Offshore Vessel Operations in Ice and/or Severe Sub-Zero Temperatures

In Arctic and Sub-Arctic Regions

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OCIMF's mission is to be the foremost authority on the safe and environmentally responsible operation of oil tankers, terminals and offshore vessels, promoting continuous improvements in standards of design and operation.

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Contents

Introduction

The purpose of this paper is to provide guidance to operators and charterers of offshore support vessels employed for use in areas impacted by ice or severe sub-zero temperatures with the aim of encouraging high standards of safety and environmental protection for those operating in Arctic and Sub-Arctic regions.

The recommendations contained in this paper are intended to embrace the full range of vessel types and services associated with offshore support activities. While much of the guidance will apply to all vessels, section 4.3 addresses the specific issues associated with a particular type of vessel or its operation. It should be noted that the guidance may not be particularly relevant to vessel activities associated with port services, such as the provision of tug or icebreaking support in port areas.

Ice and severe sub-zero temperatures may impact on offshore vessel operations in many geographical areas. Operations in ice and severe sub-zero temperatures present vessel operators with unique risks and considerations. Operating areas are often remote with very limited navigational and support infrastructure, sea ice might be encountered year-round or seasonally and may include multi-year ice and severe sub-zero temperatures. Third party ice management may be required, depending on Ice Class and installed power of the offshore vessel. Due to the specialist nature of operations and navigation in these areas, the guidance in this paper is primarily aimed at project-orientated shipping supporting upstream activities and associated vetting decisions for spot employment.

It is recommended that OCIMF members use appropriate ice-strengthened and winterised vessels, which have classification from an International Association of Classification Societies (IACS) member, for work in ice and severe sub-zero temperatures. For the purposes of this publication, severe sub-zero temperatures are defined as average daily mean ambient temperatures below -10˚C. Within this publication, the term ice regime is used to describe a region that may be composed of any mix or combination of ice types, including open water.

Due account should be taken of the ice regime characteristics, anticipated temperatures and metocean conditions. Owners will also need to contact the relevant statutory authorities or administrations to obtain details of any specific vessel or operational requirements that may apply in a particular sea area to ensure that their vessels comply with all applicable regulations. A list of websites providing details of administration contacts is provided in Annex A. Where applicable, reference should also be made to the IMO Resolution A.1024 (26) Guidelines for Ships Operating in Polar Waters and other applicable recommendations developed by the International Maritime Organization.

By the very nature of their operations, work on offshore support vessels entails personnel working outside accommodation areas on deck. Wherever possible, crew exposure to the harsh environmental conditions should be limited by, for example, vessel design and adherence to established work/rest routines. Operators conducting operations in Arctic and sub-Arctic regimes should have procedures in place to address crew exposures to the anticipated conditions. For further information, reference should be made to the International Oil and Gas Producers Association (OGP) report No 398 The Health Aspects of Work in Extreme Climates.

Abbreviations

ABS	American Bureau of Shipping
ASD	Azimuth Stern Drive
BV	Bureau Veritas
CASPPR	Canadian Arctic Shipping Pollution Prevention Regulations
CIS	Canadian Ice Service
DGPS	Differential Global Positioning System
DNV	Det Norske Veritas
DP	Dynamic Positioning
EPIRB	Emergency Position-Indicating Radio Beacon
GL	Germanischer Lloyd
GLONASS	Global Navigation Satellite System
GPS	Global Positioning System
HRU	Hydrostatic Release Unit
IACS	International Association of Classification Societies
IMO	International Maritime Organization
INL	International Navigating Limits
LIWL	Lower Ice Water Line
LR	Lloyd's Register
LSA	Life-Saving Appliances
MARPOL	The International Convention for the Prevention of Pollution from Ships
NFPA	National Fire Protection Authority
NIC	National Ice Center (US)
NKK	Nippon Kaiji Kyokai
OGP	International Oil and Gas Producers Association
OSRV	Oil Spill Response Vessel
OVID	Offshore Vessel Inspection Database
PFD	Personal Flotation Device
PPE	Personal Protective Equipment
RINA	Registro Italiano Navale
ROV	Remotely Operated Vehicle
SBV	Standby Vessel
SCBA	Self-contained Breathing Apparatus
SMS	Safety Management System
STCW	Standards of Training, Certification and Watchkeeping
TPA	Thermal Protective Aid
UIWL	Upper Ice Water Line
UKC	Under Keel Clearance
WMO	World Meteorological Organization

Glossary

A

Above water The part of an object visible above the surface of the sea or waterway in which it is observed. In the context of this document the area of ice formations visible above water is of particular relevance.

Administration The Government of the State under whose authority the vessel is operating.

B

Bathymetry The depth of water relative to sea level in any given location as well as the submarine topography or the depths and shapes of the underwater terrain over a wider area.

Bergy bits A large piece of floating ice of land origin, showing less than 5m above sea-level and no more than 20m long.

Beset To be surrounded and trapped by ice so that movement of the vessel is not possible.

Bulk tank A compartment within a vessel for the carriage of cargo in bulk.

C

Charterers Persons entered into a contract with owners for the use of a vessel. May take the form of a demise or bareboat charter under which the charterer has the use of the vessel and engages their own crew or a time or voyage charter were the vessel is let out to the charterer for a defined period of time or a specific voyage.

Cold soaking The process of the steelwork of a vessel gradually getting colder so that it acts as a 'soak' and then retains the cold, even if there is a temperature increase. It can result in the formation of ice when liquid water, either as condensation or rain, comes into contact with the affected surface.

D

Dead-legs A length of piping within a cargo system through which there is no flow.

Deepwell pumps A submersible pump located in the bottom of a cargo or ballast tank.

Design Air Temperature The temperature that a system is designed to operate in under the most extreme conditions.

Drift Ice Any sea ice other than fast ice. Drift ice is moved by wind, current and tide.

E

Egg Codes A coding system used in ice charts to provide information on concentration, development and form of ice. It is referred to as the Egg Code due to the oval shape of the symbol.

F

Fast ice Consolidated solid ice attached to the shore, to an ice wall or to an ice front. It forms by freezing to the shore of the ice cover forming in the coastal zone or as a result of freezing of drifting ice of any age category to the shore or fast ice. Vertical movement may be observed during tidal oscillations. It can be preserved without fracturing for two or more years transforming from first-year ice to multiyear ice and even shelf ice. The fast ice width can vary from several hundreds of meters to several hundreds of kilometres. That part of fast ice presenting a narrow fringe of ice directly attached to the coast with a shallow bottom and unresponsive to tidal oscillations that remains after the fast ice has moved away is called the ice foot. Fast ice, at the initial stage of formation, consisting of nilas and young ice with a width up to 100-200m is called young coastal ice.

First-year ice Sea ice of not more than one winter's growth, developing from young ice, with a thickness 30cm – 2m and sometimes slightly more. It may be subdivided into thin first-year ice/white ice, medium first-year ice and thick first-year ice.

G

Growler A piece of ice of land origin that is smaller than a bergy bit. The colour is usually white, but sometimes transparent or blue-green or nearly black, normally occupying an area of about $20m^2$ / not more than 5m long. Growlers are distinguished with difficulty when they are surrounded by ice and also in a heavy swell as they are often awash.

