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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 67, *Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries*, Subcommittee SC 8, *Arctic operations*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

This document specifies requirements and recommendations applicable to ice management for oil and gas operations in arctic and cold regions.

Ice management (IM) is defined as the sum of all activities, carried out with the objective to mitigate hazardous situations by reducing or avoiding actions from any kind of ice (sea ice or glacial ice), and includes:

— establishment of an understanding of the ice regime and potential ice hazards prior to the initiation of operations;

— operational surveillance, including detection, tracking and forecasting;

— identification and evaluation of any physical threat to the operation;

— a working ice alert system and associated procedures;

— physical ice management by the supporting IM vessels, including ice breaking and/or iceberg management;

— procedures associated with the safe avoidance of potentially hazardous ice;

— documentation of IM performance and revision of the IM system to ensure continuous improvement;

— relevant procedures associated with the safe shut-down of floating structures (moored or DP), both active (move off and ice management) or semi passive (ice management, but no move off);

— relevant procedures associated with the safe shut-down of bottom-founded structures, both active (with ice management and move-off capability), or passive (fixed with ice management).

This document describes performance requirements and recommendations to ensure timely identification of ice hazards, their mitigation through ice management, and securement of the facility if necessary.

This document is intended to ensure that ice management operations are planned, engineered, integrated and implemented whenever needed. Performance requirements of an ice management system can depend on the type of facility and the operations undertaken on the facility. Particular emphasis is placed on ensuring adequate performance in circumstances where there is little prior experience with a particular facility or in a particular geographical region.

This document consists of a normative part and an informative part. The normative part considers the overall operations, hazards and possible counter measures, systems and procedures.

Annex A contains a HAZID workbook, which is to be used in conjunction with the relevant clauses when preparing an ice management plan.

Annex B provides informative data, which supplements the normative part and is to be read in conjunction with the main body of the document.

There are other International Standards which are also relevant to ice management, such as ISO 35101 for working environments and ISO 35106 for arctic and cold regions data requirements (for design and operation). In addition, ISO 19900 specifies general principles for the design and assessment of offshore structures subjected to known or foreseeable types of actions, applicable worldwide to all types of offshore structures, including bottom-founded structures as well as floating structures, and ISO 19906 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.

Petroleum and natural gas industries — Arctic operations — Ice management

1 Scope

This document establishes the principles, specifies the requirements and provides guidance for ice management (IM) in arctic and cold regions, from the point of view of planning, engineering, implementation and documentation. Reference to arctic and cold regions in this document is deemed to include both the Arctic and other regions characterized by low ambient temperatures, sea ice, icebergs and icing conditions. These regions are often remote and lacking in marine and communications infrastructure.

Ice management to support the following in-ice activities and infrastructures are covered by this document:

— floating moored and/or dynamically positioned drilling vessels, coring vessels, production facilities and work-over vessels;

— construction and installation (includes trenching, dredging, pipe laying);

— tanker loading and other offloading operations;

— protecting subsea structures and equipment;

— seismic operations;

— oil spill response;

— bottom founded structures (fixed platforms and movable structures, including jack-ups).

This document also applies to mobilization, demobilization and construction support services, because these can be affected by ice conditions.

In view of the wide range of possible offshore operations in arctic and cold regions, this document provides guidelines, but does not present typical ice management plans for field operations.

This document does not provide requirements, recommendations or guidance pertaining to the design of structures, systems and components used in ice management, beyond the principles given. This document does not provide specific formulations for ice loads, which are covered by ISO 19906.

This document is not applicable to coastal port operations and to commercial trading vessels conducting transit or convoy operations.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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.

ISO 19901-1, *Petroleum and natural gas industries — Specific requirements for offshore structures — Part 1: Metocean design and operating considerations*

ISO 19901-6, *Petroleum and natural gas industries — Specific requirements for offshore structures — Part 6: Marine operations*

ISO 35106, *Petroleum and natural gas industries — Arctic operations — Metocean, ice, and seabed data*

POLAR CODE IMO International Code for Ships Operating in Polar Waters

IMO STCW. International Convention on Standards of Training, Certification and Watchkeeping for Seafarers

WMO n° 574, Sea ice information services in the world

3 Terms, definitions and abbreviations

3.1 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1.1
design
process of designing facilities and the IM system to be used for the intended operations

3.1.2
design ice envelope
range of offsets and combined ice and metocean actions that pose no threat to the facility or operation

Note 1 to entry: See 3.1.22 for factored design ice envelope or operating ice envelope.

3.1.3
facility
plant, rig, or platform, fixed or floating, stationary or mobile, on- or offshore, for use in oil and gas exploration, production or support.

Note 1 to entry: In this document, the term 'facility' is often used to represent the full range of facilities and operations supported by IM, as outlined in Clause 1.

Note 2 to entry: Under certain circumstances, the term 'facility' can also be deemed to include tankers and other vessels connected to the rig or platform.

Note 3 to entry: The term 'facility' is also used to define training centres.

3.1.4
hazard
potential source of harm

Note 1 to entry: Harm is typically differentiated between harm to personnel, harm to the environment, or harm in terms of costs to organization(s) or society in general.

3.1.5
hazard identification
systematic identification of all plausible hazards for IM operations, including detection, monitoring, ice alerting, dissemination and human factors

3.1.6
HAZID table
formalized tabular method of addressing hazard identification for different operations

3.1.7
ice alert
mandatory system response to an ice hazard

3.1.8
ice alert colour code
system consisting of colours, each defining a specific status of the operation, in which the colour defines the risk level

3.1.9
ice alert system
ice alerting system
staged series of mandatory system responses to ice hazards

3.1.10
ice certificate
design curves or envelopes of best estimates for admissible (safe) speeds for the vessel in various ice conditions, with or without IM vessel or escort vessel

Note 1 to entry: The ice certificate was originally developed as a Russian safe speed system and is presently adopted by several classification societies. The IMO Polar Code requires a polar ship certificate (using POLARIS or similar system) that includes similar information to the ice certificate. In addition, the IMO Polar Code requires a polar waters operations manual.

Note 2 to entry: The ice certificate is not generic, but is ship and operation specific.

3.1.11
ice detection
procedures used to identify specific ice features and conditions within prevailing metocean conditions

3.1.12
ice hazard
hazardous ice
ice event triggering an ice alert

Note 1 to entry: Ice events can involve ice conditions or ice features and their proximity to the facility, in combination with particular metocean conditions.

Note 2 to entry: Potentially hazardous ice or a potential ice hazard can involve ice features or conditions with the potential to activate an ice alert at some time in the future.

3.1.13
ice hazard distance
distance of potentially hazardous ice from the facility

3.1.14
ice hazard time
estimated time for potentially hazardous ice to reach the facility

3.1.15
ice management plan
IM plan
plan associated with offshore ice management operations for a specific facility at a specific site

3.1.16
ice management system
IM system
all elements used for ice management combined in a systematic manner

Note 1 to entry: This includes detection, monitoring and forecasting, decision making, hazard analysis, physical ice management, ice alerting, recording, performance analysis and continuous improvement.

3.1.17
ice regime
consistent and recurring ice conditions

Note 1 to entry: The ice management (IM) and ice alert systems are applied to transform the ambient ice regime into a managed ice regime reaching the protected facility or operation.

3.1.18
multi-year ice
sea ice that has survived at least two summers' melt seasons

3.1.19
nowcast
present state of ice and metocean conditions based on the best available data and interpretations, and representing the starting point for future forecasts

3.1.20
offshore installation manager
competent person, certified according to applicable regulations, appointed to manage the offshore activities of the facility

3.1.21
old ice
sea ice that has survived at least one summer's melt season

3.1.22
operating ice envelope
factored design ice envelope, representing the most severe combination of ice and metocean actions or conditions under which the facility is allowed to operate

Note 1 to entry: Factors can be specified or dictated by design standards to ensure adequate structural or operational reliability.

Note 2 to entry: A relationship can be established between the ice and metocean actions (loads) on the facility and the ice and metocean conditions associated with the managed ice regime.

3.1.23
polar low
small-scale, short-lived, atmospheric low pressure system (depression) within the context of larger mesoscale weather systems

3.1.24
recording
all processes used to record collected data

Note 1 to entry: Forms of recording can be in log books, spread sheets or as part of an electronic data collection system.

3.1.25
T-time
termination time
time required to ensure the safety of the facility

Note 1 to entry: The T-time can potentially involve securing wells, as well as disconnection and move-off for a floating structure.

Note 2 to entry: The T-time can vary according to the particular operation being carried out on the facility, whether the facility is in a normal or emergency operating state, and on the progress of procedures undertaken to ensure the safety of the facility.

3.1.26
T-distance
termination distance
distance equal to the drift speed of an ice hazard toward the facility multiplied by the T-time

3.1.27
threat assessment
analysis of occurrence, timing, extent and probability that the operating ice envelope of a facility is likely to be exceeded

3.1.28
unanticipated event
combined ice and metocean event that has not been incorporated in the IM and ice alert systems, but which could occur and affect the facility or operation

3.1.29
unforecast event
combined ice and metocean event that has not been forecast, but which could occur and affect the facility or operation

3.2 Abbreviated terms

AARI	Arctic and Antarctic Research Institute (St. Petersburg, Russia)
CIS	Canadian Ice Service (Ottawa, Canada)
CPA	closest point of approach
DP	dynamic positioning
DS	ice drift speed
EER	escape, evacuation and rescue
HAZID	hazard identification
HSSE	health, safety, security and environment
HT	ice hazard time
IM	ice management
IMO	International Maritime Organization
MMO	marine mammal observer
MT	move off time
NIC	National Ice Center (Washington DC, USA)
OIM	offshore installation manager
ST	secure time
UAV	unmanned aerial vehicle

4 General ice management requirements

4.1 Fundamental requirements for an ice management system

4.1.1 General

An IM system shall be implemented

a) if required according to the design criteria for a facility, e.g. ISO 19906, or

b) to support a facility or operation listed in Clause 1, where an assessment has been made and it has been determined that an IM system is required.

For a facility or operation covered by point b), the assessment should consider design and operational constraints, the local ice regime for the season(s) under consideration, and the capacity to withstand ice actions.

To ensure that the IM system functions as intended, acceptance criteria shall be established using the measures of IM performance outlined in Clause 6.

4.1.2 Ice management plan

All IM assets, systems and procedures shall be documented in an IM plan (see Clause 5).

The IM plan shall remain in place over the design service life of the facility or the duration of the operation protected by the IM system and shall be revised to reflect changes to the operation of the facility, to the physical environment, and to IM assets, systems and procedures.

The IM plan shall apply to a specific facility or operation and should only be reused if the operation is repeated with the same IM assets under the same circumstances.

4.1.3 Ice alert system

An IM plan shall include an ice alert system, which involves specified operational responses to hazardous ice conditions, the status of the facility and parameters associated with the facility. Specified operational responses can include:

1) physical ice management to prevent potentially hazardous ice conditions from becoming hazardous, whether by changing the drift trajectory of ice features, reducing the size of ice features or applying other strategies;

2) other procedures and activities associated with the IM system;

3) suspension of operations;

4) securement or shut-in;

5) evacuation of personnel;

6) disconnection and move-off;

7) abandonment of facilities that cannot be moved.

The status of the facility can involve:

a) the types of operations being conducted on the facility and their progress;

b) the status of the stationkeeping system, where applicable;

c) whether the facility is in a normal or emergency operating state.

Parameters associated with the facility can include:

— offsets or other displacements;

— measured loads;

— vibration levels.

The ice alert system shall involve stages or levels, each of which is defined in terms of a time to enact operational responses to specified ice hazards.

For circumstances when any part of the ice alert system cannot be executed, contingency measures shall be in place, including an emergency response plan and the assets available for its enactment.

When a facility is reliant on IM operations (see 4.1.1), compliance with the ice alert and emergency response systems is mandatory.

Further ice alert system requirements are provided in 6.5 and 9.5.

4.1.4 Hazardous ice conditions

Hazardous ice conditions are those triggering responses within the context of the ice alert system. Such conditions can involve:

a) proximity of an ice feature to the facility or operation under the protection of the IM system;

b) size or thickness of the ice feature or features;

c) manageability of the ice features or conditions;

d) drift speed or wave-induced motions of the ice feature;

e) encroachment of ice into or onto a part of the facility that is not designed to resist ice actions;

f) pack ice pressure.

4.2 Safety requirements

4.2.1 Ice management approach

The commitment of IM resources and the deployment strategy should be consistent with the type of operation undertaken and with ice and metocean conditions.

4.2.2 Redundancy

Redundancy should be considered for all aspects of IM operations, including systems, procedures, and resources. The degree of redundancy should include allowance for downtime due to maintenance.

Redundancy should also be provided for data collection, storage, communication, and presentation systems to ensure that data streams are maintained regardless of weather, temperature, precipitation, and in the event of power failures. Redundancy should include flexibility in terms of the location of the IM base of operations.

Redundant systems and barriers should be verified to ensure adequacy with respect to common causes and independent functionality.

4.2.3 Existing operations

IM operations should be planned and executed with a full knowledge of the operating procedures associated with adjacent facilities and other activities in the region. Details of existing practices, including the times, durations and circumstances associated with them, and their regional extent should be considered.

IM operations should be designed to minimize the impacts on existing practices.

4.3 Safe learning

4.3.1 Safe learning principles

Safe learning principles shall be adopted throughout the design, planning and operation phases, shall be part of the continuous improvement of the process, and shall be applied to all aspects of IM operations.

Safe learning shall involve the joint training of key participants in physical IM operations (platform, tankers, support vessels and icebreakers), particularly with respect to difficult circumstances (e.g. changes in the ice drift direction) and emergency situations (e.g. engine failure, propeller damage). When unanticipated or unforecast events have taken place, the circumstances associated with them shall be incorporated in revisions to the IM plan and in joint training programmes.

IM operations should be initiated conservatively with high contingencies until experience is gained with the operation of the facility. A cautionary approach should be adopted due to uncertainties associated with unanticipated and unforecast events, and appropriate safety margins should be applied to actions (i.e. loads) and responses (e.g. offsets).

These contingencies and safety factors may be adjusted over time, as experience and increased confidence are gained. This performance-based safety system should allow the updating of the operating ice envelope.

4.3.2 Continuous improvement

Continuous improvement should be made to the IM system in terms of personnel, equipment and system integration to ensure that the original objectives continue to be met.

Circumstances where the IM system does not function as intended shall be documented. IM performance measures are dealt with in Clause 6. Lessons learned shall be incorporated in the IM plan, and through changes to IM procedures and equipment.

4.4 Risk management

4.4.1 General requirements

Risk management shall be applied to the design and implementation of IM systems to reduce the effects of ice hazards and to limit the overall risk. Risk management should address:

a) assessment of risk potential due to ice hazards;

b) prevention of ice hazards wherever possible;

c) controls to reduce the potential consequences of ice hazards;

d) measures to mitigate the consequences of an incident, should one occur.

Reference can be made to ISO 17776 for strategies to manage risks that can potentially be applied to IM operations.

4.4.2 Hazard identification and consequences

For IM operations in arctic and cold regions, risk management shall involve:

a) identification of all plausible hazards, directly or indirectly related to the presence of sea ice, icebergs, icing conditions and cold temperatures;

b) evaluation of potential consequences to life, the environment, operational success, asset integrity and tolerance of equipment to the ice hazards identified in a);

c) inclusion of the ice hazards identified in a) into operational decision making.

4.4.3 Responsibility for risk management

The overall responsibility for risk management shall be clearly defined when planning IM operations.

Personnel and organizations involved in IM system design and operation shall take part in the HAZID studies.

4.4.4 Use of risk assessment

An assessment should be made of potentially hazardous ice situations to rank the risks associated with various events, by consideration of probabilities and consequences.

Clear go no-go criteria should be specified for each phase of the operation and incorporated in the ice alert system (see 4.1.3).

Appropriate techniques to evaluate risks include, but are not limited to:

a) design and execution: HAZID and scenario-based risk assessments;

b) execution implementation: job safety analysis, hazard hunts and tool-box talks, which can be applied at field supervision level;

c) quantitative risk assessment: to compare levels of risk between alternatives and to enable rational choices to be made.

4.5 Health, safety, security and environment

4.5.1 Health, safety, security and environment plan

The IM plan and associated operations shall be incorporated in the HSSE plan (see also ISO 19901-6). The objectives of the HSSE plan with respect to IM operations should be to:

a) document the processes and procedures that apply to the IM system;

b) identify, assess and manage hazards and risks arising from the IM system, reducing them to as low as reasonably practicable;

c) ensure that safety is inherent in planning and design of the IM system;

d) ensure minimal impact on the environment;

e) protect the health of IM team and other personnel;

f) protect IM and other assets.

The HSSE plan shall include HSSE activities during all phases of the IM system, from design and planning through to execution of the operation.

4.5.2 Safe working environment

Safe working hours shall always be part of any operation, but special consideration shall be given to operations in the arctic and cold regions characterized by darkness, low visibility, possible icing, and low temperatures. Working hours should also reflect the exposure of IM vessel personnel to noise, vibrations and sudden motions associated with icebreaking activities.

The effects of human factors shall be considered with respect to all operations on deck, other activities on the facility and IM vessels, and activities related to ice hazard identification and mitigation. Aspects of operations that are hazardous to personnel shall be identified and mitigated.

Where relevant for IM personnel, the provisions of ISO 35101 can be applied to the outdoor working environment.

4.5.3 Incident reporting

During IM operations, incident reporting should include (see also ISO 19901-6):

a) periodic reports;

b) incident, accident and near-miss accident reports;

c) pollution or substantial threat of pollution reports.

4.5.4 Compliance with health, safety, security and environment requirements

Areas of jurisdiction should be identified for all planned IM operations. The IMO Polar Code shall be applied for all phases of operations, where applicable.

The following aspects could affect IM operations:

a) vessel exclusion zone for a facility;

b) operation of UAVs;

c) operation of underwater vehicles;

d) operation of propulsion systems;

e) operation in environmentally sensitive areas;

f) deployment of tracking buoys;

g) crew transfer operations;

h) interaction with wildlife.

4.6 Organizational functions and procedures

4.6.1 General requirements

Where possible, IM systems, including ice detection and monitoring, IM vessel operations and performance monitoring should be coordinated with other operational policies and procedures.

Organizational functions and procedures for the performance of ice management marine operations shall be documented. The degree of documentation shall be commensurate with the complexity and risks involved in the operation. Manuals shall be provided. Further details of specific open water operations can be found in ISO 19901-6.

4.6.2 Organization and communication

4.6.2.1 Organization

An appropriate organizational system shall be set up, illustrating how the IM operations integrate with the rest of the operations of the facility. Key responsibilities shall be clearly defined. The following items shall be included:

a) owner's organization and management structure for the operation of the facility;

b) contractor's management structure for the operation of the facility and IM system;

c) engineering design;

d) IM including the facility and IM vessels;

e) HSSE;

f) project controls;

g) quality;

h) authority levels and line of command;

i) interface management.

4.6.2.2 Operational organization

Separate organization charts shall be drawn up for each marine operation, showing the reporting line within the overall organization. The details of the organization charts and their overall setup should be consistent with the size or complexity of the facility, the intended operations and should be limited to the parties actually involved.

