for the FPU Operation Stage is as follows:

- The FPU will be designed as an ice resistant (Arc 5 with additional strengthening for ice reversal situations and iceberg impacts) and disconnectable production unit able to withstand independently almost all ice and iceberg actions expected to occur at Shtokman. These conditions are called design limits and acceptable response criteria under these conditions and

interaction scenarios will be satisfied.

- An additional safety margin will be applied to these design limits to define the FPU operational limits (OPL). Any ice feature or ice situation forecasted to exceed these operational limits is considered an ice threat to the FPU.
- Ice management will be used to detect and mitigate sea ice and iceberg threats to minimize/avoid production downtime. If an ice threat cannot be managed in time, appropriate disconnection procedures will be initiated.
- Two types of disconnection procedures have been identified based on available time: planned disconnection (PDC) and emergency disconnection (EDC). The duration of PDC is in the range of 5 to 6 hours. When the ice threat is discovered late, emergency disconnection (EDC) will be initiated. This procedure will not take more than 3 minutes (excluding time required for decision making).
- If, during PDC or EDC, the ice threat is averted, the procedure can be reversed in order to resume production. On the other hand, if during PDC the ice threat gets too close (in terms of distance or time), there can be transition from PDC to EDC.
- Initiation of the FPU disconnection is based on forecast of the adverse ice effects, while triggering of the final disconnection step (MRB release) will be based on the real-time situation monitoring.

The primary objectives of IIM during this stage are to:

- Ensure FPU safety from sea ice and iceberg hazards by detecting and tracking ice threats
- Minimize FPU downtime due to sea ice and icebergs by forecasting and performing physical management.

The secondary objectives of IIM during this stage are to:

- Ensure safety and efficiency of marine operations, in ice and icebergs infested waters (for instance route planning, iceberg avoidance, assistance for load transfers)
- Assist FPU during transit and reconnection in ice
- Assist emergency EER from the FPU in ice conditions.

Specific tasks of IIM during this stage are to:

- Carry out sea ice surveillance (detection, tracking & forecasting)
- Conduct physical sea ice and iceberg management
- Assess ice threats and Alert the FPU operations and supply vessels.

**Ice Environment**

Sea ice does not form at Shtokman (apart from very thin ice in very cold years) but is exported from the North – Northeast by persistent winds. On rare occasions, ice may enter Shtokman area from the Southeast. Sea ice at Shtokman has been observed in approximately 35% of the years based on data from 1967 to 2011, see Figure 2-1. During the years with no ice at Shtokman, there were several occasions when an ice edge was in proximity to the Shtokman field (one to ten days of ice drift away). In total (accounting for years without ice), sea ice is present at Shtokman about 6.5% of the time.

Monthly statistics of sea ice presence at Shtokman (only years with ice are considered) is provided in Table 2-1. It shall be noted that:

- There is large inter-annual variability: ice may not enter Shtokman for many years, followed by severe invasion
- Ice may come and leave the Shtokman a few times during one ice season (see Figure 2-2)
- The years of ice occurrence can be grouped.

Month	Jan	Feb	Mar	Apr	May	Jun	July
Probability of ice presence (%)	2	11	20	33	20	12	2

Table 2. Monthly statistics of sea ice presence at Shtokman field during the period 1934 – 2000

First-year ice is the most common form of sea ice expected to occur at Shtokman. Average level ice thickness is about 0.8 m while maximum reaches 2 m. Ice ridges up to 20 m deep may occur in the ice cover, and ice ridging intensity can be high. Second-year ice can also enter the Shtokman area on rare occasions. Second-year ice is mainly represented by fragments 20-100 m in diameter frozen into first-year ice. Frequency of occurrence of second-year ice at Shtokman has been estimated as once in approximately 20 years. Fragments of refloated stamukhi (rubble bergs) can also occur at Shtokman. Average ice drift speed is around 0.2 m/s while maximum can reach 1 m/s and more. Ice pressure in the ice cover is expected to be low to moderate during the ice drift reversal events.

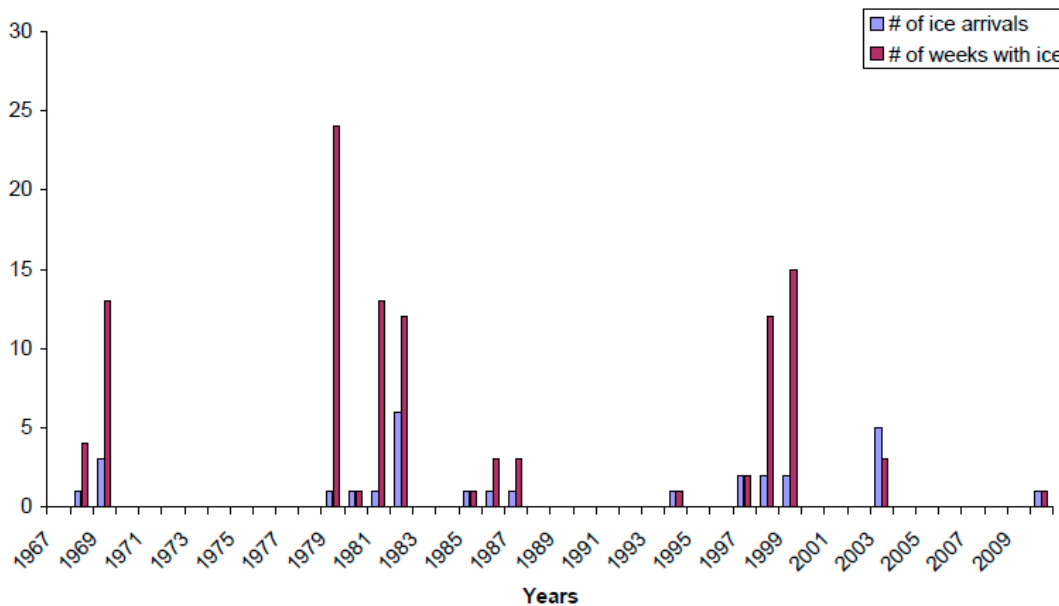


Figure 2-1 Historical data of sea ice presence at Shtokman



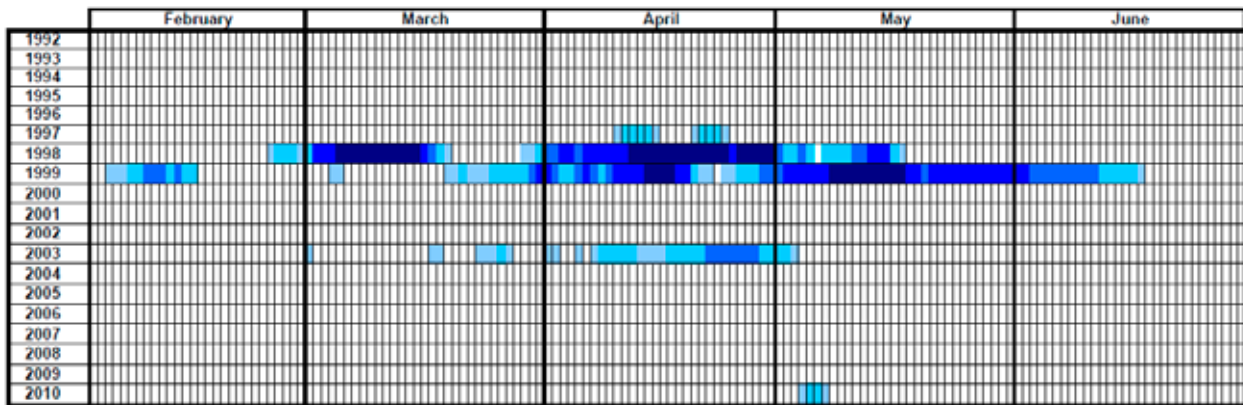


Figure 2-2 Example of sea ice arrival at Shtokman (darker colour indicates higher ice concentration)

Icebergs are rare on the Shtokman field, but nevertheless can occur, also south of Shtokman. Icebergs may drift in open water or within sea ice (where they are more difficult to detect and manage). Icebergs have a strong seasonal presence, with February to July being typically the months with the most icebergs present as shown in Figure 2-3. The probability of encountering icebergs at Shtokman in the period between late autumn and early spring is lower than for the rest of the year, but it still exists.

Table 2-2 shows the International Ice Patrol classification of icebergs sizes and their probability of occurrence in the Barents Sea. It indicates the important fact that 76% of all icebergs are bergy bits and smaller. The probability of iceberg impact on FPU, if not managed, has been estimated as once in 250 years. The probability of iceberg contact with the FPU Mooring System, if not managed, has been estimated as once in 900 years. Iceberg drift speed, including meanders, is given in Figure 2-4.

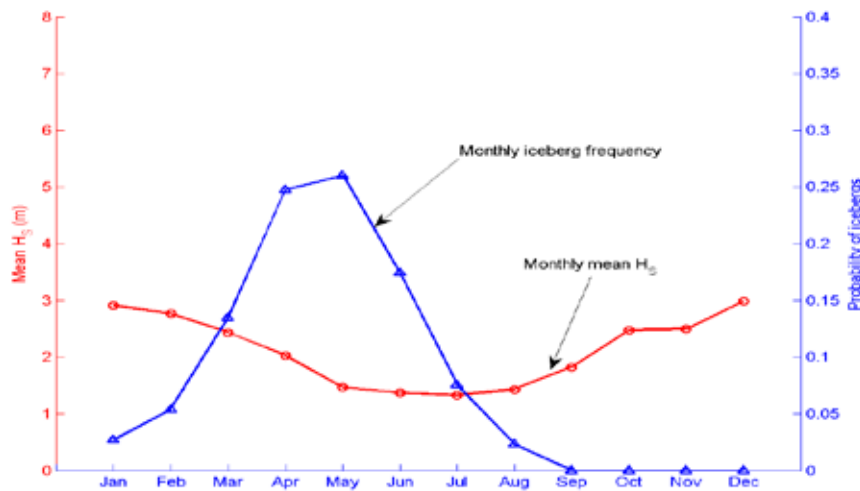
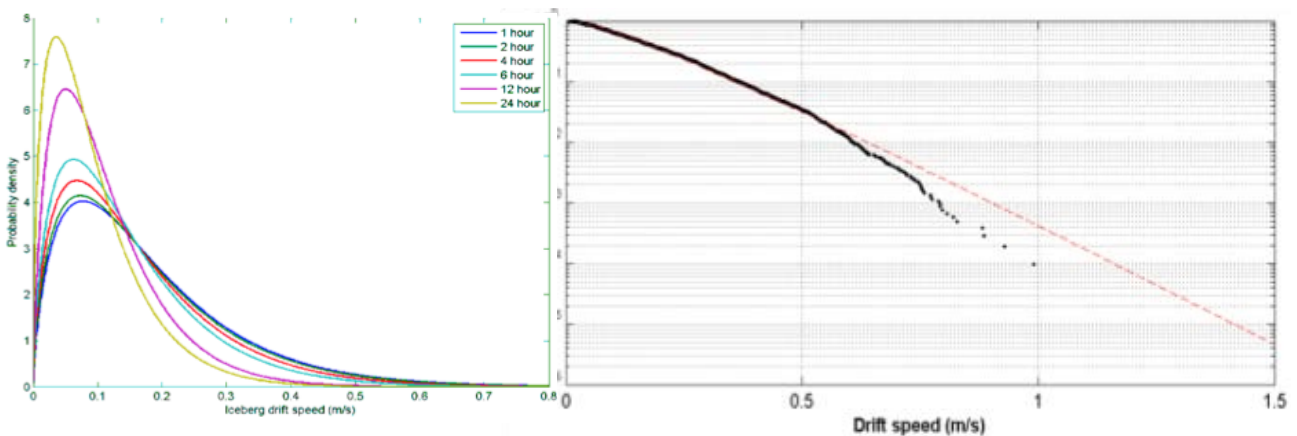


Figure 2-3 Monthly mean significant wave height and the probability of occurrence of icebergs at Shtokman

Iceberg category	Height (m)	Length (m)	Approx. draft (m)	Approx. Mass (tonnes)	Area	% Occurrence
Growler	<1	<5	<10	1000	<20 m <sup>2</sup>	6%
Bergy bit	1 - 5	5 -15	<25	10.000	<300 m <sup>2</sup>	70%
Small iceberg	5-15	15-60	>25	100.000	>300 m <sup>2</sup>	24%
Medium berg	16-45	61-120		2.000.000		
Large berg	46-75	>120		10.000.000*		

\*max iceberg mass at Shtokman is estimated at 3.670.000 tons

Table 2-2 Classification of icebergs and % occurrence in the Barents Sea



a) Meander iceberg drift speed (depending on time between speed recordings)

b) Probability of exceedence of hourly iceberg drift speed

Figure 2-4 Iceberg drift speed

### Surveillance (Detection, Tracking, Forecasting)

Detection of sea ice and icebergs will use a combination of means comprising: SAR satellite images, aerial (helicopter and unmanned aircraft) and ship observations (radars and visual).

Interpretation of daily satellites images will provide the global picture of the ice distribution around Shtokman, the ice edge location and a general characterization of the ice conditions (ice concentration, ice forms, ice surface features and ice development). Satellite images will also be used to detect and track potential icebergs around the Shtokman field on a regular basis. Synthetic Aperture Radar (SAR) sensor will be the main sensor to detect potential icebergs in open water and in sea ice. Advantage of synthetic aperture radar is its low sensitivity to weather conditions.

Helicopter reconnaissance flights will be used as required to ensure short range detection of the hazardous ice features and their tracking. Aerial survey onboard helicopter will be performed using Synthetic Aperture Radar (SAR), infrared scanner, airborne laser scanner, visual camera and visual observations. Besides, unmanned aircrafts (drones)

will be used for confirmation of detected icebergs, deploying of drift beacons on the icebergs and short range sea ice cover characterization.

Scouting icebreaker and vessels dedicated to iceberg management will be equipped with ice radar for short range ice & iceberg detection and tracking. They also will be used for deploying of drift beacons on the icebergs and measurement of icebergs draft and shape using iceberg contour equipment.

Local visual and radar ice observations will be performed from the ice breakers and logistic vessels on site and from the FPU.

Underwater observations will be performed around the FPU to measure real-time ice drift, currents and ice thickness.

Ice management Integration system (IMIS) will act as an information gathering and processing centre, further dispatching it to the end users in the best appropriate format.

IMIS will integrate different data from different sources (satellite images, aerial survey, visual observation, radars from FPU and other logistic vessels, meteocean forecast from third party, meteocean forecast from FPU, iceberg contouring,

ice profiler and current, drifting beacon, FPU ice and iceberg surveillance system...) in order to provide clear overview of the overall ice and iceberg situation offshore, and provide predictive information with the available inputs data.

The primary IMIS stations will be located in the onshore base. The secondary IMIS stations will be installed on the FPU. The tertiary IMIS stations will be installed on the drilling rig(s), logistic fleet, installation vessels and aerial surveillance means.

A twice-a-day weather forecast will be provided by a proven weather forecast agency, calibrated using weather information on the FPU on a continuous basis, also enhanced and calibrated using weather at reference locations around the periphery of the Barents Sea. Web based weather sites will be reviewed daily to see how these forecasts compare to the “official forecast”. Ice & iceberg forecasting will be performed by several different means which can be grouped into seasonal forecast and operational forecast.

Seasonal forecast of ice coverage and arrival of ice and icebergs at Shtokman, analysis and seasonal outlook of ice edge location and severity of ice condition will be based on satellite information and forecasting software.

Operational forecast of sea ice and iceberg drift will be based on wind, waves and current measurements, predicted currents, weather forecasts, and drift measurements. For operational forecasting, ice and current profilers will be installed on the site to measure ice thickness, ice drift and currents.

The forecast model will be calibrated and validated on the basis of in-situ ice drift, wind and currents measurements.

For iceberg forecast, the two following modes will be available: reverse forecasting and deflection forecasting. Reverse forecasting objectives is to define from where icebergs that could impact the platform would come. In such modes, intention is to define area that needs to be more carefully investigated. Deflection forecasting will permit to optimise iceberg deflection. The aim is to compare different forecast tracks with different deflection directions, forces and duration. As a result, user will be able to recommend a direction for iceberg deflection.

### Physical Ice Management

Physical management means to prevent iceberg entering the planned / emergency disconnection zones by deflecting the icebergs off their drift course or to reduce sea-ice loads by performing dedicated and co-ordinate ice breaking operations.

Physical sea ice management involves breaking up ice floes to target size, assisting the FPU during possible reconnection in ice and aid to EER in ice conditions. Up to 3 icebreakers will be required

for physical sea ice management in support of the FPU operations. A typical physical ice management scheme in severe ice conditions is as follows:

- In severe ice conditions pre-management activity will be performed by the most powerful (in terms of icebreaking capacity) and least manoeuvrable icebreaker (Scouting Icebreaker) and it will involve breaking large ridged floes.
- The ice breaker ranked second in terms of power, (Primary Icebreaker) will operate downstream of the Scouting Icebreaker in the Physical Ice Management Zone and it will break the incoming ice into smaller size floes by sailing in circles or loops.
- The least powerful of the three, but the most manoeuvrable icebreaker (Sentinel Icebreaker) will operate downstream of the Primary Icebreaker and upstream of the Emergency Disconnection Limit and it will further break the ice into smaller floes or clear the ice using the azimuth thrusters.

Physical iceberg management involves deflection of icebergs off their drift course by field proven techniques such as: towing with lines or nets, water jets, propeller wash etc. Such techniques, which will be used on Shtokman, have been extensively used in open sea, especially off Newfoundland in Canada. Icebergs surrounded by sea ice will require sea ice management to create an environment that would allow iceberg towing.

### Procedures for Threat Evaluation and Alerting

Threat Assessment and Alerting involves the assessment of potential consequences from the incoming ice and icebergs (with and without physical management) and communication the alert level to the operational management.

Potential ice threats (single features and particular ice situations) that can lead to exceedence of operating limits will be pre-defined. The method used for threat evaluation will consider information from detection, tracking, forecasting and real time offset measurements and will identify potential consequences to installations. Effect of physical management will be included. Threat evaluation will identify the threshold where installation specific response must be triggered.

The potential decision to suspend drilling activity, stop production or disconnect the platform, due to sea ice and iceberg hazards has a significant impact. Therefore, a detailed alert system will be established for all relevant operations. This system will assist the offshore installation managers in taking the right

decision at the right time based on the pre-established procedures. The system is called the Disconnect Decision Support Tool and will be integrated into the IMIS.

As in other sea ice and iceberg infested areas, operations on Shtokman will use the concept of ice alert colours. This provides a way to determine and communicate the degree of alarm corresponding to the ice situation.

The Ice Alert Colour will be determined by considering the specific type of ice hazards as well as the associated Hazard Arrival Time and Likelihood. The ice alert colour (IAC) valid at any time will be displayed in all facilities and vessels in the field, as well as in the onshore centre.

#### Procedures for disconnection

Different procedures for disconnection will be used for different types of facilities / operations. Disconnection procedures as such are outside the scope of ice management.

#### Organization, Responsibilities and Training

Tentative organization, roles and responsibilities of the ice management team has been defined as part of the functional organization at the different stages (design, installation, drilling, FPU operations).

Initial training of the IM team, including all personnel required for rotations will be a major task. The qualifications, training and experience of the key individuals will determine the accuracy of ice information, ice risk evaluation and dependability of the ice management system. This has a direct influence on the safety of FPU operations in the presence of ice and on down time.

A specific contract with an experienced ice management contractor will be used to prepare all materials required, plan and carry out all training activities, and test trainee's skill levels. In the first few years of ice management activities, experienced persons may be used to assist recent trainees.

Ice management efficiency increases significantly with experience. A training simulator will be made available to provide basic training year around and to maintain skill levels over the long term. Ice advisors and captains undergoing this training will be tested to ensure they have achieved acceptable skill levels.

In-ice field training in the Barents Sea on a regular basis will be mandatory. Real life ice management will be carried out, beginning two years before any potential FPU operations in ice. This will be done in areas North of Shtokman where ice occurs every year. During this phase, detailed ice management manuals will be tested and improved to make sure that they can handle all situations.

Drills related to Ice and Iceberg threats will be conducted within all stages of the project.

Specific operational procedures have not yet been developed.

#### Ice Load Monitoring

On example of the FPU, the following will be monitored:

- Measurements of the global ice action effect: offset (fully redundant) and tension in mooring lines
- Local ice loads in selected locations.

#### Performance of Ice Management (as part of overall operability assessment)

Operational downtime due to ice actions in excess of the FPU operational limits has been assessed. The design and operational components have been treated jointly as a system. Both sea ice and icebergs in ice and open sea have been considered.

All possible (realistic) ice conditions and interactions have been analysed (based on present knowledge of ice in the Barents Sea). The following are the potential adverse ice effects on the FPU leading to its disconnection:

- Load levels in the mooring system above operational limit.
- Mooring line exposure to iceberg keels.

Operability in ice has been analysed based on the FPU design and the planned operational procedures. Operational procedures include ice management and disconnection. The effectiveness of operational procedures was based on experience and available information following workshops with designers (FPU, Subsea & Risers, Safety, Logistics and Operations) and studies with external qualified expert companies. The approach aims to reflect the uncertainty inherent in the input data and modelling techniques. Assessment of the operational downtime accounts for the trunkline and the onshore facilities.

Component	Objective	Scope
<b>Ice Surveillance and Modelling</b>	<ul style="list-style-type: none"> <li>To assess and quantify ice hazard detection rates</li> <li>To quantify forecasting uncertainties</li> <li>To model ice drift</li> </ul>	<ul style="list-style-type: none"> <li>Quantification of the ability to detect ice features having potential for adverse ice effects on the FPU</li> <li>State-of-Art review of detection technologies</li> <li>Review of metocean and ice drift forecasting accuracy</li> <li>Developing and validating free ice drift model</li> <li>Generating metocean and ice (also ice drift) time series for 10.000 years</li> </ul>
<b>Physical Sea Ice and Iceberg Management</b>	<ul style="list-style-type: none"> <li>To select ice management (IM) fleet(s) that would ensure mooring loads to stay below the OPL (Operation Limit) for a target range of ice conditions and interaction scenarios, for average expected IM efficiency</li> <li>To quantify actual IM efficiency, which can be both above and below the expected average</li> <li>To quantify iceberg deflection ability</li> </ul>	<ul style="list-style-type: none"> <li>Quantification of the ability to reduce incoming ice floe size. The following relevant factors are implicitly considered while assessing the ice management efficiency:                             <ul style="list-style-type: none"> <li>The potentially adverse effects of secondary factors such as poor visibility, precipitation and darkness and human performance on the reliability of ice detection and ice management systems</li> </ul> </li> <li>Ability to tow icebergs in open water and in broken ice</li> <li>Machine failures (partial or total)</li> <li>Developing relationship between the Ice coming into the Physical Management Zone and Ice approaching the FPU</li> </ul>
<b>Mooring Loads</b>	<ul style="list-style-type: none"> <li>To assess mooring loads for a representative range of ice conditions (range of thicknesses, floe size &amp; partial concentration) and interaction scenarios (from head-on to 180 degrees vaning), including abnormal or worst conceivable situations</li> </ul>	<ul style="list-style-type: none"> <li>Developing, validating and exercising time domain numerical model for intact ice conditions</li> <li>Validating and exercising time domain numerical model(s) of the FPU in broken ice</li> <li>Developing and exercising analytical and semi-empirical models to assess limit force ice load on the FPU in various broken ice conditions and pressured events</li> <li>Analysing ice basin model test of the FPU in broken ice</li> <li>Reviewing "Kulluk" reports and extracting relevant information</li> <li>Developing relationship between Ice approaching the FPU and mooring loads</li> </ul>

Table 2-3 Objective and scope of the operability analysis components

Operability analysis has been performed for the following two cases:

- Base case operating philosophy that accounts for presence of physical ice management (different fleet combinations have been studied) and competent forecasting / alerting systems => with Ice Management.