I

Ice accretion The process by which a layer of ice builds up on solid objects which are exposed to freezing precipitation or to super-cooled fog or cloud droplets. It is most likely during time periods when surface air temperatures are between zero and -15°C. Below this threshold spray tends to freeze directly in the air so that it does not adhere to surfaces.

Ice advisor Suitably qualified person taking the lead analytical position in an ice advisory centre or similar to advise on the formation and movement of ice and the appropriate ice management actions to be taken.

Ice Class Notation The notation assigned to the vessel by a classification society showing that the vessel has been designed for navigation in sea ice conditions.

Ice classification The identification and description of observed ice formations.

Ice foot A wall or belt of ice frozen to the shore in arctic regions having a base at or below the low-water mark and formed as a result of the rise and fall of the tides, freezing spray, or stranded ice.

Ice island A large piece of floating ice protruding about 5 m above sea-level, which has broken away from an Arctic ice shelf, having a thickness of 15-30 m and an area of from a few thousand square meters to 500 km^2 or more, and usually characterised by a regularly undulating surface which gives it a ribbed appearance from the air.

Ice management Activities undertaken with the objective of reducing or avoiding interaction with any kind of ice features. This can include but is not limited to:

- Detection, tracking and forecasting of ice.
- Evaluation of the threat posed.
- Physical ice management, such as ice breaking and iceberg towing.
- Procedures for disconnection of offshore installations.

Ice navigator A properly certificated Officer who holds documentary evidence of having satisfactorily completed an approved training programme in ice navigation. Such a training programme shall have provided knowledge, understanding and proficiency required for operating a vessel in polar ice-covered waters, including recognition of ice formation and characteristics; ice indications; ice manoeuvring; use of ice forecasts, atlases and codes; understanding of hull stress caused by ice; ice escort operations; ice-breaking operations and effect of ice accretion on vessel stability. There shall also be documentary evidence of having completed on-the-job training, as appropriate, which may include simulation training.

Ice pilot A person trained and experienced in navigation in ice who will join a vessel to augment and advise the Master and his/her navigational team.

Ice ram An underwater ice projection from an ice wall, ice front, iceberg or floe. Its formation is usually due to a more intensive melting and erosion of that part which is not submerged.

Icebreaker Any vessel whose operational profile may include escort or ice management functions, whose powering and dimensions allow it to undertake aggressive operations in ice-covered waters.

Icebreaker escort Any operation in which a ship's movement is facilitated through the intervention of an escort vessel with superior ice capability.

International Navigating Limits Limits set and kept under review by the International Navigating Limits (INL) sub-committee of the Joint Hull Committee. Pertinent limits will be contained within the marine insurance policy relating to the relevant vessel. As standard navigation within most Arctic waters will be excluded and additional cover will be required for vessels operating in these areas.

To breach INL is to navigate into or through one of the either seasonal or permanently excluded areas without advising the hull insurance underwriters and without paying the additional insurance premiums, which will void the vessel's hull insurance cover.

K

Keel The underwater features of deformed ice are referred to as keels. Deformed ice is a general term for ice which has been squeezed together and broken up with the formation of surface and underwater conglomerations. Surface features are referred to as Sails.

M

Master The Officer in command of a merchant vessel. He or she is the Owner's representative on board and holds ultimate responsibility for all actions undertaken on board, particularly the safe and efficient operation of the vessel.

Metacentric height The vertical distance between the centre of gravity (the point through which the force of gravity is considered to act vertically downwards) and the metacentre (the point at which the force of buoyancy will cut the centre line at a given angle of heel).

Moon pools A vertical opening in the hull of a vessel giving access to the water below allowing sub-sea operations to take place in a protected environment.

Moraine A mass of rocks and/or sediment carried and deposited by a glacier, typically as ridges at its edges or extremity.

Multi-year Ice Old ice up to 3m or more thick that has survived at least two summers' melt. Hummocks are even smoother than in second-year ice and attain a look of mounds and hills. The surface of multi-year ice fields in places not subject to deformations is also hillocky due to non-uniform multiple melting. The ice is almost salt-free. Its colour, where bare, is usually blue. As a result of melting, round puddles appear at its surface in summer and a well-developed drainage system is formed.

O

Offshore installations A general term for mobile and fixed structures, including facilities, which are intended for exploration, drilling, production, processing or storage of hydrocarbons or other related activities or fluids. The term includes installations intended for accommodation of personnel engaged in these activities. Offshore installation covers subsea installations and pipelines.

Owners The legal owners of a vessel. Responsibility for the operation of the vessel may be delegated to third party managers.

Old ice Sea ice which has survived at least one summer's melt, with a typical thickness of up to 3m or more. It is subdivided into residual first-year ice, second-year ice and multi-year ice.

P

Port Authority The organisation that is responsible for the safe and efficient operation and management of a specific port.

The exact composition, structure responsibilities and power of a Port Authority will be determined by the laws and practices of the state within which the port is located. They may be public or private bodies.

R

Residual first-year ice First-year ice that has survived the summer's melt and is now in the new cycle of growth. It is 30 to 180cm thick depending on the region where it was in summer. After 1 January (in the Southern hemisphere, after 1 July), this ice is called second-year ice.

S

Sail The surface features of deformed ice may be referred to as sails, although reference can be made to rafted ice, rough ice, ridged ice, jammed brash barrier and hillocky multi-year ice as well. Deformed ice is a general term for ice which has been squeezed together and broken up with formation of surface and underwater conglomerations. Underwater features are referred to as Keels.

Sea chest Underwater compartment within the shell plating through which sea water is drawn in or discharged, for example, for cooling of machinery systems.

Second-year ice Old ice which has survived only one summer's melt; typical thickness up to 2.5m and sometimes more. Because it is thicker than first-year ice, it stands higher out of the water. Ridged features as a result of melting during the preceding summer attain a smoothed rounded shape. In summer numerous puddles of extended irregular shape form on its surface.

Skeg In common usage the term refers to the sternward extension of the keel to the rudder mount. In addition, in vessels designed to operate in ice, the skeg refers to any strengthened structure where the stem contour meets the keel line.

Sticking The adhesion of small pieces of broken ice to the vessel's hull as it proceeds and breaks large ice formations. Sometimes called a moustache.

T

Tow lines Lines passed from one vessel to another to facilitate towage operations.

V

Vessel A craft designed for navigation on water.

W

Winterisation Ensuring that a vessel is capable of, and suitably prepared for, operations in cold climates. This is provided for by setting functional requirements to functions, systems and equipment considered important to safety and which are intended to be in operation in cold-climate conditions.

Working decks The area of a vessel where the operations for which it is designed are carried out, for example cargo operations or towage operations. In the specific example of offshore vessels it may refer to the large open deck aft.