4.6.2.3 Operational management

Operational management and roles shall be clearly defined and communicated to all personnel, and should include:

a) definition and publication of responsibilities and duties for the various ice alert stages, associated with each position, to minimize uncertainties and overlapping responsibilities;

b) identification of hand-over period from one organization to another (e.g. fabrication to tow out, mobilisation and offshore marine operations, demobilization, or hand-over from onshore to offshore which can be affected by harsh conditions including ice);

c) fluent communication for key personnel participating in a marine operation in one common language;

d) identification of any organizational changes in the case of an emergency response;

e) identification of back-up services, including emergency services, contingency assistance and technical advisory services;

f) identification and installation of functional communication systems for the area.

4.7 Specific design, planning and execution requirements

The HAZID tables in Annex A provide guidance for the design, planning and execution phases of IM and can be used as a basis for the development of an IM plan.

Operations considered in Annex A include:

a) drilling;

b) bottom-founded structures;

c) construction and installation;

d) offloading;

e) floating production;

f) oil spill response, and

g) seismic survey.

For each type of operation, the HAZID tables include surveillance, physical IM, threat assessment, and logistics operations phases.

Reference should be made to ISO 17776 in the development and use of HAZID tables.

5 Ice management plan (IM plan)

5.1 IM plan scope

The IM plan shall contain sufficient and appropriate information to ensure safe and reliable operations when ice hazards are present.

The IM plan shall provide documentation of:

a) operational aspects of the facility;

b) physical environmental inputs and forecasting requirements;

c) the expected performance of the IM system;

d) the expected geographical range of IM operations;

e) communication systems and procedures;

f) ice detection and monitoring systems;

g) potentially hazardous ice features and conditions associated with IM operations;

h) the ice alert system (see 4.1.3), including an ice alert manual;

i) detailed procedures associated with IM, including physical IM strategies;

j) IM equipment specifications and guidelines for the use of such equipment;

k) IM vessel capabilities;

l) personnel roles, responsibilities, accountability, qualifications and training;

m) quality assurance and quality control;

n) IM performance checks (see 6.3).

5.2 IM plan implementation

For offshore facilities reliant on IM (see 4.1.1), the IM plan shall be:

— available for immediate and direct access on the facility, on IM vessels and at locations where personnel are involved in the management of the offshore operation;

— integrated with operating manuals, operations procedures manuals and other relevant manuals, potentially by means of bridging documents.

IM operations shall not commence until:

a) an IM plan has been formulated;

b) the plan has been tested by a formal hazard and operability assessment;

c) appropriate training has been undertaken (see Clause 11);

d) the plan is physically supported by the necessary resources and assets.

5.3 IM plan maintenance

The IM plan should be updated annually over the operating life of the facility to reflect safe learning principles (see 4.3). Updates to the IM plan should:

— reflect changes in the operation of the facility and the corresponding T-times;

— reflect changes in the available IM resources, technologies and capabilities;

— reflect changes to strategies and procedures;

— reflect changes to the physical environment;

— ensure that the effectiveness of the IM system is consistent with changes to the design and operational requirements of the facility.

6 Ice management system performance

6.1 High-level IM system issues

As outlined in 4.1.1, IM system performance requirements can be dictated by ISO 19906 or developed for a specialized facility. The following requirements apply in the latter case.

a) An operating ice envelope shall be developed. This envelope is typically based on a design ice envelope representing structural design limits for the facility associated with relevant ice actions (i.e. ice loads), which is suitably-factored to ensure an adequate safety margin. The operating ice envelope is generally expressed in terms of ice actions or offsets for floating structures but can also involve structural vibrations and other factors.

b) A managed ice regime that does not exceed the operating ice envelope shall be defined. While the managed ice regime typically involves a threshold ice feature size, it can also involve a wide range of combinations of ice and metocean conditions.

c) An alert system shall be developed according to 4.1.3. IM responses undertaken as part of the alert system shall be used to transform the ambient ice regime to a managed ice regime interacting with the facility by mitigating the ice hazards outlined in 4.1.4.

6.2 Measures of IM performance

Performance indicators should be clearly defined and should be measurable and actionable.

IM system performance can be evaluated in terms of:

a) maintaining the operating ice envelope for the facility, or

b) maintaining a managed ice regime that is consistent with the operating ice envelope for the facility;

c) fulfilling the provisions of the alert system;

d) design or operational adequacy of the IM system.

For measures a) and b), IM system performance can be assessed based on the proportion of successful operations over a series of events for which IM operations were actually conducted through engagement of the ice alert system.

For measure c), performance can be assessed based on the adequacy of the alert system to ensure the targeted managed ice regime or the operating ice envelope (see 6.3).

For measure d), performance can involve the ability of the IM system to perform as designed or failure to meet intended IM objectives for whatever reason (see 6.3). In such cases, a sufficient period of operational experience shall be assessed to ensure that the full range of ice conditions expected at the facility is considered.

IM performance can be assessed for the entire IM system or for some particular aspect such as ice detection or physical IM.

6.3 Demonstration of intended performance

An IM system shall achieve a level of overall system performance consistent with acceptable risks to personnel and the environment. An IM system supporting a facility covered under point a) of 4.1.1 can be subject to a level of overall system performance dictated by ISO 19906.

Additional IM performance levels can be required to minimize downtime and ensure asset integrity.

For facilities reliant on IM, a quantitative verification shall be made to demonstrate that the intended performance of the IM system can be achieved for the applicable ice regime. The verification should be made by means of field performance data for similar IM systems or through simulation procedures verified using field performance data. Where field performance data are inadequate, the verification can be assisted by means of physical model tests, numerical models and analytical models that are calibrated to field data. The accuracy associated with IM system performance assessments should be documented.

While the overall performance requirements of the integrated ice detection, monitoring and physical management system are demonstrated, consideration should be given to limitations in the performance of individual components of the IM system.

If IM performance for sea ice is established based on the managed ice regime, corresponding sea ice actions on the facility should be assessed based on field data for managed ice, or on physical model data or calculations that have been validated with field data.

6.4 IM system design

In the design phase of an IM program, analyses shall be conducted to:

a) document the ambient ice regime at the operational site or region for the planned duration of the operation, based on historical data or dedicated field programs;

b) develop IM strategies for dealing with the potential range of ice scenarios associated with the ambient ice regime for a variety of IM resources and configurations, based on IM performance in similar ice conditions or by means of dedicated field programs;

c) estimate the level of effort required to transform the ambient ice regime into a suitable managed ice regime, in terms of the number and capability of IM vessels.

An iterative approach can be used to establish an optimal solution in terms of downtime and cost.

6.5 Degradation of ice alert and IM system performance

Events for which ice alert and IM systems do not perform as intended can occur when:

a) operational situations arise that are not covered adequately by the ice alert system or the IM responses (e.g. unforecast or unanticipated ice and metocean conditions);

b) when there are design deficiencies in the ice alert and IM systems;

c) the managed ice regime is inadequate for ensuring the operating ice envelope, or the operating ice envelope does not ensure the design ice envelope or design criteria;

d) the ice alert system or IM system is not executed as intended (e.g. human error, decision-making error, failure to detect ice hazards, equipment malfunction, inadequate IM resources available, IM plan or ice alert system non-compliance).

Such events shall be documented in detail with respect to ice conditions, metocean conditions, IM operations undertaken, operational responses of the facility and the decision-making process. These events shall be used in the ongoing improvement process (see 4.3).

6.6 Operating ice envelope

Operating ice envelopes and managed ice regimes shall be documented. Contingencies and safety factors should be documented and revised as appropriate. Operating ice envelopes can potentially be modified as a result of changes to industry best practices and measured operational performance following the "learning by doing" or safe-learning approaches (see also 4.3).

Documentation should also be provided to ensure that the operating ice envelope can be maintained by execution of the responses included in the ice alert system.

6.7 Operational readiness of IM system

Prior to the start of the operation or commissioning of the facility, field calibration of the IM system and its components shall be carried out when risk to life and the environment are minimal. Forecasting systems, ice detection systems and intended managed ice regimes shall be validated.

Provision shall be made for specifying the effectiveness of IM systems, procedures and equipment, time allowances, and thresholds precipitating action.

In the case of infrequent hazardous ice events, procedures should be in place to maintain operability, rapid reactivation capability and timely mobilization of all IM system components.

6.8 Performance monitoring and documentation

The updrift ambient ice regime, and managed ice regimes around the IM vessels and the facility shall be documented over the course of IM operations. The frequency of documentation should be consistent with the identification and evolution of events discussed in 6.2. Corresponding metocean and IM activities shall be documented. For data recording (see 7.5).

The performance of the IM system shall be documented in terms of the various measures outlined in 6.2.

6.9 Maintenance and improvement

The operations and associated IM operations in arctic and cold regions shall be a process of continuous learning and improvement (see 4.3).

IM system performance from actual operations shall be used to update the IM plan and may be used to update the operating ice envelope.

The intended performance of the IM system should be maintained by meeting the acceptance criteria over the design service life of the facility. IM system performance should be documented at regular intervals.

7 Data requirements

7.1 General ice management data requirements

Ice and metocean data requirements should reflect:

a) the type of operation, whether ongoing (e.g. drilling, production), intermittent, or of finite duration (e.g. seismic, offloading, mobilization);

b) geographical location;

c) region of influence or interest;

d) time of year for operation;

e) presence, containment, and transfer of hydrocarbons and other pollutants;

f) presence and activities of personnel;

g) presence and activities of production vessels, IM vessels, and other vessels;

h) specific data requirements pertaining to IM operations in arctic and cold regions.

Consideration shall be given to information on:

1) facility performance;

2) facility operations;

3) IM vessel performance;

4) logistics and infrastructure;

5) ice hazards and their consequences, ice alerts;

6) factors affecting human performance (see ISO 35101).

Particular requirements and guidelines for ice and metocean data are provided in ISO 35106.

7.2 Parameters and conditions

7.2.1 Ice and metocean parameters

Physical environmental parameters to be monitored should include:

a) ice types and conditions, including drift speed and direction, as they pertain to IM operations;

b) dimensions of physically-identifiable features of relevance for IM operations, including sea ice thickness;

c) wave conditions (including swell);

d) wind conditions;

e) current speed and direction (including depth profiles for iceberg-prone areas), tides and sea levels;

f) water temperature (including depth profiles for anticipating ice growth and decay);

g) icing of structure;

h) visibility (fog, precipitation and darkness);

i) air temperature.

Facility operation, IM operation and region-specific considerations should be used to determine which parameters are of key importance; distinctions should be made between sea ice and glacial ice conditions.

Monitoring, analysis and forecasting shall be carried out as appropriate for the operation, the physical environmental conditions and the operational constraints. Combined events as well as potentially extreme events shall be given proper consideration.

7.2.2 Monitoring of operational parameters

During IM operations, monitoring of environmental and operational parameters shall be conducted:

1) to determine the safety of an operation;
2) to provide information that could be analysed to improve the operation and similar operations;
3) to update the ice alert system;
4) for forensic assessment, in the event of a problem.

Operational parameters that can be monitored include:

a) structure response, including offsets and accelerations (floaters, fixed platforms);
b) stationkeeping system performance (floaters);
c) distance off wellhead or offset (floaters);
d) local ice actions on structural components;
e) global actions on structure (fixed platforms);
f) ice encroachment and ice accumulation around a facility.

7.2.3 Combined situations

The simultaneous occurrence of ice and metocean processes, leading to situations that are worse than the processes in isolation, should be documented and monitored.

7.2.4 Managed ice conditions

Ice conditions should be consistently monitored and recorded:

a) in the geographical region over which the physical IM operation is undertaken;
b) over areas under observation by the IM system;
c) prior to (unmanaged ice conditions) and subsequent to engagement (managed ice conditions) by IM vessels;
d) continuously for the entire duration of the operation.

7.2.5 Wildlife observations

Wildlife activities should be monitored when:

a) wildlife pose a risk to personnel;
b) IM operations place the wildlife at risk;
c) the presence of wildlife can impede or result in suspension of IM operations.

7.3 Timeline

7.3.1 Planning situations

Site-specific physical environmental data (see 7.2.1) should be collected over several operating seasons or obtained from historic data sources. At the planning stage, these data should be assessed to assist with:

a) selection and contracting of IM vessels and equipment, including installation;

b) IM vessel performance assessment and allocation;

c) development of ice and metocean forecast capabilities;

d) instrument and system verification;

e) implementation of new systems and protocols;

f) identification of the duration of operational season (e.g. drilling).

7.3.2 Strategic situations

Strategic situations, in which physical environmental data are collected and interpreted, shall be defined in the context of the IM plan. Strategic situations do not generally involve activities to address ice alerts.

For strategic situations, data shall be collected and analysed in support of:

a) deployment or preparation of equipment;

b) IM vessel or aircraft mobilization;

c) satellite image scheduling;

d) forecasting of metocean parameters;

e) sea ice drift forecasting and glacial ice trajectory forecasting;

f) identification of potentially hazardous ice features;

g) decision-making regarding changes to operations.

For strategic purposes, potentially hazardous ice features should be identified, where possible, well before reaching the site of the operation.

Ice formation and initiation of ice movement should also be monitored, physical characteristics should be documented, and travel times to the site of the operation should be estimated.

The state of the operations should be reflected in the strategic data requirements (see ISO 35106).

7.3.3 Tactical situations

Tactical situations, involving specific actions to address ice alerts, shall be defined in the context of the IM plan. Tactical situations often involve the deployment of specialized resources, including IM vessels and evacuation systems. Data acquired for tactical operations shall recognize the state of the operations, including:

a) T-time;

b) EER constraints;

c) loading/unloading constraints;

d) IM vessel activities;

e) facility or operation constraints.

Activities for which these data can apply include:

1) direct use in management of vessel operations;

2) forecasting;

3) IM vessel and IM system support;

4) ice hazard assessment.

Prioritized monitoring protocols shall be established for tactical situations in terms of spatial resolution of data, frequency of observations, and redundancy of measurements.

7.3.4 Phases of operations

Limiting ice and metocean parameter values, and combinations of parameter values shall be defined for each phase of the operation.

Contingency plans shall be prepared for the possible delay or postponement of each phase of the operation. Ice and metocean data shall be collected and analysed to ensure that safe options are provided for each phase.

7.4 Forecasting

7.4.1 General

Personnel with experience in metocean and ice forecasting should be involved in IM forecasting services.

Metocean and ice forecasts shall address the requirements of the IM system.

Forecasts should be provided in near real-time whenever possible.

Forecasts can be distinguished in tactical or short term (up to a few days), long term (days to weeks or even months) and seasonal forecasts (freeze up and break up). All three types should be considered, depending on the planned operations. The frequency of forecasts should be determined based on the nature of the operation, the IM resources and the rate of change of the ice and metocean processes.

The physical environmental parameters to be included in ice forecasting shall be in accordance with ISO 19901-1, ISO 19901-6 and ISO 35106.

7.4.2 Accuracy

All forecasting shall be conducted in the context of a continuous improvement process (see 4.3), including:

— verification of quality and reliability of data inputs;

— regular collection of data appropriate for the verification of forecasts;

— regular re-assessment of actual forecast accuracy based on measured data;

— provision of quantitative description of forecast accuracy, uncertainty or confidence level, using appropriate statistical analyses;

— periodic improvements to model formulations and parameters based on assessments of forecast accuracy.

Corrections to forecasting models can be required when conditions change.

Ice drift forecasting shall be tailored to the actual operations and the expected conditions. Consideration should be given to best estimates and conservative estimates of drift parameters, depending on the particular requirements of the IM and alert systems.

The forecasting accuracy shall be commensurate with the needs of affected operations and with local conditions.

To ensure continuous improvement in forecasting services, all forecasts issued during IM operations shall be stored together with recorded metocean and ice data. During operations, biases in metocean and ice forecasts should be checked on a daily basis during the operation and the data collected should be used as feedback for the current operation. As a part of lessons learned at the end of each season, the quality of forecasts should be assessed.

7.4.3 Metocean data

An enhanced observational metocean network should be considered for the area of operations.

More detailed and frequent metocean forecasts should be requested for operations that are particularly sensitive to environmental conditions and for which ice forecasting is required.

7.4.4 Ice management forecast parameters

7.4.4.1 List of parameters

Forecasts should be specific to each IM situation, should consider data from a variety of sources and should typically include:

a) surface wind speed and direction;

b) assessment of surface current speed and direction, including tidal effects, commensurate with the level of predictability within the basin;

c) wind-generated waves and swell, with due account for the presence of sea ice;

d) small-scale atmospheric phenomena such as polar lows;

e) ice edge, where appropriate;

f) ice feature location, drift speed, direction, and closest point of approach to facility or operation (generally for sea ice and feature specific for icebergs, ice islands/fragments, ice shelf fragments, multi-year ice floes, and other discrete ice features);

g) pack ice pressure;

h) precipitation and visibility;

i) freeze-up and break-up dates;

j) ice accretion and assessment of impact with respect to deck surfaces and equipment operation;

k) estimate of iceberg mass;

l) any other features or anomalies specific to the location.

7.4.4.2 Wind forecasts

Wind forecasts shall be based on global and local weather systems, make use of field data and provide reliable data for extended periods. Wind data recorded locally shall be made available in near real-time to relevant forecasting agencies.

7.4.4.3 Wave forecasting

Where applicable, the presence of sea ice should be factored into wave forecasts.

Where the effectiveness of IM operations is constrained by sea state, consideration should be given to local wave measurements.

7.4.4.4 Swell forecasting

Swell forecasts should reflect the presence of sea ice and other local conditions.

7.4.4.5 Current forecasting

Local and global currents, including tidal effects, should be forecast using the best available models and tools.

7.4.4.6 Ice drift forecasting models

Ice drift modelling and forecasting for both pack ice and glacial ice shall be based on validated models, where possible.

7.4.4.7 Icing forecasting

Icing forecasting shall be based on relevant ice and metocean data, as well as the physical attributes, operating characteristics and motions of IM vessels and the facility.

7.4.4.8 Forecasting polar lows

For operations in open water in proximity to sea ice, traditional weather forecasting services should be supplemented with forecasts of conditions associated with polar lows and an assessment of the probability for occurrence of polar lows (e.g. low, medium or high) should be made. Particular consideration should be given to the integration of past experience into forecast models.

7.4.5 Nowcasts

Nowcasts shall be prepared where possible and when needed, representing the best possible compilation of the actual conditions.

Interpretation of past and present conditions shall be undertaken and forecasts shall be used to bridge any gaps from historic data to current data.

Nowcasts should be the basis of future forecasts.

7.4.6 Forecasts for weather windows

Forecasts of key parameters shall be provided for the weather window and such forecasts shall be updated when new data are available that would change the previously-issued forecast.

7.5 Data collection

7.5.1 General

Consideration should be given to:

a) spatial extent and resolution;

b) frequency of measurements;

c) the IM plan;

d) forecasting requirements.

7.5.2 Data quality

As a minimum, ice data shall be collected according to WMO n° 574 specifications.

The accuracy of the ice data should be commensurate with the requirements of the IM plan.