- Case where physical ice management is not included (optionally included forecasting / alerting) => without Ice Management.

Experience, learnings and recommendations from the SGCF Phase 1 Ice Management design and planning IM Dossier has been developed and is organized as follows:

Document name	Purpose of document	Applies to
<b>IIM Strategy</b>	Defines strategy, plan of actions, organization and interfaces	All stages / packages / activities
<b>IIM Philosophy for Installation</b>	Outlines main principles, objectives and scope of IIM activities	All installation activities offshore
<b>IIM Philosophy for Drilling</b>		Drilling
<b>IIM Philosophy for FPU operation</b>		FPU operation
<b>Ice and Iceberg Surveillance Specification</b>	Describes requirements for engineering, equipment, mobilization & availability, competence, personnel and training	Installation, Drilling & FPU Operation
<b>Physical Iceberg Management Specification</b>		Drilling & FPU Operation
<b>Physical Sea Ice Management Specification</b>		FPU Operation
<b>Ice Threat Assessment and Alerting Specification</b>		Installation, Drilling & FPU Operation
<b>Ice Management Plan for pre-Operation phase</b>	Describes ice management procedures	Installation & Drilling activities before FPU connection on site
<b>Ice Management Plan for Operation Phase</b>		All activities after FPU connection on site

Table 2-3 Objective and scope of the operability analysis components



By present, the following key learnings have been made:

- Design of Ice Management system along with design the FPU and associated logistics means allows optimization to be made.
- Ice Management can also be tailored to existing structures and specific needs.
- Ice Management involves multiple interfaces and is a truly multi-disciplinary subject.
- There is no single source of competence that could cover all aspects of Ice Management.

Ice Management can include complex elements, but the outcome is required to be simple and clear.

### 3. HAZARD IDENTIFICATION (HAZID) WORKSHOP

#### 3.1. Methodology and approach

HAZID (Hazard Identification ) is a method to systematically collect experience for a system or operation. Barents 2020, Working Group RN06 for ice management conducted a HAZID workshop with the objective to identify all possible hazards related to ice management operations. The workshop included persons with experience from general ice breaking experience and ice management experience from different areas. The main focus areas included in the Hazard Identification workshop was:

- Detection
- Tracking
- Threat evaluation
- Physical Ice Management

After identifying the main hazards, a qualitative ranking of the identified hazards was carried out.

The work, conclusions and recommendations resulting from the workshop is a result of consensus of the team participants, who are listed Table 3.1. The work is based upon the cumulative experience and expertise of the workshop participants.

The discussions were based on general impressions and generic challenges related to ice management operations.

Name	Organization
Vladimir Legostaev	Giprospetsgaz, JSC (Gazprom JSC)
Alexzander Zimin	Krylov Shipbuilding Research Institute
Oleg A. Gasnikov	State Research Navigation Hydrographic Inst.
Jarkko Toivola	Finnish Transport Agency (formerly with Nesteoil)
Karl Hamberg	Aker Arctic
Kenneth J. Eik	Statoil
Pavel Liferov	Shtokman Development AG
Ian Reed	Shell
Morten Mejlænder-Larsen (Norw. Coordinator)	DNV
Børre Johan Paaske	DNV
Gøran Liljestrøm	STENA

Table 3-1. Participants at the HAZID workshop.

### 3.2. Results

The results of the main risks from the ranking on the Barents 2020 working group are shown in Table 3-2. The results of the ranking will of course depend on the basic assumptions with regard to equipment available, the crews experience and training, the actual operation etc.

Table 3-2. Ranking of main IM risks as judged by the HAZID workshop:

Item Number	IM Phase	Generic HAZARD	Cause/ Event	Consequences	Safeguards / Mitigating barriers	Total Rank	Recommendations/ Comments/ Actions
25,0	Threat Evalaution	Timing/Late decision	human error, conflicting goals. Different contractors may lead to conflicts	wrong decision	Procedures, responsibilities, decision criterias.	23	
23,0	Threat Evalaution	No/wrong decision	human error, conflicting goals. Different contractors may lead to conflicts	ice management breaks down	Procedures, responsibilities, decision criterias.	22	
44,0	Physical IM	Monotonous operation	Crew fatigue	Reduced effect of IM and risk of collision	Vessel tracking, increased manning, off track/distance alarms, use of auto pilot	20	
9,0	Detection	Scouting Vessel not performing task	inexperienced crew on scouting vessel	Mis-identifying dangerous ice	Experienced crew, training schemes. Quality of ice identified by scouting vessel only. Ice bergs may be detected by helicopter, radar etc. Use UAV, sonars permanently installed at bottom in future and Sattellites	20	UAVs will developed in the future and expected to contribute to collecting ice/ metocean information
2,3	Detection	Scarce/ Insufficient data (for decisions)	Difficult to detect and evaluate incoming ice	Wrong decision, maybe decide shutdown, additional cost	Use several different sources	19	Have reliable backup system
19,0	Threat Evalaution	Threat not understood	Physical and geometrical (keel of ice ridge) properties of ice feature not investigated.	dangerous ice approaching zone 2 where IB may not be able to handle it	Ice monitoring, measuring sail height. Immediate reporting and communication and use same terminology	19	Development of additional monitoring equipment
13,0	Tracking	Scarce/ insufficient data	Scouting not efficient, area not covered	Incorrect decisions taken based on insufficient information	Better planning of scouting operation. Depending on actual ice and met. condition. better satteillite imagery	18	

Item Number	IM Phase	Generic HAZARD	Cause/ Event	Consequences	Safeguards / Mitigating barriers	Total Rank	Recommendations/ Comments/ Actions
12,5	Tracking	Method fails	Communication failure	wrong/lacking trajectory, position of threat is not fully understood	Common terms and criterias. Standardized maps	17	
43,0	Physical IM	Loads wrongly monitored	Error on monitoring system	Overload on risers. Wrong feedback to IM operation	Data from multiple sources/ systems.	17	
2,1	Detection	Lack or limited ice information	Difficult to detect and evaluate incoming ice	Late or wrong detection of ice	Use several different sources	17	Scouting vessel, helicopter reconnaissance, ice radar, visual observation. Terrasat useful, Radarsat useful, but expensive. Underwater sonars. Met forecast. Drift bouys, AIS/ tracking. How to evaluate the ice feature?
1,0	Detection	No satellite data, optical	Weather condition, clouds/fog	Late detection of approaching ice features. Late mobilization. Incorrect geo referencing system.	Ice radar Scouting vessels. Possible to optimize image Correct resolution	17	Depending/ limited on weather condition
2,6	Detection	Meteorological conditions impairs prediction	Occurrence of bad weather	decisions taken on misinterpreted data	Use different sources	17	bad weather, lack of info
35,2	Physical IM	Operation inefficient	Exceeding ice loads on managed vessel	exceeding predefined managed ice dimensions	Wrong procedures, lack of training.	16	
30,0	Physical IM	Suboptimal execution	mis-communication of ice data. lack of operability.	Exceeding ice loads, Partly managed ice hits structure	Training and assessed competence. Manoeuverability of IB	16	Man can only reduce performance of a system
42,0	Physical IM	Off-set wrongly monitored	Error on monitoring system	Overload on risers	Data from multiple sources/ systems.	16	
28,0	Physical IM	failure in physical growler/bergy bit management	Lack of ship handling skills and weather	Dangerous ice coming through	visual observation from managing vessel (observe bearing). Disconnect. Training. Water canon, propeller washing	15	on/off operation

### 3.3. Findings

Based on the ranked HAZID log, there were several issues that ranged high in both the working groups.

Threat Evaluation was identified as a hazard that involved both high impact and relatively high probability. The system for Threat Evaluation is highly complex, involving large amounts of communication, several data sources and monitoring a constantly changing environment. In addition to this there might be conflict of interest between the different parties involved/contractors, e.g. the vessel operators do not want to cause excessive wear on machinery or damage their vessels while the installation manager only has focus on keeping up the production.

Due to the short time intervals important decisions have to be taken on a continuous basis and decision quality assurance systems might be too time-consuming/not work sufficiently to comply with the demand for safe operation.

The challenges related to the monotonous operation in the category Physical Ice Management was also identified as a possible hazard. Ice Management operation can for long periods of time involve standby activities. During other periods when large amounts of ice is drifting at large speeds, especially if there are ridges present, ice management can be particularly strenuous, exposing the crew to the risk of fatigue as sleep becomes difficult when constantly icebreaking. The impact of this hazard could reduce the effect of ice management and increase the risk of collisions.

The whole ice management system is dependent on a reliable Surveillance System (Detection, Tracking, Forecasting). The Detection System involves different sources of data, e.g. satellite images and ice radars. The reliability and update frequency of such systems vary, e.g. due to non-controllable events like atmospheric conditions. Unless there is some redundancy small deficiencies in the data gathering system may have effects on the efficiency of the ice management system.

Concerns were also expressed with regards to the Tracing of the ice movement. Developing algorithms describing the ice trajectories requires extensive data sets developed over time. The data fed into the models will be both the local ice conditions in addition to short-term, high resolution weather forecasts. Uncertainties in the input parameters will transpose through the model and can result in a relatively high uncertainty, represented by a wide distribution of the expected trajectories.

### 3.4. Conclusions from HAZID workshop

The HAZID identifies many sources of uncertainty related to the different tasks required of efficient ice management operations. As the field of ice management is relatively immature, there is a great need for extensive full scale data sets describing the individual tasks. It is hard to conduct an efficiency/safety analysis without full scale data.

The HAZID also proved the need for special designated resources and competence to be allocated during the development and utilization of ice management operation. The complexity of the system, lack of redundancy (due to huge economic costs) and dependency on even minor components makes an ice management system especially vulnerable. This can only be mitigated through extensive knowledge and experience. Until this competence is developed most ice management operations will progress through a less scientific approach, making documentation and efficiency/safety assessments difficult.

Due to limited prediction methods and data available before starting up an ice management operation, the operation should start with large safety margins before experience is built up and data for the actual operation collected, following which the margins can be reduced.

## 4. DISCUSSION, SUMMARY AND RECOMMENDATIONS

This report gives examples of how IM has been conducted in the past and one example of how it may be executed in the near future. The examples show the ability of physical IM to reduce ice actions and remove ice threats. The technology development over the past 30 years has been significant and for IM this has had impact on ice detection, surveillance, monitoring and forecasting. The IM system outlined for Shtokman project illustrates the uptake of technology development, of building on other's experience and the importance of doing own developments.

The Shtokman example also touches upon an aspect of IM that has received some attention in ISO 19906:2010(E) - the design component of IM. In that project the design component has been treated jointly with the operational component in a two-way manner. This example convincingly demonstrates that clear and explicit defining the destination and functions of IM in the design documentation, including its both qualitative and quantitative characteristics, is the only right way for safe and efficient design,

This points to the role of the operator to ensure that the IM aspects are taken care of throughout the project from feasibility studies to implementation of the operational aspects of IM. The importance of this role neither comes clearly across in studies of earlier IM systems and activities nor are evident from guidelines and standards involving IM.

Organization of the IM over the lifetime of a project will be important. There should be a core team of people who know and understand all aspects of IM and that are allowed to be involved in all project phases from feasibility studies through detailed design and operation. Roles and responsibilities of the ice management team should be defined as part of the functional organization in all project stages (design, installation, drilling, FPU operations).

The HAZID results showed the need for special designated resources and competence to be allocated the development and utilization of ice management operation. This points to the need for continuous training and education of all personnel that will be or is involved in IM. The training should include use of simulators and in-field exercises and would benefit from common guidelines.

### 4.1. Summary of Findings

- ISO 19906 is currently the only document where IM is addressed, and suggestions for improvements are proposed by RN02
- Technology development over the past 30 years has been significant: ice detection, tracking and forecasting capabilities are enhanced, but further technology development is needed
- The IM system for Shtokman Phase 1 is based on experience and learnings from relevant operations, as well as own technology development, fit for purpose
- IM (when relevant) should be considered and planned at all development stages: from feasibility studies to implementation into operations
- Roles and responsibilities of IM team should be well defined in all development stages
- The recognition of the importance of IM team does not come across clearly in studies of earlier IM systems and activities, nor in ISO 19906
- Integration of the IM team into the Organization over the lifetime of a project is important
- There is a need for continuous training and education of all personnel that will be or are involved in IM.
- The HAZID identified several risks that are related to human behaviour or error
- Stationary floating structures able to weather vane can limit the total ice forces and hence minimize physical IM required



## 4.2. Recommendations

- The destination and functions of IM must be clearly stated in the design documentation in an explicit form, including IM's qualitative and quantitative characteristics required for safe design, e.g., supporting operational activity around the offshore structure or/and reducing ice impacts against the structure, etc.
- The operator's role and involvement in IM throughout the project development and implementation should be emphasized in relevant guidelines and standards. This includes the joint treatment of design and operational measures.
- Projects should establish a core team of people who know and understand all aspects of IM and whom should be involved in all project phases.
- Roles and responsibilities of the ice management team should be defined as part of the functional organization in all project stages (design, installation, drilling, FPU operations).
- IM considerations should be included from the start when developing a new field and the resultant limitations should be clearly communicated to the operation team.
- Due to limited operations in the past and consequent lack of experienced people there is identified a need for training in Ice Management
- For seasonal or new operations a period of time should be allowed for training and team consolidation before any critical operations start. The training should include use of field specific simulators and in-field exercises.
- An IM document describing the operation philosophy should be developed for the particular installation to ensure continuity in operations on staff change out
- Due to limited documented IM experience available today, future IM operations should be fully recorded and made publicly available

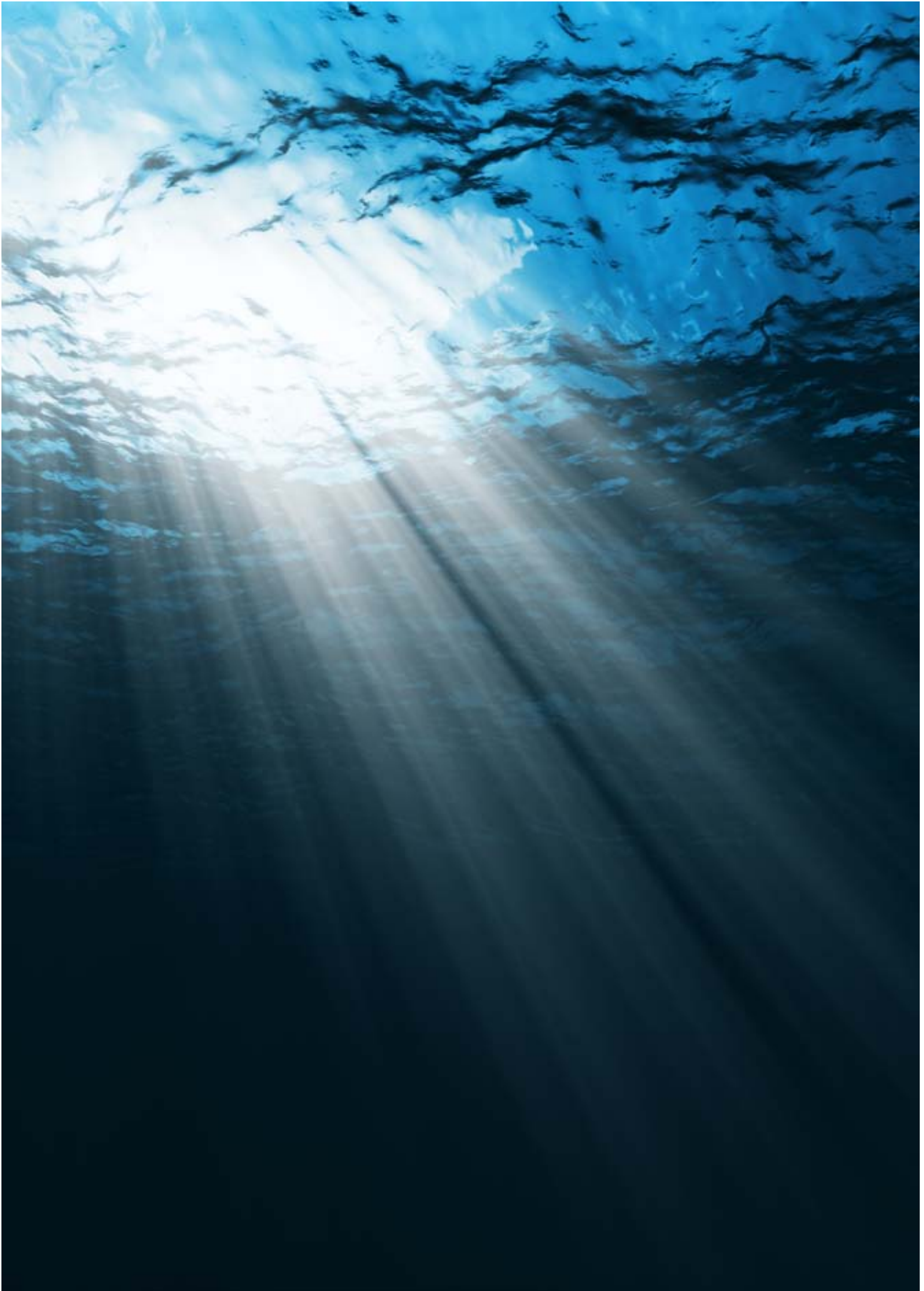




# **RN07**

Regional Guidance  
Document for Operational  
Emissions and Discharges from  
Offshore Oil and Gas Activities  
in the Barents Sea including  
Associated Shipping





# RN07: REGIONAL GUIDANCE DOCUMENT FOR OPERATIONAL EMISSIONS AND DISCHARGES FROM OFFSHORE OIL AND GAS ACTIVITIES IN THE BARENTS SEA INCLUDING ASSOCIATED SHIPPING

## FOREWORD

The purpose of the Barents 2020 project on HSE standards harmonization is to recommend HSE standards for common Norwegian - Russian application in the Barents Sea (and possibly for the entire Arctic area), for safeguarding people, environment and asset values in connection with oil and gas activities, including sea transportation of oil and gas. The underlying assumption is that petroleum operations in the Barents Sea shall at least have the same HSE performance in the North Sea.

Phase 1 of the project lasted from October 2007 to October 2008. The results of phase 1 were documented in five "Position Papers". The position papers provided the basis for further work in phase 2, lasting from November 2008 to March 2009, resulting in the special topics prioritised for further study in expert working groups in phase 3. The Barents 2020 project in phase 3 focused on potential improvements which will help prevent incidents or accidents from occurring, e.g. to reduce the probability of incidents happening, rather than to mitigate consequences of incidents. A selection of relevant standards where recommended for application in the Barents Sea and some areas for new standards development or amendments to existing standards where presented.

The objective of Barents 2020 phase 4 is to develop proposals for regional standards. One of the themes is to develop a proposal for a "Regional standard for operational emissions and discharges from offshore oil and gas activities in the Barents Sea including associated shipping".

The work in phase 4 has been undertaken in the period 2010 – 2011.

A group of experts was nominated and has developed the proposal for a new standard. The sub-group RN07 has been coordinated by Steinar Nesse (DNV) while Eduard Bukhgalter (VNIIGAZ) has coordinated the Russian effort.

The working group experts are:

- Alexander Kichigin, Gazprom
- Alexander Schvyryajev, Lomonosov Moscow State University
- Anna Savina, ANO "Industrial Risk Agency"
- Axel Kelley, Eni Norge
- Elena Ilyakova, VNIIGAZ
- Eduard Bukhgalter, VNIIGAZ
- Emmanuel Garland, TOTAL
- Erik Bjørnbom, Eni Norge
- Frederic Hannon, TOTAL
- Gina Ytteborg, OGP/Shell
- Håkon Hustad, DNV
- Knut Åsnes, Statoil
- Natalia Kutaeva, FSO "State marine rescue service of Russia"
- Nicolay Valdman, Krylov institute
- Nikolay Shaplov, Rosneft
- Salve Dahle, Akvaplan-NIVA
- Svein Flornes, Transocean
- Vadim Kharitonov, Giprospekgaz
- Yuri Alexandrovski, SDAG

This proposal for a new guidance document is to a large extent based on existing international, national and industry standards, put together in a context for application in the Barents Sea/Arctic. The main reference standards are: Russian GOST-R standards, IMF environmental standards, IMO conventions, Norwegian NORSOK S-003 and OGP guidelines on waste management.



## 1. INTRODUCTION

### 1.1. Background

The industry's need for HSE industry standards to take into account the additional challenges due to arctic conditions, i.e. low temperatures, ice, icing, long distances, darkness, etc. have become apparent in connection with proposed oil and gas development projects in the Barents Sea, and the increased maritime tanker traffic from the Barents sea along the Norwegian coast due to petroleum developments in the High North.

The international oil and gas industry applies recognised technical standards which are used worldwide. The accumulated experience of the industry over many years and from all parts of the world is included in these standards through systematic updating and issuance of new revisions. These standards therefore represent best international practice associated in order to achieve an acceptable level of safety and environmental protection for the oil and gas industry, including offshore activities.

However, the updating of standards is a time consuming process, since it requires consensus from many parties, and the improvements may come late for actual industry needs.

In new situations, such as for offshore projects in the Arctic, existing regulations and technical standards have normally not been prepared or updated to address arctic conditions.

The proposed industry guidance is general and can apply to many geographical areas and project development options. This generally applicable guidance may require the need to establish project specific requirements and design criteria by input of:

- Site-specific metocean / meteorological data;
- Site-specific environmental data (natural biological resources, habitats, ecosystems)
- Field-specific data regarding reservoir composition, pressure, temperature, etc.;
- Safety criteria for the project as basis for selection of safety factors etc.;
- Additional requirements of regulations for the specific area.