Bibliography

The following publications are referred to in the text:

World Meteorological Organizations (WMO)

1 Sea Ice Nomenclature (WMO No.259)

International Association of Classification Societies (IACS)

2 Unified Requirement (UR) S6 – Requirements Concerning Polar Class

International Maritime Organisation (IMO)

3 International Convention for the Safety of Life at Sea (SOLAS), 1974 – As amended

4 Resolution MEPC.174(58) - Guidelines for Approval of Ballast Water Management Systems

5 Resolution A 1024 (26) - Guidelines for Ships Operating in Polar Waters

6 MSC/Circ. 504 - Guidelines on Design and Construction of Sea Inlets under Slush Ice Conditions

Finnish Transport Safety Agency / Swedish Maritime Administration

7 Finnish / Swedish Ice Class Rules

Scientific Papers

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1. Ice Conditions

1.1 Ice accretion

Ice accretion is a serious hazard for marine operations. It can be caused by sea spray or by fog, sea smoke, rain or snow. The most serious form of ice accretion is usually formed by sea spray but fresh water accretion from fog, rain or sea smoke can cause radar, aerial and insulator failures as well as rigging damage and consequential danger to those on deck. The most obvious danger of sea spray ice accretion is that of vessel instability and, in extreme cases, capsizing. But there are other dangers and operational problems to consider including malfunctioning machinery, blocked vents and the physical dangers to crew members trying to work or rectify problems in such conditions. At present, there are few methods available to prevent icing and to quickly clear it should it occur.

Figure 1.1: *Ice accretion (Courtesy ©Arno Keinonen)*

Sea spray ice accretion occurs when wind and wave-generated spray comes into contact with cold exposed surfaces and the air temperature is below freezing. There are two general factors to be considered; environmental and vessel characteristics. These are briefly described below.

Environmental factors which contribute to ship sea spray icing include:

- Wind speed, e.g. typically above 18 knots or 9 m/s but sometimes lower.
- Air temperature, e.g. -2 ˚ C or lower.
- Water temperature, e.g. near freezing.
- Wind direction, relative to the ship.
- Swell and wave characteristics;
  - Wave size.
  - Wave length.
  - Wave propagation direction.

Vessel characteristics which affect the severity of sea spray ice accretion include the following:

- Speed.
- Heading (with respect to wind, waves and swell).
- Bow design.
- Length.
- Freeboard.
- Cold soaking, surface area of exposed steelwork.*

* When a vessel has been in cold temperatures for a long time, for example two or three weeks, the body of the ship will remain cold even if the air temperature rises above

zero. This cold soaking may result in icing being more severe than expected given the prevailing environmental conditions.

To minimise the effect of ice accretion, and if unable to reach shelter or warmer conditions, measures may need to be taken to reduce the amount of sea spray by heading into the wind and sea at the slowest speed to maintain steerage way. If weather conditions do not permit this manoeuvre, the vessel should be manoeuvred to run before the wind, also at a minimum speed to maintain steerage way.

Figure 1.2: *Ice accretion*

1.2 Ice types and conditions

Several forms of floating ice may be encountered at sea within the geographical areas covered by this paper. The most extensive is that which results from the freezing of the sea surface, namely sea ice, but mariners may also be concerned with 'ice of land origin' – icebergs, ice islands, bergy bits and growlers. Both icebergs and sea ice can be dangerous to shipping and their presence will impact on navigation.

The following is a brief description of the ice types likely to be encountered. A full description of ice types is contained in the World Meteorological Organization (WMO) Code Sea Ice Nomenclature (WMO No. 259).

1.2.1 Sea Ice Nomenclature

The codes used to describe ice conditions are based on the WMO's Sea Ice Nomenclature.

In most cases, such as on ice charts or interpretations of satellite imagery, the ice cover is characterised using the following categories:

- Ice concentration.
- Stages of development.
- Forms of floating ice.
- Openings in the ice.
- Ice-surface features.
- Terms related to shipping.
- Ice of land origin.

Ice categories are presented in table 1.1. Full details and a more extensive list of ice terms are contained within the WMO Sea Ice Nomenclature (WMO No. 259).

Table 1.1: *Ice terminology*

ICE TERMS	DESCRIPTION
Floating Ice	
Ice Concentration	The ratio expressed in tenths describing the mean areal density of ice in given area
Consolidated Pack Ice	10/10 and no water is visible
Very Close Pack Ice	9/10 to less than 10/10
Close Pack Ice	7/10 to 8/10
Open Pack Ice	4/10 to 6/10
Very Open Pack Ice	1/10 to 3/10
Open Water	Less than 1/10
Bergy Water	No sea ice present; ice of land origin is present
Ice-Free	No ice of any kind is present
Ice massif	A variable accumulation of close or very close ice covering hundreds of square kilometres which is found in the same region every summer
Ice field	An area of floating ice of any size, which is greater than 10km across. The characteristics, position and sizes of fields are described as separate zones.
Stages of Development	
New Ice	Includes frazil ice, grease ice, slush and shuga; composed of ice crystals

Table 1.1: *Ice terminology*

Nilas	Up to 10cm (4in)
Dark Nilas	Up to 5cm (2in)
Light Nilas	5 - 10cm (2 - 4in)
Young Ice	10 - 30cm (4 -12in)
Grey Ice	10 - 15cm (4 - 6in)
Grey-White	15 - 30cm (6 - 12in)
First-year Ice	30cm - 2m (1ft – 6ft 7in)
First-year Thin Ice	30 - 70cm (1ft - 2ft 6in)
First-year Medium Ice	70 - 120cm (2ft 6in - 4ft)
First Year Thick Ice	120 - 200cm (4ft - 6ft 7in)
Old Ice	Includes second-year and multi-year ice
Multi-year ice	Old ice up to 3m or more thick that has survived at least two summers' melt
Forms of Floating Ice	
Brash Ice	Fragments not more than 2m (3.5ft) across; the wreckage of other forms of ice
Pancake Ice	Predominantly circular pieces of ice 30cm - 3m (1 - 10ft) across
Ice Cake	Up to 20m (66ft) across
Small Ice Cake	Up to 2m (6.6ft) across
Floe	Piece of sea ice 20m (66ft) or more across
Small Floe	20 - 100m (66 - 330ft)
Medium Floe	100 - 500m (110 - 550yd)
Big Floe	500 -2,000m (550 - 2200yd)
Vast Floe	2 - 10km (1.1 - 5.4nm)
Giant Floe	> 10 km (> 5.4 nm)
Fast Ice	Sea ice which forms and remains fast along the coast, where it is attached to the shore
Openings in the Ice	
Fracture	Any break or rupture through fast ice, compact pack ice or very close pack ice
Crack	Any fracture which has not parted
Lead	Any fracture or passage-way through sea ice which is navigable by surface vessel
Polynya	Any non-linear shaped opening enclosed in ice
Ice Surface Features	
Level Ice	Sea ice which is unaffected by deformation
Deformed Ice	Sea ice which has been squeezed together and forced upwards and downwards
Rafted Ice	Deformed ice formed by one piece of ice overriding another
Ridge	A line or wall of broken ice forced up by pressure
Rubble Field*	Floating or grounded ice feature composed of broken ice pieces refrozen in a contiguous feature of areal extent large with respect to its height
Dirty Ice	Ice that has a mineral or organic content of natural or anthropogenic origin on the surface or in its strata
Terms Related To Shipping	
Ice Under Pressure	Ice in which deformation processes are actively occurring
Beset	The situation of a ship surrounded by ice and unable to move
Nip	Ice which forcibly presses against a ship