The accuracy of the ice data shall be in accordance with ISO 35106, which can include comparison with historic data, public data bases or other sources.

Validation shall be carried out in near real-time for all ice and metocean data. Errors should be identified and corrected.

7.6 Data organization

7.6.1 General requirements

All data collected should be organized with respect to:

a) date and time of the observation;

b) source of the data and physical location;

c) destination in terms of dissemination system, location, and personnel;

d) type of product — measurement, forecast, climatological value, and statistic (mean, standard deviation, extreme value);

e) representation (e.g. point, grid, vector, text, image, video);

f) spatial representation and resolution, including regularity of points;

g) time resolution, including regularity of points.

7.6.2 Accuracy and bias of data

The accuracy and bias of each data source should be noted, made available on demand, and updated regularly.

7.6.3 Instrument specifications

Instrument specifications and calibration values shall be readily accessible.

7.6.4 Data backup

Back-up storage means shall be provided for all data collected, with due consideration of alternative media, power failures, and separate physical locations.

Back-up means of access shall be available for all data in the event of failure of the primary means of access.

7.7 Data dissemination

7.7.1 General

The decision-making process and chains of command shall be taken into account in the specification of recipients for data products and for the means of communication.

Systems shall be in place to ensure that all ice and metocean data, both recent and historical, are available on request to all personnel involved in the IM operation. All relevant information should be processed, including data collected from IM vessels.

Data shall be available on a timely basis. If data processing systems require significant processing times, essential (raw) data shall be made available in the interim.

Reliable means of voice communication shall be in place and available for dissemination of important data in critical situations.

7.7.2 Communications and infrastructure

A communications infrastructure shall be developed, including the primary facility, IM vessels, support vessels, local onshore locations, and relevant remote locations. Means and methods of communication as well as bandwidth restrictions shall be determined. The type, content, and frequency of data exchanges shall be factored into the system design and operation.

All vessels involved in an operation should have the means to share ice and system performance data with the other vessels in the fleet. Consideration should also be given regarding real-time availability of such information onshore and at offshore platforms or facilities.

The provision of a wireless local area network (WLAN) should be considered in remote areas where permissible to ensure reliable and independent communications.

7.7.3 Presentation

Provision should be made to ensure:

1) access to data in standardized formats;

2) that requirements for data quality and timeliness are included in the IM plan;

3) use of fixed protocols and associated coding for data exchanges and recording.

The dissemination and tagging of data should consider the end users, access to information and data priority.

8 Ice detection and tracking

8.1 Objectives

Ice detection and tracking systems shall:

a) provide discrimination capability for all ice conditions, ice types and ice features in the region of interest;

b) provide sufficient information to allow for the ongoing tracking of potentially hazardous ice features;

c) provide sufficient information to characterize potential threats associated with point a), consistent with the ice alert system;

d) be supported by metocean monitoring, including wind, waves, current strength and direction (at various depths), atmospheric conditions, snow, visibility, polar lows, and others.

The capabilities of detection and tracking systems should be sufficiently broad to deal with the potential for infrequent, unanticipated and unforecast events.

Consideration should also be given to provision of:

— long-range detection and tracking capability to ensure adequate detection success and forecasting accuracy;

— an increasing level of detail and coverage with proximity to the facility;

— enhanced ice navigation information to be used in strategic and tactical IM operations.

8.2 System criteria

Systems used for ice detection and tracking shall:

a) involve appropriate and effective technology;

b) be calibrated and tested prior to the start of IM operations for the range of ice conditions and operational situations expected;

c) provide adequate and demonstrable capability for the expected ranges of sea states, visibility (darkness, fog, precipitation) and ice conditions;

d) allow for the measurement of accurate geographical locations, physical dimensions, physical states, and drift of ice features;

e) provide a means for near real-time and accurate integration of measurements into databases and threat assessment systems;

f) provide the capability to identify and correct erroneous information;

g) be staffed by trained and experienced personnel, with the skills to discriminate between different ice types and features and to understand the physical environmental processes acting on them;

h) be reliable and maintainable by the crew;

i) provide sufficient redundancy to ensure uninterrupted coverage over the geographical region of interest;

j) provide information accessible from the facility and all IM vessels.

Ice detection probability can vary according to sensor type, range, sea state, feature size and shape, ice type and precipitation. Detection capabilities can be degraded significantly in adverse weather conditions.

Suitable ice detection systems shall be in place in the event that IM operations are extended beyond the expected operating period, when more severe ice and metocean conditions can occur.

8.3 Detection capabilities

Observation platforms can include satellites, aerial assets (fixed wing aircraft, helicopters, and unmanned aerial vehicles), facilities and IM vessels.

The use of dedicated ice radars should be considered for use on the facility and on IM vessels.

Where possible, aerial reconnaissance assets should be considered as a primary means of ice detection or as a secondary means to verify data collected from remotely sensed imagery. If used as a primary means of detection, adequate planning and back-up systems should be in place for when weather restrictions prevent their use. Aerial reconnaissance assets should have a functional ice radar for low visibility situations and to increase observation range.

Ice features and conditions interpreted from satellite imagery should be verified on an ongoing basis with data obtained from IM vessels, the facility and other more direct sources.

8.4 Tracking capabilities

The re-identification of identifiable ice features shall be made with time and space resolutions that are consistent with threat assessment protocols.

The re-identification of ice features shall be sufficiently reliable to prevent misidentification that could result in significant underestimation or overestimation of threats.

Consideration should be given to the use of automated tracking algorithms and tracking systems that involve forecast information. Tracking methods should be verified and validated with recorded data.

Checks on re-identified ice features shall be made by placing realistic bounds on drift parameters (e.g. speed) and by means of other considerations, including ice feature dimensions and positional errors associated with the measurement technique.

In critical situations, uncertainty in re-identification of ice features shall be resolved using other information sources. If unable to ensure re-identification in such situations, potential concerns should be flagged and relevant IM personnel should be notified.

If remotely sensed images or other periodic data collection methods are used to track ice features, the potential for error should be acknowledged.

IM vessels can be used to track ice hazards on a continuous basis by drifting with particularly hazardous conditions or features.

9 Threat evaluation and response

9.1 Threat evaluation strategy

Threat evaluation strategies involve:

a) data collection, forecasting and analysis (see Clause 7);

b) ice detection and tracking (see Clause 8);

c) identification of potential ice hazards (see 4.1.4);

d) designation of ice hazards through the activation of alert levels and implementation of the alert system (see 4.1.3);

e) responses dictated by the alert system, including escalation or de-escalation of the alert level, physical IM (see Clause 10), changes to the operational procedures of the facility (e.g. shut-in, de-manning, disconnection, move-off), and activation or deactivation of the emergency state of the facility;

f) identification of other threats associated with the ice regime that are not dealt with by the alert system or the IM plan (see 6.5, 9.9), assessment of risks and consequences, and the appropriate responses identified in point e).

9.2 Identification of ice hazards

All potential ice hazards shall be identified and the ice alert system shall be applied to upgrade these to ice hazards, where appropriate.

Hazardous ice situations can be defined according to:

a) the origin and type of ice (e.g. sea ice, old sea ice, ridges and rubble fields, stamukhi, brash ice, icebergs, ice islands);

b) the dimensions of the ice (e.g. thickness, floe size, plan dimensions, draft, height);

c) the state of the ice (e.g. concentration, pack ice pressure, degree of decay or melt, and consolidation of brash ice, ice rubble, ridges and stamukhi);

d) the proximity of the ice feature to the facility or operation under consideration (accounting for travel distance and time, closest approach distance and time, and T-time);

e) other difficult or unexpected circumstances that can influence the effectiveness of the IM system (such as sudden and unexpected changes in drift direction; difficult visibility as a result of darkness, fog, snow and other forms of precipitation; combinations of ice and metocean conditions).

False identification of ice hazards should be minimized, particularly if this detracts from the overall effectiveness of the IM system, but without impairing ice hazard identification capability. This can potentially be accomplished through ground truthing, verification by independent means, and through increased frequency of observations.

Hazardous ice situations shall be reassessed regularly to ensure that their state and evolution (e.g. drift) are correctly ascertained.

9.3 Methods for threat evaluation

For complete, accurate and up-to-date situational awareness, consideration should be given to integrated IM and decision support systems, with access to:

a) detection and tracking systems;

b) visualized near-real time ice and metocean information;

c) ambient ice regime and status of managed ice regime;

d) ice action measurements and offset status;

e) forecasting systems;

f) IM vessel location, performance and status;

g) functional assignments;

h) decision-making system, ice alerting and ice hazard analysis;

i) real-time assessment of IM performance;

j) historical ice regime;

k) facility-specific historical ice conditions and IM system data.

Specialized software-hardware solutions should be considered for the facility or, where possible, for the facility and IM vessels.

The systems listed in points a) to k) should incorporate best industry practices and be upgraded based on safe learning principles (see 4.3).

A decision process documenting the sequence of procedures used for threat assessment and mitigation shall be prepared for all IM operations.

The methods used for threat evaluation should:

1) consider the information provided by the ice detection system;

2) forecast drift and changes to any potential ice hazards and their expected ice hazard time;

3) characterize ice hazards in terms of potential consequences to the facility for the various operations and where active intervention in the form of physical IM activities is required;

4) identify the thresholds where facility-specific operational responses (e.g. production shut-down, disconnect, personnel evacuation) are triggered as well as the time required for these actions to be carried out.

9.4 Key concepts

9.4.1 T-time

The T-time shall be evaluated as the time required to ensure the safety of the facility, which can potentially involve securing wells, down-manning, as well as disconnection and move-off for a floating structure. The T-time may be reduced as distinct stages in these procedures are completed.

Different T-times can apply when different operations are being conducted at the facility. When the facility is in an emergency state, shorter T-times can be applied.

Operationally, the T-time should be re-evaluated on a regular basis according to changes in the operational status of the facility and the ice alert level.

9.4.2 T-distance

The T-distance shall be calculated as the drift speed of an ice hazard toward the facility (see 9.4.5) multiplied by the T-time.

9.4.3 Ice hazard distance

The ice hazard distance shall be determined as the distance of potentially hazardous ice features or ice conditions from the facility.

Operationally, the ice hazard distance shall be re-evaluated on a regular basis to reflect any new information.

9.4.4 Ice hazard time

The ice hazard time shall be evaluated as the time for a potentially hazardous ice feature or ice conditions to reach the facility.

For physically recognizable ice features or ice conditions, the ice hazard-time should be calculated as the ice hazard distance divided by the ice drift speed toward the facility (see 9.4.5).

9.4.5 Ice drift speed

In the context of the ice alert system, the drift speed of potentially hazardous ice features shall be estimated over the anticipated time for such features to reach the facility. The uncertainty associated with drift speed estimates should be assessed on an ongoing basis, based on the accuracy of previous estimates and on actual information at hand.

In special situations such as when the facility is in an emergency operational state or when critical operations are being undertaken on the facility, an extreme drift speed at an appropriate exceedance level shall be used. This extreme drift speed should be based on measured data if sufficient records are available or derived from an extreme combination of winds, wave and currents.

9.4.6 Closest point of approach

The closest point of approach (CPA) to the facility of potentially hazardous ice features or ice conditions shall be calculated based on the present position and extent of the ice hazard and a projection or forecast of the drift track over the ice hazard time. Because the drift track is subject to uncertainty, a drift forecast cone rather than a single forecast track may be used.

9.5 Ice alert levels and zones

9.5.1 Zoning strategy

Ice alert levels involve pre-defined responses to specified ice hazards. Since the alert levels are related to the T-time, these levels can also be expressed in terms of distances from the facility through the drift speed (see 9.4.5).

A series of zones around the facility can be defined based on distances associated with the initiation of ice alerts. It is emphasized that the zone boundaries are typically variable, because they depend on the times associated with the ice alerts which are tied to the T-time.

The IM plan should describe the range of procedures associated with ice hazards in each of these zones.

9.5.2 Monitoring zone

This is a zone that is not typically associated with any ice alerts and is farthest from the facility. Ice in this zone should be monitored, and assessed in terms of potential ice hazards and manageability.

9.5.3 Management zones

These zones are typically associated with ice alerts involving responses by the IM system, including the tracking and physical IM of ice hazards. Acceptable types of operations on the facility should be documented for these zones.

9.5.4 Secure zones

These zones are typically associated with ice alerts involving responses by the facility to secure wells, remove personnel, disconnect and move-off. Physical IM responses can also be engaged on ice hazards within these zones. Acceptable types of operations on the facility should be documented for these zones.

9.5.5 Exclusion zone

IM activities shall be consistent with the limitations associated with the vessel exclusion zone adjacent to the facility. Ice hazards should not be present within this zone unless the facility has been secured and other risks have been mitigated.

An ice exclusion zone of specified extent can be defined adjacent to the facility to allow unimpeded EER and vessel access, and to ensure the safety of other operations associated with the facility. In such cases, the maintenance of this zone should be ensured by means of the ice alert system.

9.6 T-time calculations

The time to secure operations or T-time shall be prepared for all possible operations; some can have longer or shorter T-times. The routine operations T-time should be based on securing the facility in a controlled way.

The T-time shall account for uncertainties in the response time for unanticipated and unforecast events.

In case of very long T-times and T-distances, IM vessels can be stationed very far updrift. In such conditions, T-times associated with an emergency operating state can be considered.

These T-times shall be obtained from the OIM, senior drill team representative or operations centre in cases of drilling and related operations, or the captain or operations site manager in other operations.

The move off time (or down-manning time) shall be obtained from the marine staff or other responsible person.

The ice hazard time should be a product of the IM system using appropriate forecasting tools and should be obtained from the ice advisory staff.

All above times used in the assessment and ice alerting shall be properly documented (integrated IM monitoring system).

The T-time and the ice hazard times (HT) shall be assessed and revised on a regular basis according to actual conditions.

9.7 Stages of threat assessment

Assessment of present and forecast ice conditions shall involve an ongoing decision-making process, carried out according to a protocol that minimises the effect of human error.

An ice alert assessment shall involve a robust decision-making process, making optimal use of available data, even in cases of instrument malfunction or communication problems with IM vessels.

The decision-making system shall take into consideration the quality and reliability of all input data. The effects of varying ice drift direction shall be considered in all IM operations.

The effects of ice drift changes should be understood and the strategies of the IM vessels should anticipate such drift direction changes.

9.8 Models for ice actions

Models relating ice actions (i.e. ice loads) and offsets to encroaching ice features or conditions can be used to assist with the threat assessment. Such models should be thoroughly calibrated in situ when the operation begins, starting with less severe ice regimes and working toward more severe conditions. The models should be updated as more experience becomes available.

9.9 Situations requiring increased vigilance

Ice situations requiring increased vigilance can include of the occurrence of any combination of the following events:

a) rapid ice drift changes and reversals;

b) faster than usual ice drift speeds due to local or global phenomena, including ice rivers;

c) pack ice pressure;

d) local and global current and weather changes;

e) polar lows;

f) refloating of stamukhi;

g) iceberg grounding and calving.

9.10 Infrequent, unanticipated and unforecast ice events

Circumstances leading to infrequent, unanticipated and unforecast events can involve those identified in 9.9.

Infrequent, unanticipated and unforecast ice events can occur swiftly and the alert system (see 4.1.3) should incorporate sufficient contingency to address them. Equipment and operational features should be built into the IM system to extend capabilities beyond the anticipated ice conditions for the region.

Subject matter expertise, local expertise and local knowledge should be consulted in all phases of the operation, thereby decreasing the likelihood of unanticipated events.

Particular consideration should be given to the documentation of physical environmental parameters, IM performance and operational considerations associated with unanticipated and unforecast events.

For sea ice conditions, the threat assessment should involve ice considerations affecting the ability of the IM vessels to move and manoeuvre in the ice.

Contingency for unanticipated and unforecast events shall be considered in the HAZID assessment, the design phase, the planning phase and in the execution phase of IM.

Mitigation of the consequences of unanticipated and unforecast events can be accomplished by:

a) increased experience and training (see Clause 11);

b) increased redundancy (see 4.2.2);

c) increased safety factor in estimating T-times;

d) enhanced IM activities, including ice monitoring and physical IM;

e) placing the facility in an emergency operating state (e.g. allowing for emergency disconnection);

f) being prepared for all plausible events and ensuring that clear procedures are in place.

10 Physical ice management

10.1 Selection criteria

The selection of IM vessel types and number of vessels should consider:

a) IM vessel performance and endurance characteristics;

b) operations to be undertaken, including multi-function capability (e.g. icebreaking and IM, crewing, supplies, cargo);

c) ice and metocean conditions anticipated, including seasonal differences;

d) experience of other vessels in a particular geographical region, with IM system characteristics and with proposed IM vessel types;

e) sailing distances and times to operational sites;

f) crew changes;

g) logistics and infrastructure requirements;

h) operational risks, hazards and remedial activities;

i) applicable local and global regulatory requirements;

j) facility support and role in emergency procedures.

10.2 IM vessel requirements

All IM vessels should:

a) as a minimum, be classed by a member of the International Association of Classification Societies (IACS) for operations in the ice regimes that can be present at the site and in all waters transited during the course of IM operations, re-supply and refuelling;

b) be suitable and effective for undertaking the required IM operations, including vessel transit, iceberg towing and icebreaking, as required;

c) be staffed with personnel trained in the performance of various IM duties and with an understanding of the IM plan;

d) be equipped according to the IM plan to satisfy the needs of the intended operations;

e) have the necessary permissions for navigation;

f) have functional equipment in place to allow for constant communication with other IM vessels and with the facility.

Additional requirements to those for transiting vessels should be considered because of the added responsibilities of IM vessels.

10.3 Operation-specific procedures

Specific IM procedures can be required, which include:

a) ice escort;

b) physical IM, involving icebreaking and towing procedures with IM vessels, and other procedures such as bubbler systems, hull wash or thrusters;

c) special monitoring and forecasting requirements;

d) prevention, minimization or removal of ice rubble, where loads and safety aspects (e.g. access, egress, emergency evacuation) are involved;

e) prevention of ice formation around mooring systems;

f) clearance of ice around intakes, moonpools or appendages;

g) clearance of deep draft ice keels affecting subsea or fixed structures.

10.4 Preparedness

IM vessels and other systems used for physical IM shall:

a) be available on a fit-for-service basis, when required;

b) be designed to operate under the anticipated range of physical environmental conditions;

c) provide a demonstrated level of effectiveness;

d) operate at an efficiency level that is consistent with the performance and reliability requirements of the overall IM system (see Clause 6).

Qualified personnel and appropriate IM vessels should be available on a timely basis, consistent with the IM plan, as well as the actual operational state of the facility, ice conditions and metocean conditions.

Systems used for physical IM should be able to operate on a continuous basis for extended periods of time.

10.5 Physical IM strategies and techniques

The choice of IM strategies and techniques should be consistent with the requirements of the ice alert system (see 4.1.3 and 4.1.4), and other aspects of the threat assessment process (see Clause 9). Further consideration should be given to the operating ice envelope upon which the alert system is based.

IM strategies and tactics should take into consideration the number and capability of IM vessels, including their manoeuvrability and the nature of the ice regime.