The proposed guidance is developed in order to be quickly applied by industry in specific projects. If applied in accordance with the intention of the guidance it will generally ensure an acceptable environmental performance. It is stressed however, that these proposed standards will only be additional

to national requirements, which on particular issues may be stricter than that of the current proposed (minimum) standard.

In the medium and long time perspective the proposed industry guidance document may be adapted as part of national or ISO environmental standards.

### 1.2. Objective

The objective of the current proposed guidance is to: "Specify and propose a regional standard for operational emissions and discharges from ships and offshore units in the Barents Sea, including applying MARPOL Special Area (SA) requirements."

It is not the objective or within the mandate of the working group to suggest Special Area status under IMO for particular areas. If relevant such processes will be run by national authorities in the context of IMO. Within areas recognized for its environmental characteristics and additional needs for protection, national authorities may put into effect stricter discharge provisions to protect the marine environment.

### 1.3. Working process

The Barents 2020 HSE harmonization project is a joint industry-authority initiative with financial support from these parties. It started as a joint Russian-Norwegian initiative but was later expanded to an international project with wider contribution. The process is managed by a Steering Committee with its secretariat. The actual standards development work is organized through dedicated expert groups of which RN07 is one. The mandate of this expert group is to develop a proposal for an environmental standard in accordance with the objective stated above.

The expert group has had six meetings at which the relevant topics have been discussed and draft standard text reviewed. Written material has been prepared and circulated between the meetings.

## 2. SCOPE

### 2.1. Environmental themes and offshore petroleum activities

This proposal for a regional guidance document presents environmental recommendations related to design and operations to achieve an environmental performance minimum equal to that of the North Sea offshore oil and gas operations. The environmental requirements are divided into five main themes:

- Emissions to air from offshore oil and gas installations
- Discharges to sea from offshore oil and gas installations
- Emissions and discharges from associated shipping
- Waste management
- Environmental monitoring

The environmental recommendations are solely addressing operational emissions and discharges from planned activities. Issues related to the accidental releases of undesirable substances e.g. oil and chemicals are not part of this proposed guidance document. Underwater noise is not specifically covered as the knowledge basis for giving recommendations is considered too poor.

The issue is currently subject to different national and international R&D initiatives.

This proposal for a regional industry guidance document is applicable for all phases of offshore oil and gas operations, including exploration, drilling, development, operation and decommissioning (Figure 1). Specific recommendations are given as found applicable otherwise general recommendations.

The environmental guidance is focusing on offshore oil and gas operations. Onshore operations and services (e.g. infrastructure, processing plants) are not part of the proposed standards. Onshore infrastructure (e.g. waste reception facilities) is anyway essential for the success of implementing the current guidance.

### 2.2. Barents Sea specific issues

The process in the Barents 2020 HSE Harmonization Phase 3 revealed some areas to which certain environmental standards were considered differently to that of other environmental standards (applicable to other areas or environments). Hence the current proposed guidance is based on general environmental standards with a wide area of application and in addition is specifically targeting particular Barents Sea / Arctic environmental conditions.



Figure 1. Scope of petroleum activities and supporting aspects of the present environmental industry guidance document (Source: Barents 2020 Phase 3 report)

In the context of physical and ecological (environmental) issues it is important to note that the Barents Sea is not a homogenous area. The Barents Sea varies significantly among different parts of this vast oceanic area. Ocean climate, ice conditions and the presence and distribution of natural resources (fish, seabirds etc.) varies both spatially and seasonally. Such conditions were evaluated in more detail in the phase 1 reports. (For further information it is recommended to consult the “Environmental Baseline – Maritime and offshore” and “Ice & Metocean”, cf. Bibliography) These factors may affect the selection of technical environmental standards, making different standards (or environmental solutions) applicable in different parts of the Barents Sea. In the work performed it has been focused on identifying generic environmental standards for the Barents Sea and in addition trying to point at conditions that may trigger the application of different level of standards or solutions.

As relevant conditions may vary significantly within sub-areas of the Barents Sea /the Arctic and within seasons, the standard should be used as a guidance document where local environmental conditions shall be of primary importance.

The particular Barents Sea / Arctic environmental conditions identified and considered by the expert work include:

- Low temperatures
- Ice
- Darkness during winter
- Remoteness
  - Lack of / limited infrastructure
- Vulnerable Environment
  - Ecosystem structure
  - Aggregation of individuals (e.g. seabirds, sea mammals)
- Pollution

### 2.2.1. Temperature and darkness

Temperature and light conditions are important issues with regard to oil spill preparedness/ response, but for operational (planned) discharges and emissions they are not considered of primary importance. For certain applications (in the design phase) it is however important to ensure a material selection process taking into consideration the actual (low) temperatures that may prevail.

### 2.2.2. Ice

The presence of ice and/or particular vulnerable natural resources may be of importance with regard to the environmental performance of offshore and maritime activities hence may influence on the level of standards recommended. This has e.g. been identified as important with regard to proximity to

the ice edge, burning with precipitation of particulate matter (black carbon) on ice.

### 2.2.3. Remoteness and lack of infrastructure

Remoteness of major parts of the Barents Sea with regard to relevant infrastructure (or lack of such) has been identified as the most important particular condition in the area with regard to technical environmental standards. In order to ensure the full implementation of sound environmental standards the associated infrastructure must be in place and functional. This may be challenging and in some circumstances not technically or economically feasible. If not feasible alternative conceptual solutions must be addressed.

### 2.2.4. Associated gas

Gas associated with oil production (associated gas) is a valuable resource which historically has been flared in many areas. Today, in developed areas this gas is most often collected and monetized, or injected and used as lift gas. Due to the lack of developed infrastructure in and the remoteness of the Barents Sea, associated gas is considered a priority environmental challenge. Development solutions, infrastructure, technology development and standards may form important means to avoid this gas being flared and CO<sub>2</sub> and other exhaust gases being emitted to the atmosphere..

### 2.2.5. Waste management

Waste management is another issue for which relevant standards exist, however the issue is particularly challenging in remote areas with limited or no infrastructure. Ensuring that the adequate onshore reception facilities exist, means of transport, logistics and recycling are crucial to achieve a proper environmental performance through the entire “waste life cycle”.

### 2.2.6. Pollution

Parts of the Barents Sea have previously been subject to nuclear testing and other activities with the consequence of elevated background level of radioactive components in water and seabed sediments. Such background conditions are relevant to some areas and not generally to larger areas of the Barents Sea. However, in the case of petroleum exploration and production activities in such areas this may trigger the need for particular environmental precautions and technical standards. This issue has not been addressed in detail by RN07.

### 3. NORMATIVE REFERENCES

The references given below include standards of both international (global, regional) and national (Russian, Norwegian) application. In the context of this industry guidance document the standards are applicable as referenced in the specific individual technical guidance independent on status of national implementation, geographic area of application etc.

*ISO 14001 Environmental Management System (2004).*

International Finance Corporation. *Environmental, Health, and Safety Guidelines: Offshore Oil and Gas Development (2007).*

International Finance Corporation. *Environmental, Health, and Safety Guidelines: Ambient Air Quality (2007).*

International Finance Corporation, Environmental, Health, and Safety Guidelines, Thermal Power Plants (2007)

GOST 53241-2008. DEEP SEA EXPLORATION. Requirements for Protection of Marine Environment under Exploration and Development of Oil-Gas Fields in Continental Shelf, Territorial Sea and Littoral Area (in force January 2010).

GOST 17.1.5.01-80 Nature protection. Hydrosphere. General requirements to sampling bottom sediments of water bodies for contamination analysis

GOST 17.1.3.08-82 Nature protection. Hydrosphere. Procedures for quality control of marine waters.

NORSOK S-003 *Environmental Care* (2005).

Norwegian Guidelines for offshore environmental monitoring (Norwegian Climate and Pollution Control Directorate), TA-2849/2011.

*Guidelines for waste management with special focus on areas with limited infrastructure*, rev 1. OGP (International Association of Oil & Gas Producers), March 2009.

IMO MARPOL 73/78; *International Convention for the Prevention of Pollution from Ships:*

Annex I. Prevention of pollution by oil

Annex II. Control of pollution by noxious liquid substances

Annex III. Prevention of pollution by harmful substances in packaged form

Annex IV. Prevention of pollution by sewage from ships

Annex V. Prevention of pollution by garbage from ships

Annex VI. Prevention of air pollution from ships

IMO Ballast water Convention; *International Convention for the Control and Management of Ships' Ballast Water and Sediments (not ratified at completion of this report).*

IMO Anti-fouling convention; *International Convention on the Control of Harmful Anti-fouling Systems on Ships (2001/2008)*

Relevant OSPAR documents related to the selection and use of chemicals:

- OSPAR Guidelines for Toxicity Testing of Substances and Preparations Used and Discharged Offshore (Reference number: 2005-12)
- OSPAR Decision 2000/2 on a Harmonised Mandatory Control System for the Use and Reduction of the Discharge of Offshore Chemicals (as amended by OSPAR Decision 2005/1)
- Protocols on Methods for the Testing of Chemicals Used in the Offshore Oil Industry (*reference number: 2005-11*)

## 4. TERMS AND DEFINITIONS

For the purposes of this document, the following terms and definitions apply:

### **requirement**

expression in the content of a document conveying criteria to be fulfilled if compliance with the document is to be claimed and from which no deviation is permitted

In the current document requirements are expressed by the term “shall”.

### **recommendation**

expression in the content of a document conveying that among several possibilities one is recommended as particularly suitable, without mentioning or excluding others, or that a certain course of action is preferred but not necessarily required, or that (in the negative form) a certain possibility or course of action is deprecated but not prohibited

In the current document recommendations are expressed by the term “should”.

### **state of the art**

developed stage of technical capability at a given time as regards products, processes and services, based on the relevant consolidated findings of science, technology and experience

### **BAT**

“Best available techniques” (BAT) means the most effective and advanced stage in the development of activities and their methods of operation which indicate the practical suitability of particular techniques for providing in principle the basis for emission limit values designed to prevent and, where that is not practicable, generally to reduce emissions and the impact on the environment as a whole.

- a) “Techniques” include both the technology used and the way in which the installation is designed, built, maintained, operated and decommissioned;
- b) “Available techniques” means those developed on a scale which allows implementation in the relevant industrial sector, under economically and technically viable conditions, taking into consideration the costs and advantages, whether or not the techniques are used or produced inside the Member State in question, as long as they are reasonably accessible to the operator;
- c) “Best” means most effective in achieving a high general level of protection of the environment as a whole.

### **emission**

An act or instance of emitting, in the context of this document used for a gas or a substance emitted into the air, e.g. by an internal combustion engine

### **discharge**

“Discharge”, in relation to harmful substances or effluents containing such substances, means any release to sea howsoever caused from a ship or offshore unit and includes any escape, disposal, spilling, leaking, pumping, or emptying

### **operational (emission/discharge)**

An emission or discharge (or waste stream) which is part of a regular offshore oil and gas activity, which is planned for and not caused by accident or non-deliberate action

### **ship**

“Ship” means a vessel of any type whatsoever operating in the marine environment, as defined and regulated under IMO MARPOL 73/78, engaged in activities related to the offshore oil and gas industry in the Barents Sea.

### **offshore installation**

offshore facility, plant and other equipment for petroleum activities, however not supply and support vessels or ships that transport petroleum in bulk.

### **environmental monitoring**

measuring concentrations of pollutants in air, water, sediments etc. and impacts to the environment in the vicinity of the offshore oil and gas activities

### **environmental control**

measuring the concentration of substances in operational emission or discharge streams on an offshore installation or ship



## 5. SYMBOLS AND ABBREVIATED TERMS

<b>AFS</b>	Anti Fouling System
<b>API</b>	American Petroleum Institute
<b>AVOS</b>	Environmental Impact Assessment (Russian)
<b>BAT</b>	Best available techniques
<b>BTEX</b>	Benzene, toluene, ethylbenzene, and xylenes
<b>CO<sub>2</sub></b>	Carbon dioxide
<b>EIA</b>	Environmental Impact Assessment
<b>EHS</b>	Environment, Health and Safety
<b>FSU</b>	Floating Storage Unit
<b>FPSO</b>	Floating Production Storage Offloading system
<b>GHG</b>	Green House Gas
<b>GOST R</b>	Russian national standard
<b>GOST</b>	Interstate standard (former states of CSSR)
<b>HSE</b>	Health Safety and Environment
<b>HOCNF</b>	Harmonized offshore chemical notification format (under OSPAR)
<b>IFC</b>	International Finance Corporation
<b>IMO</b>	International Maritime Organisation
<b>ISO</b>	International Organisation for Standardisation
<b>LC50</b>	Median lethal dose
<b>MARPOL</b>	International Convention for the Prevention of Pollution from Ships
<b>MOU</b>	Mobile Offshore Units
<b>MWth</b>	Thermal power produced (in Mega Watt)
<b>Nm<sup>3</sup></b>	Normal cubic meters
<b>NOX</b>	Nitrogen oxides
<b>NS</b>	Norwegian Standard
<b>NSR</b>	Northern Sea Route
<b>OCIMF</b>	Oil Companies International Marine Forum
<b>OGP</b>	International association of oil and gas producers
<b>OLF</b>	Norwegian Oil Industry Association
<b>OSPAR</b>	The OSPAR Convention for the protection of the marine environment of the North-East Atlantic
<b>PAH</b>	Poly cyclic aromatic hydrocarbons
<b>PCB</b>	Poly chlorinated biphenyls
<b>PM</b>	Particulate Matter
<b>ppmv</b>	parts per million (volume)
<b>PSA</b>	Petroleum Safety Authority of Norway
<b>REACH</b>	Registration, Evaluation, Authorisation and Restriction of Chemicals (EU Regulation No 1907/2006)
<b>RMRS</b>	Russian Maritime Register of Shipping
<b>RN</b>	Group of Russian Norwegian experts in this project
<b>ROV</b>	Remotely Operated Vehicle
<b>SO<sub>2</sub></b>	Sulphur dioxide
<b>TC</b>	Technical Committee for standardisation
<b>TOM</b>	Total organic matter (applies to sediment) – refers to all combustible material containing organic carbon
<b>VOC</b>	Volatile Organic Compound
<b>WHRU</b>	Waste Heat Recovery Unit

## 6. ENVIRONMENTAL DESIGN AND PERFORMANCE GUIDANCE

### 6.1. Emissions to air from offshore oil and gas installations

One of the aims of this part of the guidance document: “Emissions to air during operation of offshore structures and facilities” is that it shall be applied taking into account to the projected and actual seasonal conditions and ice conditions and its implementation shall ensure no significant change of colour and chemical composition of ice cover.

#### 6.1.1. Exploration phase

##### Seismic acquisition:

No specific requirements in addition to those relevant to maritime vessels operation in the area, e.g. fuel quality (cf. section 6.3.1).

##### Exploration drilling:

Exploration drilling will be performed by drilling installations with engines (3MWth-50MWth) using diesel as fuel. The emission requirement for NO<sub>x</sub> is equal to those presented in section 6.1.3 (3MWth – 50 MWth), where it is specified for engines. For particulate matter (PM) the requirement is set to be below 50 mg/Nm<sup>3</sup>. For SO<sub>2</sub> the requirement is set to maximum 0.5% sulphur content (weight) in the fuel. For the Barents Sea, especially close to the ice, PM and SO<sub>2</sub> are important parameters, and it cannot be justified by project specific considerations to increase these emissions up to respective 100 mg/Nm<sup>3</sup> PM and 3.0% Sulphur content in fuel, as the IFC standard [IFC, 2007-a; IFC 2007-b] opens up for.

##### Well testing

Burning of well fluids and well clean-up residues from testing and restart of wells shall, as far as possible, be avoided. If unavoidable, this shall be documented from a technical, economic and environmental point of view.

When testing or restarting wells on or with connection to a fixed installation, the well fluid should be routed to the production facilities.

For testing on a mobile rig, at least the following options should be evaluated:

- injection of the well fluid at location or at a nearby field, when test separators are designed to handle well stream from testing for this option;
- use of facilities with possibility to collect the oil produced during testing;
- downhole testing.

If it is not possible to send the well fluid or gas to another installation, or collect them by other means, they may be burned on the mobile installation. Incomplete burning shall be avoided to limit potential of environmental impact. Burners with high efficiency shall be used.

#### 6.1.2. Field development phase (including design requirements and pre-production drilling)

It is during the field development design that critical choices are made which impact the emissions to air. All technical decisions are taken during that phase, and energy optimal solutions must be found in order to achieve a project with low emissions to air. Minimum design limits that need to be met for emission to air are given below under the production phase and in the IFC tables in appendix 1.

The following design requirements should be used in order to reduce emissions.

##### Energy management

Good energy management is a key factor in achieving as low emissions as practicable. A power and heat requirement analysis shall be performed comprising the process and utility systems over the lifetime of the production facility. The objective is to minimize emissions of CO<sub>2</sub> and NO<sub>x</sub> by:

- reducing energy requirements
- increasing the efficiency of energy generation and utilization
- potential use of renewable energy

The following are examples of measures that should be considered for minimizing energy demand when relevant:

- well design to minimize water cut and minimize pressure loss;
- subsea or downhole separation;
- subsea compression or pumping;
- maximize operating pressure in the first stage separator;
- partly separate process trains for high and low pressure wells;
- use of turbo-expanders to utilize well pressure;
- correct sizing of power demanding equipment to achieve maximum efficiency;
- use of variable speed drives on larger equipment with variable loads;
- direct turbine drive on large compressors;
- optimal sizing of long export pipelines for oil and gas to reduce pressure loss;
- waste heat recovery/process integration to minimize the need for fired heaters or electrical heaters;
- energy use monitoring and control systems to allow optimum operation and tuning;

- multiphase pumping compared to gas-lift;
- use of flow improvers for oil export pipelines.

In order to increase the efficiency of energy production, the following measures should be considered:

- gas turbine cycle enhancement, e.g. steam bottoming cycle;
- integrated or shared power generation with other installations, as well as the possibility of power supply from shore;
- selection of optimum number, size and make of turbines according to power demand profile.

### Flaring

The process system shall be designed in accordance with the BAT principle to minimize flaring. This should include, but not be limited to, consideration of the following measures:

- recycling of gas from high/low pressure relief systems during normal operation;
- process design and control of systems that minimizes risk of unplanned shut down of compressors etc.;
- planning of start-up activities to reduce flaring.

### Oil storage and loading

FPSO, floating storage units, shuttle tankers, offshore and onshore loading systems shall be designed to minimize emissions of methane and VOC. The following measures should be considered, but not be limited to:

- optimized geometry of tanks and sequential loading/unloading with respect to evaporation of hydrocarbons,
- loading/discharge rate with respect to evaporation,
- use of hydrocarbon gas as blanket gas in floating storage tanks, with recovery,
- installation of a VOC recovery plant

The process system should be designed to optimize the vapour pressure and temperature of the oil, in order to minimize emissions of methane and other VOCs.

### Fugitive emissions and cold vents

Fugitive emissions and cold vents include all emissions of hydrocarbons (CH<sub>4</sub> and other VOCs) other than combustion processes. The main sources on these emissions are principally linked to:

- leakages at valves and flanges,
- emissions from the atmospheric vent system,
- emissions from miscellaneous decentralized systems.

The process system should be designed to minimize emissions to air of hydrocarbon gas from different sections of the system. The gas should be either contained or routed back to the process system, if the pressure level and safety considerations allow this.

This applies, but is not limited to:

- gas from seal oil traps,
- gas from sampling points,
- purge gas and leak gas,
- gas from start up of the fuel gas system,
- gas from compressor seals,
- gas from produced water.

Emissions of hydrocarbon gas to the air, including glycol and BTEX, from stripping processes shall be minimized, e.g. by use of:

- systems that do not require stripping gas (e.g. trace water extraction process),
- systems using low glycol concentrations,
- glycol recycle systems,
- systems that recover hydrocarbon stripping gas,
- systems based on vacuum de-aeration systems using inert gas.

Cold venting should be avoided. Exceptions should be documented from a technical, economic and environmental point of view.

Hydrocarbon gas used as a blanket gas shall be recovered.

Selection of valves, flanges and gaskets should be based on due considerations in order to reduce gas leakages and fugitive emissions to air.

Pre-production drilling, cf. section 6.1.1 on exploration drilling.

### 6.1.3. Production phase (including export/transportation)

#### Energy Management

Reference is made to section 6.1.2.

#### Flaring

Flaring of gas should be minimised and proper solutions and infrastructure for utilization and export/disposal of the gas be developed. In an Arctic perspective flaring will be a source of unwanted soot pollution and GHG emission.

Flaring of associated gas from oil fields as a disposal solution is not recommended.

Flaring for safety and non-permanent operational reasons is acceptable, however emissions shall be minimised. Field specific plans shall be developed to ensure this.

### Energy and heat generation

Best Available Techniques (BAT) should be used when selecting turbines, engines and boilers.

In the production phase in the Barents Sea, normally the fuel source will be available gas. Hence gas turbines will normally be chosen for the energy and heat production, and will be the main contributors to the emission to air. It is therefore important to choose and operate turbines with high energy efficiency in order to reduce CO<sub>2</sub> emissions and ensure low emissions of NO<sub>x</sub> and SO<sub>2</sub>.

For gas turbines above 15MWth the emissions of NO<sub>x</sub> shall be below 25 ppm. This is the guidance from the IFC guideline for ambient air quality and for thermal power plants. An emission of NO<sub>x</sub> below 25 ppm means that low NO<sub>x</sub> technology must be used, for example DLE (Dry Low Emissions) turbines. For most installations the energy needed will be above 15 MWth.

For an installation with an energy need from 3 - 15 MWth, the NO<sub>x</sub> emissions from the turbines shall be below 42 ppm (Electric generation).

It will not be very common that turbines will use fuel other than natural gas. If this should be the case, the NO<sub>x</sub> emissions shall be below 74 ppm (above 15MWth), and respectively below 96 ppm (electric generation) and 150 ppm (mechanical drive) for installations with an energy need from 3 – 15 MWth. If the fuel for the turbines is other than natural gas, the sulphur content in the fuel shall be below 0.5%.

If engines are used, it will be important to reduce especially particulate matter (PM) and emission of SO<sub>2</sub>. For Particulate matter (PM) the requirement is below 50 mg/Nm<sup>3</sup>. For SO<sub>2</sub> the requirement is set to maximum 0.5% sulphur content (weight) in the fuel. It will not be very common to use engines from 50 – 300 MWth, and above 300 MWth. If this should be the case, the sulphur content shall respectively be below 0.5% and 0.2% S in the fuel.