Table 1.1: *Ice terminology*

Ice Bound	A harbour, inlet, etc. where navigation is prevented on account of ice, except possibly with the assistance of an icebreaker
Separate Ice Features	
Hummock	A hillocky conglomeration of broken ice formed by pressure at the place of contact of the angle of one ice floe with another ice floe. The underwater portion of a hummock is termed a bummock
Ridge	A comparatively rectilinear conglomeration of ice fragments formed by pressure at the contact line between ice floes, usually along earlier existing cracks and leads or at the boundary between ice floes of different age
Floeberg	A massive piece of sea ice composed of a hummock, or a group of hummocks frozen together, presenting a separate floating ice fragment in ice-free water or among separate ice fragments
Stamukha (Grounded Hummock)	A thick hummocked grounded ice formation. Stamukhas form from floebergs and hummocked grounded ice fragments
Ram	An underwater ice projection from an ice wall, ice front, iceberg or floe. Its formation is usually due to a more intensive melting and erosion of the part which is not submerged
Ice of Land Origin	
Iceberg	A massive piece of ice, greater than 5m above sea-level
Bergy Bit	A large piece of floating ice of land origin, showing less than 5m above sea-level and no more than 20m long
Growler	A smaller piece of ice of land origin than a bergy bit. The colour is usually white, but sometimes transparent or blue-green or nearly black, normally less than 5m long
Glacier Berg	An irregular shaped iceberg
Tabular Berg	A flat-topped iceberg
Iceberg Tongue	A major accumulation of icebergs projecting from the cost.
Ice Island	A large piece of floating ice protruding about 5m above sea-level, which has broken away from an ice shelf

* This term is not included in WMO Standard Sea Ice Nomenclature but is widely used by navigators and engineers.

Table 1.1: *Ice terminology*

Examples of some of the ice categories presented in table opposite are shown in the pictures that follow.

1.2.2 Ice concentration

Figure 1.3: *Medium pack ice (ice concentration of 6/10 - 8/10)*

Figure 1.4: *Very close pack ice (ice concentration of 9/10 - 10/10)*

1.2.3 Stages of development

Figure 1.5: *Grey ice (10 – 15cm)*

1.2.4 Forms of floating ice

Figure 1.6: *Pancake ice (30cm – 3m across)*

1.2.5 Ice surface features

Figure 1.7: *Ice ridges*

1.2.6 Ice of land origin

Icebergs are large masses of floating ice originating from glaciers. They are very hard and can cause considerable damage to a vessel that collides with them. Ice islands are vast tabular icebergs originating from floating ice shelves.

Smaller pieces of icebergs are called bergy bits and growlers and are particularly dangerous to vessels as they are very difficult to detect both by sight and radar, especially in restricted visibility and storm wave/swell conditions, or when pack ice is also present. Specialist ice radars exist, whose manufacturers claim will better detect growlers, but experience has shown that detection may still be problematic. Growlers often are awash and have no structure above the sea but can still be of considerable weight and hardness. Moraine trapped in glacial ice may reduce the buoyancy and cause bergy bits and growlers to float lower in the water.

Figure 1.8: *Tabular berg*

Figure 1.9: *Growlers or bergy bits*

1.3 Navigating in sea ice

There are many sea ice properties that can affect a vessel's navigation performance. The most obvious is the thickness of the ice but other properties, such as hardness, are also important. Multi-year ice is normally harder than first-year ice owing to the amount of salt that will have leached out during warmer periods. There can also be differences in the hardness of first-year ice, depending on the formation process and source. The amount and type of snow cover on the ice adversely impacts the friction against the hull of a vessel.

Another impediment to navigation is ice deformation. Drifting sea ice is continually in motion, under the influence of wind, current and internal stresses, and where it becomes subjected to pressure the surface often becomes deformed. Pressure can be caused by a number of factors but can be expected where drifting sea ice comes into contact with stationary fast ice, coastline features, cyclonic weather events and converging currents. Where the ice is thinner, it may raft with ice sheets or floes riding over each other. Where the ice is thicker, pressure is likely to cause ridging or hummocks.

Normally, the visible top of a ridge, known as the sail, is significantly smaller than the downward extension below, known as the keel. As ridges form, more ice is forced downwards than upwards in order to support the weight of the ice above the surface. In deep water a typical ratio of keel to sail may be four or five to one. The consolidated ice in a ridge is not as strong as level ice because it is made up of chunks refrozen together. However the dimensions can be considerable and may present a significant navigational obstacle to vessels, including ice-capable vessels.

A less obvious but significant impediment to ice navigation is pressure itself. As described above, ice pressure features in the development of deformed ice but not all deformed ice is under pressure. When a vessel encounters pressure, its ability to break ice and clear ridges is diminished, as is its ability to manoeuvre. The hulls, rudders and propellers of vessels beset in ice may be subject to pressure forces that can become significant.

When land fast ice forms over shallow waters and there are defined port approach channels, continual breaking of the ice can lead to the eventual blocking of the ice channel by refreezing of broken submerged ice chunks. Keeping these channels clear can be enhanced by the careful selection of suitable icebreakers and propulsion systems.

Key to safe and efficient navigation in ice, even for ice capable ships, is avoiding as far as possible difficult ice conditions and maintaining freedom to manoeuvre. In ice the shortest route is often not the safest and quickest route. Real time knowledge of the ice conditions through ice reports, observations and satellite imagery aided by ice forecasting, route modelling, weather, current and tidal informational play an important role in aiding the selection of the safest and most efficient routes.

In determining the ability of a vessel to safely operate in a particular area, the specific ice conditions should be carefully studied, with particular regard to the ice regime characteristics and anticipated weather conditions for the period of operation.

It is recommended that Masters avoid or navigate with extreme caution when working in open water close to the leading edge of pack ice, particularly during rough weather. Sections of the ice edge are liable to break off, creating a danger to ships as they have the potential to strike a vessel above an ice strengthened belt, causing significant damage.

Anchoring in ice conditions can be hazardous due to the high loads that may be imposed on the anchoring system by drifting ice, which may lead to the anchor dragging and/or damage to the anchor, cable or windlass.

The most typical ice conditions for sticking are young ice (grey-white ice) or first-year thin ice.

1.3.1 Sea ice accumulation on the hull

Sea ice accumulation on the hull of the vessel, or sticking, can typically occur when the ambient air temperatures fall just below zero. However, in rare cases, it can be observed in severe sub-zero conditions. The most typical ice conditions for sticking are young ice (grey-white ice) or first-year thin ice. Sticking represents a particular hazard as icebreaking vessels may be capable of steaming at speeds of 10-14 knots in light ice conditions. The sudden onset of sticking quickly reduces their speed and manoeuvring capabilities which, when the vessel is leading a convoy or undertaking ice management operations, introduces danger of collision from any following vessels.

The intensity of the ice accumulation on the hull depends on the air temperature and the roughness of the vessel's shell plating. Ice accumulation can be reduced by applying special coatings to the shell plating, thereby reducing its roughness.

Compressed air bubbling systems or deluge systems are installed on some vessels with the purpose of reducing friction between the vessel's hull and the ice and may be effective in preventing ice accumulation on the vessel's hull. The air-bubbling system works by blowing compressed air under the water in the forward part of the vessel and from the sides, creating an ascending water flow and water turbulence around the vessel's sides, which mechanically prevents ice formation. Deluge systems work on a similar principle, using water flow instead of compressed air.