Physical IM operations should be carried out at distances from the facility that optimize IM efficiency and ice alert system compliance. An effective line of defence should be created, including strategic IM vessels working up-drift, tactical IM vessels working closer to the facility and IM vessels conducting ice clearance adjacent to the facility.

When dealing with specific ice conditions, IM vessels should follow a joint strategy, developed in consultation with the main facility. Protocols should be in place to alter the joint strategy in circumstances where the current strategy is ineffective or inefficient.

Other factors to be considered during the execution of physical IM procedures include:

a) ice drift speed and direction changes;

b) storm forecasts;

c) ice regime changes, including sea ice (e.g. ice concentration, pack ice pressure) and/or glacial ice (e.g. presence and distribution of icebergs and ice island fragments);

d) availability and functionality of IM vessels, including the effect of mechanical failures and contingency measures in such cases;

e) fatigue levels of IM personnel, if carrying out extended operations requiring high levels of concentration.

10.6 Ice-restricted operations

Safe operation and ramming speeds in various ice and metocean conditions shall be determined and applied for all IM vessels operating in ice.

The following steps should be taken in conditions where ice-restricted operations apply:

a) creation of detailed operations and execution plans;

b) determination of ice capabilities of the chosen fleet of IM vessels;

c) where applicable, determination of ice certificates, providing guidance on safe speeds.

10.7 Effects of IM

The effects of IM on the physical, chemical and biological environments should be considered (see ISO 35103).

With respect to the ice environment, specific consideration should be given to the creation of open water, potential de-stabilization of landfast ice and the generation of brash ice that can accelerate ice growth.

11 Personnel and training

11.1 IM personnel requirements

All personnel directly involved in IM activities should have knowledge of the metocean and ice environment, the performance capabilities and limitations of the facility (or system) being supported, the operations of the facility, the performance capabilities and limitations of the IM vessel(s), and the interrelationships within the overall IM system.

The number of IM personnel required should reflect the ice conditions, the operation under consideration and the number of IM vessels deployed. Personnel roles can include ice observers, ice advisors, ice navigators, marine mammal observers (MMOs), and ship's crew.

Skilled IM personnel should be available to monitor and forecast metocean conditions and to provide advice on hazardous ice conditions.

The IM team should be supplemented by appropriately skilled marine crew and operations personnel as and when required.

Other considerations for personnel requirements can include the type of coverage (continuous or periodic), main facility provisions and resources; remoteness (ease of crew changes) and communication (ease of transferring shore-based files or offshore generated files across the operations).

At the pre-planning stage, the availability and relevant experience of IM personnel and IM vessel crews should be assessed to develop the scope of training programs.

11.2 General training requirements

Training shall be provided to relevant personnel to address the different aspects of the IM system and IM operations. The type and level of training should reflect individual roles and responsibilities.

Consideration should be given to the integration of IM training with training associated with operations of the facility.

Training under field conditions for crew members involved in IM activities should be conducted when practicable.

Training protocols shall be updated to reflect changes to the IM plan. Relevant personnel should be made aware of changes to the IM plan and retrained as necessary.

11.3 Requirements for training

11.3.1 Organizations offering ice management training

11.3.1.1 General

An organization offering IM training shall have the requisite administration, management and governance structure to deal with registration, instruction, certification and record-keeping.

The organization shall meet the applicable industry training standards governing the setup and administration of educational facilities and service providers.

A proper retention process for records and certificates shall be in place.

Where academic standards are required, clear and defined records shall be used, indicating the applicable standards and the means by which they are satisfied.

The organization offering the IM training should have solutions in place to verify that the trainee actually achieved a minimum level of competency after the training.

11.3.1.2 Use of internal audits for monitoring purposes

An internal audit program followed by scheduled external audits shall be used to provide an ongoing monitoring of the quality of the delivered programs.

Training programs shall be updated according to changes to legislation and shall incorporate advances achieved through research and development.

11.3.2 Training personnel

For operations in arctic and cold regions, special attention shall be given to the selection and training of employees as well as potential subcontractors.

The personnel directly involved in the development and delivery of ice management training shall:

a) possess ice operational experience or experience/qualifications in similar activities;

b) hold certification indicating training in the development and delivery of training programs;

c) be capable of demonstrating their continued professional development as part of the improvement of courses and programs;

d) be competent in the use of simulators, computers, and any other technologies required for the delivery of the training.

Training methods can involve simulators or other navigational training tools, which should include relevant vessel types and physical environmental conditions, and provide flexibility in simulating the actual operations and organizational systems.

11.3.3 Training facility

IM training should involve on-board or simulator-based training, which can be supplemented with classroom instruction, remote teaching facilities and distance learning.

11.3.4 Training elements

The training framework should involve the following considerations and elements.

a) The content and duration of an IM training scheme should be tailored to the previous relevant qualifications, training and experience of the clientele being trained, which includes monitoring and advisory personnel, operational personnel, and other personnel directly or indirectly involved with IM both onshore and offshore.

b) Where the personnel being trained are based on IM vessels, the training personnel shall have a background or previous experience in different types of IM operations and in the type of ice to be managed.

c) IM training programs shall be specific and reflect complex objectives. Training should include, where applicable:

   1) meteorological factors that influence IM and forecasting;

   2) ice breaking support and operations (i.e. single and multiple IM vessels);

   3) operations in close proximity to assets and other vessels;

   4) operations in pack ice and iceberg-infested waters;

   5) site-specific operations and support (e.g. emergency response, tanker escort).

d) Skills for risk assessment and risk management.

e) Human factors for operations in harsh environments.

f) Additional systems directly or indirectly affecting the IM performance (performance of main engines, type of propulsion system — in line shafts or azimuth — thrusters, power generation, emergency services, mooring or DP and other monitoring systems).

g) For individuals or groups with no ice management experience and little to no experience operating in ice, a basic course consisting of fundamental IM training elements, which should include:

   1) ice terminology;

   2) ice types;

   3) the effects of variable environmental parameters on ice movement;

   4) ice loading on different types of structures;

   5) the roles and responsibilities of various stakeholders in the IM plan;

6) basic ship operations in ice.

h) For individuals with IM experience, an advanced course, which should include:

1) type of operation (exploration or production, other) and the type of ice, pack (or sea) ice and glacial ice;

2) actual ships planned for the operation, realistic ice regimes for the intended operation and a number of specific operating scenarios serving as case studies.

i) Other elements of the IM plan, such as:

1) decision-making process and ice alerting, the types of actions required and the roles and responsibilities of the stakeholders;

2) flow of communications;

3) testing of the processes simulation scenarios highlighting the application of methods, and the individual's ability to adapt to the plan under changing circumstances.

11.3.5 Training requirements for monitoring and advisory personnel

Competency of ice monitoring and advisory personnel should involve a combination of training and field experience, with consideration of:

a) the severity of the conditions;

b) technical expertise;

c) experience gained in sea ice or iceberg conditions;

d) experience with the intended operations (e.g. drilling, surveying, construction);

e) experience in remote areas and harsh environments;

f) facilities and IM vessel fleet experience;

g) experience gained in simulator training;

Marine officers should be knowledgeable in the area of IM and use of the IM data (see also 11.3.4).

11.3.6 Training requirements for other personnel

Other personnel, directly or indirectly involved in IM, shall be trained to various degrees and become knowledgeable in IM operations, functions and procedures.

The required competency shall be based upon experience and training in different types of operations, severity of the ice regime and the risks associated with such operations.

Consideration should be given the training of all IM vessel personnel according to IMO Polar Code requirements.

11.3.7 Training curriculum

The training programs should:

a) distinguish between front line operational personnel, which include the ice monitoring team, marine officers and operators, support personnel in various functions on board, and shore personnel;

b) address the responsibilities of ice advisors, ice observers and any other personnel involved in the detection and monitoring of IM operations, from the facility, from IM vessels and from the air;

c) where relevant, use ice training simulators with programs containing a number of basic IM functions.

Training programs shall follow international rules and standards (i.e. IMO Polar Code, classification rules, IMO STCW), in areas of requirements, procedures and certification.

11.4 Ice management training: specific requirements

11.4.1 General

All training programs should be validated against field operations and experience.

Proper consideration should be given to human factors in training for all operations in arctic and cold regions.

11.4.2 Operations in arctic and cold regions

Where applicable for the role, the following operations and skill sets should be given specific consideration:

a) ship handling in ice conditions;

b) ice reconnaissance;

c) physical IM, ice hazard assessment, risk analysis and ice alerting;

d) stationkeeping and dynamic positioning;

e) anchored operations and anchor handling;

f) logistics operations;

g) well incident and oil spill response;

h) EER training and familiarization;

i) sea ice and iceberg situations;

j) joint ice management activities by a number of IM vessels and on different facilities.

11.4.3 Field experience

Field experience in arctic and cold regions shall be integrated into the education, training and professional development for operators and engineers involved with IM operations. Offshore experience in open water situations is recommended before personnel can be involved in operations in arctic and cold regions.

Training for operations in ice should be similar to that for dynamic positioning operator in open water. IM related training can be based on existing ice navigator training programs by recognized training institutes.

Annex A
(informative)

Ice management HAZID workbook

This annex includes a link to the IM HAZID workbook in Microsoft Excel format that can be used when preparing an IM plan (see also Clause 5). This IM HAZID workbook is only available in electronic format via http://standards.iso.org/iso/35104.

This IM HAZID workbook consists of the following worksheets:

a) "read me" instructions;

b) definitions;

c) common features;

d) HAZID tables for drilling, bottom founded structures, construction and installation, offloading, floating production, oil spill response, seismic operations);

e) sample HAZID table.

The HAZID tables:

1) can be used in the design, planning and execution phases of an IM system;

2) can be used in the development of training programs;

3) identify the requirements for IM for different types of offshore operations as per Clause 1.

A number of possible solutions are shown when preparing an IM plan, with tools, procedures or systems to address possible hazards in the form of requirements ('shall' statements), recommendations ('should' statements) and possibilities ('can' statements).

The IM HAZID workbook also provides guidance to the designer, planner and operator, when preparing site-specific IM plans.

The following example distances contained in the HAZID tables can be used, which should be tailored to the actual operation.

— Far field: exceeds 5 nautical miles and in some cases 10 to 20 nautical miles, but could also exceed 20 nautical miles and can even include areas up to several hundreds of nautical miles (for example iceberg calving areas, river estuaries, areas with severe grounded ice).

— Mid field: ranging from 2 to 3 nautical miles to 5 nautical miles, and for some applications up to 10 to 20 nautical miles.

— Near field: less than 2 to 3 nautical miles.

Areas where ice features might be under observation are located in the monitoring zone (see 9.5.2).

Areas where ice features are under management are located in a management zone (see 9.5.3).

The offloading HAZID table consists of a generic evaluation of factors for consideration, as there are many variants to offshore offloading systems. Specific systems can require in depth study during the FEED/HAZOP/operability review to ensure that sufficient safeguards are in place to address the type of operation to be carried out. The same can apply to the other operations contained in HAZID tables.

Annex B
(informative)

Additional information and guidance

B.1 Scope

Preparation and execution of arctic and cold regions operations use different considerations as compared to operations in other areas, including[6][7]:

a) general lack of reliable long-term measurement data (in particular ice conditions) and subsequent uncertainties in extreme estimates (used for designs but also planning of operations);

b) planning for a wide range of possible environmental conditions;

c) use of enhanced tools and processes to determine ice hazards and risks, to determine the effects of drift ice on operations, the ability to forecast season start and end dates, and the ability to predict the actions on systems operating in ice and the effects of such actions;

d) remoteness affecting the communication and data transfer capabilities.

The climate in arctic and cold regions has experienced both short and long term fluctuations in the past and the future change is uncertain. Prudence should be exercised in determining the environmental design parameters for future projects, including the use of hindcast data. For example, areas which in the past showed limited wave action, could change over time due to larger open water areas or the opposite.

In this document, the focus is primarily on drilling or production facilities supported by IM, where the objective is to secure the wells and personnel. Key steps can involve shut-in, disconnection and move-off. If IM is used to support another kind of operation (e.g. EER, pipe-laying, tow-out, seismic), the steps can be different but the principles are the same. Reference to 'facility' in this document can typically be interpreted to mean 'facility or other operation being supported by IM'.

B.2 Normative references

No additional guidance is offered.

B.3 Terms, definitions and abbreviations

No additional guidance is offered.

B.4 General ice management requirements

B.4.1 Fundamental requirements for an ice management system

B.4.1.1 General

Published examples of ice management systems include Bonnemaire[24], Browne[25], Coche[26], Keinonen[36], Liferov[41][42] and Timco[54].

B.4.1.2 Ice management plan

No additional guidance is offered.

B.4.1.3 Ice alert system

Ice alerts involve staged responses to specified ice hazards. These responses can involve IM activities and enactment of procedures associated with securing the facility. The responses can include:

a) a change to the operational status of the facility, whether normal or emergency;

b) initiation, cessation and reversal of shut-in, disconnection or move-off procedures;

c) initiation, changes to or cessation of IM procedures;

d) permissible activities;

e) frequency of monitoring;

f) the general state of readiness required.

Ice alerts can be different, depending on whether the facility is in a normal or emergency operating state. When a facility is in a normal operating state, the facility can be secured according to procedures that ensure life and environmental safety, as well as minimizing downtime and ensuring asset functionality. When a facility is in an emergency operating state, the facility can be secured by means of procedures that ensure life and environmental safety. Typically, increased asset and downtime risks are assumed in such situations. An emergency operating state can be initiated as part of ice alert procedures.

Ice alert levels can be assigned to different types of operations within those defined in Clause 1 and for different seasons.

Ice alert levels are triggered by the approach of hazardous ice within defined limits. Ice alerts can involve:

1) relationships between the ice hazard time and the T-time or the ice hazard distance, closest point of approach and the T-distance;

2) a combination of ice and metocean conditions;

3) measured or predicted ice actions on part of the facility;

4) horizontal offsets or other displacements of the facility;

5) ice encroachment onto a part of the facility that is not designed to withstand ice actions.

Often the most important ice alert is when the ice hazard time is equal to the T-time (i.e. when the ice hazard distance is the T-distance), at which point shut-in procedures are initiated.

Alert systems associated with IM activities can also involve a staged series of responses, starting with simply monitoring ice conditions at greater distances from the facility or longer lead times. Tracking specific ice features or ice conditions might be initiated for intermediate lead times, followed by physical ice management activities for shorter lead times. These kinds of ice alerts can be triggered by the ice hazard time being some specified time in excess of the T-time, where the specified time involves a particular IM activity, whether to complete a physical IM procedure or to bring additional IM assets to the site.

The alert system can also include protocols for resuming the normal operations of a facility when the severity of the ice hazard is reduced. A particular alert level can specify that no response is necessary.

Ice alerts dealing with certain types of ice hazards such as sudden drift direction changes or onset of ice pressure can involve IM responses involving sea ice clearing in the immediate vicinity of a facility, but need not involve shut-in, disconnection or move-off if ice conditions are not severe.

An ice alert system can provide warnings for bottom-founded structures in the context of glacial ice or sea ice conditions to permit safe shut-in and evacuation.

Ice alert systems can also apply to mobile facilities performing seasonal works or operations in ice-prone areas.

B.4.1.4 Hazardous ice conditions

Potentially hazardous ice is all ice which exceeds the design/operational criteria of the facility or operations. It is perceived that this ice, far field, cannot be managed in a continuous fashion by the available IM vessels, and within the available time, for it to be considered safe. After detailed detection, inspection and where possible management, such potentially hazardous ice can be relabelled as non-hazardous ice.

Factors leading to hazardous ice conditions can include combinations of:

a) environmental factors;

b) meteorological and environmental conditions, such as darkness, fog, icing, waves, polar lows, snowstorms and others;

c) low temperatures leading to thick refrozen brash ice;

d) sea ice drift speeds in excess of the icebreaking capabilities of the IM fleet;

e) unanticipated ice drift reversals;

f) pack ice pressure;

g) thick large ice floes and deformed ice floes (ridges, rubble, hummocks);

h) ice islands;

i) stamukhi;

j) icebergs, bergy bits, clusters of bergy bits and growlers.

Types of hazardous operations can include:

— manoeuvring in ice in proximity to the facility or other vessels;

— stage or criticality of operation;

— specific operations, such as those related to oil and gas and offloading (critical loads, impact of tanker or IM vessel, personnel evacuation, loading operations, etc.);

— seasonal extension in support of geological work or construction.

B.4.2 Safety requirements

B.4.2.1 Ice management approach

See also under B.10.3.

B.4.2.2 Redundancy

No additional guidance is offered.

B.4.2.3 Existing operations

No additional guidance is offered.

B.4.3 Safe learning

B.4.3.1 Safe learning principles

Safe learning principles for operations in pack ice regimes and iceberg regimes are well understood. Experience in areas with icebergs embedded in sea ice is limited.

Further improvements and refinements can be considered, including the effects of data collected, performance results and human factors.

Enhancements in central data bases can also be considered.

Expertise can be drawn from the following operations:

— Sakhalin Energy (pack ice mostly);

— Varandey terminal (pack ice);

— DeKastri terminal (pack ice);

— Arctic Gate terminal (pack ice);

— Prirazlomnoye platform (pack ice);

— ACEX coring expedition (pack ice and thick multi-year ice);

— Greenland seismic operations (icebergs mostly; pack ice with icebergs);

— Beaufort Sea experience in both pack ice and old ice;

— iceberg management operations (Canadian East Coast, Labrador and Greenland).

Safe learning principles apply to all activities as part of IM and include actions of all participants and physical operations in the ice conditions (i.e. platform, tanker, IM vessels). Both extreme and unexpected circumstances should be considered (e.g. drift direction change) as well as emergency situations (e.g. engine failures, broken propellers).

It is recommended to consider dry-run tests and trials of critical systems or IM operations. These can be conducted when there is no need for IM by the facility.

B.4.3.2 Continuous improvement

No additional guidance is offered.

B.4.4 Risk management

B.4.4.1 General requirements

Specific consideration should be given to the provisions of ISO 17776 relating to hazard identification, barrier design and operation, and performance standards.

B.4.4.2 Hazard identification and consequences

Past experience has shown that new locations, new types of operations supported by IM, new IM vessels and fleet composition and new organizational structure can all lead to unintended consequences.

Past experience for pioneering operations in new regions has also led to difficulties in achieving reliable ice drift forecasts.

B.4.4.3 Responsibility for risk management

No additional guidance is offered.

B.4.4.4 Use of risk assessment

No additional guidance is offered.

B.4.5 Health, safety, security and environment

B.4.5.1 Health, safety, security and environment plan

No additional guidance is offered.

B.4.5.2 Safe working environment

See also ILO MLC:2006[10][11] and IMO MSC/Circ 1014[16] with respect to fatigue and hours of work. Specific country regulations can apply.

B.4.5.3 Incident reporting

Incident analysis can use proven systematic processes for finding the real root causes of problems [e.g. TapRooT®[53], Fault Tree analysis (Smartdraw)[50] or Fishbone diagrams (Mindtools)[45]].

B.4.5.4 Compliance with health, safety, security and environment requirements

No additional guidance is offered.