Energy will normally be generated by turbines equipped with a Waste Heat Recovery Unit (WHRU) for heat generation. Waste heat recovery will be a better way to generate heat, than by using boilers or heaters. If natural gas is used as fuel source for boilers, emission of particulate matter (PM) and SO<sub>2</sub> is normally not a problem. If boilers must be used, natural gas should be the preferred fuel source, not liquid fuel.

Using boilers and liquid fuel will generate particulate matter (PM) and SO<sub>2</sub>, and such a solution should be avoided. For particulate matter (PM) the requirement is below 50 mg/Nm<sup>3</sup>. For SO<sub>2</sub> the requirement is set to maximum 0.5% sulphur content (weight) in the fuel, as for boilers.

For more information regarding minimum emission levels for emission to air that shall be met, see IFC EHS tables for Ambient air quality and Thermal power plants in Appendix 1.

### NO<sub>x</sub> control on turbines

New gas turbines should be of low-NO<sub>x</sub> type to achieve an emission level of 25 ppmv (dry offgas, 15 % O<sub>2</sub>) or better. Steam or water injection to achieve a similar level may be considered.

### NO<sub>x</sub> control on engines

For larger engines (> 1 MW) that will normally be in operation (not stand-by or emergency use), NO<sub>x</sub>-reducing measures should be considered, such as:

- selection of engine made with a low NO<sub>x</sub> emission rate,
- use of gas fuel when possible,
- use of water emulsion in the diesel,
- selective catalytic reduction or similar.

### Emission control, monitoring and reporting

Relevant process parameters should be recorded and processed in order to allow on-line (or nearly online) reporting and trending of emission data for CO<sub>2</sub>, NO<sub>x</sub>, VOC and methane. The information should be available for the operators in order to allow optimisation of the operation.

CO<sub>2</sub>, NO<sub>x</sub>, methane and other VOCs' emissions shall be calculated based on the fuel gas composition, the amount of fuel utilized for power generation (gas and diesel) and the amount of gas being flared, which are measured according to authority requirements.

NO<sub>x</sub> emissions may be calculated based on different methods with increasing degree of accuracy:

- generic emission factors for turbines, engines and flares (independent of load);
- emission factors that are specific for the equipment and the average load they operate at;
- online calculation of emissions based on calibrated emission factors at different operating loads for the specific equipment.

Methane and other volatile organic compounds are usually calculated by use of emission factors for the different source categories. Significant point sources should be measured.

#### 6.1.4. Decommissioning/post decommissioning phase

Fuel quality requirement for maritime vessels (cf. section 6.3). No other specific requirements for emissions to air from decommissioning activities. (Depending on national regulations the operator shall obtain the permit for emissions from competent authorities.)

### 6.1.5. Reporting

- National/regional authority requirements regarding reporting shall be followed. Normally this implies a yearly report of all emissions to air.
- Based on consumption of flare gas, fuel gas and diesel consumption, e.g. yearly reporting of CO<sub>2</sub>, NO<sub>x</sub>, VOC, CH<sub>4</sub>, SO<sub>2</sub>, CO, N<sub>2</sub>O, PAH, PCB and dioxins.
- Field specific factors shall preferably be used to calculate the emissions, otherwise standard factors (e.g. OLF, 2009).
- Monthly internal reporting of production data, gas to flare, gas to fuel, diesel consumption, including emissions

## 6.2. Discharges to sea from offshore oil and gas installations

The provisions stated below are relevant to offshore oil and gas installations operating in the Barents Sea/ Arctic.

### 6.2.1. Exploration phase

The following recommendations address exploration drilling. Ship activities are covered in section 6.3 (maritime vessels).

#### Used water based drilling fluid attached to drill cuttings

It is not allowed to discharge whole mud.

It is allowed to discharge used water based drilling fluid attached to drill cuttings if:

- the 96hr LC50 of the drilling fluid is greater than 30,000 ppm (3% by volume) using the Suspended Particulate Phase (SPP) Toxicity Test. Testing should primarily be for drilling fluids, or alternatively testing based on standard toxicity assessment species (preferably on site specific species), cf. Appendix 2.
- Maximum chloride concentration must be less than four times ambient concentration of fresh or brackish receiving water (e.g. estuaries). This is not relevant in open Barents Sea waters.
- Requirements for barite: Hg < 1 mg/kg dry weight in stock barite, Cd < 3 mg/kg dry weight in stock barite.
- Exclusion of highly toxic components of drill fluids with LC50 (for 96 hours) less than 0.1 mg/dm<sup>3</sup>

- Complies with local legal requirements for discharges of drilling fluids and chemicals

#### Drill cuttings from drilling with water based drilling fluid are

It is allowed to discharge drill cuttings from drilling with water based drilling fluid are if:

- Oil concentration not exceed 10 g/kg (1%) of dry weight on the disposed cuttings
- The region is mapped for sensitive habitats/ fauna (e.g. cold water corals, sponges, etc.) and discharges are evaluated as having a low potential for damage (cf. section 6.5).

#### Used water based drilling fluid attached to drill cuttings when crossing the oil-bearing horizons

It is allowed to discharge used water based drilling fluid attached to drill cuttings when crossing the oil-bearing horizons if:

- the 96hr LC50 of the drilling fluid is greater than 30,000 ppm (3% by volume) using the Suspended Particulate Phase (SPP) Toxicity Test.

Oil content on cuttings shall be measured daily in the period of discharge when the content of oil in discharge is possible.

#### Used Non Aqueous Drilling Fluid (oil based, synthetic based) attached to drill cuttings

For used Non Aqueous Drilling Fluid (oil based, synthetic based) attached to drill cuttings:

- Discharge to sea is not allowed

#### Drill cuttings from drilling with non aqueous drilling fluid (oil based, synthetic based)

For drill cuttings generated from drilling with non aqueous drilling fluid (oil based, synthetic based):

- Discharge to sea is not allowed
- Cuttings may be injected back to the formation if this is evaluated as technically safe and feasible.
- Onshore or offshore treatment facilities should be developed at the shortest distance practicable, in order to avoid long transport (cf. section 6.4)



### Completion and Well work over fluid

Completion and Well work over fluid is allowed to discharge if:

- 30 day average oil-in-water concentration does not exceed 29 mg/l, daily discharge of oil and grease does not exceed 40 mg/l
- pH 5–9
- Toxic components have a 96-hour LC50 less than 0.1 mg/l
- chemicals and oil-content comply with local legal requirements

### Ballast water, storm/rain water and other liquid water

Ballast water, storm/rain water and other liquid water contaminated with oil:

- Discharge should be in compliance with Marpol 73/78 Annex I, regulation 39.

Oil content shall be measured once a day in the period of discharge. This may be done by using an auto sampler, taking out representative samples in order to make a representative daily average sample. Continuous monitoring of oil in water can also be used in order to find the daily average discharge concentration.

Rain water from clean zones can be discharged to sea.

### Snow and ice:

- Snow and ice shall be handled as rain water (storm water), cf. above.

### Industrial household and sanitary sewage:

- The provisions for treatment and discharges of sewage as set out for ships in Marpol Annex IV shall also apply to offshore installations. On ice and in proximity to ice discharge of black and grey sewage water should be avoided.
- The discharge of garbage shall be prohibited, except from food waste that can be discharged subject to the discharge provisions as set out for ships in MARPOL 73/78 Annex V. Such discharge shall be made as far as practicable from nearest ice.

### Chemicals

- All chemicals to be used and / or discharged should be subject to an environmental assessment, striving to find and apply chemicals with the best possible environmental performance.
- It should be strived to achieve information on chemical composition and test data (toxicity, biodegradation, bio-accumulation), e.g. REACH or HOCNF. Internationally recommended test protocols should be followed, cf. Appendix 2.
- A plan for substitution of chemicals harmful to the environment should be developed in order to strive for continuous improvement and development of chemicals with the best possible environmental performance.

#### 6.2.2. Field development phase (including design requirements and pre-production drilling)

Requirements for drilling fluids, cuttings, well work over fluids, ballast water, storm water, industrial household water and sanitary sewage will be as described above (section 6.2.1) for exploration drilling.

#### Produced water

Reinjection of produced water is the preferred option and shall be assessed. If not possible due to technical or economic reasons, discharge may be allowed if:

1. Produced water is treated using the Best Available Technique, and
2. Discharges comply with local legal requirements (residual oil content, use of chemicals, etc.)

For specific discharge criteria see 6.2.3

#### 6.2.3. Production phase (including export/transportation)

Requirements will be as described for the field development phase above (section 6.2.2).

#### Produced water

For a produced water solution not based on reinjection (6.2.2) discharge is allowed if:

1. Average monthly concentration of oil in produced water does not exceed 29 mg/l, with a maximum deviation of 40 mg/l
2. Discharges comply with local legal requirements for chemicals and oil-contaminated waters

3. Best Available Techniques have been documented for water cleaning

#### Produced sand and solids (Formation sand, deposit and other solid waste contaminated with oil)

Discharge to sea and ice is not allowed.

#### Cooling water

Cooling water is allowed to discharge if:

- The effluent should not result in a temperature increase of more than 3 degrees C at edge of the zone where initial mixing and dilution takes place. Where the zone is not defined, 100 meter from point of discharge shall be used.

#### 6.2.4. Discharge control and measurement in the production phase

In the production phase discharge has to be controlled and measured. Recommendations for such are described below.

#### Discharge of produced water during production operation

- Oil content shall be analysed once a day. This may be done by using an auto sampler, taking out samples in order to make a representative daily average sample, or by continuous monitoring of oil in water. Continuous monitoring of oil in water or using an auto sampler is the recommended practise. If this is not possible, representative daily average samples can be made manually, by taking out spot samples at different times of the day, and put these into one average sample.
- An extended set of indicators following the results of chemical analysis shall be measured once per three months in the period of discharge

As a minimum, the following components shall be analysed (Other components may be added if necessary or required by authorities):

Components			
Oil in water	C1- Dibenzotiofene	Phenols:	Inorganic acid:
NPD/BTEX:	C2- Dibenzotiofene	Phenol	Naphtenic acid
Benzene	C3- Dibenzotiofene	C1-alkyl phenols	Heavy metals
Toluene	16 EPA-PAH	C2-alkyl phenols	As
Ethylbenzene	Acenaphylene	C3-alkyl phenols	Pb
Xylene	Acenaphtene	C4-alkyl phenols	Cd
NPD/PAH:	Fluorene	C5-alkyl phenols	Cu
Naphthalene	Fluoranthene	C6-alkyl phenols	Cr
C1-naphthalene	Pyrene	C7-alkyl phenols	Hg
C2-naphthalene	Chrysene	C8-alkyl phenols	Ni
C3-naphthalene	Benzo(a)anthracene	C9-alkyl phenols	Zn
Phenanthrene	Benzo(a)pyrene	Organic acids:	Ba
Anthracene	Benzo(g,h,i)perylene	Formic acid	Fe
C1-phenanthrene	Benzo(b)fluoranthene	Acetic acid	Radioactivity
C2-phenanthrene	Benzo(k)fluoranthene	Propionic acid	<sup>226</sup> Ra
C3-phenanthrene	Indeno(1,2,3-c,d)pyrene	Butyric acid	<sup>228</sup> Ra
Dibenzotiofene	Debenz(a,h)anthracene	Valeric acid	<sup>210</sup> Pb

Table 1. Dissolved components in produced water for analysis. (Source: KLIF, 2010)

### Ballast water, storm water, bilge water and other water contaminated with oil during production operations

- Oil content shall be measured once a day in the period of discharge. This may be done by using an auto sampler, taking out samples in order to make a representative daily average sample (see above).

#### Reporting

- Daily registration of the amount of produced water reinjected or discharged to the sea, of the content of oil in produced water, and total amount of oil in produced water discharged to sea.
- Daily registration of oil in ballast, storm, bilge and other water contaminated with oil during production operations, amount of water and amount of oil in water.
- Daily registration of consumption of added chemicals.
- Consumption and discharge of drilling chemicals shall be registered per well section
- Production data for oil production, produced water, produced gas, gas to fuel, gas to flare and diesel consumption shall be daily registered through the normal production data system.
- Monthly internal reporting of production data, chemical consumption and discharge, oil in water, including discharges
- Yearly report of all discharge to sea, including chemical consumption and discharge.

#### 6.2.5. Decommissioning/post decommissioning phase

Discharges related to cleaning during decommissioning:

- Process equipment, vessels, tanks and pipes shall preferably be drained and cleaned prior to removal for end disposal.
- Waste water shall to the extent possible be contained and any oily discharge shall not exceed 30 mg/l.
- Pipelines decommissioned for potential future reuse shall be cleaned of hydrocarbons and inhibited to limit corrosion.

- Pipelines disposed of in situ shall be subject to risk assessment / assessment as to identify the best environmental option with regards to cleaning (pigging, flushing, chemical use).

### 6.3. Emissions and discharges from associated shipping

This section applies to ships and offshore units as regulated under MARPOL 73/78, engaged in activities related to the offshore oil and gas industry in the Barents Sea.

Requirements/recommendations are stated below.

#### 6.3.1. Emissions to air

1. Emissions to air shall be in compliance with the provisions of MARPOL 73/78 Annex VI, and in addition according to the following requirements [2.1.2 – 2.1.3].
2. Marine fuels should be of marine distillate type, with characteristics equal to the DM (X, A, Z, B) qualities under ISO8217:2010(E) or Russian GOST 305-82 “Diesel fuel. Technical specifications” or similar. Maximum sulphur content in fuels shall be 0.5 % by weight.
3. Shuttle tankers shall be equipped to minimize emissions of methane and VOC. General examples on VOC emission reduction measures are given in section 6.1.2 of this guidance document.

#### 6.3.2. Discharges to sea

1. Discharges to sea shall be in compliance with the provisions of MARPOL 73/78 Annex I-V and other applicable IMO instruments as set out in, but not limited to, the requirements 2.2.2 – 2.2.4 of this standard, and in addition the following requirements 2.2.5 – 2.2.9.
2. Pollution from anti-fouling compounds shall be in compliance with the provisions of the IMO Anti-fouling System (AFS) Convention.
3. Ballast water discharge and management shall be in compliance with the provisions of the IMO Ballast Water Management Convention.
4. Any discharge of oil or oily mixtures from the cargo areas of an oil tanker, as defined in MARPOL 73/78 Annex I, shall be prohibited.

5. The leakage of lubricants from stern tube bearings, seals and main propulsion components located outside the hull shall be minimized. Stern tube bearing lubrication systems should utilize oil causing the lowest possible damage to the environment, preferably the use of sea-water based lubricating systems should be applied.
6. The discharge of garbage shall be prohibited, except from food waste that can be discharged subject to the discharge provisions of MARPOL 73/78 Annex V. Such discharge shall be made as far as practicable from nearest ice.
7. No tank residues, including tank washing residues, shall be discharged to sea from offshore supply and service vessels.
8. Vessels shall be provided with sufficient additional storage capacity or treatment systems for waste to account for any of the no-discharge provisions and potentially limited local waste reception capacity.

### 6.3.3. Disturbance of marine life

1. When performing voyage planning, the potential negative impacts on marine mammals, such as collisions and disturbance, shall be taken into consideration.

2. When performing planning of seismic survey activities, potential negative impacts on marine life shall be taken into consideration

For identification of environmentally sensitive areas cf. baseline surveys described in section 6.5.

### 6.4. Waste management

Remoteness and poorly developed infrastructure for waste reception and handling is a real waste management challenge of the Barents Sea (offshore and coastal areas). The aim is to ensure proper environmental performance through a life cycle approach. Guidance documents exist on an international and national level but need to be adjusted and harmonized to the relevant infrastructure and remoteness in the Barents region.

The general principle for waste management is aligned to the waste hierarchy described by numerous regulatory bodies and international organizations. This hierarchy is based on remove (prevent generation of waste), reduce, re-use, recycle, recover, treat, dispose (cf. figure 2). To enable this approach design of the facilities, processes and equipment must be considered to eliminate and reduce generation of waste. Further on the facilities and logistic activities must be designed to allow for segregation of waste at source, and to keep segregated waste separated. This will enable safe handling of the waste. It will also enable re-use, recycling, treatment and final disposal of the waste.

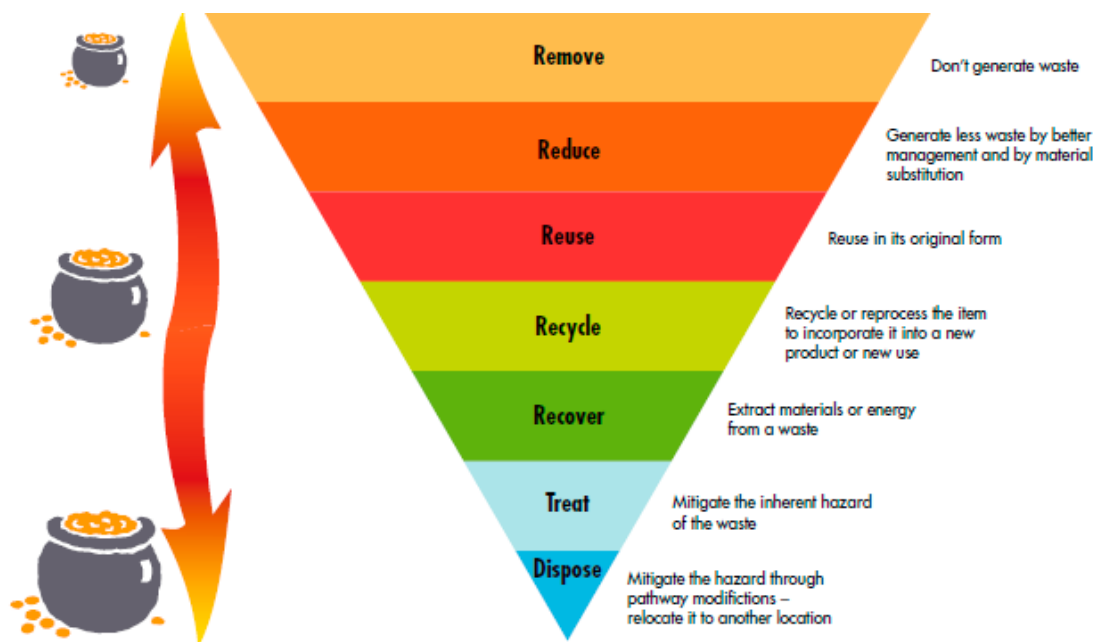


Figure 2. Waste hierarchy (Source: OGP, 2009)

Planning of the waste management and handling of the waste will follow the same principle for all phases from exploration, development, production and decommissioning. However the challenges might change as the infrastructure offshore and onshore is likely to develop through the four mentioned lifecycle phases.

Section 6.2 describes philosophy and acceptance criteria for discharge to sea of cuttings from drilling, oily water, produced water, industrial household and sanitary sewage.

Incineration of combustible non-hazardous waste should be avoided. Hazardous waste shall not be incinerated.

#### 6.4.1. Seismic acquisition and exploration drilling

This activity is expected to be performed by existing mobile units. These units must allow for suitable space to segregate and store waste. A potential challenge during this phase can be the remoteness of the offshore activities and limited infrastructure onshore. When planning the waste handling system, assessment of both offshore and onshore consequences must be performed. It is important to understand what will happen with the waste that is brought onshore in a remote area and possible environmental consequences of this waste.

In exploration drilling, water based mud will be used. Cuttings should be discharged to sea, cf. section 6.2 for acceptance criteria, in order to avoid problems these cuttings could create onshore in a remote area without infrastructure.

Waste should be divided into hazardous and non-hazardous waste. Non-hazardous waste could be segregated at the rig or vessel in the following fractions, if there are suitable solutions onshore to handle the different fractions:

- Metal
- Wood
- Plastic
- Paper
- Glass
- Rest fraction non hazardous

It is not allowed to dump any of these fractions to sea.

Hazardous waste shall be segregated, classified, sent onshore and handled according to national legislation.

In case there is no waste processing infrastructure, the controlled waste incineration using approved incineration units can be considered as an alternative. This intermediate solution shall be only temporary until the acceptable waste processing infrastructure is established.

#### 6.4.2. Field development phase (including design requirements and pre-production drilling)

Activity in this phase will consist of mobile units and fixed offshore installations (floating, production, storage and offloading units (FPSO), submersible installations etc.). Mobile units assisting in the development phase (supply/supporting vessels, flotel, drilling units) should operate with the same principle as the fixed offshore installations. The mobile units will use the same onshore infrastructure as the fixed offshore installations.

Design of the fixed offshore installations must be in accordance with the principle of the waste hierarchy. During the development phase onshore treatment facilities should be identified and the infrastructure to these treatment facilities should be developed. The planning of segregation of waste on the offshore units must be in accordance with the onshore infrastructure.

Segregation of hazardous and non-hazardous waste fractions should be done as described in 6.4.1

#### 6.4.3. Production phase (including export/transportation)

Activity in the production phase will primarily be on the fixed offshore installations and associated supply/supporting vessels. The waste hierarchy principle will be the same as for the exploration phase and the waste management infrastructure onshore is for the production phase most likely developed to handle the waste streams.

Segregation of hazardous and non-hazardous waste fractions should be done as described in 6.4.1.

#### 6.4.4. Decommissioning/post decommissioning phase

The decommissioning must be carefully planned in order to avoid spill to sea and to manage all waste streams. Activities and end disposal should be based on impact assessment.

The fixed offshore installations shall be designed to allow for removal of the unit. The units should be disposed of in accordance with IMO resolution A.672(16) or more stringent regional/national regulation when applicable. In practice this means that all installations are to be removed with very limited exceptions. The exceptions are stated by IMO or competent regional/national bodies (e.g. OSPAR for the NE Atlantic (cf. Decision 98/3)). When removed, and if a reuse opportunity is not identified, the structures should be dismantled and materials responsibly disposed.

For the removal and dismantling process the following recommendations are given:



- A comparative assessment of relevant removal/end disposal solutions shall be undertaken to identify the “best environmental option”.
- The operations shall seek to minimise environmental footprint and optimise on energy consumption.
- Hazardous materials shall to the extent practicable be identified prior to removal. Such materials shall be managed safely though removal, dismantling till final disposal is ensured and documented.
- Yards for execution of dismantling operations shall have dedicated permission for such work and shall have systems in place for proper HSE and waste management.
- After final end disposal has been carried out the former industrial area offshore shall be surveyed for debris and potential sources of pollution or nuisance to third parties.
- Identified debris shall be removed or secured to prevent future littering and/or other pollution.

#### 6.4.5. Reporting

Waste shipped to shore should be reported on a monthly basis or as otherwise stated by national regulations.