2. Ice Information

The planning of operations should be based on analysis of an appropriate period of historic ice and metocean data which should include an understanding of issues such as:

- Area of navigation.
- Season (time of the year) at which the operation is intended.
- Operational support availability (ice management, icebreaker escort, ice pilot).
- Operational profile: occasional or regular operation.
- Relevant IMO, coastal and flag state regulations.
- Ice navigation regimes, guidelines and recommendations.

For long-term charters it is important to understand ice regime characteristics and that year-to-year variations in ice conditions can be significant. Statistical data should therefore include a range of ice conditions over an appropriate period in order to properly assess likely impacts.

For every voyage the most recent and forecasted ice information should be obtained and, if possible, updated during the voyage as often as practical.

The latest and most comprehensive ice information is available from national ice services (see table 2.1). It is recommended that you contact them directly, or visit their websites, and download the available historic and recent data. Most can provide detailed climatic conditions, bathymetry, ice data sets and ice charts. Some of the ice information centres can provide data and ice charts outside of their national region, e.g. NIC (US) satellites cover the entire world and ice charts are available for both the Western and Eastern Arctic regions.

It is also important to take into account information on arctic icebergs provided by Canadian and US governments through their iceberg tracking services (table 2.2).

Table 2.2: *Arctic iceberg monitoring services*

Region	Ice Information Services	Contact Information
Canadian Arctic	Canadian Ice Service	373 Sussex Drive Block E, Third Floor, Ottawa, Ontario, K1A 0H3 Canada
	Latest ice conditions available	www.ice-glaces.ec.gc.ca/WsvPageDsp.cfm?ID=1&Lang=eng
	Sea Ice Climatic Atlas	http://ec.gc.ca/glaces-ice/default.asp?lang=En&n=090AF7D6-1
	Icebreaking services	www.ccg-gcc.gc.ca/eng/CCG/Ice_Home
Greenland	Danish Meteorological Institute	3910 Kangerlussuag, Greenland Phone +299-84-1022 www.dmi.dk/dmi/en/gronland/iskort.htm
Norway	Norwegian Meteorological Institute (DNMI)	PO Box 43, Blindern 0313 Oslo, Norway Phone +47-22-963000 Fax +47-22-963050 email: met.inst@met.no www.met.no/english/index.html
	Norwegian Polar Institute Polar Environmental centre	N-9296 Tromsø, Norway (Norsk Polarinstitutt, Polarmiljøsenteret, 9296 Tromsø) Phone +47-77-750500 Fax +47-77-750501 email: postmottak@npolar.no www.npolar.no/en/
Sweden	Swedish Maritime Administration	601 78 Norrkoping Sweden www.sjofartsverket.se/en/ Phone +46 771 63 00 00 Fax +46 11 10 19 49 email: ulf.gullne@sjofartsverket.se

Table 2.2: *Arctic iceberg monitoring services*

Finland	Finnish Transport Agency/ Winter Navigation Unit	PO Box 185 FI-00101 Helsinki Finland http://portal.liikennevirasto.fi/sivu/www/e/professionals/winter_navigation Phone +358 295 343 327 Phone + 358 295 343 325 Fax + 358 202 48 4360 email: winternavigation@fta.fi
	The Finnish Meteorological Institute	P.O.BOX 503 FI-00101 Helsinki FINLAND www.itameriportaali.fi/en_GB/ Phone: +358 295 391 000 email: ice@fimr.fi
Iceland	Icelandic Meteorological Office	Bustaoavegur 7-9, 108 Reykjavik, Iceland Phone +354-522 6000 Fax +354-522-6001 http://en.vedur.is/sea-ice/sea-ice-reports/
Russian Arctic	Federal Agency of Sea and River Transport Administration of the Northern Sea Route	109012, Moscow, Ul.Rozhdestvenka, 1,building 1 Phone +7 495-626-1100, +7 495-626-1064, email: MonkoNA@morflot.ru
	Arctic and Antarctic Research Institute	38 Bering Street, St. Petersburg, 199397, Russia Phone +7-812-352-1520 Fax +7-812-352-2688 email: service@aari.nw.ru aaricoop@aari.nw.ru www.aari.nw.ru/index_en.html
Caspian Sea	Arctic and Antarctic Research Institute	www.aari.nw.ru./clgmi/sea_charts_en.html
USA	National Ice Center	Federal Building # 4, 4231 Suitland Road, Washington D.C. 20395, USA Phone +1-301-394-3100 www.natice.noaa.gov

Table 2.1: Details of selected national ice services

Region	Iceberg Monitoring Services	Contact Information
North of 50^{0}N	Canadian Ice Service Iceberg monitoring service	373 Sussex Drive Block E, Third Floor, Ottawa, Ontario, K1A 0H3 Canada www.ice-glaces.ec.gc.ca/WsvPageDsp.cfm?ID=1&Lang=eng
Northern Hemisphere South of 50^{0}N	International Ice Patrol	1082 Shennecosselt Road, Connecticut 06340, USA Phone +1-860-441-2626 Fax +1-860-441-2773 email iipcomms@uscg.mil www.uscg-iip.org/

Table 2.2: *Arctic iceberg monitoring services*

Electronic versions of the nomenclature are available from several sources including www.aari.nw.ru/gdsidb/XML/wmo_259.php.

When reviewing data presented in ice charts published by different organisations, it should be noted that minor differences exist in the way that data is depicted. Symbols used on ice charts prepared by North American organisations such as NIC (US) and the Canadian Ice Service (CIS) are based on the World Meteorological Organization's (WMO) Sea Ice Nomenclature (WMO No.259). This provides the standards for sea ice terminology and the coding of sea ice parameters (coding tables and scales) as well as presentation on ice charts. Electronic versions of the nomenclature are available from several sources including www.aari.nw.ru/gdsidb/XML/wmo_259.php.

It should be noted that, although Russia uses the WMO standard nomenclature, ice charts prepared by Russian sources look different from those from other organisations. This is due to the use of different codes and sets of symbols to describe the same ice conditions. The major difference is the use of 'egg-codes' in North America and circle shaped symbols in Russia. The Egg Codes include alphabetic and numeric symbols but the Russian code uses graphical descriptions of floe size and stage of development (See Annex G).

The understanding, use and correct interpretation of data depicted on ice charts requires specialist training, irrespective of which code is applied. Training should be provided to relevant personnel operating in areas with ice to ensure that they are familiar with the code used in forecasts for that specific area.

3. Capability for Operations in Ice and/or Severe Sub-Zero Temperatures – Design Aspects

3.1 Introduction

The design of vessels intended for operation in an ice regime and/or severe sub-zero temperatures requires careful preparation and planning to ensure the vessel is fit for purpose. Additional requirements, above and beyond that of a basic ice-strengthened vessel, are often necessary to ensure that the vessel can operate safely and effectively. The requirements cover hull, machinery and human elements, and are dependent on the intended vessel service and area of operation.

The optimum design concept for any vessel intended for ice service will depend on the intended critical role. However, offshore support vessels are often expected to be capable of multiple roles both in ice and in open water and it must be appreciated such an expectation will probably result in a compromise in specific role performance capability. The following describes some of the technical aspects that require examination, including a description of structural issues and machinery requirements. In addition, the various ice classes and the different approaches taken by Flag and Coastal States are outlined.