B.4.6 Organizational functions and procedures

B.4.6.1 General requirements

No additional guidance is offered.

B.4.6.2 Organization and communication

B.4.6.2.1 Project organization

No additional guidance is offered.

B.4.6.2.2 Operational organization

Each operational organization chart should indicate, as appropriate, the functional links among the following entities:

a) owner's representative;

b) overall project management;

c) operational management that can include IM vessels, mooring systems and marine spread, ballast system operation, IM operation (onshore and offshore) and metocean and ice/iceberg forecasting (onshore and offshore);

d) support services and logistics;

e) advisory panel providing expertise as required;

f) HSSE;

g) statutory, regulatory and approving bodies.

B.4.6.2.3 Operational management

The risk to operations for a floater is determined by a combination of ice, metocean, equipment capabilities, and operational strategies. The use of the equipment and its operational efficiency are important. Ice input and advice alone fall short of indicating any real risk to the operation before that ice input data is specifically combined with the two other inputs.

An important person in a potentially risky arctic and cold regions operation is a risk analysis expert who combines all the above inputs. In a routine operation it can be expected that the ice and metocean inputs are adequate and suitable as a measure of safety. These measures alone however are insufficient in many arctic and cold regions operations that are being carried out for the first time.

Incomplete or 'patchy' satellite coverage can result in communications of poor quality or be intermittent. The area of operation and the sensitivity of such operations can play a role. Duplicate systems can be required, with a suitable back up.

HAZID tables have been created for use in the design, planning and execution phases to be used as lookup when preparing specific IM plans. The tables are included in Annex A.

An example from the tables included in Annex A is shown in Table B.1. The colours define the discrete types of operations.

Table B.1 — Generic HAZID table for each operation (sea ice scenario)

System	Sub-system	Element	'Shall' statements (requirements)	'Should' statements (recommendations)
Sea ice prone areas				
Physical environmental data				
Surveillance	Forecasting	Short term (3 days)	— Review before issue — Confidence in accuracy — Engage — Ice radar in IM vessels	— Compare multiple forecasts — Forecasters available for liaison with operators
Physical IM	IM vessels	Far field, scouting	— Detection in place — Far field coverage — Detect hazardous ice — Robust communication — Plan in place — Proper manpower	— Compare multiple forecasts — Liaise with forecasters — Observations from vessels/platforms/shore locations
Threat assessment and ice alerting	Properties of facilities	Operation limits (OPL)	— Establish clear lines of communication — Understand operating limits with regard to ice	— Defined stakeholders — Relevant operations manuals

Table B.1 *(continued)*

System	Sub-system	Element	'Shall' statements (requirements)	'Should' statements (recommendations)
Sea IM system	Organization	Authority levels	— Document — Review — Include with induction	— Audit effectiveness
Site operations	In position	Operating procedures	— Regular review — Feedback — Use change notifications — Ensure document control — Use contingency plans	— Advise IM centre of movements/operations at an agreed time period — Integrate platform and IM vessels
Resupply	Approach	Navigation	— Establish lines of communication — Follow procedures — Liaise with IM centre — Regular review	— Advise IM centre of all intended movements — Integrate inbound resupply vessel into IM report system

B.4.7 Specific design, planning and execution requirements

No additional guidance is offered.

B.5 Ice management plan (IM plan)

B.5.1 IM plan scope

No additional guidance is offered.

B.5.2 IM plan implementation

Aspects which can be considered include the availability of:

— competent personnel;

— necessary systems (IM vessels and IM equipment);

— detection and monitoring systems with suitable redundancy.

B.5.3 IM plan maintenance

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 a facility. Consideration for such changes should be included in the design and maintenance of the IM plan.

These changes can be influenced by climatic trends (see ISO 35106). In such cases, the length of record should reflect the time frame over which such changes have taken place. Recent trends should not be used to alter parameters influencing operational decision-making in a way that would lessen potential consequences.

Caution should be exercised when specifying parameters that can vary significantly inter-annually and within a given season.

B.6 Ice management system performance

B.6.1 High-level IM system issues

No additional guidance is offered.

B.6.2 Measures of IM performance

Since the relationship between the managed ice regime (e.g. ice conditions, number of features, feature dimensions) and the operating ice envelope for measure in 6.2 b) (i.e. maintaining a managed ice regime that is consistent with the operating ice envelope for the facility) involves uncertainty, this measure of performance is likely to be less accurate than measure in 6.2 a) (i.e. maintaining the operating ice envelope for the facility).

Events used for performance assessment can involve the diversion or destruction of distinct ice features. For more continuous ice conditions (e.g. pack ice floe size reduction), success or failure to meet specified criteria over constant periods of time can be used to define events. The following aspects can be considered:

— desired outcome in terms of floe size distribution, ice concentrations, and local clearance of the incoming ice floes;

— deflection of icebergs and other ice features that cannot be broken by IM vessels to a safe drift course within a prescribed time;

— the proportion of ice features reaching the facility;

— the magnitude of ice actions or horizontal offsets resulting from ice interactions with the facility.

Unless based on an extensive period of record, IM performance expressed in terms of downtime or frequency of emergency operational states of the facility over a period of time can be misrepresented. This is because performance is governed by the ice conditions encountered in addition to IM effectiveness. In some iceberg environments, few icebergs can be present in a significant proportion of years. Similarly, sea ice is not always present every year at some locations. In some sea ice environments, old ice incursions can be episodic and infrequent. Careful consideration of bias in ice conditions should be made when using downtime as a measure of IM success.

B.6.3 Demonstration of intended performance

No additional guidance is offered.

B.6.4 IM system design

The importance of IM system design cannot be overemphasized. Unless significant IM experience exists under very similar ice conditions and facility operations, simulation techniques should be considered. The performance of IM vessels and other IM systems should be characterized mathematically for the range of physical environmental conditions expected at the site to allow the simulation of expected IM performance. Key considerations include simulation of periods long enough to ensure realistic ranges for contributing parameters and that important correlations are captured. Furthermore, the models used for simulation and the anticipated strategies should be verified based on actual field experience.

B.6.5 Degradation of ice alert and IM system performance

No additional guidance is offered.

B.6.6 Operating ice envelope

The operating ice envelope is established to ensure that the operating safe working load (of a mooring system, propeller — thruster system, or a combined system, or the resulting global load on a fixed facility), or the horizontal offset of the facility above its nominal position on the seabed, should be at such a level that the natural variability of ice actions does not result in exceedance of the maximum safe action or offset for the system.

The desired level of success is a function of:

a) the ability to stay on location within acceptable limits;

b) the ability to resist the ice actions, including soil response;

c) maintenance of ice ride up, ice override or the creation of rubble, within acceptable criteria;

d) the ability to continue operations at slow speeds (e.g. seismic operations or oil spill response), conducting construction works as well as oil offloading operations.

Establishing safe operating ice envelopes for sea ice regimes requires reliable estimates of the time-dependent characteristics of ice actions and the response of the facility to those actions. The basis for estimating actions and displacements resulting from ice regimes is provided in ISO 19906. General information regarding these issues can also be obtained from literature surveys and some examples that can be used as starting points are:

1) Kubat and Sayed[37] which lists publications dealing with ice management, stationkeeping in ice and the determination of ice actions as well as the response of floaters.

2) Eik[29] gives a review of experiences with sea ice and iceberg management.

3) Keinonen[36] addressed the principles of IM and practical issues based on field experience from several key operations.

4) Reviews of the requirements of IM systems and available experience were given by Hamilton, et al. [31][32].

5) Advances in IM and requirements for future operations were examined by Maddock, et al.[43].

6) Guidance regarding the use of mooring and DP systems for stationkeeping in ice was provided by Riska and Coche[48].

7) Relationships for estimating icebreaking vessel performance are given in Keinonen[35].

8) Wright[56] provided a methodology for obtaining ice force information, using ice action records of the Kulluk.

B.6.7 Operational readiness of IM system

In practice, it has been shown that a high degree of operability can be attained, when using well-designed and built equipment, highly trained personnel, and a well-designed and executed IM plan.

B.6.8 Performance monitoring and documentation

Ice actions can be measured based on thruster and/or mooring line loads on floaters and/or on local or global structural response as a measure of the actions on fixed structures.

Responses in the form of horizontal offsets and rotations of the facility can be monitored in real time, where possible, through the use of reliable monitoring systems. Ice actions can be monitored in real time.

For floating structures, the relationship between the responses and specified ice conditions can be quite complex.

B.6.9 Maintenance and improvement

No additional guidance is offered.

B.7 Data requirements

B.7.1 General ice management data requirements

Environmental monitoring data and their requirements are included in ISO 35106.

B.7.2 Parameters and conditions

B.7.2.1 Ice and metocean parameters

The following main operational gaps in standards and guides have been found related to metocean and ice parameters[7]:

a) wind and current (including depth profiles) monitoring;

b) temperature monitoring for personnel exposure;

c) weather windows and metocean and ice conditions for different operational seasons — summer, extended summer and early winter;

d) sea ice and iceberg data and monitoring, for example satellite imagery can be enhanced providing higher frequency, more coverage and better resolution;

e) ice behaviour and sea ice/iceberg drift monitoring and forecasting.

Ice conditions can cover a large number of parameters, not all of which have the same importance for offshore operations.

For sea ice or pack ice, some key parameters are ice concentration, floe size distribution, ice thickness, ice type and strength, drift velocity, pack ice pressure and ridging. For glacial ice, iceberg mass, shape, size and drift velocity are most important.

Areas requiring specific data related to IM include data for forecasting efforts, ice drift, ice feature severity and strength, and icing. Other factors include the albedo effects, drag coefficients, local currents and bathymetry effects.

Examples of hazardous ice conditions are listed in B.4.1.4. Examples of conditions that can generate extreme events are:

— drift of ice islands and fragments;

— drift of ice that was land-fast and large areas of pack ice;

— large ice drift changes and reversals;

— drift of old ice and glacial ice (icebergs) towards the operations sites;

— fast changes of wind speed and direction causing pressure;

— fast changes of currents (outflow from river or ice dam failure);

— effects of polar lows.

B.7.2.2 Monitoring of operational parameters

Monitoring procedures should ensure that the most important parameters are prioritized.

B.7.2.3 Combined situations

Examples of combined situations include:

a) metocean (wind, wave and current) and sea ice;

b) metocean, sea ice (with varying concentration, age and floe size) and drift ice;

c) metocean, sea ice, and glacial ice, including drifting ice and pressure;

d) metocean, sea ice, and stamukhi, including drifting ice;

e) metocean and landfast or stationary sea ice;

f) effects of local eddies and bathymetry on ice drift behaviour, and the effects of localized phenomena such as ice rivers and wind-driven currents.

Glacial ice can contain icebergs, bergy bits and growlers of various sizes and shapes, each affecting operations differently.

B.7.2.4 Managed ice conditions

No additional guidance is offered.

B.7.2.5 Wildlife observations

Wildlife observations are very important as they can stop an operation. Many operations in arctic and cold regions include wildlife observers who operate around the clock on the facility and IM vessels, and if they see potential dangers to mammals, then operations can cease or stop temporarily. Operations can be required to stop for a period to permit indigenous hunts to proceed without interference.

MMOs can be used in support of ice observers under the above conditions.

B.7.3 Timeline

B.7.3.1 Planning situations

No additional guidance is offered.

B.7.3.2 Strategic situations

Depending upon the particular operation, hazardous ice features can be identified many days and even weeks in advance.

Icebergs and potentially hazardous sea ice features can be monitored at their source.

B.7.3.3 Tactical situations

Tactical situations generally involve ice conditions or ice features that are under active management and typically less than one day's travel time from the site of the operation. Time frames are typically in terms of hours and distances in the order of 10 nautical miles. This is sometimes referred to as the near-field from an operational standpoint.

B.7.3.4 Phases of operations

No additional guidance is offered.

B.7.4 Forecasting

B.7.4.1 General

No additional guidance is offered.

B.7.4.2 Accuracy

No additional guidance is offered.

B.7.4.3 Metocean data

Special monitoring skills can be required as specified in ISO 19901-6.

Site-specific metocean forecasts (including detailed wind forecasts) can be required for:

a) drilling operations that require ice and wave forecasts;

b) offshore tanker loading operations from production platform, which require ice and wave forecasts;

c) diving operations in ice infested waters;

d) remotely operated vehicle (ROV) operations.

For complex and/or long weather-restricted operations, forecasters with local experience can be present on-site, to check the local situation and provide regular weather briefing based on forecasts from at least two independent sources. Alternatively, such expertise can be accessed from remote locations and onshore locations when needed providing that there is good feedback of metocean data from the site in real time. This can apply to major marine operations such as:

— tow-out and float-over;

— offshore installation and lifting;

— dredging and construction operations;

— towing.

B.7.4.4 Ice management forecast parameters

B.7.4.4.1 List of parameters

Forecast can make good use of aerial reconnaissance and provide geo-tagged photos on ice features for record and distribution to IM vessels.

NOTE See also the Forecaster's handbook for general guidance[19].

B.7.4.4.2 Wind forecasts

Wind forecasts are obtained from large scale climate models and are based on current and future pressure conditions and knowledge of the movement of weather systems (atmospheric lows) throughout the region of interest. Most of the other parameters in this subclause are based on the wind forecast. Experience shows that forecasted winds to about 3 days are reasonably reliable, but their reliability decreases for longer term forecasts.

B.7.4.4.3 Wave forecasting

In arctic and cold regions, errors in wind wave height forecasts can occur with lack of knowledge of open water fetch size, as this depends on ice concentration, and the effects of low ice concentrations.

In ice concentrations over about 3/10, waves are severely damped, but swell can still be significant even in higher ice concentrations.

B.7.4.4.4 Swell forecasting

Swell developed in open water can propagate through an ice cover, and cause the break-up of landfast ice or reduce floe sizes locally. Many operations have to close down in high swell conditions and operators need to know the limitations of IM vessel or rig to swell both from the point of view of motions, workability and damage to areas outside of the ice belt.

Waves and swell as well as ocean and tidal currents are an issue in marginal ice zones in winter, such as the east coast of Canada and the Barents Sea, and at all locations in summer, except the very high Arctic.

B.7.4.4.5 Current forecasting

Information about ocean current and tides is very important for both iceberg drift and pack ice forecasting and any data recorded would be of great benefit to IM operations.

Local bottom founded current profilers can be considered in the ice-free season and in the ice season if the ice conditions allow.

B.7.4.4.6 Ice drift forecasting models

Ice drift models can play an important role in forecasting speeds and trajectories used for setting the T-distance associated with ice hazards. The objective of these models is to make best use of data on the state of the sea ice cover, the dimensions of potentially hazardous ice features, recent and historical drift trajectories, and the metocean processes contributing to ice drift and changes to ice features or conditions.

Ice drift models can incorporate deterministic and statistical components. Deterministic aspects typically involve contributions of wind, current, wave, earth rotation (Coriolis) and sea surface tilt forces to the drift. Coupling with ocean current models is sometimes incorporated. For sea ice, the mechanical behaviour of the ice cover can also influence its response to external forces.

Statistical aspects can be addressed in a variety of ways. Data from previous drift measurements or dedicated process measurements can be incorporated in probability distributions for the parameters of deterministic models. Historical or recent drift measurements can be used to correct, enhance or characterize drift patterns, particularly when the metocean driving forces are poorly characterized. Either way, probability distributions of drift patterns can be used to provide important information on the accuracy of ice drift forecasts.

Some common model types include:

— Free drift models for sea ice — Estimates of ice drift are sometimes obtained by assuming that ice drifts with velocity equal to the sum of a ratio of wind velocity (e.g. 0,02 of wind velocity) and current velocity. Such estimates imply that the internal stresses in the ice cover are negligible and do not account for stresses transferred through the ice cover and for Coriolis forces. These models can be adequate in situations where ice concentrations are relatively low and away from land boundaries.

— Sea ice dynamics models — Such models account for ice deformation and drift by solving the equations for conservation of mass and linear momentum as well as the stresses transferred through the ice cover to land boundaries (ice mechanics). Hibler's formulation[33] for sea ice mechanics has been employed in a number of sea ice models because of computational convenience. Changes to the sea ice cover can involve thermodynamic processes leading to growth and deterioration and mechanical processes leading to changes in the relative proportions of ice of different thicknesses, including lead, ridge and rubble formation (thickness distribution or redistribution).

— Iceberg models — Iceberg drift is determined by solving the equations that balance linear momentum. The iceberg is treated as a rigid geometrical form subjected to the forces listed above. Because of the complexity of iceberg shapes and in the flow of water around them, recent drift information can be used to correct the drift parameters and the balance of forces. Thermodynamic and radiative processes, in combination with sea state and currents, contribute to iceberg melting, calving and rolling[38][39].

B.7.4.4.7 Icing forecasting

There are two types of icing: atmospheric and sea spray.

Atmospheric icing occurs when environmental conditions exist that cause water in the atmosphere, in the form of rain, fog, or wet snow, to freeze onto exposed surfaces, antennas, and cables; it is generally of little consequence.

Sea spray icing is the result of spray from vessel interaction with waves, and also due to wind-driven spume droplets from wave crests, freezing onto the vessel's superstructure. This is more severe than atmospheric icing and can lead to a thick layer of ice forming on the vessel's structure, which can make decks dangerous, prevent doors and hatches from being opened, and if allowed to continue, can possibly result in stability issues for the vessel. This type of icing can be reduced by prudent operation of a transiting vessel or stationary platform, but if it occurs, it might require physical removal of the ice before it becomes too serious.

Sea spray icing can affect the IM vessels and sheltering can be effective. If severe icing occurs, IM vessels can be pulled from duty, which can affect the safety of the facility or operation[51].

A number of approaches can be considered to calculate icing build-up, like the ones presented by Kulyakhtin (MARICE)[40] and Overland, et al.[46]. Further references are listed in the review paper by Sultana, et al.[48]. The approach of Kulyakhtin is considered to be the most advanced detailed physics-based time-dependent model. It requires more inputs than other models, including specific geometrical aspects of the ships or structures, and so it is not as simple to use as the other models.

RIGICE is an icing model developed for various offshore platforms[30]. RIGICE is more appropriate for the large fixed/floating structures whereas Overland's expression (associated with fishing vessels) might be appropriate for IM vessels.

These methods do not always lead to the same end result. For instance, results from Overland's expression differ from the other models at low sea surface temperatures; at higher sea surface temperatures, the models roughly agree[44].

Alternatively, simple nomograms can be used[47].

A survey of icing data and guidelines was performed when developing the Arctic Operations Handbook[7].

There is a lack of good quality field data that can be used to validate icing models. The uncertainty in the estimates obtained from the models should be considered.

B.7.4.4.8 Forecasting polar lows

Monitoring and also forecasting for polar lows can be considered as an integral part of daily operations[19].

Polar lows are very difficult to forecast and a nowcasting approach is often used, with the systems being transported with the mid portion of the Earth´s atmosphere flow. Numerical weather prediction models are only just getting the horizontal and vertical resolution to represent these systems. Polar lows tend to form when cold air flows over relatively warm open water. The storms can develop rapidly, reaching their maximum strength within 12 hours to 24 hours of formation, but they dissipate just as quickly, lasting on average only one day or two days.