### 6.5. Environmental monitoring

This section applies to environmental monitoring of offshore oil and gas activities, exploration and production facilities. The guidelines cover measuring contaminants from discharges and impacts to the environment in the vicinity of offshore oil and gas activities. The purpose of the environmental monitoring is to provide an overview of environmental status and trends over time as a result of oil and gas activities. The focus is on operational discharges. Detection and monitoring after accidental discharges is not covered in this guideline, but systems need to be in place both for detection and monitoring of restitution in the environment affected by the discharge.

Measurement of certain key environmental factors (concentration levels of pollutants and impacts of the activity to the environment) in the vicinity of offshore installations is the foundation for the current environmental assessments and monitoring systems in both Norway and Russia. In both countries samples are collected from the sea floor (sediments and benthic animals) and from the water column. It is a goal to establish general

recommendations for the environmental monitoring of oil and gas activities in the Barents Sea.

Regional Environmental Impact Assessment Before any kind of petroleum activity is initiated in a new area, a general Environmental Impact Assessment (EIA) is undertaken (e.g. by national/regional authorities) including an environmental baseline survey for the actual area. The EIA normally also addresses the contents of a monitoring program, based on assessment of the biological resources in the new area and its environmental vulnerability. Hence, this establishes a baseline for later petroleum activity specific environmental monitoring.

#### 6.5.1. Exploration phase

Baseline environmental surveys of sediments are mandatory prior to exploration drilling in new areas. The baseline survey shall include reference sampling locations at the field and in the larger region (“field” is the actual reservoir drilled, “region” is a larger predefined geographical area containing many fields).

The sampling shall include top sediments to be analyzed for given oil related contaminants and metals (Russian GOST 17.1.5.01-80); Norway TA-2849/2011), and benthic macro fauna (animals < 0.1 mm) for analyses of impacts (species occurrence and community structure/biocenosis). In Norway sampling of soft bottom macro fauna shall follow TA-2849/2011.

A list of the key contaminants (metals and PAHs) that shall be measured during the baseline survey, and optional ones, is given in appendix 3. The chemical samples shall be analyzed by standard international methods (see appendix 3) or nationally approved/recommended standards.

The benthic fauna shall be analyzed according national standards (Norway: ISO 16665, TA-2849/2011) (Russia: equipment as given in GOST R 8-589-2001). The analytic methods used during baseline survey should also be used during all later monitoring surveys.

#### 6.5.2. Development phase

##### Sediments

Baseline environmental surveys of sediments (see 6.5.1) at a field shall be carried out prior to production drilling.

**Monitoring surveys:** The baseline sampling locations shall be monitored at least every 3rd year during the production phase of the field (ref section 6.5.3).

In areas where hard bottom and rocks are prevailing, and in specially sensitive areas (e.g.: corals), visual monitoring (ROV) should be used in combination with standard sea floor sampling.

### 6.5.3. Production phase, production drilling and operational discharges from operations

#### Sediments

**Monitoring surveys:** Environmental monitoring shall be carried out at given intervals during the production phase of the field (see 6.5.2). Sampling locations, contaminant and types of fauna and methods for sampling and analyses shall be the same as in the baseline survey (see 6.5.1 and 6.5.2).

#### Water column

It should be assessed if monitoring in the given area is needed. If needed, monitoring shall be done according to national standards.

In Russia, key and additional contaminants of sea water should be analyzed under GOST 17.1.3.08-82.

In Norway, the concentration of certain contaminants in the water column at given distances from the drilled well is monitored every year (Norwegian standard TA-2849/2011).

Condition monitoring of wild stocks of fish should be undertaken in order to document whether the fish are affected by discharges from the oil and gas activities. This monitoring should be carried out every third year. If important spawning grounds or nursery areas are present in the vicinity of the field, more frequent sampling may be required.

Impact monitoring on fish and mussels are carried out experimentally by placing fish and mussels in cages at certain distance from the produced water discharge outlet. Biomarker analyses are being used to assess the impact.

#### Marine mammals, ice and biota

The need for such monitoring should be assessed on a case by case basis. If needed monitoring should be carried out according to national standards.

#### Subsea leakage monitoring and leakage to air emission monitoring

Not subject to the scope of the current guidance document, however should be part of the overall environmental monitoring as applicable under national /regional regulation.

### 6.5.4. Post decommissioning (field end)

After the production has ended and before the installations have been removed, monitoring at the field shall be carried out. The sampling shall include the same set of variables and at the same sampling locations as in the baseline study.

After the production has ended and the installations have been removed, the monitoring shall be carried out at least twice (over a period of 6 years)

### 6.5.5. Quality Assurance and Accreditation

The environmental consultants and laboratories involved shall be accredited to national or international standards (Norway: NS-EN ISO/IEC 17025:2005; Russia: GOST R ISO/IEC 17025), for all the services and analyses they provide. Suppliers shall also document their internal quality assurance routines.

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# APPENDIX 1. IFC EMISSION STANDARDS

Table A1-1. IFC emission standard which should be achieved  
(Table in 1.1 Air emission and Ambient Air Quality)

Small Combustion Facilities Emissions Guidelines (3MWth – 50MWth) – (in mg/Nm <sup>3</sup> or as indicated)				
Combustion Technology / Fuel	Particulate Matter (PM)	Sulfur Dioxide (SO <sub>2</sub> )	Nitrogen Oxides (NO <sub>x</sub> )	Dry Gas, Excess O <sub>2</sub> Content (%)
<b>Engine</b>				
Gas	N/A	N/A	200 (Spark Ignition) 400 (Dual Fuel) 1,600 (Compression Ignition)	15
Liquid	50 or up to 100 if justified by project specific considerations (e.g. Economic feasibility of using lower ash content fuel, or adding secondary treatment to meet 50, and available environmental capacity of the site)	1.5 percent Sulphur or up to 3.0 percent Sulphur if justified by project specific considerations (e.g. Economic feasibility of using lower S content fuel, or adding secondary treatment to meet levels of using 1.5 percent Sulphur, and available environmental capacity of the site)	If bore size diameter [mm] < 400: 1460 (or up to 1,600 if justified to maintain high energy efficiency.) If bore size diameter [mm] > or = 400: 1,850	15
<b>Turbine</b>				
Natural Gas =3MWth to < 15MWth	N/A	N/A	42 ppm (Electric generation)	15
Natural Gas =15MWth to < 50MWth	N/A	N/A	25 ppm	15
Fuels other than Natural Gas =3MWth to < 15MWth	N/A	0.5 percent Sulphur or lower percent Sulphur (e.g. 0.2 percent Sulphur) if commercially available without significant excess fuel cost	96 ppm (Electric generation) 150 ppm (Mechanical drive)	15
Fuels other than Natural Gas =15MWth to < 50MWth	N/A	0.5% S or lower % S (0.2%S) if commercially available without significant excess fuel cost	74 ppm	15
<b>Boiler</b>				
Gas	N/A	N/A	320	3
Liquid	50 or up to 150 if justified by environmental assessment	2000	460	3
Solid	50 or up to 150 if justified by environmental assessment	2000	650	6

**Notes:**

- N/A/ - no emissions guideline; Higher performance levels than these in the Table should be applicable to facilities located in urban / industrial areas with degraded airsheds or close to ecologically sensitive areas where more stringent emissions controls may be needed.; MWth is heat input on HHV basis; Solid fuels include biomass; Nm<sup>3</sup> is at one atmosphere pressure, 0°C.; MWth category is to apply to the entire facility consisting of multiple units that are reasonably considered to be emitted from a common stack except for NO<sub>x</sub> and PM limits for turbines and boilers. Guidelines values apply to facilities operating more than 500 hours per year with an annual capacity utilization factor of more than 30 percent

Table A1-2. IFC emission standard which should be achieved (Thermal Power plants) Emissions Guidelines (in mg/Nm<sup>3</sup> or as indicated) for Reciprocating Engine (IFC Table 6 (A)).

Combustion Technology / Fuel	Particulate Matter (PM)		Sulfur Dioxide (SO <sub>2</sub> )		Nitrogen Oxides (NO <sub>x</sub> )		Dry Gas, Excess O <sub>2</sub> Content (%)
	NDA	DA	NDA	DA	NDA	DA	
<b>Reciprocating Engine</b>	NDA	DA	NDA	DA	NDA	DA	
<b>Natural Gas</b>	N/A	N/A	N/A	N/A	200 (Spark Ignition) 400 (Dual Fuel) (a)	200(SI) 400 (Dual Fuel / CI)	15
<b>Liquid Fuels (Plant &gt;50 MWth to &lt;300 MWth)</b>	50	30	1,170 or use of 2% or less S fuel	0.5% S	1,460 (Compression Ignition, bore size diameter [mm] < 400) 1,850 (Compression Ignition, bore size diameter [mm] ≥ 400) 2,000 (Dual Fuel)	400	15
<b>Liquid Fuels (Plant ≥300 MWth)</b>	50	30	585 or use of 1% or less S fuel	0.2% S	740 (contingent upon water availability for injection)	400	15
<b>Biofuels / Gaseous Fuels other than Natural Gas</b>	50	30	N/A	N/A	30% higher limits than those provided above for Natural Gas and Liquid Fuels.	200 (SI, Natural Gas), 400 (other)	15

**General notes:**

- MWth = Megawatt thermal input on HHV basis; N/A = not applicable; NDA = Non-degraded airshed; DA = Degraded airshed (poor air quality); Airshed should be considered as being degraded if nationally legislated air quality standards are exceeded or, in their absence, if WHO Air Quality Guidelines are exceeded significantly; S = sulfur content (expressed as a percent by mass); Nm<sup>3</sup> is at one atmospheric pressure, 0 degree Celsius; MWth category is to apply to the entire facility consisting of multiple units that are reasonably considered to be emitted from a common stack. Guideline limits apply to facilities operating more than 500 hours per year. Emission levels should be evaluated on a one hour average basis and be achieved 95% of annual operating hours.
- (a) Compression Ignition (CI) engines may require different emissions values which should be evaluated on a case-by-case basis through the EA process.

**Comparison of the Guideline limits with standards of selected countries / region (as of August 2008):**

- Natural Gas-fired Reciprocating Engine – NO<sub>x</sub>
  - Guideline limits: 200 (SI), 400 (DF)
  - UK: 100 (CI), US: Reduce by 90% or more, or alternatively 1.6 g/kWh
- Liquid Fuels-fired Reciprocating Engine – NO<sub>x</sub> (Plant >50 MWth to <300 MWth)
  - Guideline limits: 1,460 (CI, bore size diameter < 400 mm), 1,850 (CI, bore size diameter ≥ 400 mm), 2,000 (DF)
  - UK: 300 (> 25 MWth), India: 1,460 (Urban area & ≤ 75 MWe (≈ 190 MWth), Rural area & ≤ 150 MWe (≈ 380 MWth))
- Liquid Fuels-fired Reciprocating Engine – NO<sub>x</sub> (Plant ≥300 MWth)
  - Guideline limits: 740 (contingent upon water availability for injection)
  - UK: 300 (> 25 MWth), India: 740 (Urban area & > 75MWe (≈ 190 MWth), Rural area & > 150 MWe (≈ 380 MWth))
- Liquid Fuels-fired Reciprocating Engine – SO<sub>2</sub>
  - Guideline limits: 1,170 or use of ≤ 2% S (Plant >50 MWth to <300 MWth), 585 or use of ≤ 1% S (Plant ≥300 MWth)
  - EU: Use of low S fuel oil or the secondary FGD (IPCC LCP BREF), HFO S content ≤ 1% (Liquid Fuel Quality Directive), US: Use of diesel fuel with max S of 500 ppm (0.05%); EU: Marine HFO S content ≤ 1.5% (Liquid Fuel Quality Directive) used in SO<sub>x</sub> Emission Control Areas; India: Urban (< 2% S), Rural (< 4%S), Only diesel fuels (HSD, LDO) should be used in Urban

Source: UK (S2 1.03 Combustion Processes: Compression Ignition Engines, 50 MWth and over), India (SO<sub>x</sub>/NO<sub>x</sub> Emission Standards for Diesel Engines ≥ 0.8 MW), EU (IPCC LCP BREF July 2006), EU (Liquid Fuel Quality Directive 1999/32/EC amended by 2005/33/EC), US (NSPS for Stationary Compression Ignition Internal Combustion Engine – Final Rule – July 11, 2006)

**Note:**

- Guidelines are applicable for new facilities.
- EA may justify more stringent or less stringent limits due to ambient environment, technical and economic considerations provided there is compliance with applicable ambient air quality standards and incremental impacts are minimized.
- For projects to rehabilitate existing facilities, case-by-case emission requirements should be established by the EA considering (i) the existing emission levels and impacts on the environment and community health, and (ii) cost and technical feasibility of bringing the existing emission levels to meet these new facilities limits.
- EA should demonstrate that emissions do not contribute a significant portion to the attainment of relevant ambient air quality guidelines or standards, and more stringent limits may be required



Table A1-3 Turbine requirements Emissions Guidelines (in mg/Nm<sup>3</sup> or as indicated) for Combustion Turbine.  
IFC Table 6 (B)

Combustion Technology / Fuel	Particulate Matter (PM)		Sulfur Dioxide (SO <sub>2</sub> )		Nitrogen Oxides (NO <sub>x</sub> )	Dry Gas, Excess O <sub>2</sub> Content (%)
Combustion turbine			NDA/DA		NDA/DA	
Natural Gas (all turbine types of Unit > 50MWth)	N/A	N/A	N/A	N/A	51 (25 ppm)	15 %
Fuels other than Natural Gas (Unit > 50MWth)	50	30	Use of 1% or less S fuel	Use of 0.5% or less S fuel	152 (74 ppm) <sup>a</sup>	15 %

**General notes:**

- MWth = Megawatt thermal input on HHV basis; N/A = not applicable; NDA = Non-degraded airshed; DA = Degraded airshed (poor air quality); Airshed should be considered as being degraded if nationally legislated air quality standards are exceeded or, in their absence, if WHO Air Quality Guidelines are exceeded significantly; S = sulfur content (expressed as a percent by mass); Nm<sup>3</sup> is at one atmospheric pressure, 0 degree Celsius; MWth category is to apply to single units; Guideline limits apply to facilities operating more than 500 hours per year. Emission levels should be evaluated on a one hour average basis and be achieved 95% of annual operating hours.
- If supplemental firing is used in a combined cycle gas turbine mode, the relevant guideline limits for combustion turbines should be achieved including emissions from those supplemental firing units (e.g., duct burners).
- (a) Technological differences (for example the use of Aeroderivatives) may require different emissions values which should be evaluated on a cases-by-case basis through the EA process but which should not exceed 200 mg/Nm<sup>3</sup>.

**Comparison of the Guideline limits with standards of selected countries / region (as of August 2008):**

- Natural Gas-fired Combustion Turbine – NO<sub>x</sub>
  - Guideline limits: 51 (25 ppm)
  - EU: 50 (24 ppm), 75 (37 ppm) (if combined cycle efficiency > 55%), 50\*η / 35 (where η = simple cycle efficiency)
  - US: 25 ppm (> 50 MMBtu/h (≈ 14.6 MWth) and ≤ 850 MMBtu/h (≈ 249MWth)), 15 ppm (> 850 MMBtu/h (≈ 249 MWth))
  - (Note: further reduced NO<sub>x</sub> ppm in the range of 2 to 9 ppm is typically required through air permit)
- Liquid Fuel-fired Combustion Turbine – NO<sub>x</sub>
  - Guideline limits: 152 (74 ppm) – Heavy Duty Frame Turbines & LFO/HFO, 300 (146 ppm) – Aeroderivatives & HFO, 200 (97 ppm) – Aeroderivatives & LFO
  - EU: 120 (58 ppm), US: 74 ppm (> 50 MMBtu/h (≈ 14.6 MWth) and ≤ 850 MMBtu/h (≈ 249MWth)), 42 ppm (> 850 MMBtu/h (≈ 249 MWth))
- Liquid Fuel-fired Combustion Turbine – SO<sub>x</sub>
  - Guideline limits: Use of 1% or less S fuel
  - EU: S content of light fuel oil used in gas turbines below 0.1% / US: S content of about 0.05% (continental area) and 0.4% (non-continental area)

Source: EU (LCP Directive 2001/80/EC October 23 2001), EU (Liquid Fuel Quality Directive 1999/32/EC, 2005/33/EC), US (NSPS for Stationary Combustion Turbines, Final Rule – July 6, 2006)

**Note:**

- Guidelines are applicable for new facilities.
- EA may justify more stringent or less stringent limits due to ambient environment, technical and economic considerations provided there is compliance with applicable ambient air quality standards and incremental impacts are minimized.
- For projects to rehabilitate existing facilities, case-by-case emission requirements should be established by the EA considering (i) the existing emission levels and impacts on the environment and community health, and (ii) cost and technical feasibility of bringing the existing emission levels to meet these new facilities limits.
- EA should demonstrate that emissions do not contribute a significant portion to the attainment of relevant ambient air quality guidelines or standards, and more stringent limits may be required

Table A1-4. Boiler requirements Emissions Guidelines (in mg/Nm<sup>3</sup> or as indicated) for Boiler. IFC Table 6 (C)

Combustion Technology / Fuel	Particulate Matter (PM)		Sulfur Dioxide (SO <sub>2</sub> )		Nitrogen Oxides (NO <sub>x</sub> )		Dry Gas, Excess O <sub>2</sub> Content (%)
	NDA	DA	NDA	DA	NDA	DA	
Boiler	NDA	DA	NDA	DA	NDA	DA	
Natural Gas	N/A	N/A	N/A	N/A	240	240	3 %
Other Gaseous Fuels	50	30	400	400	240	240	3 %
Liquid Fuels (Plant >50 MWth to <600 MWth)	50	30	900 – 1,500 <sup>a</sup>	400	400	200	3 %
Liquid Fuels (Plant ≥600 MWth)	50	30	200 – 850 <sup>b</sup>	200	400	200	3 %
Solid Fuels (Plant >50 MWth to <600 MWth)	50	30	900 – 1,500 <sup>a</sup>	400	510 <sup>c</sup> Or up to 1,100 if volatile matter of fuel < 10%	200	6 %
Solid Fuels (Plant ≥600 MWth)	50	30	200 – 850 <sup>b</sup>	200			6 %

**General notes:**

- MWth = Megawatt thermal input on HHV basis; N/A = not applicable; NDA = Non-degraded airshed; DA = Degraded airshed (poor air quality); Airshed should be considered as being degraded if nationally legislated air quality standards are exceeded or, in their absence, if WHO Air Quality Guidelines are exceeded significantly; CFB = circulating fluidized bed coal-fired; PC = pulverized coal-fired; Nm<sup>3</sup> is at one atmospheric pressure, 0 degree Celsius; MWth category is to apply to the entire facility consisting of multiple units that are reasonably considered to be emitted from a common stack. Guideline limits apply to facilities operating more than 500 hours per year. Emission levels should be evaluated on a one hour average basis and be achieved 95% of annual operating hours.
- a. Targeting the lower guidelines values and recognizing issues related to quality of available fuel, cost effectiveness of controls on smaller units, and the potential for higher energy conversion efficiencies (FGD may consume between 0.5% and 1.6% of electricity generated by the plant). b. Targeting the lower guidelines values and recognizing variability in approaches to the management of SO<sub>2</sub> emissions (fuel quality vs. use of secondary controls) and the potential for higher energy conversion efficiencies (FGD may consume between 0.5% and 1.6% of electricity generated by the plant). Larger plants are expected to have additional emission control measures. Selection of the emission level in the range is to be determined by EA considering the project's sustainability, development impact, and cost-benefit of the pollution control performance. c. Stoker boilers may require different emissions values which should be evaluated on a case-by-case basis through the EA process.

Comparison of the Guideline limits with standards of selected countries / region (as of August 2008):

- Natural Gas-fired Boiler – NO<sub>x</sub>
  - Guideline limits: 240
  - EU: 150 (50 to 300 MWth), 200 (> 300 MWth)
- Solid Fuels-fired Boiler - PM
  - Guideline limits: 50
  - EU: 50 (50 to 100 MWth), 30 (> 100 MWth), China: 50, India: 100 – 150
- Solid Fuels-fired Boiler – SO<sub>2</sub>
  - Guideline limits: 900 – 1,500 (Plant > 50 MWth to < 600 MWth), 200 – 850 (Plant ≥ 600 MWth)
  - EU: 850 (50 – 100 MWth), 200 (> 100 MWth)
  - US: 180 ng/J gross energy output OR 95% reduction (≈ 200 mg/Nm<sup>3</sup> at 6%O<sub>2</sub> assuming 38% HHV efficiency)
  - China: 400 (general), 800 (if using coal < 12,550 kJ/kg), 1,200 (if mine-mouth plant located in non-double control area of western region and burning low S coal (<0.5%))

Source: EU (LCP Directive 2001/80/EC October 23 2001), US (NSPS for Electric Utility Steam Generating Units (Subpart Da), Final Rule – June 13, 2007), China (GB 13223-2003)

**Note:**

- Guidelines are applicable for new facilities.
- EA may justify more stringent or less stringent limits due to ambient environment, technical and economic considerations provided there is compliance with applicable ambient air quality standards and incremental impacts are minimized.
- For projects to rehabilitate existing facilities, case-by-case emission requirements should be established by the EA considering (i) the existing emission levels and impacts on the environment and community health, and (ii) cost and technical feasibility of bringing the existing emission levels to meet these new facilities limits.
- EA should demonstrate that emissions do not contribute a significant portion to the attainment of relevant ambient air quality guidelines or standards, and more stringent limits may be required

## APPENDIX 2. ECOTOXICOLOGICAL TESTING

The following gives guidance on ecotoxicological testing, cf. Norwegian Activities Regulation section 62:

Ecotoxicological properties should be tested in accordance with the following:

### 1) Biodegradability

Chemicals that consist of several substances shall be tested for the individual organic substances' biodegradability. If possible, the substances shall be tested in accordance with the seawater test OECD 306 "Biodegradability in Seawater". If OECD 306 cannot be used, one of the following seawater tests shall be carried out:

- marine BODIS test (for insoluble substances) modified ISO 10708
- marine CO<sub>2</sub> headspace test, modified ISO/TC 147/SC 5/WG 4 N182

For substances that are moderately degradable (corresponding to biodegradability BOD<sub>28</sub> between 20% and 60%), the properties of the degradation products shall also be evaluated.

### 2) Bioaccumulation

Chemicals that consist of several substances shall be tested for the individual organic substances' potential for bioaccumulation. The requirement applies to substances with molecular weight lower than 700 g/mol. The substances shall be tested according to OECD 117 "Partition Coefficient (n-octanol/water), High Performance Liquid Chromatography (HPLC) Method" or OECD 107 "Partition Coefficient (n-octanol/water): Shake Flask Method". For substances that cannot be tested according to standardised methods, such as surface-active agents, a calculation or professional evaluation of bioaccumulation potential shall be carried out. Professional evaluations shall preferably be carried out by an independent party, and shall be documented.