3.2 Definition and use of air temperature

Low air temperatures should be considered in the design of ships navigating in cold regions. However, the definition of the Design Air Temperature is a complex issue, which requires a number of different technical, commercial and operational aspects to be considered.

There are a multitude of different definitions for the Design Air Temperature depending on the:

- Standard used.
- Applicable ship type.
- Operating season.
- Voyage.
- Component considered.
- Material selected.

As a result, definitions used include, for example, the extreme air temperature, mean daily average air temperature and monthly lowest air temperature (IACS Unified Requirement (UR) S6, paragraph 6.3).

Low air temperatures should be considered in the design of ships navigating in cold regions.

Typical ship operations associated with steel structures as defined by IACS UR S6 are confined to worldwide temperatures down to -10°C and with increasing steel grade requirements for temperatures below this. IACS UR S6 is specifically applicable to the structural integrity and uses the lowest mean daily average air temperature which is based on historical data for 20 years. This average air temperature is used due to the frequency and likelihood of encountering low temperatures for typical ship voyages, steel properties and testing criteria and calibrated against service experience including the wave conditions and latent ship heat (such as in ballast or cargo tanks and machinery spaces) among other factors.

The above standard is applicable to the hull construction materials, while it may be noted that equipment and systems on deck may experience lower temperatures due to direct exposure to the air (i.e. not adjacent to machinery, cargo spaces or seawater). Typically, design standards for these will use a lowest mean daily low, i.e. a lowest air temperature. This is also often referred to as a minimum temperature and is typically associated with the approach used in SOLAS. Mean Lowest Daily Low (Minimum) temperature refers to the mean value of lowest (minimum) temperatures during a 24-hour period and calculated over a year or over the ship operation period. The mean value is to be derived from at least 10 years of data.

There are, however, instances in which other temperatures may be used. For example, the Guidelines for Approval of Ballast Water Management Systems, Part 3, Specification for Environmental Testing for Approval of Ballast Water Management

Systems, contain the provision that temperature tests for equipment that may be installed in exposed areas on the open deck, or in an enclosed space not environmentally controlled, should be subjected, for a period of not less than two hours, to a low temperature test at -25°C.

A further aspect is crew exposure to air temperatures, which is an instantaneous exposure temperature, i.e. regardless of averaging and any latent heat influences. Typically these may be used for determination of crew rotations for watch-keeping and include the wind-chill. In these instances an extreme low air temperature is often used.

Based on the above, it is noted that there is a wide range of Design Air Temperatures which may relate to a particular design standard, crew operation or criticality of equipment. As such, it is important that the temperature used is carefully selected and precisely defined or referenced to relevant standards containing such definitions.

3.3 Hull structure

Hulls have to be capable of withstanding the ice conditions likely to be encountered in the vessel's operating area. Typically these would be ice features such as multi-year ice inclusions, deformed ice and ice pressure. In some operational areas unintended contact with glacial ice such as bergy bits and growlers may be anticipated.

Due to the demanding conditions, offshore vessels should have a high level of reinforcement to protect against the ice loads. In particular the bow strength is increased and the hull form employs an icebreaking bow form. Proceeding in multi-year ice results in high ramming force loads, which may be experienced within the structure both locally and globally. Longitudinal strength also becomes an issue when beaching on thick ice. As a result, a feature commonly found on Arctic icebreakers is an ice skeg, used to prevent riding onto the ice.

Due to the demanding conditions, offshore vessels should have a high level of reinforcement to protect against the ice loads.

For icebreakers designed for operation in shallow water, the bottom plating will require adequate ice strengthening due to the potential for frequent contact with grounded ice.

When manoeuvring in ice, high forces may be experienced, particularly on the stern quarter, shoulder and bow region. In addition, it should be noted that, during turns, broken ice may be driven down into the propellers.

Material grades for the hull structure should be carefully selected. The carriage of hot cargoes in cold air creates large thermal stress in the hull. The cold air will also affect the steel, which may become brittle, unless it is of a type designed for cold conditions.

A rudder, if fitted and designed for backing into ice, may also experience higher loads. An ice knife or other protective feature may be installed to deflect the ice and prevent it from wedging between the top of the rudder and the vessel's hull. In addition, rudder stops should be fitted to prevent the rudder from exceeding its normal maximum operating angle.

It should be noted that the effect of side thrust in azimuth propelled vessels is not necessarily taken into account when assessing hull strength.

Details of ice class notations from various classification societies can be found in Annex B.

3.4 Stability

The required stability analysis is typically more extensive than that required for vessels not operating in ice and depends on the intended operation. The following provides some general guidance on issues. However, it should be noted that these will be dependent on the envisaged operation and ice conditions.

As the vessel proceeds in ice it is subject to movements from ramming and ice impacts. As a result, it is recommended that suitable calculations are carried out to demonstrate that the vessel can maintain sufficient positive stability, particularly when travelling in thick ice conditions and for icebreaking vessels that ride up onto the ice, where they may remain momentarily poised on the stem. High global loads are experienced together with reduced stability, since the vessel may lose a large amount of displacement. Ice accretion may have a negative impact on the metacentric height (GM) and reduce the vessel's stability up to the point of capsize. Trim should also be carefully assessed to ensure that the propeller remains completely immersed below the ice level.

Damage stability criteria concern the ability for a ship to withstand flooding resulting from hull penetration due to ice damage, and to provide a condition of equilibrium after such damage. The extent and location of damage should be considered with regard to the intended operations and envisaged ice conditions.

Reference should be made to the IMO Resolution A 1024 (26) Guidelines for Ships Operating in Polar Waters for further information on intact stability, damage stability and subdivision requirements.

3.5 Engineering and propulsion systems

It is recommended that the design of the engineering and propulsion systems is based on the loads and vibrations resulting from propeller, hull and rudder interactions with ice. It is also recommended that propellers are located to provide protection from ice and designed to operate when the vessel is inclined at any combined angle of heel or trim that may be expected during operations in ice. Means to prevent the prime movers from over-speeding, excess torque, overloading and overheating should be considered.

The machinery system design for ice operations is intended to provide the vessel with adequate performance in ice through a number of means, principally by increasing or controlling the engine torque to a steady level during propeller/ice interactions by the selection of appropriate propulsion type and control systems. Where applicable, engine manufacturers should be consulted with respect to an allowable over-torque as this will greatly increase ice capability. The propulsors' geometry can be optimised and the steering system protected against ice impacts, which also reduce ice loads on the propulsion system.

When high and low sea suctions are fitted, the lower suctions should be used, where possible, to reduce the risk of ice blockage.

A careful balance between the structural reinforcement and ice performance through the propulsion system design is required. If the engine does not have enough power or the propeller cannot provide enough thrust force, the ship may become beset.

A standard measure of performance is for a vessel to proceed through ice of a specified thickness at a particular speed, e.g. 1.5m ice at 5 knots. However, this is typically associated with straight line performance. The ability to turn should also be considered as this significantly improves the capability of the vessel to be able to take advantage of leads in ice.