NOTE Polar lows need high quality and reliable forecasts, since less reliable weather forecasts combined with small scale very local atmospheric phenomena increase the probability of failing or disrupted operations (see Barents 2020, Clause 3.2.1[23]).

B.7.4.5 Nowcasts

No additional guidance is offered.

B.7.4.6 Forecasts for weather windows

No additional guidance is offered.

B.7.5 Data collection

B.7.5.1 General

Items which are different in arctic and cold regions compared to open water conditions include:

— Visibility: Safe operating speeds are used, in order to prevent possible risks in hitting free drifting ice floes like growlers, especially in conditions of low visibility. Special equipment including the use of night cameras to detect sea ice as well as wild life can be considered.

— Weather windows: The presence of ice can affect metocean conditions such as wave/swell and currents. Partial ice concentrations affect the forming of ice and the break up. Strong winds can cause ice pressure in some areas and opening up of leads (narrow open water areas between ice floes) in other areas.

— Operational duration: ISO 19901-6 provides operational durations for open water operations. These durations can differ in ice.

Where possible, best available technology should be utilized in all areas.

Table B.2 shows a general list of data that can be required for monitoring (adopted from Arctic Operations Handbook, 2014, Table 7-4[7]). Further data specifications for monitoring are included in ISO 35106. The use of the same type of instrument, calibrated and the same procedure for measurement is important.

The contents of Table B.2 should be adjusted to actual operations with assigned priorities for all parameters, where possible. Priorities will be determined by the operator, having assessed the metocean and ice parameters which are relevant for their specific operation type.

Table B.2 — General monitoring requirements

Subject	Conditions
Environment	Mammals
	Noise
	Spills
	Emissions
	Turbidity
	Daylight hours
Meteorology	Water temperature (at the surface and at various depth)
	Wind speed sustained and direction
	Wind speed gust and direction
	Wind speed and temperature
	Precipitation (drizzle, rain, sleet, snow, graupel, hail)
	Ice accretion (atmospheric and marine icing) — thickness, area of application and extent of application
	Visibility
	Weather, present
Oceanography	Water depth and water level
	Wave height and direction; wind and wave direction
	Wave period; wave spectrum
	Swell height and direction
	Swell period
	Current speed and direction (at various water depths, including tidal component and oscillatory or spiralling behaviour) including conductivity, temperature and density.

Table B.2 *(continued)*

Subject	Conditions
Sea ice and icebergs	Sea ice types (from nilas to thick and old ice)
	Ice type (i.e. first year ice, second year ice, multi-year ice, glacial ice)
	Ice concentrations 0–10/10 and coverage over the area of interest, extent of ice cover including ice edges
	Ice forms (floe sizes, pancake to big floe)
	Ice motion (drift, divergence, convergence, shear)
	Ice pressure (none, slight, moderate, heavy)
	Ice features (growlers, hummocks, icebergs, rafted, ridges, rubble, stamukhi, strips)
	Iceberg size and type; frequency and distribution; shape; keel depth
	Iceberg groupings; bergy bits
	Other classes as function of the season (strength, melting, snow cover)
	Ice rivers
	Brash ice
Seabed	Soil conditions (sand, soft clay, hard clay, rock, permafrost)
	Boulders
	Ice gouging
	Seabed slope

Environmental data can be obtained by the IM vessels, as indicated in Table B.3. These data are generally collected by marine crew and relayed to the facility. Table B.4 provides a list of operational parameters that can be monitored on a floating platform, drillship or rig. Table B.5 shows parameters that can be collected on a stationary platform, to identify features which might affect the stability of the facility.

Table B.3 — IM vessel parameters that could be recorded

Parameters	Range	Format
Latitude (°)	0 to 90	Integer
Longitude (°)	0 to 360	Integer
Speed (kt)	0 to 25	Integer
Direction of motion (°)	0 to 360	Integer
Distance from rig (nautical miles)	0 to 300	Integer
Bearing from rig (°)	0 to 360	Integer
Power setting (%)	0 to 100	Integer
Activity		Text 128 characters
Wind speed (kt)	1 to 70	Integer
Wind direction (°)	0 to 360	Integer
Ice concentration	0 to 10	Integer
Ice types and concentrations	Type	Text
Heave, pitch and yaw rate and rate of rise	Metres and degrees	Variable

Table B.4 — List of operational parameters that could be recorded for a floating drillship, rig or construction vessel or other types of floaters

Item	Value	Format
Pitch, roll, and sway	Degrees	Variable
Heave, yaw	Metres	Variable
Offset distance from well	Metres	Variable

Table B.4 *(continued)*

Item	Value	Format
Direction of offset from well	Degrees	Variable
Accelerations (typically surge values inferred from offsets)	Metres per second squared	Variable
Mooring line tensions	Tonnes	Variable
Thruster loads on shaft	Tonnes	Variable
Ice conditions and features adjacent to and within facility (from radar, surveillance video or surveillance camera)	Time stamped digital photography or video	Variable, raw

Table B.5 — List of parameters that could be recorded for stationary structure

Parameter	Units	Format
Global ice actions, local ice pressures; various sensors	Converted to Tonnes	Variable
Accelerations	Metres per second squared	Variable
Area of ice impact	Metres	Variable
Heights of pileups around structure	Drawing on map	Drawing and text
Movement of structure on base		
Pore pressure in core or under structure		
Pressure on base of structure		
Vibrations of structure		
Ice conditions and features adjacent to and within facility (from radar, surveillance video or surveillance camera)	Time stamped digital photography or video	Variable, raw

B.7.5.2 Data quality

See also the HSE guidelines for metocean and arctic surveys[18] and MANICE[8].

B.7.6 Data organization

B.7.6.1 General requirements

B.7.6.1.1 Organization of data collected

No additional guidance is offered.

B.7.6.1.2 Data access

A gap has been identified in information technology systems for the high Arctic and the corresponding requirements for setting up systems and making effective use of such data systems[7].

Offshore operations can require monitoring, such that all users have access to key information for reliable access and use. Exchange of data is key to safe operation. Systems should be in place to monitor data received, allow sorting and filing, and allow all data to be exchanged effectively in a form that can be sent around; data formats can require to be checked and standardized.

The database will also be improved by an increase in quality of the measurements due to enhancement of the observational network. Such enhanced data capture can include data collection on icebergs, corresponding requirements and criteria, and operating limits and impacts. Further work is required, specifically on hazardous ice conditions. These hazardous ice conditions involve among others icebergs and pack ice with a high rate of ridges as well as pressured ice and ice drift.

Considerations can be given to an enhanced meteorological network for arctic and cold regions operations and to supplement the existing network where needed (see Barents 2020, S3.2.3[23]).

B.7.6.1.3 Data organization

An example of codes that can be used for the dissemination of ice and metocean parameters for an IM operation is given in Table B.6 and Table B.7. Different parameters and data types can be tagged with these kinds of codes for prioritization of information access.

Table B.6 — Zone code (example)

Zone code	Description
1	Seasonal/Long-term
2	Strategic/Observation
3	Tactical/Management
4	Critical/Exclusion

Table B.7 — Role code (example)

Role code	Description
1	Offshore installation manager (OIM)
2	Platform ice advisor
3	IM vessel 1 ice advisor
4	IM vessel 2 ice advisor
	...
11	Ice forecast
12	Metocean forecast
	...
21	Ice support
22	Metocean support
	...
31	Technical support
32	System administrator

B.7.6.2 Accuracy and bias of data

No additional guidance is offered.

B.7.6.3 Instrument specifications

No additional guidance is offered.

B.7.6.4 Data backup

No additional guidance is offered.

B.7.7 Data dissemination

B.7.7.1 General

No additional guidance is offered.

B.7.7.2 Communications and infrastructure

Particularly for large projects, consideration should be given to self-reliant communications networks to ensure effective communications between the different IM vessels, other vessels, the offshore facility and the shore base.

To ensure safe arctic and cold regions operations, the operator is advised to consider:

a) robust data and communication systems;

b) redundancy;

c) integrated communications between all systems offshore;

d) setting up a LAN or cellular network locally for data exchange;

e) proper communications between vessels involved in offshore operations and onshore support;

f) proper bandwidth;

g) exchanges of key operational data between all parties involved;

h) analysis of arctic and cold regions data affecting operations, before, during and following operations;

i) availability of historical data.

Remoteness and logistics challenges can require personnel to be offshore for long periods of time. The communication system should be dimensioned and set considering the potential need for suitable personal communication and entertainment solutions.

B.7.7.3 Presentation

No additional guidance is offered.

B.8 Ice detection and tracking

B.8.1 Objectives

No additional guidance is offered.

B.8.2 System criteria

The design and selection of the ice detection system should take into consideration the harsh environment and the capability of the detection systems.

This can be influenced by a number of factors including:

i) effects of waves on growler detections;

ii) iceberg properties (size, shape, draft, state of deterioration);

iii) iceberg tracking;

iv) effects of low visibility and darkness;

v) frequent and proper satellite coverage;

vi) resolution of satellite coverage;

vii) effects of polar lows;

viii) broadband communication issues;

ix) local tidal and current information;

x) localized wind effects;

xi) icing and snow;

xii) human factors.

Enhanced monitoring sensors and systems can include:

— visual information, pictures, can be supplemented with radar/sonar information;

— special equipment to detect growlers and icebergs in high sea states and in bad visibility;

— tracking of multiple radar targets on marine charting displays;

— satellite based tracking of major ice features;

— ice tracking buoys;

— underwater sonar;

— integrated ice detection, monitoring and forecasting/alerting systems.

Depending on the complexity of operations, the facility and the IM fleet used, the following systems can be considered:

a) detection and monitoring systems:

  1) communication, internet, intranet, email;

  2) data base, spreadsheets and other type of data records;

  3) electronic chart display and information system (ECDIS);

  4) historic data for the local area;

  5) ice charts;

  6) marine radar data;

  7) metocean data from observations, instruments and from data buoys, in open water and ice;

  8) navigational radar displays;

  9) aerial reconnaissance by fixed wing aircraft, helicopter, UAV (unmanned aerial vehicle) or tethered balloon;

  10) satellite data (optical or synthetic aperture radar); micro and nano satellites;

  11) ship performance data;

  12) shore stations;

  13) sonar data;

  14) IM vessel position data;

  15) visual data from all available ships in the operations spread, weather, ice, icebergs;

b) forecasting systems:

  1) reliability and quality of all data;

2) nowcast;

3) ice drift prediction;

c) decision-making system:

1) special systems and software, for the integrated detection, monitoring and IM system including hazard analysis.

A survey of monitoring platforms was compiled by Van der Schoor, et al.[55].

B.8.3 Detection capabilities

B.8.3.1 Visibility considerations

Poor visibility and fog, normally occurring at 100 % relative humidity, can affect operations in open water and in sea ice. Navigational equipment used for the metocean and ice detection, monitoring, and forecasting, can require testing to ensure it is functioning properly in these conditions. Special infrared cameras can be considered.

B.8.3.2 Sensors

Detection and tracking of ice conditions can consider the use of:

a) satellites:

1) Cryosat (optical);

2) Cosmo-SkyMed (radar — Constellation);

3) Envisat (out of service, but historical data available);

4) Radarsat (radar);

5) Sentinel (radar — Constellation);

6) Spot (optical);

7) MODIS (optical) — both Terra and Aqua;

8) TerraSAR-X (synthetic aperture radar);

9) others, like Landsat, Formosat, Quickbird, RapidEye, Worldview;

10) mini satellites (in the near future);

b) ice charts;

c) aerial observations by means of fixed wing, helicopter or unmanned aerial vehicle;

d) visual observations;

e) other sensors, such as marine radar or a specialized ice radar.

Satellite data are of limited use for tactical purposes, as they can be one or more hours old when obtained, and are only available once every 12 hours to 24 hours. The lower resolution data, which show a large area, do not show small ice pieces. Conversely, high resolution data show small ice pieces, but over a limited area.

NOTE 1 Radar satellites are all weather, day or night, whereas visual satellites are limited to good weather and daylight. Images from the radar satellites are interpreted by experienced persons, whereas images from visual satellites are easier to interpret. The resolution and areal coverage of the images vary greatly and depend on the satellite.

NOTE 2 Ice charts can be obtained from local government ice services (like CIS, NIC, AARI) or commercial entities. These ice charts are mostly issued daily in many arctic and cold regions. The ice charts provide areas of "open water" — areas of less than 1/10 ice cover, and the principle ice areas, coded using the EGG Code (MANICE). The ice charts also identify large ice floes, and generally provide an estimate of ice drift over the next 24 hours, based on forecast winds.

B.8.3.3 Aerial reconnaissance

Ice reconnaissance assets can provide a map using the standard EGG Code (MANICE) summarizing the visual observations by a trained observer for the area immediately around the operations site and in a larger area updrift of the operations site. The helicopter generally uses an experienced observer from shore or picks up one of the ice observers/ice advisors from the ship or rig.

Unmanned aerial vehicles or drones can provide a bird's eye view or can be used to place beacons on ice features, although updrift range can be a limiting consideration.

Aerial assets can include: records and maps with target detections collected by the radar or automatic identification systems (AIS), displays, records and video provided from the radar or forward looking infrared camera (FLIR, if available), controls real time and near real time digital satellite communications, permits from the operator to classify, identify and annotate targets and mission events, controls of all radar functions and the geo-pointing capabilities of the FLIR system.

B.8.3.4 Radar observations from ship or structure

Marine radar can be used to supplement visual or aerial observations. Marine radar provides information on the presence of ice, the ice roughness and ice concentration. There is a limit to the minimum size ice piece that can be detected using marine radar, particularly in rough seas. Specialized "ice radars" can provide more detailed ice information by means of digital scan-averaging.

Radar as well as other remote sensing type instruments are continuously evolving and the most suitable equipment can be selected for the type of operation.

NOTE Radar is potentially the best way of monitoring ice movement, as it does not require any instruments on the ice, and all ships have radar; X-Band radars work best for ice. The new "ice radars" provide a greatly improved image of the ice over the normal ship's radar.

Radar can be unreliable for sea ice as the ice reflection changes over time, and one can accidently confuse reflections if there are many ice targets in the area of interest. Normal marine radar can also be unreliable for detecting growlers or small bergy bits in sea states. Icebergs provide a more reliable reflection, but again iceberg reflections can be confused when there are many in the area of interest.

Marine radar with automatic radar plotting aid (ARPA) radar is used to track ships, but is unreliable for ice, unless the ice radar reflection is very strong and reliable otherwise target-swap can occur.

A radar reflector does not guarantee unambiguous identification of a floe, if the ice is rough, and in fact, are not needed when the ice is rough.

Radar with integrated cameras and thermal imaging can also be considered.

The use of an ice radar combined with ice observers should be considered.

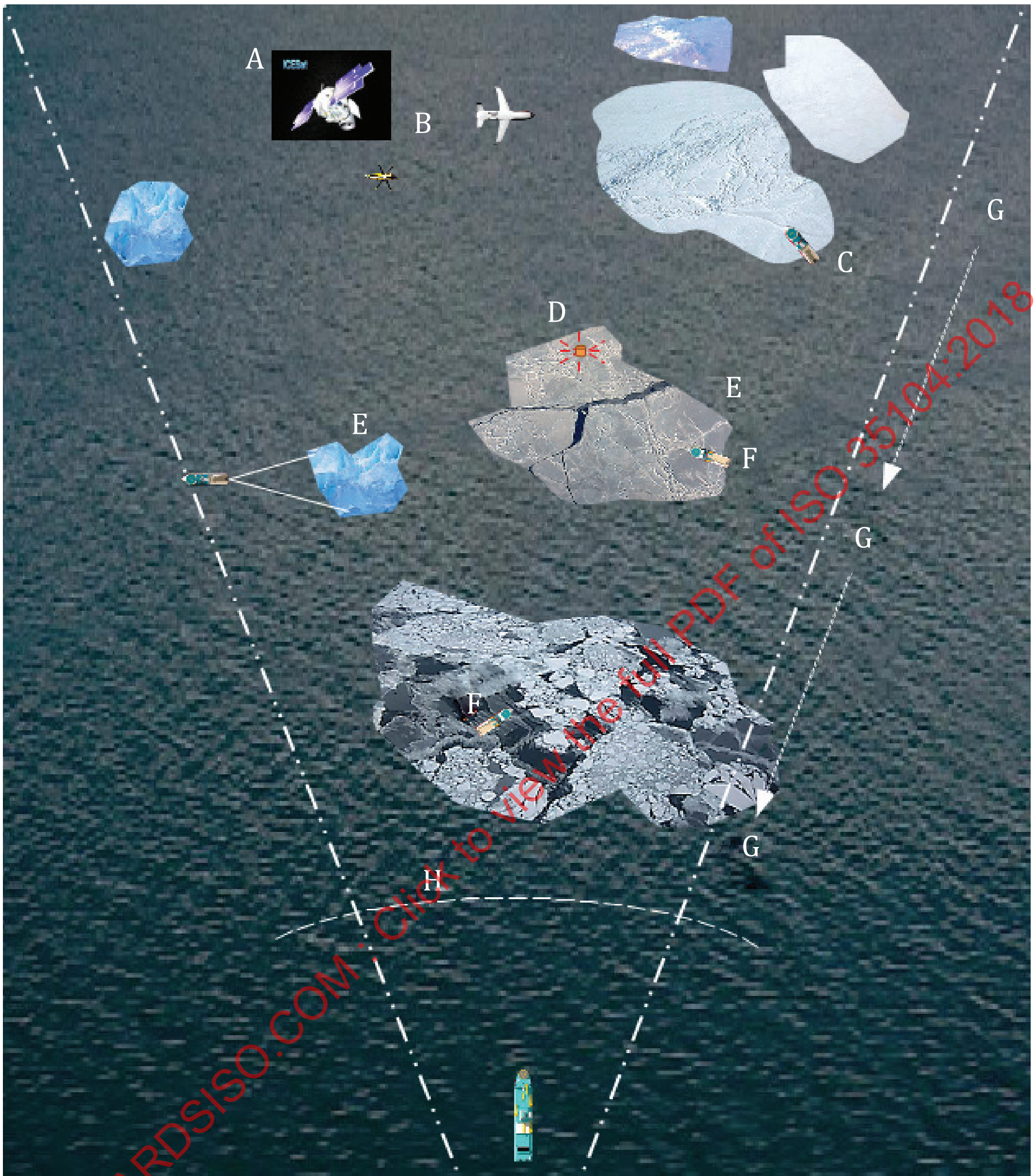
B.8.4 Tracking capabilities

Beacons deployed on ice floes or icebergs can be tracked using satellite transmission systems or by means of radio transmission directly to IM vessels. Methods of deploying beacons on icebergs are discussed in Acevedo, et al.[21].

B.9 Threat evaluation and response

B.9.1 Threat evaluation strategy

Figure B.1 shows an example of an IM strategy with a predominant ice drift direction from the top to the bottom of the figure.



Key

A Metocean and ice forecasting from trusted weather service and satellite data. Continuous operation.