### 3) Acute toxicity

Inorganic and organic chemicals shall be tested for acute toxicity at the substance level. The requirement does not apply to chemicals on OSPAR's PLONOR list.

The following toxicity tests are required:

- *Skeletonema costatum*, ISO 10253
- *Acartia tonsa*, ISO 14669
- *Scophtalmus maximus*; Part B of OSPAR Protocols on Methods for the Testing of Chemicals Used in the Offshore Oil Industry, 2006. *Cyprinodon variegatus* is accepted as an alternative fish species.
- *Corophium* sp, Part A of OSPAR Protocols on Methods for the Testing of Chemicals Used in the Offshore Oil Industry, 2006; Required if the chemicals are adsorbed to particles (Koc > 1000) and/or sink and end up in the sediments (e.g. surface-active substances).

Toxicity tests on freshwater organisms can be accepted if results from marine tests are not available, and if they are conducted according to standardised methods.

Fish tests are not required if the chemical is:

- non-organic and has a toxicity in relation to other test organisms of EC<sub>50</sub> or LC<sub>50</sub> ≤ 1 mg/l
- organic and has a toxicity in relation to the other test organisms of EC<sub>50</sub> or LC<sub>50</sub> ≤ 10 mg/l.

## APPENDIX 3. CHEMICAL ANALYSIS

### Standards for analysis:

- Total organic matter: NS-4764 Determination of dry matter and burn residue in water, sludge and sediments (Bestemmelse av tørrstoff og gløderest i vann, slam og sedimenter)
- Grain size: Bale & Kenny (2005): Bale, A.J. & Kenny, A.J. 2005. Sediment analysis and seabed characterisation. In: Eleftheriou, A.; McIntyre, A.D. “Methods for the study of marine benthos”. 3rd edition. Blackwell Science. Oxford, UK. ISBN 0-632-05488-3. pp. 43-86.
- Total Hydrocarbons (THC), and 16 EPA-PAH and NPD: ANON, 1982. Manual and Guides No. 11 (1982). The determination of petroleum hydrocarbons in sediments. IOC/UNESCO, Paris.
- Metals:
  - NS-EN ISO 15587-2 ;
  - Hg : NS-EN 1483
- GOST 17.15.01-80
- GOST 17.1.3.08-82

### Components/species:

Table A3-1 Sediment samples, sample sizes and analyses (Source: KLIF, 2011)

Parameter	Sample depth	Benthic baseline and first monitoring surveys	Subsequent benthic monitoring surveys (2 <sup>nd</sup> and 3 <sup>rd</sup> etc.) <sup>3</sup>	Sample storage and size
TOM	0–1 cm	1 sample (from the mixed sample for grain size)	1 sample	-20° C 100 g
Grain size	0–5 cm	Mixed sample from 3 grab samples at the station	Mixed sample from 3 grab samples at the station	300 g
Hydrocarbons - THC - Synth. drilling fluid - NPD and PAHs <sup>1</sup>	0–1 cm 1–3 cm 3–6 cm	3 samples 1 sample <sup>2</sup> 1 sample <sup>2</sup>	3 samples	- 20° C 300 g
Metals -Ba <sup>4</sup> , Cd, Cr, Cu, Pb, Zn, Hg	0–1 cm 1–3 cm 3–6 cm	3 samples 1 sample <sup>2</sup> 1 sample <sup>2</sup>	3 samples	- 20° C 50 g
Macrofauna <sup>5</sup>		5 samples	5 samples	10% formalin Bengal Red/ Eosin

1 If THC exceeds 50 mg/kg, analyses of NPD and PAH are also required (in the upper 0–1 cm of the sediment only).

2 Only the two downstream stations closest to the discharge point, if THC exceeded 50 mg/kg in the previous survey. Applies to NPD, PAHs and metals.

3 The number of parameters to be analysed may vary depending on the degree of contamination and the level of activity on the field in question.

4 Or an equivalent weighting agent (e.g. Ti).

5 In the longer term, samples of the sediment meiofauna may be required in addition to the macrofauna, for example in areas that are inaccessible with conventional sampling equipment.

Table A3-2. US Environmental Protection Agency (EPA) list of 16 main PAH compounds identified in relation to the presence of pollution

PARAMETER	STORET No <sup>1</sup>	CAS No <sup>2</sup>
Acenaphthene	34205	83-32-9
Acenaphthylene	34200	208-95-8
Anthracene	34220	120-12-7
Benzo (a) anthracene	34526	56-55-3
Benzo (a) pyrene	34247	50-32-8
Benzo (b) fluoranthene*	34230	205-99-2
Benzo (ghi) perylene	34521	191-24-2
Benzo (k) fluoranthene*	34242	207-08-9
Chrysene**	34320	218-01-9
Dibenzo (a, h) anthracene	34556	53-70-3
Fluoranthene	34376	206-44-0
Fluorene	34381	86-73-7
Indeno (1,2,3-cd) pyrene	34403	193-39-5
Naphthalene	34696	91-20-3
Phenanthrene	34461	85-01-8
Pyrene	34469	129-00-0

1 Storage and Retrieval number (EPA)

2 Chemical Abstract Service registry number (American Chemical Society)

\* Figures for benzo (b, j, k) fluoranthenes are reported together

\*\* Chrysene is reported together with triphenylene









**RN01**  
Co-ordination  
of Deliverables





# RN01: CO-ORDINATION OF DELIVERABLES

## 1. INTRODUCTION

### 1.1. Mandate

Working group RN01 was given the following mandate for phase IV of the Barents 2020 project:

1. Recommend how Phase 3 recommendations and Phase 4 deliverables should be structured, edited and published to fit well into the collection of existing standards
2. Review deliverables from working groups for compliance with the recommendations report of RN01, and prepare roadmaps for implementation of deliverables
3. Create awareness among the potential recipients (e.g. standards organisations) as to what is coming and acting as an intermediary as necessary and appropriate
4. Provide proposal for an Arctic long term international standards program (ref. ISO/TC67 MC Ad-hoc group Arctic Operations) and including potentially missing international standards for the broader Arctic environment

### 1.2. Participants

The members of the working group have been:

Name	Company	E-Mail
Vladimir Vernikovskij	GAZPROM / TC23	V.Vernikovskiy@gpr.gazprom.ru
Dennis Thikomirov	VNIIGAZ	D_Tikhomirov@vniigaz.gazprom.ru
Alexander Ermakov	S-DAG	a.ermakov@shtokman.ru
Annie Audibert-Hayet	TOTAL	annie.audibert-hayet@total.com
Jan Gustaf Eriksson	STANDARDS NORWAY	jge@standard.no
Alf Reidar Johansen	OGP	Alf.Reidar.Johansen@ogp.org.uk
Per Eirik Fosen	STATOIL	peifo@statoil.com
Morten Bøhlerengen	Moss Maritime	Morten.Bohlerengen@mossww.com
Anatoly Baryshnikov	ENI E&P	Anatoly.Baryshnikov@eni.com
Tore Sildnes	DNV	Tore.Sildnes@dnv.com

Mr. Vernikovskij has acted as Russian co-ordinator, and Mr. Sildnes as working group co-ordinator.

### 1.3. Working program

RN01 has met for 5 workshops during 2010/11. Three workshops have been held at VNIIGAZ premises in Moscow, and two workshops have been arranged at DNV Head Office in Oslo, Norway.

The working group has communicated by E-mail between the workshops.



## 2. MANDATE TASK NO. 1 – RECOMMENDATION FOR DELIVERABLES

Task 1 was given as: “Recommend how phase 3 recommendations and phase 4 deliverables should be structured, edited and published to fit well into the collection of existing standards”.

The working group reported on this task with report GTSNO838/TSI/NOC-J-195 dated 2010-12-07, and presented the recommendations at the Barents 2020 conference in Moscow 2010-12-09.

### 2.1. Alternatives for reporting

In summary the working group identified the following possible options (in no particular order) for formats and labels of final reporting:

1. Barents 2020 technical report (similar to B2020 phase 3)
2. Proposal for industry Guideline(s) or Recommended Practice(s), These could come from:
  - Gazprom (STO)
  - DNV (RP)
  - OGP (Guideline or RP)
3. Proposal for identical Russian/Norwegian national supplementary standard to an ISO Standard:
  - GOST R Standard, Recommendation or “set of rules”
  - NS or NORSOK standard
4. Proposal for national annex to adopted ISO or EN-ISO standard
5. Proposal for an ISO Technical Specification (ISO/TS)
6. Proposal for an ISO Technical Report (ISO/TR)
7. Proposal for an ISO Publicly Available Specification (ISO/PAS)
8. Proposal for an ISO International Workshop Agreement (ISO/IWA)
9. Proposal for an ISO Amendment to existing standard (ISO/Amd)

Further description of the different reporting options are given in the RN01 report 2010-12-07.

As it was realised that the different working groups would have differing needs and target groups for their deliverables, recommendations on most suitable format had to be concluded individually for each group.

The main purpose for considering other than DNV Barents 2020 reports for the deliverables from the different work groups, was to facilitate the next steps in this process (following Barents 2020 project termination) of providing good standards and guidelines for use in oil and gas exploration and

production activities in the Barents Sea and other Arctic areas.

### 2.2. Format of deliverables

Format for deliverables was recommended to be structured and edited as far as reasonably practical in conformance with ISO/IEC Directives, Part 2, “Rules for the structure and drafting of International Standards”. This applied irrespective of type document produced.

Adherence to this principle would assure best possible harmonisation of language and formats used of the Barents 2020 deliverables as seen together with the many international standards references in this project.

### 2.3. Summary of initial recommendations

The initial recommendations are summarised in the table below. For discussion and justification, please refer the RN01 report 2010-12-07.

	Deliverables	Short term use	Long term use
RN02	Technical report with commentaries to ISO 19906	Input to ISO TC67/SC7/WG8	Revised ISO 19906
	Guidance document to ISO 19906 on ice loads	National annex to GOST R ISO and NS-EN-ISO 19906	ISO 19906 revision
RN03	Seminar proceedings on Risk Management	B2020 Paper	N.A.
RN04	Technical report including commentaries to ISO 19906	National annex to GOST R ISO and NS-EN-ISO 19906 ISO Technical Report	ISO 19906 revision or new ISO EER std.
	Guideline on Concept Req. for Arctic Survival Craft	B2020 Technical report Guideline (DNV RP ?)	ISO 19906 revision or new ISO EER std.
	Guideline on tech. spec. for Emergency Response Vessel	B2020 Technical report Guideline (DNV RP ?)	
RN05	Tech. report with proposals to ISO19906	National annex to GOST R ISO and NS-EN-ISO 19906	ISO 19906 revision or new ISO WE std.
	Guideline on Working Environment in the Barents Sea	GAZPROM (STO) DNV RP	New ISO WE std.
RN06	Tech. report including commentaries for ISO19906 state-of-the-art on Ice Management	Input to ISO TC67/WG	ISO 19906 revision or new ISO std. on IM Input to ISO, ref. RN02
RN07	Regional environmental industry standard	TK23 (GOST R and SanPin) (Russia) OLF (Norway)	OGP Arctic Environmental Guidelines

### 3. MANDATE TASK NO. 2 – IMPLEMENTATION OF DELIVERABLES

RN01 task no.2 was given as: “Review deliverables from working groups for compliance with the recommendations report of RN01, and prepare roadmaps for implementation of deliverables”.

The recommendations for implementation of deliverables for the individual working groups are given in the following sub-sections. The recommendations are based on review of draft working group reports as available to RN01 by 2011-12-08.

#### 3.1. RN02 Ice Loads

##### 3.1.1. Deliverables

The deliverables of RN02 will be a report with compilation of suggested changes to ISO 19906 as received from members of the group.

This report which consists of four parts:

1. Introduction
2. The Gap Analysis
3. Background for the suggested changes and some additional information
4. A Guidance Document with the suggested amendments and changes, written in ISO format and ready for submission to the relevant ISO/TC67/SC7 for consideration at the first update of ISO 19906.

##### 3.1.2. Recommendations for implementation of deliverables

It is recommended that the Barents 2020 Steering Committee takes the following actions:

1. Submit Part 4 – Guidance Document – of the report to the national standardisation organizations in Russia and Norway for approval as an identical regional amendment to the Russian and Norwegian national adoption of ISO 19906:2010(E) until a new edition of the international standard is issued.
2. Submit the amendments and changes suggested in Part 4 of the report – the Guidance Document – to the ISO/TC67/SC7 for consideration by the relevant ISO technical panels as an input to an Amendment or as a starting point for work on a new edition of ISO 19906.

##### 3.1.3. Commentary

RN01 recommends to the Steering Committee that effort should be made to ensure that the Russian and Norwegian regional annexes become identical. This means that Russia (Rosstandart) and Norway (Standards Norway) are encouraged to work together (form joint work group) to accomplish this.

The final recommendations for RN02 are in line with the initial recommendations given at the start of phase IV of the Barents 2020 project.

#### 3.2. RN03 Risk Management

##### 3.2.1. Deliverables

RN03’s task for phase IV was the arrangement of two seminars on risk assessment/management in the offshore design process for the Barents Sea, and the application of functional safety standards.

The deliverables will be limited to proceedings from these seminars.

##### 3.2.2. Recommendations for implementation of deliverables

It is recommended that the seminar proceedings are made generally available as B2020 papers/reports:

1. Include seminar introduction/conclusions in the general phase 4 report
2. Produce conference/seminar proceedings as a separate report, also including extract from phase 3 conclusions for this group.
3. Submit the RN03 results to Russian standardization committee TC 23 as basis for development of Russian standard:
4. – Oil and Gas Industries – Offshore Production Units. Guidelines on tools and techniques for hazard identification and risk assessment (based on ISO 17776 and NORSOK Z-013)

##### 3.2.3. Commentary

The final recommendations for RN03 are in line with the initial recommendations given at the start of phase IV of the Barents 2020 project.

RN01 notes that ISO 17776 will shortly be revised with input from NORSOK Z-013.

Following the seminars, it is noted that a number of arctic condition related questions are still left open for possible future deliberation for Barents Sea application.

### 3.3. RN04 Evacuation and Rescue

#### 3.3.1. Deliverables

The deliverables of RN04 will be a report containing:

1. A commentary on the EER provisions in ISO 19906
2. A guidance on creating performance standards
3. A guidance for arctic evacuation methods
4. A guidance for emergency response vessel

#### 3.3.2. Recommendations for implementation of deliverables

It is recommended that the Barents 2020 Steering Committee takes the following actions:

1. Submit the RN04 report to the new ISO Arctic Operations sub-committee (ISO/TC67/SC8) as input for possible new work items within the area of arctic evacuation and rescue.
2. Submit the RN04 report to the Russian standardization organisation TC 23 as basis for development of new national Russian standards:
  - Oil and Gas Industry – Offshore Production Units. Evacuation and Rescue systems. Terms and Definitions
  - Oil and Gas Industry – Evacuation Routes and Temporary Shelters. Major Requirements

#### 3.3.3. Commentary

Initial recommendations also included a recommendation for submittal to Russian-Norwegian national standards associations for issue regional annex to ISO-19906. However, it is considered by RN01 that the report as delivered is best suited for use by standardisation organisations and committees as input for possible future updating of industry standards, rather than as specific annex to the existing ISO 19906.

Furthermore it was initially recommended that guidelines on arctic survival craft and emergency response vessel should be developed and, depending on the maturity of the outcome, be considered implemented as DNV Recommended Practices. RN04 concluded during their work that, standards and suitable equipment for EER in Arctic and sub-Arctic conditions are not yet fully developed and that this is still an area for further research and development. The report provides initial guidance in these areas, however, not yet of a maturity suitable for individual standardization documents.

### 3.4. RN05 Human Factors

#### 3.4.1. Deliverables

The deliverables of RN05 will be a report containing industry guidance for safe working environment for personnel on board ships and offshore installations operating in the Barents Sea.

#### 3.4.2. Recommendations for implementation of deliverables

It is recommended that the Barents 2020 Steering Committee takes the following actions:

1. Submit the RN-05 report to the new ISO/TC67/SC8 Arctic Operations for consideration as a possible new work item proposal for an ISO standard.
2. Submit the RN05 report to the national standardisation organizations of Russia and Norway for information and use as an identical regional amendment to the Russian and Norwegian national adoption of ISO 19906:2010(E) until a new edition of the international standard is issued.
3. Specifically, for Standard Norway, the report is also recommended for input to planned revision of NORSOK S-002 “Working Environment”.

Submit the RN05 report to Classification Societies of Russia and Norway (Russian Maritime Register and DNV) for information and possible use as input to arctic specific class rules/notations.

#### 3.4.3. Commentary

RN01 recommends to the Steering Committee that effort should be made to ensure that possible Russian and Norwegian regional annexes become identical. This means that Russia (Rosstandart) and Norway (Standards Norway) are encouraged to work together (form joint work group) to accomplish this.

It is noted the ISO TC67/SC8 has already identified human factors in their preliminary programme of work.

The initial recommendations of considering the RN05 results for use as a GAZPROM STO or DNV Recommended Practice are recommended to be abandoned.

### 3.5. RN06 Ice Management

#### 3.5.1. Deliverables

The deliverable of RN06 will be a technical report describing “state-of-the-art” for Ice Management.

#### 3.5.2. Recommendations for implementation of deliverables

It is recommended that the Barents 2020 Steering Committee takes the following actions:

- Submit the RN06 report to the new ISO Arctic Operations sub-committee (ISO/TC67/SC8) as input for a series of new ISO standards within the area of ice management.

### 3.5.3. Commentary

It is noted that the preliminary work programme of ISO TC67/SC8 has already identified 5-6 possible work item proposals within the ice management area.

It was initially recommended that the RN06 deliverables should be considered for commentary/ amendment to ISO 19906. This was later excluded from the RN06 scope as to avoid duplication with group RN02, which included ice management assessment in relation to ISO19906 as part of their work.

## 3.6. RN07 Operational Emissions and Discharges

### 3.6.1. Deliverables

The deliverable of RN07 will be a technical report containing a proposal for “Regional guidance document for regular emissions and discharges from offshore oil and gas activities in the Barents Sea including associated shipping”

### 3.6.2. Recommendations for implementation of deliverables

It is recommended that the Barents 2020 Steering Committee takes the following actions:

1. Submit the RN07 report to the Russian standardization committee TC 23 as basis for development of a GOST R standard within this area.
2. Submit the RN07 report to the Norwegian standardisation organization Standards Norway as input to amendment of the NORSOK standard S-003 “Environmental Care”.
3. Submit the RN07 report to OGP (International Association of Oil and Gas Producers) for input to the OGP’s work with an Arctic Environmental Guideline.
4. Issue the deliverables as a separate Barents 2020 report for general industry use.

### 3.6.3. Commentary

The initial proposals of using the results for development of Russian SanPin standard and as input to Norwegian OLF guideline has been abandoned.

## 4. MANDATE TASK NO. 3 – AWARENESS

RN01 task no. 3 was given as: “Create awareness among the potential recipients (e.g. standards organisations) as to what is coming and acting as an intermediary as necessary and appropriate”.

### 4.1. Activities

The following initiatives have been undertaken:

#### International initiatives

- Plenary meeting of ISO TC67/SC7, Singapore, Jan. (participation/presentation)
- ISO/TC67/Management Committee meeting, San Francisco, June (participation/presentation)
- OGP Standards committee meetings (participation/presentation)
- Arctic Co-ordination Task Force meetings (participation/presentation)
- Article published in Article in OGP Standards bulletin 2011

#### Russian Initiatives

- Conference «Arctic is a territory of dialogue» (participation/presentation)
- Annual conference NEFTEGAZ STANDARD 2011 (participation/presentation)
- Two articles in specialist magazines

#### Norwegian initiatives

- Norwegian Sector Board for Petroleum Standardisation (participation/presentation)
- Conference and seminar presentations

## 5. MANDATE TASK NO. 4 – ISO ARCTIC LONG TERM INITIATIVE

RN01 task no. 4 was given as: "Provide proposal for an Arctic long term international standards program (ref. ISO/TC67 MC Ad-hoc group Arctic Operations) and including potentially missing international standards for the broader Arctic environment".

RN01 delivered a proposal for an Arctic long term international standards program by RN01 memo GTSNO838/TSI/NOC-J-197 (Appendix 1) to ISO TC67 Management Committee issued on 2011-06-21. The proposal was intended as an input to the recently formed ISO Ad-hoc group on Arctic Operations within the Technical Committee 67 Management Committee. The memo provided a list of suggested work items for a potential new Arctic Operations Sub-Committee or Working Group under ISO TC67.

The proposal was based upon evaluation of existing standards' suitability for arctic application (ref. Barents 2020 phase 3 report) and identification of potential missing standards.

### 5.1. New Work Item Recommendations

A total of 11 new work item proposals (NWIP) were suggested. These are listed below and described in further detail in the RN01 memo of 2011-06-21.

#### NWIP proposals for Arctic Operation:

- NWIP 1: New ISO Standard: Arctic Operations – "Ice Loads in Structural Design"
- NWIP 2: Arctic Operations – "Topside Facilities" (including among other items):
  - NWIP 2a: Updating/Amendment to ISO 13702 "Control and mitigation of fires and explosions on offshore production installations"
  - NWIP 2b: Amendment of "ISO 15138 Offshore Production Installations – Heating, ventilation and air conditioning"
  - NWIP 2c: Amendment to "IEC60079 – Electrical equipment, Explosive atmospheres and IEC/ISO 80079 Non-electrical equipment - Explosive atmosphere."
  - NWIP 2d: Amendment of: "IEC 61892-7 – Mobile and fixed offshore units, electrical installations, Part 7 – Hazardous areas"
- NWIP 3: New ISO Standard: Arctic Operations – "Escape, Evacuation and Rescue for Arctic conditions"
- NWIP 4: New ISO Standard: Arctic Operations – "Working Environment for Arctic Operations"
- NWIP 5: New group of ISO standards: Arctic Operations – "Ice Management", including 5 standards, covering:
  - Data collection;
  - Oceanological, hydrological and geological survey information supply
  - Ice conditions, monitoring and forecasting
  - Quality standards of IM training companies
  - Ice management training. Specific requirements
- NWIP 6: New ISO standard: Arctic Operations – "Onshore logistics"
  - Specific requirements for loading and unloading operations of transportation of personnel, bulk cargo, liquids, containers, raw materials, crude oil and LNG
- NWIP 7: New ISO standard: Arctic Operations – "Offshore logistics"
  - Specific requirements for loading & unloading operations of transportation of personnel, bulk cargo, liquids, containers, raw materials, crude oil and LNG
- NWIP 8: New ISO standard: Arctic Operations – "Maintenance service"
- NWIP 9: New ISO standard: Arctic Operations – "Staff management"
- NWIP 10: New ISO standard: Arctic Operations – "Offshore structures corrosion protection"
- NWIP 11: New ISO standard: Arctic operations – "Plant security"



## 5.2. Conclusions

The ISO/TC67 MC Ad-hoc group on Arctic Operations used the Barents 2020 memo as a basis for their recommendations to the ISO/TC67 plenary meeting in Moscow, 14-15<sup>th</sup> September 2011, to set up a new subcommittee for Arctic Operations and to invite Russia to propose a chairman and secretary. Reference is made to the ISO/TC67 N 1148 Report ISO TC67 MC AHG Arctic operations, dated: 2011-09-07. (attached as enclosure 1 for reference).

