



BSI Standards Publication

Petroleum and natural gas industries — Arctic operations — Ice management

National foreword

This British Standard is the UK implementation of EN ISO 35104:2020. It is identical to ISO 35104:2018. It supersedes BS ISO 35104:2018, which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee PSE/17, Materials and equipment for petroleum, petrochemical and natural gas industries.

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Ice management (ISO 35104:2018)**

Industries du pétrole et du gaz naturel - Opérations en
Arctique - Gestion des glaces (ISO 35104:2018)

Erdöl- und Erdgasindustrie - Arktisbetrieb -
Eismanagement (ISO 35104:2018)

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European foreword

The text of ISO 35104:2018 has been prepared by Technical Committee ISO/TC 67 "Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries" of the International Organization for Standardization (ISO) and has been taken over as EN ISO 35104:2020 by Technical Committee CEN/TC 12 "Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries" the secretariat of which is held by NEN.

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Endorsement notice

The text of ISO 35104:2018 has been approved by CEN as EN ISO 35104:2020 without any modification.

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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.