B Ice detection for pack ice and glacial ice — in far-field by satellite, fixed wing aircraft, helicopter and far-field IM vessel (especially in poor visibility) — determine ice features, drift direction and speed.

C Ice strength testing (for pack ice) and threat assessment — by IM vessel in far field and closer — determine ice types, roughness and strength to evaluate possible hazard. Assign ice alert status.

D Ice tracking — by B and ice beacon.

E Threat assessment relative to IM vessel fleet capability — by calculation and judgment based on previous experience, prior system field calibration and knowledge of the drilling vessel capability. Address ice alert status at each stage and for each identified target.

F For pack ice — physical IM by IM vessel — heavy IM vessel followed by lighter IM vessels reduces ice regime to 20 m — 40 m floes and rubble/brash ice. Floe sizes less than 20 m can be required under certain circumstances. IM should be completed prior to [secure + move off distance, i.e. (ST + MT) × ice drift speed], so that the well can be secured and the drilling vessel moved off, if ice regime is still hazardous. ST varies with the stage of the well, and ice drift speed is subject to change. For glacial ice, physical IM involves towing, pushing and washing the ice features in order to move them off the predicted drift track towards the structure.

G Multi-stage ice alert system follows each ice regime/feature through the complete operation.

H Before ice reaches secure + move-off distance, a final threat assessment of the managed ice regime is made. Depending on the assessment, drilling continues or drilling vessel moves off; IM system continues by continuous processing of all potential ice hazards.

Figure B.1 — Ice management strategy[49]

Warning of potentially hazardous ice conditions is one of the tasks of IM activities for which colour codes are used. Other tasks include decision making, planning of operations, determining safe periods of work (weather windows) for loading operations and operations of people transfer, determining the need to perform IM manoeuvring, determining required number of icebreakers for this manoeuvring (based on actual available fleet), determining optimum type of manoeuvre (depending on tasks to be performed, IM vessel performance and actual ice conditions).

A sample of ice alert colour code is shown in Table B.8[49].

Table B.8 — Sample of ice alert colour code

Ice alert level	Description
Green	Normal operation — No potentially hazardous ice conditions near the operational site. Issued when no potentially hazardous ice conditions are expected within the T-time plus some margin (e.g. 24 hours).
Blue	Approaching ice — Potentially hazardous ice is approaching the site and consideration should be given to stopping the operations. There is typically increased preparedness and ice and metocean conditions are monitored more closely. The ice is still not expected to arrive within the T-time, but the margin is less than that used for a green ice alert. Metocean forecasts and ice forecasts are verified frequently.
Yellow	Secure the well — Hazardous ice is expected to arrive within the T-time. The well is to be secured to eliminate associated risks. Logistical steps are initiated to allow for an orderly withdrawal from location.
Red	Initiate disconnection — The ice is within the time required to disconnect the platform from location. The platform is to be disconnected.
Black	Hazardous ice is imminent. The platform has to be removed from the location — typically using pre-planned emergency disconnection methods and egress routes to a safe holding location.

Facility plans including activity specific operating guidelines (ASOG) and the critical activity mode of operation (CAMO)[12] can be used.

B.9.2 Identification of ice hazards

Although ice hazards are clearly outlined in the alert system in terms of origin, dimensions and proximity, their identification using available systems and personnel can be difficult. The identification of potential ice hazards before alert levels are activated should be an ongoing process involving:

a) ranking in terms of smallest hazard time;

b) fact-finding on origin and proximity;

c) prioritization in terms of size, forecast closest point of approach or other risk factors;

d) evaluation in terms of manageability subject to availability and state of readiness of IM resources;

e) atmospheric conditions or precipitation that could impair the quality of detection data;

f) verification of potentially anomalous tracking information;

g) present ability to forecast metocean parameters or ice drift;

h) anticipated changes to any of the above factors over the hazard time.

B.9.3 Methods for threat evaluation

In order to check the incoming ice conditions, both the type, severity and manageability could and often should be tested by IM vessels, including scouting vessels, icebreaking vessels and any other ships used in this operation. Inspection and testing is conducted to verify the IM vessels' ability to manage the ice. Remote ice thickness measurement systems can be considered, time permitting.

B.9.4 Key concepts

B.9.4.1 T-time

The T-time can include provision for uncertainties associated with the procedures involved, including mechanical failures associated with shut-in and disconnection procedures.

The T-time can be further defined depending on application:

a) for disconnectable floaters — time required to suspend and secure operations, make the work environment secure and move off to a safe location;

b) for non-disconnectable floaters — time required to suspend and secure operations, and if required move personnel to a safe location (down-manning);

c) for fixed structures — time to suspend and secure operations, and if required move personnel to a safe location;

d) for movable structures — time required to suspend and secure operations, make the work environment secure and move off to a safe location.

B.9.4.2 T-distance

No additional guidance is offered.

B.9.4.3 Ice hazard distance

Depending on the type of facility supported by IM, the ice hazard distance can potentially be measured from the edge of the exclusion zone.

B.9.4.4 Ice hazard time

No additional guidance is offered.

B.9.4.5 Ice drift speed

Ice hazard time is based on ice drift speed. Under normal circumstances, prior measurements of ice drift speed toward the facility (if representative) or a forecast of ice drift speed toward the facility averaged over the ice hazard time is used. These estimates of ice drift speed can involve:

— tidal and inertial effects;

— changes to driving forces;

— seasonal effects;

— changes to the sea ice cover, including break-up;

— spatial differences in drift speed over the ice hazard distance;

— uncertainties in measurements, extrapolations and forecasts.

For emergency operating states of facilities or other critical situations, the maximum plausible drift speed is direction independent and can reflect historical measurements or verified relationships between ice drift and maximum plausible combinations of driving forces.

The ice drift speed and direction can be variable over a period of time. The ice drift speed used for the calculation of the ice hazard time can be based on observation frequency, weather forecasts, past experience, ice drift model forecasts and professional judgment of ice observers or ice advisors.

Since the local ice drift speed can vary appreciably during an offshore operation, it is typically updated regularly by means of ice drift forecasts.

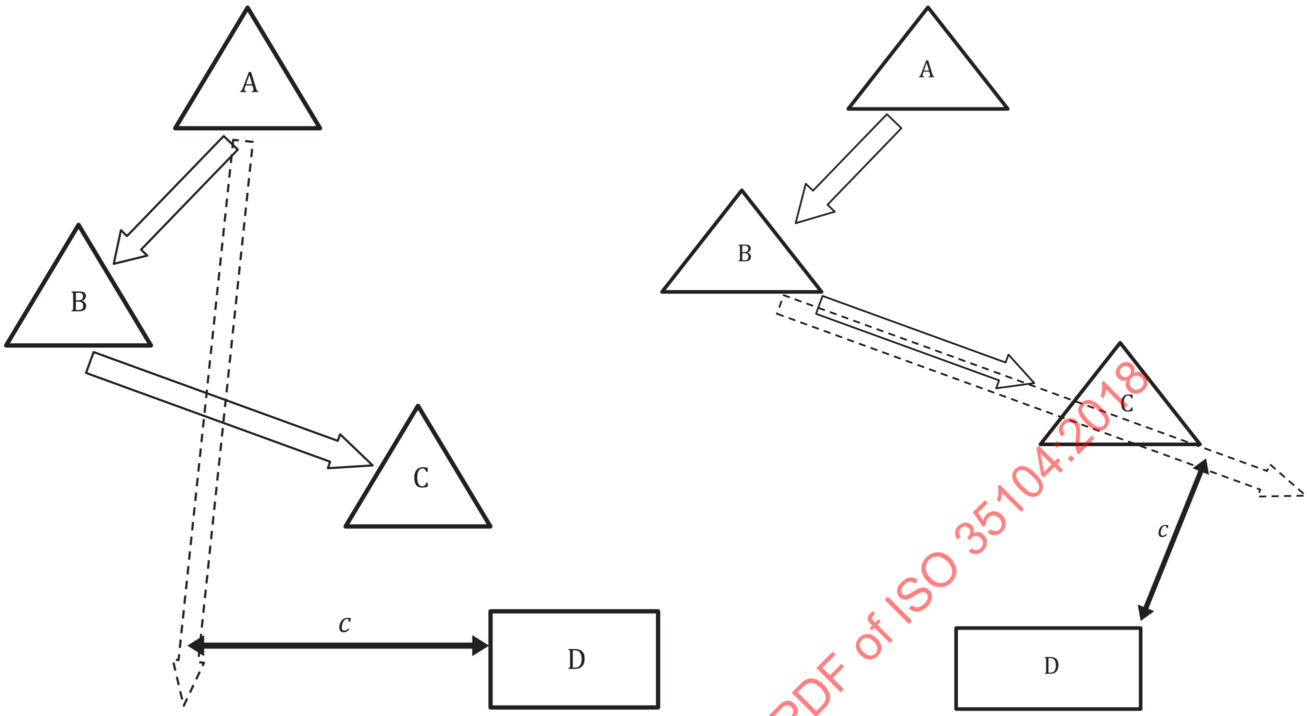
For icebergs, drift speed estimates should reflect the meandering speed and speed made good.

B.9.4.6 Closest point of approach

The following material reflects the iceberg situation for Canadian East Coast operations. A similar approach can be used for sea ice.

When ice is first detected, the operator can assume that it is on a collision course until it is proved otherwise. The closest point of approach (CPA) is the minimum distance from the ice feature to the facility or operation under consideration. The CPA can be calculated as the perpendicular distance from centreline of the actual or forecast drift track to the facility or operation, less half the plan dimension of the ice feature. Once data are available, the CPA can be calculated using the average track over at least two recent positions from the initial detection position. The time span can be selected over three or more hours and depends on the operation and drift speed.

Figure B.2 shows a graphic representation of two methods used to calculate the CPA distance to the facility. The left scheme, a), in Figure B.2 shows the approach for ice in the monitoring zone, where the speed and direction are averaged over the last two records of iceberg position and speed — direction. The right scheme, b), in Figure B.2 shows an iceberg in a management zone, where the CPA is based on an extrapolation of the last trajectory using a point-to point projection. This allows for a more precise recognition of any potential change in drift direction, with a consequent faster reaction to any adverse effects that can be created by the short-term change in track. Both samples disregard forecast wind, current and drift speed and direction. More detailed approaches can be used, depending on the actual sensitivity of the operation.



a) Calculating CPA for iceberg in monitoring zone

b) Calculating CPA for iceberg in management zone

Key

A iceberg position 1

B iceberg position 2

C iceberg position 3 (current position)

D offshore facility

c CPA

observed track

projected track

Figure B.2 — Procedure for CPA — Glacial ice (example as used for East Coast Canada)

Figure B.3 shows a flow diagram for an iceberg threat analysis, while Figure B.4 shows a decision flow diagram for operations in sea ice.

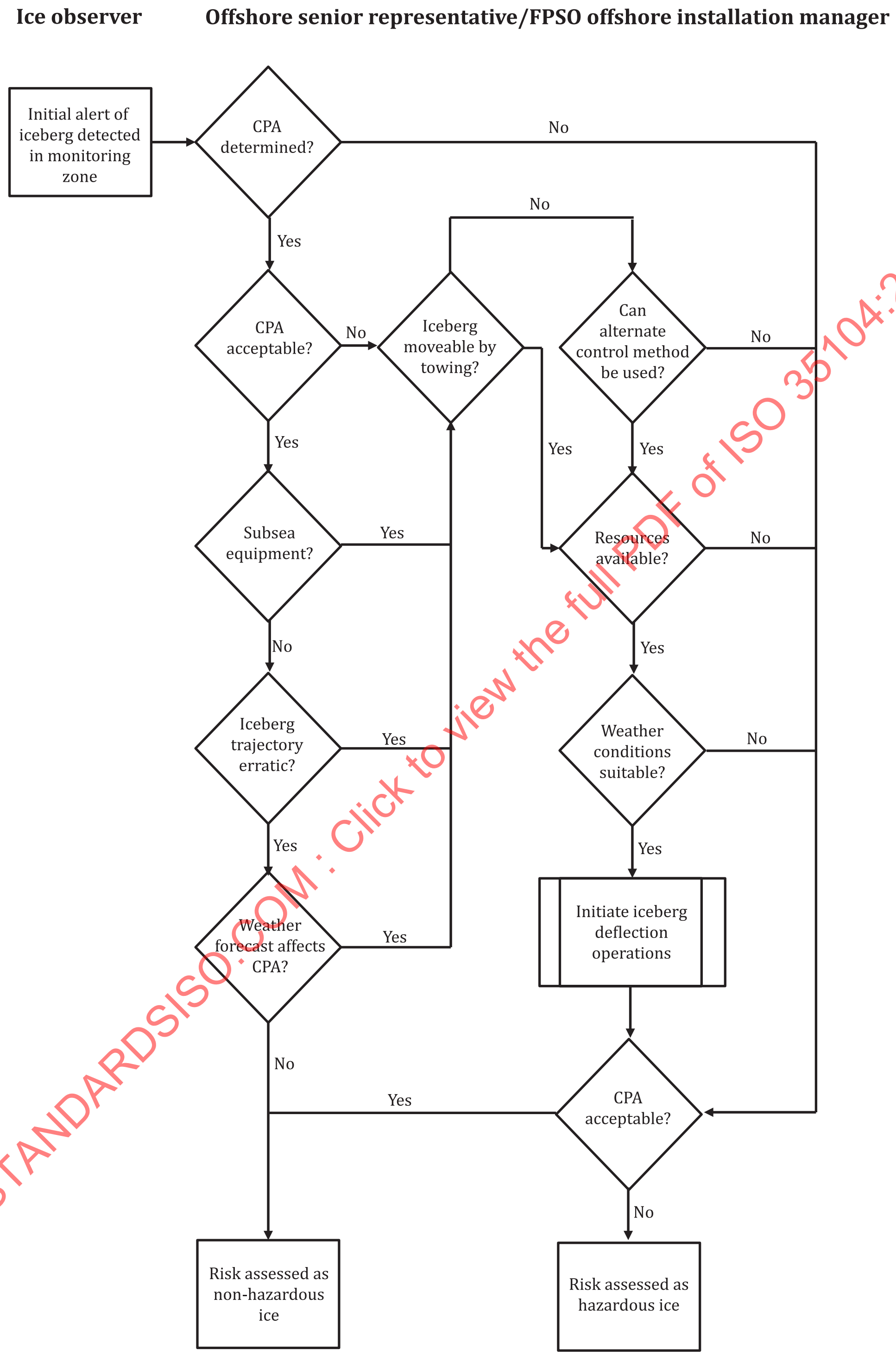


Figure B.3 — Flow diagram for an ice threat analysis in glacial ice areas

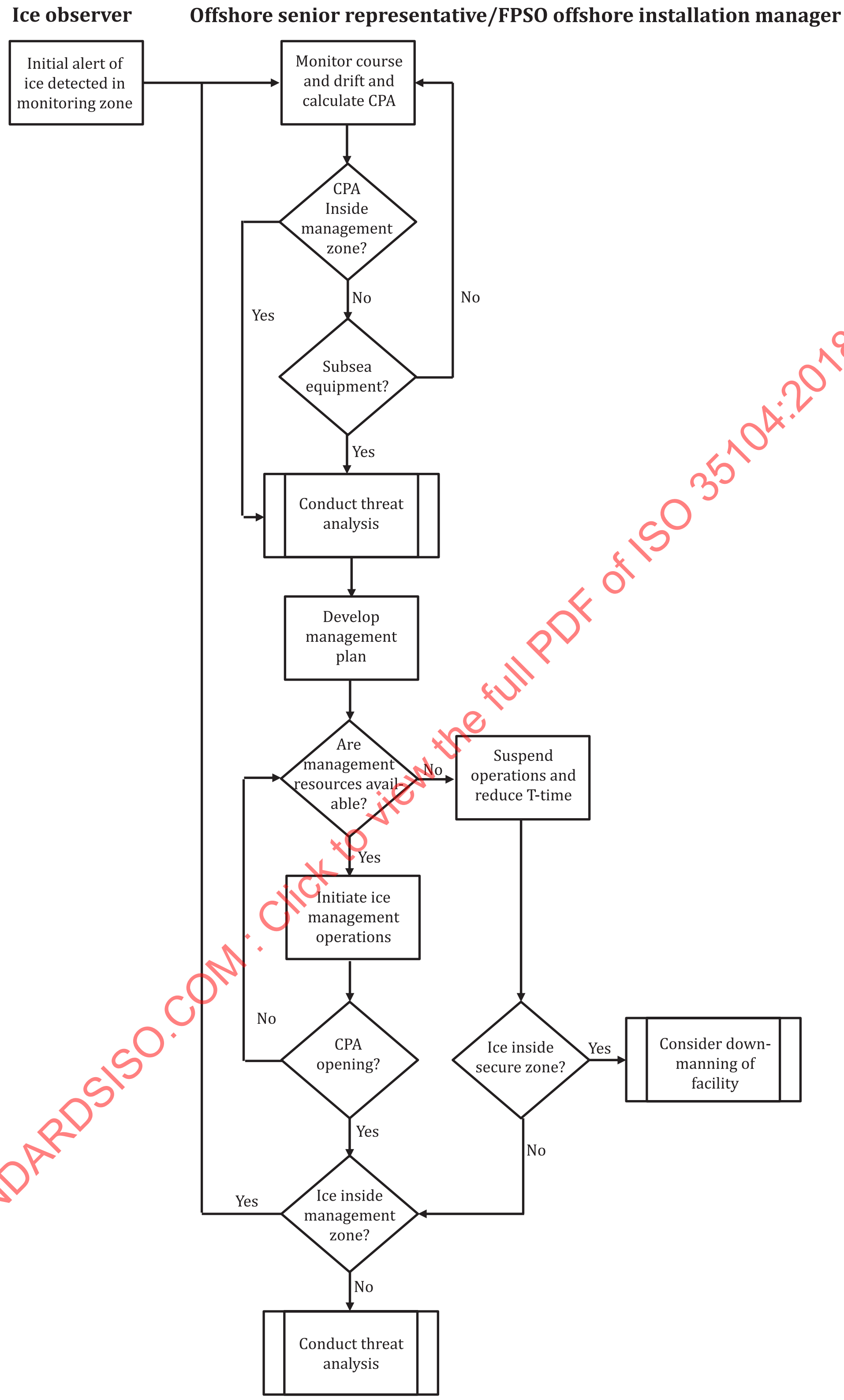


Figure B.4 — Flow diagram for operations in sea ice areas

B.9.5 Ice alert levels and zones

B.9.5.1 Zoning strategy

B.9.5.1.1 Sea ice example

An example of the ice alert levels used for offshore drilling operations in sea ice is shown in Table B.9. This table shows five ice alert levels that are linked to the time that hazardous ice is forecast to be at the facility, and the time required to secure the current operations and move the facility off location, if it becomes necessary. Roles, responsibilities and actions required are specified according to the ice alert level.

The actual times can vary with the specific operation and the design of the system. Depending upon particular operational requirements and/or limitations, alternate approaches to ice alerts can be followed.