The plenary meeting of ISO/TC67 took a resolution in its meeting 2011-09-15 to establish SC8 “Arctic Operations”. The ISO decision document is attached as enclosure 2.

The SC8 work programme will be developed on the basis of the abovementioned work items.



The formal establishment of SC8 has been approved by ISO Technical Management Board and preparations for the first meeting can start. Detailed new work item proposals are being prepared.

## 6. SUMMARY OF RECOMMENDATIONS

	Deliverables	Recipients	Application
RN02	Guidance (amendment) Document to ISO 19906 on Ice Loads	National Standards Org. Russia/Norway	Regional amendment (identical) to ISO 19906 (until new edition)
		ISO TC67/SC7	Input to next revision of 19906
RN03	Seminar proceedings on Risk Management (including phase 3 conclusions)	Barents 2020 steering committee	General industry use
		National Standards Organisation in Russia (TC23)	New GOST R standard on Risk Assessment
RN04	Technical report on Evacuation and Rescue	ISO TC67/SC8	Future possible NWIP
	Guide for Arctic Evacuation	ISO TC67/SC8	Future possible NWIP
		GOST R TC23	New GOST R standards on EER
	Guide for Emergency Response Vessel	ISO TC67/SC8	Future possible NWIP
RN05	Tech. report on Human Factors	National Std. Organisations Russia/Norway	Regional annex (identical) to ISO 19906 Input to NORSOK S-002 update
		ISO TC67/SC8	Future NWIP
		Russian/Norwegian Class Societies	Basis for Arctic rules
RN06	Tech. report on Ice Management	ISO TC67/SC8	Basis for future NWIP (5-6 proposed standards)
RN07	Regional guidance report on Operational Emissions and Discharges	Industry	Separate Barents 2020 report
		Russian/Norwegian National Std. System	GOST R or SanPin std. NORSOK S-003 amendment
		OGP	Input to Arctic Environmental Guideline

## 7. ENCLOSURES

### 7.1. Enclosure 1: N 1148 Report ISO TC67 MC AHG Arctic operations

			
<b>Secretariat</b> Netherlands Standardization Institute NEN P.O. Box 5059 NL-2600 GB, Delft Netherlands Telephone +31 15 2690 326 Telefax +31 15 2690 207 <a href="mailto:isotc67@nen.nl">isotc67@nen.nl</a>		<b>doc.nr.</b> <b>ISO/TC N 1148</b>	
<b>Secretary :</b> Harold Pauwels telephone +31 15 2 690 163 <a href="mailto:harold.pauwels@nen.nl">harold.pauwels@nen.nl</a>		<b>date</b> 2011-09-07	<b>total pages</b> 4
		<b>item nr.</b>	<b>supersedes doc.</b>
		<b>Committee</b> Title	ISO/TC 67 Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries

Circulated for:	<input type="checkbox"/> comments	<input checked="" type="checkbox"/> discussion
	<input checked="" type="checkbox"/> decision	<input checked="" type="checkbox"/> information

### Report of the ISO/TC 67 Management Committee Ad Hoc Group 'Arctic Operations' (Agendapoint 8.9 of the plenary meeting)

Enclosed the report and advice of the ISO/TC 67 Management Committee Ad Hoc Group 'Arctic Operations'.

Since early 2010 the need for a standards programme on Arctic operations is being discussed in the Management Committee of ISO/TC 67. The Russian Federation started the initiative (as result of the Barents2020 project).

At the ISO/TC 67 Management Committee meeting of February 2010 it was proposed by the OGP Arctic Coordination Task Force to create an AHG (in the management committee) with the scope to advice on the need for standards for arctic (or cold conditions) operations and the way ISO/TC 67 should deal with such standards (based on the Barents 2020 Project).

It was agreed to create this AHG convened by Mr. Mansurov (Russian Federation) This AHG was asked requested to prepare recommendations be ready for discussion at the plenary ISO/TC 67 meeting in October 2010. Members of the AHG:

Marat Mansurov, (chair); Alf Reidar Johansen, OGP (vice chair), Anatoly Baryshnikov, Jan Inge Dalane, Muayyad Ajjawi, Annie Audibert-Hayet, Bill Banner, Roberto Masoni, Greg Lever and a representative from UK.

The terms of reference of the group were:

- Provide a proposal for an Arctic (or cold conditions) operations long term international standards programme.
- Propose the way ISO/TC 67 should deal with such standards.
- Take input from the Barents 2020 project.
- Present a proposal to the ISO/TC67

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At the ISO/TC 67 plenary meeting in 2010 the progress was summarised but the final recommendations and work programme were not ready at that time.

The advice/proposals have been received now from the AHG and are summarised in the following slides.

At the plenary meeting more details on the proposal will be presented.

## ISO/TC 67 MC Ad-hoc Group «Arctic Operations»

Proposal to ISO/TC67 Plenary  
meeting 2011, Moscow

### Terms of References

- ISO/TC67 MC Resolution MC-01-2010 gave AHG the following terms of references:
  - Provide a proposal for an Arctic (or cold conditions) operations long term international standards programme.
  - Propose the way ISO/TC 67 should deal with such standards.
  - Take input from the Barents 2020 project.
  - Present a proposal at the ISO/TC67 plenary meeting in Moscow, September 2011.



## Members

- Marat Mansurov, VNIIGAZ/GAZPROM (chair)
- Alf Reidar Johansen, OGP (vice chair)
- Anatoly Baryshnikov, North Caspian Operating Company
- Jan Inge Dalane, STATOIL
- Muayyad Ajjawi, QATAR PETROLEUM
- Annie Audibert-Hayet, TOTAL
- Bill Banner, TOTAL
- Roberto Masoni, ENI
- Greg Lever, CANADA
- UK (no member nominated)

We propose the following long term program, taking input from Barents 2020:

Title	Timeline			
	2012	2013	2014	2015
PNGI – Arctic operations – Ice loads in structural design	▶			
PNGI – Arctic operations – Topside Facilities, additional tech. requirements (supplements on the basis of ISO 13702, 15138, IEC 60079, 61892-7 etc)	▶			
PNGI – Arctic operations – Working environment	▶			
PNGI – Arctic operations – Escape, evacuation and rescue (based on ISO 19906 and ISO 15544)	▶			
PNGI – Arctic operations – Maintenance services	▶			
PNGI – Arctic operations – Offshore structures corrosion protection	▶			
PNGI – Arctic operations – Ice management. Data collection	▶			
PNGI – Arctic operations – Ice management. Oceanological, hydrological and geological survey information supply	▶			
PNGI – Arctic operations – Ice conditions, monitoring and forecasting	▶			
PNGI – Arctic operations – Ice management. Quality standards of IM training companies	▶			
PNGI – Arctic operations – Ice management training. Specific requirements	▶			
PNGI – Arctic operations – Onshore logistics	▶			
PNGI – Arctic operations – Offshore logistics	▶			
PNGI – Arctic operations – Staff management	▶			
PNGI – Arctic operations – Plant security	▶			

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## ISO/TC67 Structure

- We propose that:
  - ISO/TC 67 establish a new subcommittee “Arctic Operations” to deal with such standards.
  - Russia is invited to propose the Scope and offer the Secretariat for such a new subcommittee.
  - This work is coordinated with ISO/TC67/SC7 and its WG8 Arctic Structures and other relevant SCs and WGs.



7.2. Enclosure 2: ISO Form 03: Decision to establish a subcommittee Arctic Operations

	<table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <th colspan="2" style="text-align: center; padding: 2px;">DECISION TO ESTABLISH A SUBCOMMITTEE</th> </tr> <tr> <td style="width: 50%; padding: 2px;">Date of decision</td> <td style="width: 50%; padding: 2px;">New subcommittee number</td> </tr> <tr> <td style="padding: 2px;">2011-09-15</td> <td style="padding: 2px;">ISO/TC 67/SC 8</td> </tr> </table>	DECISION TO ESTABLISH A SUBCOMMITTEE		Date of decision	New subcommittee number	2011-09-15	ISO/TC 67/SC 8
DECISION TO ESTABLISH A SUBCOMMITTEE							
Date of decision	New subcommittee number						
2011-09-15	ISO/TC 67/SC 8						
<p>This form shall be completed by the secretariat of the ISO parent technical committee concerned and be submitted to the Central Secretariat which will assign it a reference number and submit it to the Technical Management Board for ratification of the decision.</p>							
<p><b>Title of subcommittee</b> (the title shall be unambiguous and as concise as possible)</p> <p><b>Arctic Operations</b></p>							
<p><b>Scope</b> (the scope shall define precisely the limits of the proposed field of activity of the subcommittee within the defined scope of the parent technical committee and shall begin with "Standardization of ..." or "Standardization in the field of ...")</p> <p><b>Standardization of operations associated with exploration, production and processing of hydrocarbons in onshore and offshore arctic regions, and other locations characterized by low ambient temperatures and the presence of ice, snow and/or permafrost.</b></p> <p><b>The work will be executed in coordination with the relevant ISO/TC 67 subcommittees and work groups.</b></p> <p><b>Excluded: Requirements for offshore pipelines that are under SC 2, requirements for offshore structures that are under SC 7.</b></p>							
<p><b>Purpose and justification</b> (the justification shall explain why it is considered necessary to establish a subsidiary body within the parent technical committee, taking into account the additional resources that will be required to operate the subcommittee secretariat)</p> <p><b>To establish a sub committee to concentrate experience and knowledge in cold-climates and work on specific standards for safe operations in Arctic regions.</b></p> <p><b>Today an increasing number of oil and gas companies focus on Arctic regions in the light of promising oil and natural gas fields. However severe weather conditions and lack of practical experience in cold climates result in great challenges for companies to provide safe and cost effective operations in these regions.</b></p> <p><b>Over the last decades the oil and gas industry has accumulated very valuable practical experience and knowledge in onshore projects in cold climates on one hand and offshore projects in more temperate conditions on the other.</b></p> <p><b>The vision is to build on and extend existing practical experience and solutions and to create a new set of standards that take into the account the specific environmental conditions and help define acceptable levels of safety and security for all facilities and processes associated with Arctic operations exploration.</b></p> <p><b>The subcommittee aims to accumulate knowledge of a number of countries like Canada, Denmark, Norway, Netherlands, Russian Federation, United Kingdom and USA. Countries have experience in different aspects of cold-climate and offshore exploration so the best way to consolidate it is to establish a new subcommittee, the more so as such scope is not included in any existing subcommittee of ISO/TC 67.</b></p>							

**Programme of work** (list of principal questions which the parent technical committee wishes to be included within the limits given in the proposed subcommittee scope, indicating what aspects of the subject should be dealt with, e.g. terminology, test methods, dimensions and tolerances, performance requirements, technical specifications, etc.) (attach a separate page as annex, if necessary).

The envisaged SC 8 work programme to start with is about 15 work items. The new subcommittee should include the next subjects and/or standards:

- Working environment in connection with cold-climate conditions (1 standard ready in late 2014);
- Escape, evacuation and rescue (1 standard ready in early 2014));
- Maintenance of onshore and offshore structures (2 standards ready in late 2014);
- Ice management (6 standards ready in 2015);
- Onshore and offshore logistics (2 standards ready in late 2014);
- Plant security (1 standard ready in early 2014).

The detailed new work item proposals are being prepared.

**Survey of similar work undertaken in other bodies** (relevant documents to be considered: national standards or other normative documents)

The following list of standards are some of the relevant standards to be considered:

- ISO 19906 Petroleum and natural gas industries - Arctic offshore structures
- ISO 14040 Environmental management - Life cycle assessment - Principles and framework
- ISO 15138 Petroleum and natural gas industries - Offshore production installations - Heating, ventilation and air-conditioning
- NORSOK C-001 Living quarters area
- NORSOK C-002 Architectural components and equipment
- NORSOK S-001 Technical safety
- NFPA 20 Standard for the Installation of Stationary Pumps for Fire Protection
- DNV-OS-A101 Safety principles and arrangements
- ISGOTT International Oil Tanker and Terminal Safety Guide
- Russian Maritime Register of Shipping: Guide to survey of construction and maintenance of subsea pipelines
- Russian Maritime Register of Shipping: Guide to survey of construction and maintenance of drilling and production offshore platforms

**Member bodies** (at least five P- or O-members of the parent technical committee, having expressed their intention to participate actively in the work of the subcommittee)

Canada  
France  
Netherlands  
Norway  
Russian Federation  
United States of America

**Secretariat** (member body — one of those listed above — having confirmed its readiness to undertake the secretariat of the subcommittee) (see 1.9 and annex E of part 1 of the ISO/IEC Directives)

**Russian Federation (Rosstandart)**

**Nominated Secretary Mrs. Liudmila Zalevskaya (Gazprom VNIIGAZ)**

**(Nominated Chairman Mr. Mikhail Rusakov (Gazprom))**

**Liaison organizations** (list of organizations or external or internal bodies with which cooperation and liaison should be established)

**NFPA**

**Det Norske Veritas**

**International Maritime Organisation (IMO)**

**Other comments** (if any)

**ISO/TC 67 Resolution 2011/34 (Moscow, 2011) - Establishment of Subcommittee Arctic operations**

**Noting**

- the report and advice of the ISO/TC 67/MC AHG Arctic Operations,
- the presentation of Mr. Michael Petrovsky on behalf of the Russian delegation,
- the Russian delegation offered to undertake the secretariat,

**ISO/TC 67**

- decides to establish a new subcommittee "Arctic operations" and to allocate the secretariat to the

**Russian Federation.**

- Welcomes the proposed draft scope Standardisation of technological, processing and service operations in arctic offshore exploration and production including requirements to human safety and plant security.

- welcomes the nominated Secretary Mrs. Liudmila Zalevskaya and Chairman Mr. Mikhail Rusakov as presented by the Russian Delegation.

- requests the Russian Delegation in cooperation with the ISO/TC 67 Management Committee to review and, if necessary, amend the scope, justification and proposed working programme of the Sub Committee and submit the detailed outline to the ISO/TC 67 secretariat within 14 days.

- requests the TC 67 Secretariat to inform the ISO Technical Management Board to ensure ratification of the establishment of the new ISO/TC 67/SC 8 'Arctic Operations'.

Signature of the TC secretary **Harold Pauwels**

**NEN**

# APPENDIX 1. INPUT TO ISO ARCTIC LONG TERM INTERNATIONAL STANDARDS PROGRAM

<i>Memo To:</i>	<i>Memo No.:</i>	GTSNO838/TSI/NOC-J-197
<b>ISO/TC67 MC Ad-hoc Group Arctic Operations:</b> <ul style="list-style-type: none"> <li>• Marat Mansurov, VNIIGAZ, chair</li> <li>• Alf Reidar Johansen, OGP, co-chair</li> <li>• Jan Inge Dalane, Statoil</li> <li>• Anatoly Baryshnikov, NCOC</li> <li>• Muayad Ajjawi, Qatar Petroleum</li> <li>• Annie Audibert-Hayet, TOTAL</li> </ul>	<i>From:</i>	Barents 2020 Work Group RN01
	<i>Date:</i>	2011-06-21
	<i>Prep. by:</i>	Tore Sildnes Co-ordinator Work Group RN01
	<i>Copy:</i>	
<ul style="list-style-type: none"> <li>• Elisabeth Harstad</li> <li>• Leif Nesheim</li> </ul>		

## Introduction

This memo contains a proposal from the Barents 2020 project for an Arctic long term international standards program. The proposal is intended as an input to the recently formed ISO Ad-hoc group on Arctic Operations within the Technical Committee 67 Management Committee.

The memo provides a list of suggested work items for a potential new Arctic Operations Sub-Committee or Working Group under ISO TC67.

The proposal is based upon evaluation of existing standards' suitability for arctic application (ref. Barents 2020 phase 3 report) and identification of potential missing standards. The work has been co-ordinated by the Barents 2020 expert panel RN01 with input from other working groups and from the Russian oil & gas standardisation committee TC 23, VNIIGAZ and Gazprom. The work was commissioned by the Barents 2020 project steering committee in December 2010.

We trust that this information will be of use in your further work, and rest at your disposal in case you should require any further information or assistance.

For further information and details about the Barents 2020 project please refer:

[www.tksneftegaz.ru](http://www.tksneftegaz.ru)

[www.dnv.com/resources/reports/barents2020.asp](http://www.dnv.com/resources/reports/barents2020.asp)

## New Work Item Recommendations

A total of 11 new work item proposals (NWIP) have been suggested. These are listed below and described in further detail in the enclosed NWIP tables.

### NWIP proposals for Arctic Operation:

- NWIP 1: New ISO Standard: Arctic Operations – *Ice Loads in Structural Design*
- NWIP 2: Arctic Operations – *Topside Facilities* (including among other items):
  - NWIP 2a: Updating/Amendment to ISO 13702 “Control and mitigation of fires and explosions on offshore production installations”
  - NWIP 2b: Amendment of “ISO 15138 Offshore Production Installations – Heating, ventilation and air conditioning”
  - NWIP 2c: Amendment to “IEC60079 – Electrical equipment, Explosive atmospheres and IEC/ISO 80079 Non-electrical equipment - Explosive atmosphere.”
  - NWIP 2d: Amendment of: “IEC 61892-7 – Mobile and fixed offshore units, electrical installations , Part 7 – Hazardous areas”
- NWIP 3: New ISO Standard: Arctic Operations – *Escape, Evacuation and Rescue for Arctic conditions*
- NWIP 4: New ISO Standard: Arctic Operations – *Working Environment for Arctic Operations*
- NWIP 5: New group of ISO standards: Arctic Operations – *Ice Management*, including 5 standards, covering:
  - Data collection;
  - Oceanological, hydrological and geological survey information supply
  - Ice conditions, monitoring and forecasting
  - Quality standards of IM training companies
  - Ice management training. Specific requirements
- NWIP 6: New ISO standard: Arctic Operations – *Onshore logistics*
  - Specific requirements for loading and unloading operations of transportation of personnel, bulk cargo, liquids, containers, raw materials, crude oil and LNG
- NWIP 7: New ISO standard: Arctic Operations – *Offshore logistics*
  - Specific requirements for loading & unloading operations of transportation of personnel, bulk cargo, liquids, containers, raw materials, crude oil and LNG
- NWIP 8: New ISO standard: Arctic Operations – *Maintenance service*
- NWIP 9: New ISO standard: Arctic Operations – *Staff management*
- NWIP 10: New ISO standard: Arctic Operations – *Offshore structures corrosion protection*
- NWIP 11: New ISO standard: Arctic operations – *Plant security*



## **Deliverables from Barents 2020 project phase 4**

In addition to the new work items listed above, phase 4 of the Barents 2020 project will produce deliverables which may be useful input for future work in an ISO Arctic Operations committee.

A summary of the planned deliverables by end of 2011 is given in Enclosure 1.

## Detail Description of New Work Item Proposals

<b>BARENTS 2020 PROJECT PHASE IV</b> New Work Item Proposal for ISO TC67 Arctic International Standards Development	NWIP 1
<b>TITLE OF PROPOSAL</b>	
New ISO Standard: Ice Loads in Structural Design (alternatively revision of ISO 19906)	
<b>SCOPE OF PROPOSAL</b>	
<p><b>Background information</b></p> <p>Barents 2020 is developing a guidance document for design against ice loads on stationary floating structures that may serve as a common Russian-Norwegian separate supplement to ISO 19906 for the Barents Sea. The Guidance Document may be submitted, partly or in full, to ISO for their consideration in connection with the first update of ISO19906.</p> <p><b>Proposal</b></p> <p>Barents 2020 has identified ten (10) topics for considerations as amendments to or changes in ISO/DIS 19906 or topic for separate standard on ice loading. The ten topics which were identified by the group are listed in prioritized order below (prioritized meaning largest gaps on top of list):</p> <ol style="list-style-type: none"> <li>1. Floating structures</li> <li>2. Load combinations</li> <li>3. Ice data collection</li> <li>4. Ice management</li> <li>5. Ice basin model tests</li> <li>6. Improved guidance on when and how the ice load approaches in ISO19906 are applicable and their ranges of validity</li> <li>7. Ice induced vibrations</li> <li>8. Loads from icebergs</li> <li>9. Uncertainties</li> <li>10. Icing</li> </ol>	
<b>PURPOSE AND JUSTIFICATION</b>	
<p>Prepare a document for design and operations in the Arctic that will include the identified gaps and may be used as input to the first update of ISO19906 or separate standard.</p> <p>Information on floating structures in the ISO 19906 is limited. E.g., only generalities are offered in the normative part A8 or A13 involving check lists and general recommendations for design, but no guidance on induced ice actions, including ice scenarios is offered.</p> <p>Ideally one would like a standard/code to include information and guidance on a methodology that is accurate. Currently this is missing for floating structures in ice infested waters.</p>	
<b>RELEVANT DOCUMENTS TO BE CONSIDERED</b>	
<ul style="list-style-type: none"> <li>• ISO 19906</li> <li>• Guidance document from Barents 2020, planned end 2011.</li> </ul>	

<b>BARENTS 2020 PROJECT PHASE IV</b> New Work Item Proposal for ISO TC67 Arctic International Standards Development		NWIP 2
<b>TITLE OF PROPOSAL</b>		
New ISO Standard: Arctic Operations – Topside Facilities		
<b>SCOPE OF PROPOSAL</b>		
<p>To make a stand-alone standard for topside oil &amp; gas production facilities with amendments to existing standards. See 2a, 2b, 2c and 2d as examples.</p> <p>Reference is also made to list of standards requiring modification for use in Arctic environment given in Barents 2020 report phase3.</p>		
<b>PURPOSE AND JUSTIFICATION</b>		
<p>ISO 19906 “Arctic Structures” is covering arctic operation specific additional requirements to existing structural ISO TC67 standards. Similarly an “Arctic topsides” standards could be a collection of arctic operation specific additional requirements for topsides systems and installations.</p>		
<b>RELEVANT DOCUMENTS TO BE CONSIDERED</b>		
<ul style="list-style-type: none"> <li>• ISO 19906</li> <li>• Guidance document from Barents 2020, planned end 2011.</li> </ul>		

**BARENTS 2020 PROJECT PHASE IV**  
New Work Item Proposal for  
ISO TC67 Arctic International Standards Development

NWIP  
2a

#### TITLE OF PROPOSAL

Updating/Amendment to  
ISO 13702 “Control and mitigation of fires and explosions on offshore production installations”

#### SCOPE OF PROPOSAL

Amend existing with Arctic specific requirements within areas of:

- Containment (prevent releases of hydrocarbons, chemicals and/or toxic substances)
- Ignitions source control
- Gas detection
- Active fire protection
- Passive fire protection
- Effect of ice/snow on passive fire protection
- Ventilation (natural and mechanical)
- Design and proper operation of HVAC systems in cold environments.
- Explosion mitigation and protection
- Effect of active weather panels on explosion overpressures.
- Explosion risk management
- Guidance on methodology for explosion risk modelling.