The ice class rules specify ice loads on propellers, drive train and the complete propulsion system. For propellers, the fitting of individual blades to the hub, rather than as one casting is a common design practice. In the event of damage, only a single blade may need to be replaced. Controllable Pitch Propellers, with the ability to reverse the propeller thrust without reversing shaft rotation, have an advantage over fixed pitch units that have to be stopped when manoeuvring from ahead to astern or vice versa. Azimuth thrusters and podded propulsion units can improve manoeuvrability. They may also offer both low weight and size and have been fitted to a number of offshore vessels.

Tunnel thrusters are susceptible to blocking and clogging and should be used with caution in ice.

3.6 Classification society rules

To provide protection against ice loads an appropriate ice class should be stipulated. The main components of ice class consist of strengthening along the hull ice belt (region between the operating waterlines), the hull bottom (high Arctic ice classes), rudder, propeller and shafting.

The level of ice strengthening must therefore be selected based on the intended service area of operation, level of operational support, flexibility and national administration requirements. This will require an assessment of the ship's operational profile and should include the envisaged ice conditions and operational scenarios. Examples of interactions between the vessel and ice include the following:

- Proceeding ahead or astern in level or deformed ice.
- Ramming.

- Impact while manoeuvring and turning.
- Wedging between two ice pieces (or in a narrow lead).
- Impact with a multi-year floe.
- Impact with an underwater projection of an iceberg.
- Impact with ice pieces in the track of an icebreaker.
- Ice pushed against ship by an icebreaker (similar to jamming ice between ship and quay when berthing).
- Ice pieces impacting on bottom and bilge in shallow water.
- Ship beset in ice (subjected to ice pressure/compression).

For first-year ice classes, the Finnish-Swedish ice class rules are the de-facto standard adopted by Classification Societies and a comparison between the various ice class notations is shown in Table 3.4.

Finnish/ Swedish Ice Class	ABS	BV	China	DNV	GL	Korean Register	LR	NK	Polish Register	RINA	RS Russian Register[1]
IA Super	1AA	1A SUPER	B1*	ICE – 1A*	E 4	1A SUPER	Ice Class 1AS FS(+) Ice Class 1AS FS	1A Super	L1A	1A Super	LU5/ Arc 5
IA	1A	1A	B1	ICE – 1A	E 3	1A	Ice Class 1A FS(+) Ice Class 1A FS	1A	L1	1A	LU4/ Arc 4
IB	1B	1B	B2	ICE – 1B	E2	1B	Ice Class 1B FS(+) Ice Class 1B FS	1B	L2	1B	LU3/ Arc 3
IC	1C	1C	B3	ICE – 1C	E1	1C	Ice Class 1C FS(+) Ice Class 1C FS	1C	L3	1C	LU2/ Arc 2
			B			1D	Ice Class 1D	1D	L4		LU1/ Arc 1

[1]The Russian Register notations 'LU' were replaced by 'Arc/Ice' notations in 2007.

Table 3.4: *Comparison between the ice class notations of classification societies for ships, the keels of which were laid or which were at a similar stage of construction on or after 1 September 2003 (ref FMA Bulletin 23/11/2010).*

For operations in Arctic waters, each classification society has historically developed and applied their standards for Arctic vessels. As such, there is a wide spectrum of different requirements for Arctic ice classes. A summary of the Classification Societies' Arctic ice classes are given in Annex B.

Transport Canada has defined a Canadian Arctic Category (CAC) for the ice class of vessels comparing the CAC rating to class rules (see Annex B). If a vessel is classed with a non IACS member, Transport Canada Marine Safety division will review the vessel prior to it being permitted to operate in Canadian Waters (see Canadian Arctic Shipping Pollution Prevention Regulations).

In 2007, the International Association of Classification Societies (IACS) published Unified Requirements Concerning Polar Class (UR I). The requirements included Polar

Class Descriptions, summarised in Table 3.5.

Polar Class	Ice Description (based on WMO's Sea Ice Nomenclature)
PC 1	Year-round operation in all Polar waters
PC 2	Year-round operation in moderate multi-year ice conditions
PC 3	Year-round operation in second-year ice which may include multi-year ice inclusions.
PC 4	Year-round operation in thick first-year ice which may include old ice inclusions
PC 5	Year-round operation in medium first-year ice which may include old ice inclusions
PC 6	Summer/autumn operation in medium first-year ice which may include old ice inclusions
PC 7	Summer/autumn operation in thin first-year ice which may include old ice inclusions

Table 3.5: *IACS Polar Ice Classes*

Although there is no accepted equivalency between the various ice classes, the Russian Federation have published the following table. The table should be used with caution and individual classification society rules should be referenced on a case-by-case basis.

Classification Society	Ice Class				
IACS	PC 2	PC 3	PC 4/5	PC 6	PC 7
Russian Maritime Register of Shipping (Rules 2007)	Arc9/Arc8	Arc7	Arc6	Arc5	Arc4
American Bureau of Shipping	A4	A3	A2	A1	A0
Det Norske Veritas	POLAR-20	POLAR-15	POLAR-10 ICE-15	ICE-10 ICE-1A*	ICE-05 ICE-1A
Lloyd's Register	AC2	AC1.5	AC1	1AS	1A
Germanischer Lloyd	Arc3	Arc2	Arc1	E4	E3
Finnish-Swedish Ice Class Rules				1A Super	IA

Table 3.6: *Approximate comparisons between ice classes (Russian Federation)*

Due to the wide range of requirements, the equivalence and comparison between ice notations is difficult to achieve. It is recommended that the relevant Maritime Administration should be consulted about the acceptance and equivalence of ice notations.

The IACS Polar Ship Rules (the Rules) have been developed to provide harmonisation between classification society requirements.

The Rules are divided into structural and machinery requirements. The ice loads for the hull scantlings are due to a typical collision scenario; an oblique ice collision. The other scenario used for scantling requirements covers the longitudinal strength due to ramming icebreaking. Machinery requirements cover the propeller/ice interaction loads based on a block of ice coming in contact with the propeller, where the size of ice block varies with the ice class.

4. Capability for Operations in Ice and/or Severe Sub-Zero Temperatures – Operational Aspects

4.1 Crew training and carriage of an ice navigator

It should be noted that the safe operation of a vessel trading in an ice regime throughout seasonal changes requires skill and technical proficiency in excess of that required during normal operating conditions. It is therefore important that suitable training is offered to crew to complement existing experience.

For vessels trading to the Arctic, IMO recommends (ref. A26.Res.1024 Guidelines for Ships Operating in Polar Waters) that at least one qualified Ice Navigator is carried and local regulations may mandate such carriage. The Ice Navigator may be a suitably qualified member of the ship's crew or a supernumerary. When only one certified Ice Navigator is carried onboard the vessel as a member of the ship's crew, it is recommended that he/she be either the Master or Chief Officer.

The Ice Navigator may be a suitably qualified member of the ship's crew or a supernumerary.

The Ice Navigator is defined by IMO as being any individual who, in addition to being qualified under the Standards of Training, Certification and Watchkeeping (STCW) Convention, is specially trained and otherwise qualified to direct the movement of a ship in ice-covered waters. Qualifications of an Ice Navigator should include documentary evidence of having completed on-the-job training, as appropriate, and may include simulation training.

IMO recommends that the Ice Navigator has documentary evidence of having satisfactorily completed an approved training programme in ice navigation.