Table B.9 — Ice alerting colour code, pack ice (drilling operations) (example only)

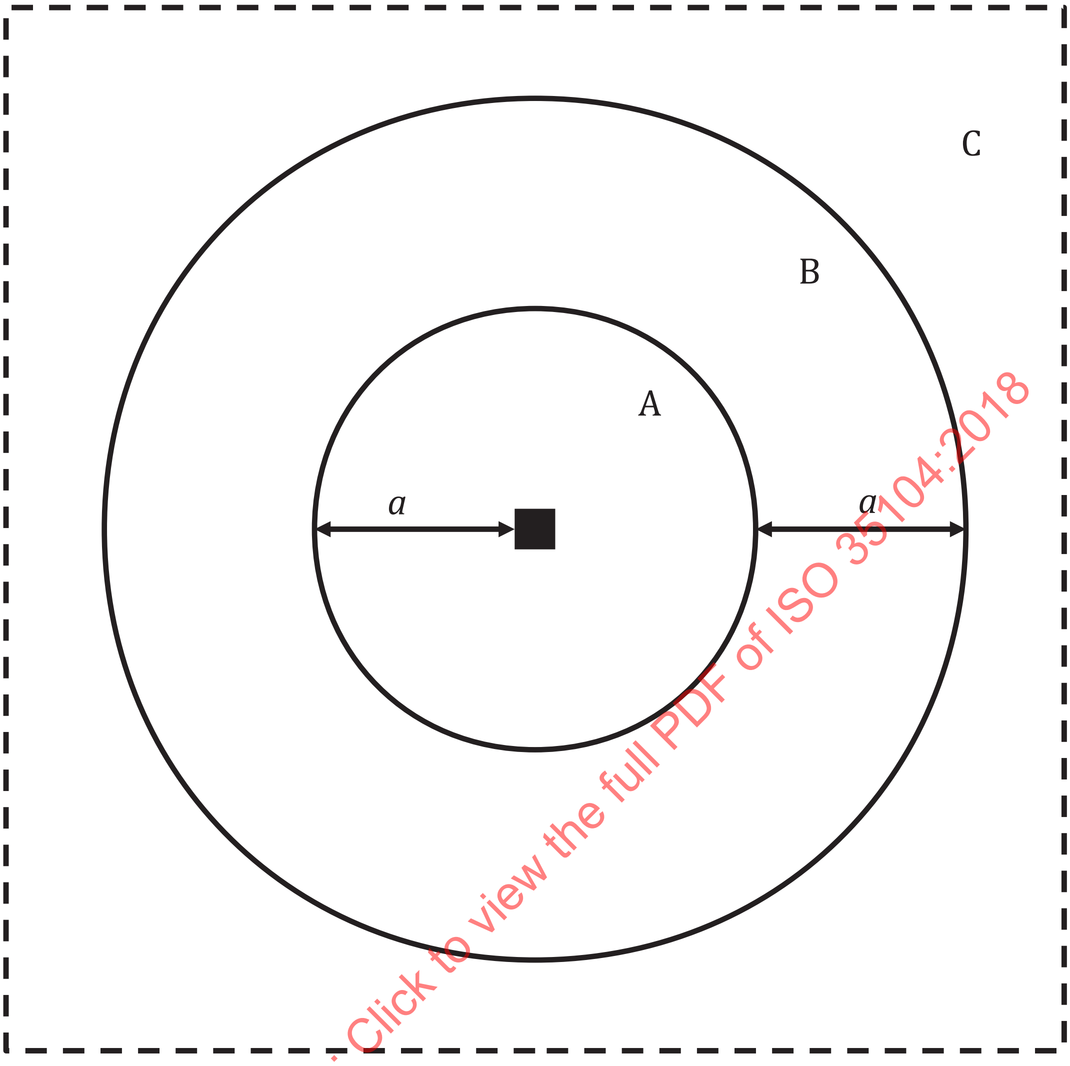
Ice alert level	Operations closure time calculation (HT Ice hazard time, ST Secure time, MT Move off time)	Action
0	HT — (ST + MT) > 24 h	Normal operations
1	12 h < HT — (ST + MT) < 24 h	Operate with caution
2	6 h < HT — (ST + MT) < 12 h	Restricted operations
3	HT — (ST + MT) = 6 h	Secure well operations
4	HT — MT = 6 h	Recover anchors
5	2 h < HT < 6 h	Move rig

The move-off and disconnection time (MT) occurs after the operation is secure and is added to the ST to obtain the T-time. The result of adding the ST to the MT, subtracted from the HT gives the operator a factor to base the ice alert level on. The ice alert level drives what can be, or needs to be, done on the facility, or not done, as shown in Table B.9.

B.9.5.1.2 Iceberg example

This subclause describes an example of ice zones for operations in a glacial ice regime off the East Coast of Canada. An illustration of the zones surrounding the offshore facility is given in Figure B.5 for a MODU and in Figure B.6 for an FPSO. Background information is provided in Table B.10. It is emphasized that these examples are for illustrative purposes only and pertain to a site-specific operation. Further details are given in B.9.5.3 for activities in the management zone and in B.9.5.4 for the secure zone.

Although the zones illustrated in Figures B.5 and B.6 are circular, ice drift forecasts could allow for zones with other shapes based on preferred drift directions.



Key

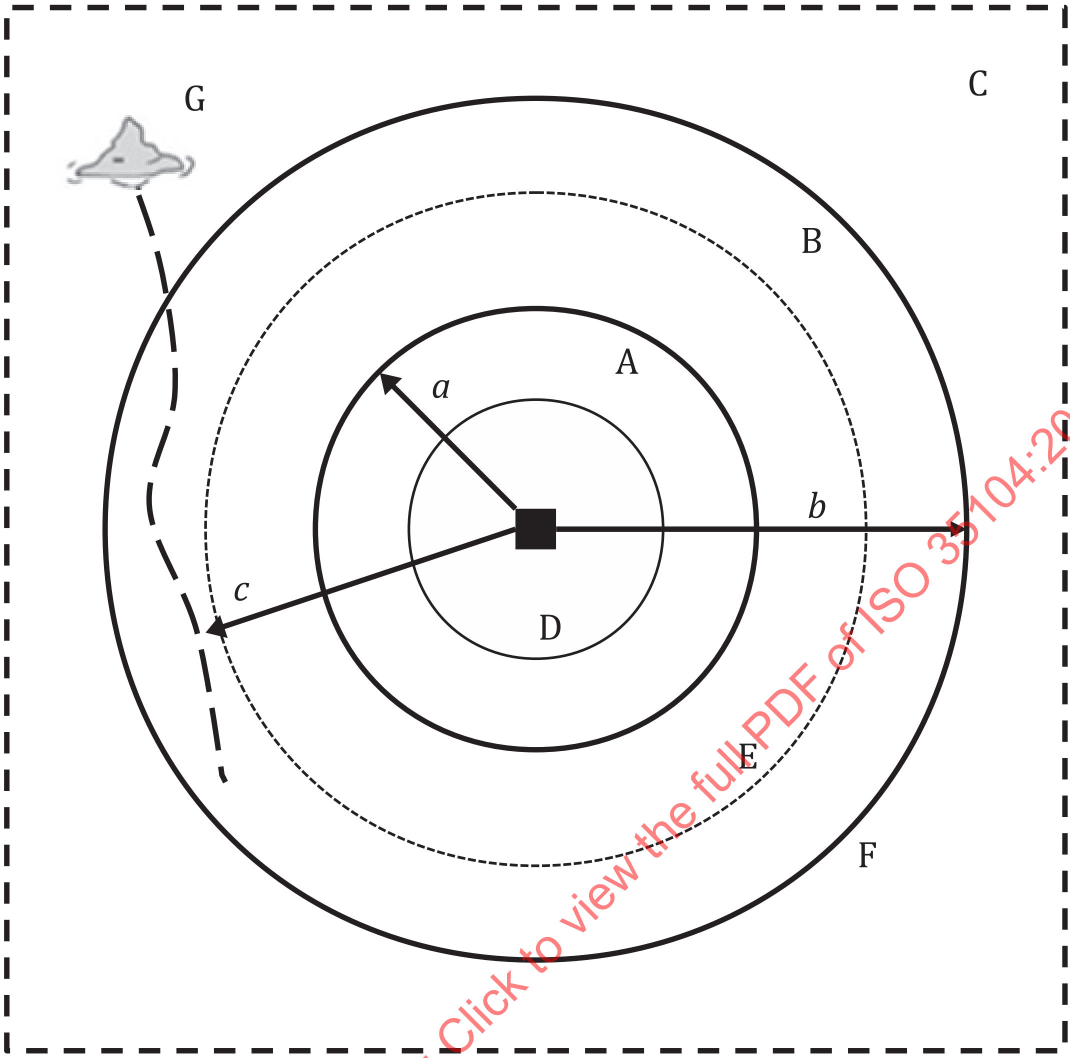
A secure zone

B management zone

C monitoring zone

a width of zone (i.e. DS × T-time) — in this example, the width of the management and secure zones is the same, although this need not be the case

Figure B.5 — Ice zones for a MODU in a glacial ice regime



Key

A secure zone
B management zone
C monitoring zone
D ice exclusion zone
E middle of management zone
F outer edge of management zone
G iceberg
a radius of secure zone
b radius of management zone
c closest point of approach (CPA)

NOTE Secure zone:
disconnect FPSO
estimated T-time = 0,416 hours
radius = [(T-time × DS) + ¼ nautical mile]

Figure B.6 — Ice zones for an FPSO in a glacial ice regime

Table B.10 — Ice zones for glacial ice (example only)

Ice zone	Name or item	Description or response
Secure	Ice alert	Safety buffer — quick departure to designated safe area
		Secure zone radius = MT × DS, where MT is move-off time and DS is drift speed
Management	DS times	Drift speed of the approaching ice in knots
	T-Time	Total time for: — suspending operations — securing the well or secure working on site — prepare offshore facility to disconnect — evacuate the personnel or move the facility to a safe area
	Reaction	Secure operations and prepare for departure of offshore facility to designated safe area from well or worksite
		IM can continue in order to avert ice alerts and possible disconnect or move off location
		Management zone radius = (MT + ST) × DS, where ST is secure time
		Width of management zone = ST × DS
Monitoring	Ice monitoring	Tracking, forecasting, decision support system and management

B.9.5.2 Monitoring zone

The monitoring zone extends beyond the management zone and has no fixed width. However, monitoring out to all radar horizons is maintained (includes rig, IM vessels and aircraft). Ice within this zone is assessed and monitored and potentially hazardous ice features can be managed where prudent.

B.9.5.3 Management zones

The following discussion relates to the iceberg example described in B.9.5.1.2. The numbers are provided for illustrative purposes only.

The width of the management zone is defined by the drift speed "DS" in the direction of the approaching ice, multiplied by the offshore facility T-time (DS × T-time). When threatening ice reaches the outer edge of the management zone, T-time can potentially be reduced and IM continued.

The following contemplates "suspending the well or the work" and is defined for each facility as applicable.

MODU

Suspension of a well being drilled with a mobile offshore drilling unit means to properly secure the well providing pressure integrity at the seabed to allow for disconnecting the lower marine riser package or the blowout preventer from the well and at the seabed.

As suspension operations progress, T-time decreases and, by definition, the size of the management zone decreases. When ice reaches the secure time, T-time will equal 0, since the management zone starts at the edge of the secure zone. If it appears that during suspension operations, by the reduction of T-time and management zone size, the ice will now remain outside of the management zone, the suspension operation can be stopped, while monitoring the ice continues.

EXAMPLE An iceberg is approaching with a drift speed of 1,0 knot and a T-time of 5,0 hours:

T-distance or management zone width = 1,0 knot × 5 hours = 5 nautical miles

FPSO

The width of the management zone is defined by the drift speed "DS" of the threatening ice, multiplied by the overall FPSO T-time for shutdown and disconnection (DS × T-time). This distance is then added to the ¼ nautical mile FPSO ice exclusion zone.

Suspension of operations for the FPSO is defined as:

— the orderly planned shut down and depressurization of production operations; and

— the preparation of FPSO topsides, marine and utility systems for disconnection.

The progressive nature of the FPSO ice threat production shutdown operation results in two distinctions for the management zone:

1) The outer edge of the management zone is defined by the shutdown of satellite drill centres.

2) An additional area inside of the middle of the management zone, which signals the commencement of shutdown operations to the central drill centre.

B.9.5.4 Secure zones

The following discussion relates to the iceberg example described in B.9.5.1.2. The numbers are provided for illustrative purposes only.

MODU

For a semi-submersible mobile offshore drilling unit (MODU) the radius of the secure zone is the greater of one nautical mile (International Standard) or one-hour drift from the MODU.

FPSO

The width of the secure zone is defined by the assigned drift speed in consideration to direction "Ds" of the threatening ice, multiplied by the FPSO T-time for disconnection (DS × T-time for disconnect). To this distance is then added a safety margin and for this example the operator used ¼ nautical mile for the FPSO ice exclusion zone.

Once ice is coming close to the exclusion zone, the FPSO will start the disconnect sequence and will be brought to the point where it is ready to disconnect.

Width of secure zone = (T-time for disconnect × DS) + ¼ nautical mile

B.9.5.5 Exclusion zone

A typical vessel exclusion zone radius is 500 m.

B.9.6 T-time calculations

The move-off time is normally constant, but can also be variable (e.g. depending on the status of IM vessels, whether vessel decks are clear, and IM requirements associated with ice conditions).

Depending on the nature of operations, some responses contributing to the T-time can potentially be executed simultaneously.

B.9.7 Stages of threat assessment

No additional guidance is offered.

B.9.8 Models for ice actions

No additional guidance is offered.

B.9.9 Situations requiring increased vigilance

Stamukhi can be of potential concern during the formation process, when re-floated and as obstructions for vessel traffic.

B.9.10 Infrequent, unanticipated and unforecast ice events

Particularly in pioneering IM operations, unanticipated and unforecast ice events can take place. These events have not necessarily occurred during the period of record, or occurred but were not recorded.

Regular consideration of 'what-if' scenarios, with pre-emptive actions can be considered where appropriate.

The use of simulators and simulation programs has been shown to make IM personnel less complacent and more prepared for unanticipated and unforecast events. 'What if' scenarios can be considered to address the routine activities for those involved in the decision-making hierarchy/network.

Until the science and means of predicting ice events is perfected, the threat will persist. Since unanticipated, unforecast and unmanageable ice loading events can occur within the T-time, emergency strategies should be in place to avoid loss of life and damage to the environment (see 4.1.3).

Past IM operations have all started out as pioneering operations for the first few years. These operations experienced surprises, where the IM procedures were unable to anticipate some ice events or sequences of events, posing unpredictable risks and delays in response. A full understanding of all the permutations of environmental and operational scenarios leading to risk is not possible until the operation has been conducted long enough to witness these events.

Although lessons from past operations can help accelerate the learning process by informing operators of potential ice events, it is difficult to avoid unanticipated and unforecast events for new operations.

B.10 Physical ice management

B.10.1 Selection criteria

Supporting IM vessels can perform differently, depending on their type, propulsion system, hull form and method of operation. The selection of the type of IM vessel can be based on the expected type of operation and possible IM operations, and also include:

— strategic icebreaking far afield;

— tactical IM;

— manoeuvring close to a vessel or facility;

— directing ice floes away from a facility;

— towing, pushing and directing icebergs away from a facility;

— management of bergy bits and growlers;

— ice escorting and towing.

IM vessels can provide accurate real time ice monitoring, ice forecasting and risk assessment, in order to adjust IM operations, as ice and other environmental conditions change.

An integrated command and control system can be used to provide a common situational awareness for all IM vessels and the defended facility.

The following issues can be considered:

a) ice regimes and the overall nature of the operation (pack ice and/or glacial ice conditions and iceberg management);

b) single or multiple ship operation;

c) IM capability;

d) tasks of the IM vessels, including ice reconnaissance, icebreaking and ice clearing;

e) type, class and number of IM vessels:

   1) ice class;

   2) power;

   3) propulsion system type;

   4) bollard pull;

   5) icebreaking features;

   6) vessel performance;

   7) manoeuvring capability;

   8) vessel machinery response (radical manoeuvring);

   9) monitoring systems;

   10) width of ice belt;

   11) emergency response capability;

   12) carrying capacity;

   13) endurance (autonomous time);

f) logistics requirements;

g) craneage requirements;

h) vessel power and performance in icebreaking and manoeuvring;

i) crew: skill and competency, experience and crew changes;

j) bunkering, refuelling arrangements;

k) other functional and/or operational requirements, which could include anchor handling, iceberg towing, crew transport, monitoring and detection, EER;

l) support of stationary systems, slowly moving systems or transiting systems (requiring escort);

m) operational risks and hazards and remedial activities; and

n) the types of ships available and description of their performance and manoeuvrability in expected/ planned ice conditions.

The performance capabilities can include icebreaking capability in various ice conditions (level ice of different thickness, brash ice of different compaction, ice ridge (ramming) for ahead and astern operation and turning radius).

B.10.2 IM vessel requirements

Over and above applicable class requirements, permissions for navigation can be specified by the Northern Sea Route Administration or the flag state.

Consideration should be given to fitting anti-collision monitoring equipment to IM vessels.

Key requirements for icebreaking IM vessels are the uninterruptable functioning in prevailing ice conditions, which can be achieved through:

a) sufficient icebreaking capability, taking into account effects of snow thickness, ridging and pressure;

b) sufficient manoeuvrability in ice conditions;

c) propulsion/steering unit ensuring manoeuvrability in heavy ice conditions;

d) resistance of the propulsion/steering unit to ice impact during manoeuvring and astern movement;

e) the possibility of channel creation in continuous sheet ice.

Iceberg tow vessels should:

1) have sufficient bollard pull for the anticipated iceberg sizes and towing strategies;

2) be equipped with suitable tow ropes or nets in good repair, and drums for their storage and deployment;

3) be equipped with suitable winches and towing hawsers;

4) have sufficient unencumbered deck space for tow rope or net deployment;

5) have crew trained in deployment procedures to avoid fouled propellers.

B.10.3 Operation-specific procedures

Examples of operation-specific procedures are given in the following list:

a) Moored systems: these systems require IM to protect the facilities, which requires anchor handling and IM. Close-in approaches to the facility can require localized ice breaking and clearing. In circumstances where the facility is restricted in aligning to the predominant drift additional attention is required to allow ice drift angle changes. Where the facility is free to rotate, ice breaking and clearing can be required to handle ice drift changes and manage the flow of ice around such systems.

b) DP vessels: these vessels follow the same basic procedures as under the moored systems, without the need for anchor handling and associated management.

c) Drilling vessels for exploration, including coring and work over: see under moored systems or DP vessels.

d) Production systems: see under moored systems or DP vessels.

e) Construction vessels, including trenching, dredging, pipe laying, construction, installation, diving, ROV deployment: most of these operations require active and where possible passive IM around the construction spread. IM can consist mainly of localized breaking and clearing, depending on the T-time.

f) Tanker offloading, loading and other offloading operations, stationkeeping at loading towers, larger structures or at loading buoys: these operations require close-in breaking and clearing and allowing tandem offloading vessels to approach and depart in acceptable ice conditions. The effects of ice drift can be taken into consideration.