#### PURPOSE AND JUSTIFICATION

- The main reference for guidance and requirements for technical safety barriers is “ISO 13702 – Control and mitigation of fires and explosions on offshore production installations”. The objectives and main principles of the standard are generic and can be used for the Arctic.
- The standard should include an informative reference to ISO 19906 for general design principles of offshore arctic structures.
- The functional requirements of ISO 13207 can be used as they are. The informative parts of ISO13207 should be updated to reflect specificities related to design of offshore structures in cold climate. The need for update of the different sections in ISO 13207 giving requirements and guidance on each specific safety barriers is described in the B2020 phase 3 report.

#### Topics include:

- Containment (prevent releases of hydrocarbons, chemicals and/or toxic substances)
- Ignitions source control
- Gas detection
- Active fire protection
- Passive fire protection
- Effect of ice/snow on passive fire protection
- Ventilation (natural and mechanical)
- Design and proper operation of HVAC systems in cold environments.
- Explosion mitigation and protection
- Effect of active weather panels on explosion overpressures.
- Explosion risk management
- Guidance on methodology for explosion risk modelling.

#### RELEVANT DOCUMENTS TO BE CONSIDERED

- ISO 19906
- Barents 2020 phase 3 report

<p style="text-align: center;"><b>BARENTS 2020 PROJECT PHASE IV</b> New Work Item Proposal for ISO TC67 Arctic International Standards Development</p>	<p style="text-align: center;">NWIP 2b</p>
<p><b>TITLE OF PROPOSAL</b></p>	
<p>Amendment of “ISO 15138 Offshore Production Installations – Heating, ventilation and air conditioning”</p>	
<p><b>SCOPE OF PROPOSAL</b></p>	
<p>See description under PURPOSE</p>	
<p><b>PURPOSE AND JUSTIFICATION</b></p>	
<ul style="list-style-type: none"> <li>• This standard specifies requirements and provides guidance for design, testing, installation and commissioning of HVAC and pressurization systems and equipment for offshore installations, fixed or floating, normally and not normally manned. The standard includes requirements and guidance for both natural and mechanical ventilation.</li> <li>• The functional requirements and guidance can be used in the Barents Sea as they are. It is considered that this standard in combination with ISO13207 and NORSOK Z-013 Annex G, gives the best guidance on the relationship between ventilation and explosion risk, and need for simulations to investigate this relationship and provide input to design.</li> <li>• The standard will however be further strengthened by including or referring to the same kind of guidance on ventilation and explosion risk in cold climate as is proposed for ISO 13207 and NORSOK S-001.</li> <li>• The standard should also refer to ISO19906 for main principles with respect to design of HVAC systems for cold regions, and to IEC 61892-7 for requirements to power supply for HVAC systems.</li> </ul>	
<p><b>RELEVANT DOCUMENTS TO BE CONSIDERED</b></p>	
<ul style="list-style-type: none"> <li>• ISO 19906</li> <li>• Barents 2020 phase 3 report</li> </ul>	



**BARENTS 2020 PROJECT PHASE IV**  
New Work Item Proposal for  
ISO TC67 Arctic International Standards Development

NWIP  
2c

#### TITLE OF PROPOSAL

Amendment to  
“IEC60079 – Electrical equipment, Explosive atmospheres and IEC/ISO 80079 Non-electrical equipment - Explosive atmosphere.”

#### SCOPE OF PROPOSAL

Update standards for arctic application in areas as exemplified as follows:

- Validity for temperatures below -20 °. IEC TC31 MT to consider the operating temperature range -20°C to -60 C°, in all relevant standards listed.
- Component protection according to Part 5 and 18 of IEC 60079 which must be used inside other protections need to be fit for arctic temperatures like lighting fittings, electronic units, amplifiers, transmitters, fuses, control units.
- Requirements for temperature during installation and maintenance
- Lubrication of bearings, need for special grease for low temperatures
- Charging of batteries is difficult at low temperatures (below -5° C)
- Fluorescent lightning will have reduced/no effect (not possible to switch on below – 25° C)
- Electric heat tracing provides more accurate temperature control.
- The operating procedures of equipment shall be adjusted for operation in arctic and cold regions environments, and the criticality of such equipment or systems shall be taken into consideration.
- Intrinsically safe characteristics can change and this must be reflected by selecting barriers accordingly.

#### PURPOSE AND JUSTIFICATION

These serial of standards contain descriptions on how to produce and calculate explosion protected equipment and systems with different methods of protection, selection of equipment, and installation requirements for each protection type to avoid ignition. Both IEC60079 and IEC80079 need to be updated for application in cold regions and in the Barents Sea.

#### RELEVANT DOCUMENTS TO BE CONSIDERED

- ISO 19906
- Barents 2020 phase 3 report

**BARENTS 2020 PROJECT PHASE IV**  
New Work Item Proposal for  
ISO TC67 Arctic International Standards Development

NWIP  
2d

#### TITLE OF PROPOSAL

Amendment of:  
“IEC 61892-7 – Mobile and fixed offshore units, electrical installations , Part 7 – Hazardous areas”

#### SCOPE OF PROPOSAL

See description under PURPOSE

#### PURPOSE AND JUSTIFICATION

- IEC 61892 forms a series of International Standards intended to enable safety in the design, selection, installation, maintenance and use of electrical equipment for the generation, storage, distribution and utilization of electrical energy for all purposes in offshore units which are used for the purpose of exploration or exploitation of petroleum resources.
- Part 7 contains provisions for hazardous areas classification and choice of electrical installation in hazardous areas in mobile and fixed offshore units.
- Arctic condition require that the standard need to take in new requirements for selection of materials to be described, cable and cable installation requirements, layout to get access to exposed equipment for maintenance purposes and heating methods of walls and structures.
- Part 7 does not give any general requirements to ambient temperatures.
- The standard need to take in additional requirements for arctic conditions to secure that the artificial ventilation will function even if the main system failure. The air intakes and capacity of the HVAC system must not be affected by atmospheric or sea spray icing.
- The HVAC system must also ensure that the concentration of explosion substances in atmosphere shall not increase due to sheltering of process or drilling areas.
- On these areas it is recommended that the standard refer to ISO13207 and ISO 19906, to give consistent guidance. ISO 19906 requires that redundancy shall be provided for emergency power generation for all structures in cold regions (ISO19906). IEC61892 - Part 7 must describe back up sources requirements to maintain the ventilation required for area classification or other means of protecting the plant if the system should fail. This can for example be to require a higher level of explosion protection of operating equipment.

#### RELEVANT DOCUMENTS TO BE CONSIDERED

- ISO 19906
- Barents 2020 phase 3 reports

**BARENTS 2020 PROJECT PHASE IV**  
New Work Item Proposal for  
ISO TC67 Arctic International Standards Development

NWIP  
3

#### TITLE OF PROPOSAL

New ISO Standard: Escape, Evacuation and Rescue for Arctic conditions

#### SCOPE OF PROPOSAL

See description under PURPOSE

#### PURPOSE AND JUSTIFICATION

- Evacuation and rescue may have higher probability to fail and less efficiency due to darkness, cold and ice conditions. Evacuation and rescue require a high degree of manual actions and visual observation that can be difficult in cold climate and darkness or low visibility.
- Icing may impair the operability of movable parts, like launch mechanisms for lifeboats. Doors and hatches to enter lifeboats may get impaired by ice, and boxes where safety equipment like lifevests are stored might be difficult to open. There is little experience on evacuating offshore installations in pack ice and drifting ice.
- In such case conventional lifeboats or free fall lifeboats can not be applied. Standby vessels/ice breakers should therefore be ready to assist in the evacuation.
- Rescuing personnel from the sea or from lifeboats relying on external resources (helicopter etc.) will be less efficient due to remoteness and arctic weather conditions.
- Emergency Preparedness plans need to be detailed and accommodate for arctic conditions.
- Safety equipment (dry suits) and personal protective equipment must be appropriately designed for arctic conditions. Evacuation means must be able to be operated manually in cold climate, and must not be affected by icing of doors and release mechanisms etc.
- The long response time from shore may increase the time it takes to bring rescued personnel to hospital for required treatment. This may raise the need for medical doctors stationed onboard the installations, to be able to give necessary medical treatment in sufficient time.
- Man over board situations is more difficult to handle in darkness, reduced visibility and in high seas. Work above sea shall always be subject to a work permit taking into considerations the weather conditions, and establishing emergency preparedness in order to be able to rescue personnel falling into the sea within a required time. In the North Sea this time is 8 minutes

#### RELEVANT DOCUMENTS TO BE CONSIDERED

- ISO 19906
- Barents 2020 phase 3 report
- Guidance document from Barents 2020 phase 4

**BARENTS 2020 PROJECT PHASE IV**  
New Work Item Proposal for  
ISO TC67 Arctic International Standards Development

NWIP  
4

#### TITLE OF PROPOSAL

New ISO Standard: Working Environment for Arctic Operations

#### SCOPE OF PROPOSAL

**Develop new ISO standard based on NORSOK S-002 including following arctic specific aspects:**

- Work in cold environment: health aspects of work in extreme climates
- Winterization: design and technical solutions related to cold climate
- Noise & vibration: specific problems related to cold climate and ice conditions
- Stress management: work situations in extreme climate zones
- Training and competence: working in the Arctic

#### PURPOSE AND JUSTIFICATION

NORSOK S-002 provides reasonably comprehensive guidance — at a functional level — on working environment issues, yet is weak on Arctic-relevant aspects. These weaknesses can be resolved by development of a new ISO standards based on NORSOK S-002 and development of arctic specific requirements related to this standard.

Much relevant information, standards, regulations and guidance, are available, particularly from Russian sources, on cold climate and Arctic operations.

#### RELEVANT DOCUMENTS TO BE CONSIDERED

- ISO 19906
- NORSOK S-002
- Barents 2020 phase 3 report
- Guidance document from phase 4 of Barents 2020

**BARENTS 2020 PROJECT PHASE IV**  
New Work Item Proposal for  
ISO TC67 Arctic International Standards Development

NWIP  
5

#### TITLE OF PROPOSAL

**New group of ISO standards: Ice Management, including 5 standards:**

- PNGI – Ice management. Data collection;
- PNGI – Ice management. Oceanological, hydrological and geological survey information supply
- PNGI – Ice management. Ice conditions, monitoring and forecasting
- PNGI – Ice management. Ice management. Quality standards of IM training companies
- PNGI – Ice management. Ice management training. Specific requirements

#### SCOPE OF PROPOSAL

**These standards specify general requirements for:**

- Hydro-meteorological security of offshore constructions in the Arctic Basin
- Data collection of models of Arctic multiphase system
- Arctic multiphase system of nature, ocean, men (humans), technologies – content and general requirements
- Ice management as a part of Arctic Basin management
- Circulations of sea current, heat and fresh water – monitoring and forecasting
- Diagnostic and forecasting modeling for ice system development
- Evaluation of abnormal situations of ice system – data requirements

#### PURPOSE AND JUSTIFICATION

**Purpose:**

To specify all necessary information for hydro- meteorological security and ice protection for offshore constructions, evaluation of abnormal situations of ice system, to prevent the incidents

**Justification:**

- E&P of oil gas in Arctic Basin requires the full data complex about state of Arctic multiphase system
- Ice management needs to get a wide range of oceanological, hydrological and geological survey information.
- New standards should contain requirements to information which is collecting for monitoring and forecasting of ice movement.

#### RELEVANT DOCUMENTS TO BE CONSIDERED

- ISO 19906
- Barents 2020 phase 3 report
- Guidance document from Barents 2020 phase4



<b>BARENTS 2020 PROJECT PHASE IV</b> New Work Item Proposal for ISO TC67 Arctic International Standards Development		NWIP 6
<b>TITLE OF PROPOSAL</b>		
New ISO standard: Onshore logistics <b>Specific requirements for loading and unloading</b> operations of transportation of personnel, bulk cargo, liquids, containers, raw materials, crude oil and LNG		
<b>SCOPE OF PROPOSAL</b>		
<p><b>This standard specifies general requirements on:</b></p> <ul style="list-style-type: none"> <li>• Onshore drilling maintenance facilities</li> <li>• Subsea production complex and equipment maintenance facilities</li> <li>• Custom requirements on staff and cargo transportation:                             <ul style="list-style-type: none"> <li>– Security of personnel transportation</li> <li>– Specific demands for loading&amp;unloading operations in cold climate and darkness</li> <li>– Operations, limited due to weather conditions</li> </ul> </li> </ul>		
<b>PURPOSE AND JUSTIFICATION</b>		
<p><b>Purpose:</b></p> <ul style="list-style-type: none"> <li>• To identify undesirable events that pose a safety risk, and define reliable protective measures that will prevent such events or minimize their effects if they occur</li> <li>• To establish guidelines for analyzing the steps of operations that are significantly different from those outside the Arctic</li> </ul> <p><b>Justification:</b>                      Verify the needs for basic safety operations in the entire process</p>		
<b>RELEVANT DOCUMENTS TO BE CONSIDERED</b>		
<ul style="list-style-type: none"> <li>• ISO 19906</li> <li>• Barents 2020 phase 3 report</li> <li>• Guidance document from Barents 2020 phase4</li> <li>• ISO 19901-6:2009 Petroleum and natural gas industries – Specific requirements for offshore structures – Part 6: Marine operations</li> </ul>		

**BARENTS 2020 PROJECT PHASE IV**  
New Work Item Proposal for  
ISO TC67 Arctic International Standards Development

NWIP  
7

#### TITLE OF PROPOSAL

New ISO standard: Offshore logistics Specific requirements for loading & unloading operations of transportation of personnel, bulk cargo, liquids, containers, raw materials, crud oil and LNG

#### SCOPE OF PROPOSAL

The scope of this new project is to provide an international standard :

- Specific requirements for loading and unloading operations of staff and cargo transportation and also on transportation of, liquids, containers, raw materials, crude oil and LNG:
  - Security of personnel transportation,
  - Specific demands of loading & unloading operations in cold climate and darkness
  - Operations, limited due to weather conditions

#### PURPOSE AND JUSTIFICATION

**Purpose:**

- To identify undesirable events that pose a safety risk, and define reliable protective measures that will prevent such events or minimize their effects if they occur
- To establish guidelines for analyzing the steps of operations that are significantly different from those outside the Arctic region

**Justification:**

Verify the needs for basic safety operations in the entire process of transportation operations

#### RELEVANT DOCUMENTS TO BE CONSIDERED

- ISO 19906
- Barents 2020 phase 3 report
- Guidance document from Barents 2020 phase4
- ISO 19901-6:2009 Petroleum and natural gas industries – Specific requirements for offshore structures – Part 6: Marine operations

<b>BARENTS 2020 PROJECT PHASE IV</b> New Work Item Proposal for ISO TC67 Arctic International Standards Development		NWIP 8
<b>TITLE OF PROPOSAL</b>		
New ISO standard: Maintenance service		
<b>SCOPE OF PROPOSAL</b>		
<ul style="list-style-type: none"> <li>• Support manning of the offshore oil and gas production complex, pipeline transportation systems, risers, anchor’s arrangements of buoys</li> <li>• Maintenance of facilities including on-site inspection, exploratory survey, testing, reconditioning and unscheduled repairs</li> </ul>		
<b>PURPOSE AND JUSTIFICATION</b>		
<p><b>Purpose:</b></p> <ul style="list-style-type: none"> <li>• To identify regular service operations for equipment and constructions</li> <li>• To define the main requirements to the industrial outsourcing</li> </ul> <p><b>Justification:</b></p> <ul style="list-style-type: none"> <li>• To provide the rules for choosing, examining and training of outsourcing firms for regular service operations for equipment and constructions</li> </ul>		
<b>RELEVANT DOCUMENTS TO BE CONSIDERED</b>		
<ul style="list-style-type: none"> <li>• ISO 19906</li> <li>• ISO 10418</li> <li>• ISO 13702</li> </ul>		

**BARENTS 2020 PROJECT PHASE IV**  
New Work Item Proposal for  
ISO TC67 Arctic International Standards Development

NWIP  
9

**TITLE OF PROPOSAL**

PNGI – Arctic operations – Staff management

**SCOPE OF PROPOSAL**

**Background information:**

Arctic offshore E&P process makes a number of strong requirements to organizational structure and management regarding to cold climate conditions, risk assessment and high safety level. This requirements become more significant for big international oil and gas companies inasmuch as they have large branchy organizational structure that is not yet adapted for Arctic conditions.

**These standards specify general requirements for:**

- Principles of organizational structure
- List of staff positions
- Hierarchy of staff positions
- Main response for each staff position
- Information and control communications

**PURPOSE AND JUSTIFICATION**

**Purpose:**

To identify special staff positions, responsibilities and communications required in oil Arctic offshore gas exploration and production.

**Justification:**

E&P of oil&gas fields in Arctic area is a challenge for international petroleum and natural gas industry. Lack of practical experience in Arctic offshore exploration requires setting up of new approach of staff management to meet cold climate requirements and provide safe and effective operations.

**RELEVANT DOCUMENTS TO BE CONSIDERED**

- ISO 19906
- Barents 2020 phase 3 report
- Guidance document from Barents 2020 phase 4

<b>BARENTS 2020 PROJECT PHASE IV</b> New Work Item Proposal for ISO TC67 Arctic International Standards Development		NWIP 10
<b>TITLE OF PROPOSAL</b>		
PNGI – Arctic operations – Offshore structures corrosion protection		
<b>SCOPE OF PROPOSAL</b>		
<p><b>Background information:</b>                      Offshore installations and structures need highly effective corrosion protection. Existing corrosion protection standards setting up a number of requirements for offshore structures regarding to operation in seawater thus there is no requirements at all with respect to protection of structures operating in seawater and cold climate simultaneously.</p> <p><b>These standards specify general requirements for:</b></p> <ul style="list-style-type: none"> <li>• Principles of corrosion protection of structures and equipment operating in cold seas</li> <li>• Approach to corrosion protection</li> <li>• Organizational measures for corrosion protection</li> <li>• Technical measures for corrosion protection</li> </ul>		
<b>PURPOSE AND JUSTIFICATION</b>		
<p><b>Purpose:</b>                      To specify custom requirements for corrosion protection system of offshore structures, installations and equipment suitable for Arctic sea conditions</p> <p><b>Justification:</b>                      E&amp;P of oil&amp;gas in Arctic area is a challenge for international petroleum and gas industry. Miss of appropriate standards containing requirements for corrosion protection of offshore structures, installations and equipment can not provide reliable and safe operations/</p>		
<b>RELEVANT DOCUMENTS TO BE CONSIDERED</b>		
<ul style="list-style-type: none"> <li>• ISO 19906</li> <li>• Barents 2020 phase 3 report</li> <li>• Guidance document from Barents 2020 phase 4</li> </ul>		

**BARENTS 2020 PROJECT PHASE IV**  
New Work Item Proposal for  
ISO TC67 Arctic International Standards Development

NWIP  
11

#### TITLE OF PROPOSAL

PNGI – Arctic operations – Plant security

#### SCOPE OF PROPOSAL

##### Background information

Recent catastrophic events at Macondo and Montatra wells showed to the world how bad an oil spillage could be and its devastating impact to marine biosphere. Those accidents were caused by technical issues. Though such consequences might be caused by other causes also technical or non-technical like terrorism, human factor etc. Therefore there is a need of a specific standard setting up a set of requirements in regard to security of offshore facilities operating in Arctic seas

##### These standards specify general requirements for:

- Identification of risks
- Organizational measures for risks reduction
- Technical measures for risk reduction

#### PURPOSE AND JUSTIFICATION

##### Purpose:

To specify requirements for risk identification and reduction at offshore structures, installations and equipment operating in Arctic seas

##### Justification:

Recent accidents at offshore oil rigs caused extremely bad consequences and nature destruction. Arctic conditions significantly complicate elimination of negative effects of oil spills in that cold, polar night and other negative natural factors.

#### RELEVANT DOCUMENTS TO BE CONSIDERED

- ISO 19906
- Barents 2020 phase 3 report
- Guidance document from Barents 2020 phase 4



## Enclosure 1 – B2020 Project Phase 4 Planned Deliverables

### BARENTS 2020 PHASE 4

#### LIST OF PLANNED DELIVERABLES (Status per 2011-05-20)

	Deliverables	Short term use	Long term use
RN02	Technical report with commentaries to ISO 19906	Input to ISO TC67/SC7/WG8	Revised ISO 19906
	Guidance document to ISO 19906 on ice loads	National annex to GOST R ISO and NS-EN-ISO 19906	ISO 19906 revision or new ISO ice loading std.
RN03	Seminar proceedings on Risk Management	B2020 Paper	N.A.
RN04	Technical report including commentaries to ISO 19906	<ul style="list-style-type: none"> <li>National annex to GOST R ISO and NS-EN-ISO 19906</li> <li>ISO Technical Report</li> </ul>	ISO 19906 revision or new ISO EER std.
	Guideline on Concept Req. for Arctic Survival Craft	<ul style="list-style-type: none"> <li>B2020 Technical report</li> <li>Guideline (DNV RP ?)</li> </ul>	ISO 19906 revision or new ISO EER std.
	Guideline on tech. spec. for Emergency Response Vessel	<ul style="list-style-type: none"> <li>B2020 Technical report</li> <li>Guideline (DNV RP ?)</li> </ul>	
RN05	Tech. report with proposals to ISO19906	National annex to GOST R ISO and NS-EN-ISO 19906	ISO 19906 revision or new ISO WE std.
	Guideline on Working Environment in the Barents Sea	<ul style="list-style-type: none"> <li>GAZPROM (STO)</li> <li>DNV RP</li> </ul>	New ISO WE std.
RN06	Tech. report including commentaries for ISO 19906 on Ice Management	Input to ISO TC67/WG8	ISO 19906 revision or new ISO std. on IM
RN07	Regional environmental industry standard	<ul style="list-style-type: none"> <li>TK23 (GOST R and SanPin) (Russia)</li> <li>OLF (Norway)</li> </ul>	OGP Arctic Environmental Guidelines