It is recommended that Masters, officers in charge of a navigational watch and officers in charge of an engineering watch have relevant experience and training with regard to operating ships in ice and/or severe sub-zero temperatures.

It is recommended that all officers and crew are adequately trained for circumstances likely to be encountered when operating in low temperatures, undertaking ice navigation and/or icebreaker escort. This may take the form of in-service training, simulator training and/or Computer-Based Training (CBT) and should include cold weather survival.

It is recommended that the vessel's senior officers have at least 30 days experience of operating in ice and/or severe sub-zero temperatures.

When reviewing the experience and training of officers, it is preferred that experience is gained in the rank that they are serving onboard, although it is recognised that this is not always achievable.

The helmsman undertakes a critical role when navigating in ice and consideration should be given to providing simulator training or using experienced ice helmsmen.

Canadian Arctic Shipping Pollution Prevention Regulations state that Ice Navigators are assessed and must have served on a ship as a Master or person in charge of a deck watch for 50 days or more. Thirty of those days must have been spent in Arctic waters where the ship required assistance from an icebreaker or had to make manoeuvres to avoid concentrations of ice.

A specimen outline training syllabus is provided in Annex E.

Some administrations differentiate between an Ice Navigator and an Ice Advisor and their respective training requirements.

An Ice Advisor may be provided by a local Port Authority to ensure safe ice navigation in specific conditions in the local area of the port approaches.

4.2 Vessel preparations for operations – general considerations

When offshore vessels are being chartered for operation in ice or severe sub-zero temperatures, owners and charterers should understand:

- The ice regime characteristics.
- The season of operations.
- The vessel's ice capability.
- The experience of the crew.

This section outlines basic issues relating to the vessel's particulars and operating procedures which should be considered.

It is recommended that when a vessel is operating in ice or severe sub-zero temperatures, appropriate insurance is maintained or arranged, especially when the trade involves a breach of International Navigating Limits.

It is important that the significance and limitations of the ice class notation are understood. Ice class notation alone does not automatically imply that the ship itself is suitable for commercial operations in extreme (cold) environmental conditions. Ice classification refers only to structural strength, propulsion power and arrangements. The fact that the hull has an ice classification means that it has been constructed to incorporate the minimum required speed/power output in ice and has hull structural integrity that allows the ship to navigate independently or under icebreaker escort in ice conditions up to classification limits. Beyond these limits, additional considerations, such as the calculation of ice numerals (Canadian Ice Regime System) or Ice Certificate recommendations (Russia), will have to be taken into account. The optional winterisation class notation provides an indication of the preparation of the vessel to operate to an acceptable standard in extreme cold conditions.

Owners and charterers are recommended to ensure that vessels intended for operations in harsh environments are capable and properly prepared. This includes:

- The provision of adequate suitable equipment.
- Preparations for equipment protection.
- Procedures established to ensure safe operation.
- Personnel welfare.

It is recommended that the following be considered for operations involving low temperatures, associated with operations in ice and/or icebreaker escort and that operators produce a suitable checklist to cover these requirements. Reference should also be made to the IMO Assembly Resolution A26.Res.1024 Guidelines for Ships Operating in Polar Waters.

The following provides a brief summary of issues that should be considered for operations in ice or severe sub-zero temperatures:

It is important that the significance and limitations of the ice class notation are understood.

Classification

- Ice Class Notation. Most of the classification societies provide a guide to ice class selection based on the region, season and mode of operation (independent or escorted). It is recommended that offshore vessels having an appropriate ice class are used for operations in the Arctic.
- In accordance with the vessel's ice class, the vessel will have an upper ice water line (UIWL) and a lower ice water line (LIWL) defined and the actual draught of the vessel should remain within these limits when operating in ice.

Insurance

Hull and machinery insurance should be checked for validity in the intended operating area.

Crewing

- The Master and navigating officers should have suitable experience of navigation in ice or operating in extremes of cold weather.
- Navigating officers should be provided with basic ice navigation training.
- Agreement should be reached on the need for the carriage of an Ice Navigator for the transit through ice. Evidence of the Ice Navigator's training and experience should be obtained.
- The crew should be properly trained to provide effective damage control and undertake minor hull repairs.
- The crew should be trained in cold weather survival techniques.
- Manning levels should be assessed and should take into account the potential need for additional deck crew owing to working shorter shift patterns in adverse environmental conditions.

- A fatigue management plan should be in place due to the demands of operating in ice which may include a requirement to double up watches.

4.2.1 Procedures and precautions

The operator should have procedures and/or precautions in place that include the following:

- Management of the vessel's draught to keep sea suction inlets, propellers, thrusters and moon pools below the level of ice.
- Operating and training manuals specifically for operations in ice and/or severe sub-zero temperatures, taking into account the distances from available Search and Rescue (SAR) facilities.
- Assessment of ice navigation and cold weather operational risks.
- Conduct of ice navigation/icebreaker escort navigation.
- Receipt of ice navigation information (e.g. ice charts, satellite images).
- Cold weather operation and protection of, and access to, accommodation spaces, emergency escapes, fire-fighting systems, lifesaving appliances, critical equipment and deck machinery, including mooring equipment.
- Provision of suitable means for preventing slips and falls on open decks, walkways and ladders, e.g. trace heating, sand or non-slip coatings.
- Prevention of freezing of services on exposed decks including fire lines, air systems, control systems and instrumentation and the minimisation or elimination of any dead-legs.
- Prevention of freezing of bulk cargo and ballast systems including ballast water and venting systems.
- Prevention of dangerous ice accretion.
- Stability calculations should include the capability to input the effect of ice accretion, including freezing of entrapped water.
- Provision of adequate cold weather clothing and personal protective equipment (PPE) for crew, possibly including spiked boots or strap-on spikes for working on deck.
- Provision of suitable tools and materials for the prevention and removal of ice and snow on board, e.g. covers, mallets and shovels.
- Ice emergency towing procedures.
- Personnel transfer procedures in ice and/or severe sub-zero temperatures.
- Medivac contingency plans in ice and/or severe sub-zero temperatures.
- An ice management plan for the area of operation.
- A plan for interaction with wildlife.
- Actions in the event of being beset.

4.2.2 Bridge procedures

The operator's navigation procedures should address situations where ice navigation requires a different approach or higher level of caution to open water navigation. The following list is not exhaustive and operators should ensure their bridge procedures are relevant to the conditions likely to be experienced.

- Use and hazards associated with terrestrial navigation aids in polar waters e.g. buoys dragged off station, lighthouses obscured.
- Limitations in nautical charts and precautions when navigating in poorly-charted waters, ensuring familiarity with chart projections that may be in use.
- Limitations of electronic positioning systems at high latitudes.
- Ice interference with depth sounding equipment.
- Effect of glare on lookouts.
- High-latitude compass errors, taking into account that magnetic compasses may need to be adjusted.
- Discrimination of radar targets and ice features in ice clutter.
- Limitations of search and rescue capabilities.
- Limitations imposed by the lack of good quality metocean data such as tides, currents and tidal streams.

4.2.3 Bridge equipment

Bridge equipment should take into account the extra challenges of operating in ice and should include:

Figure 4.1: *The effect of inadequate heating for wheelhouse windows*

- Wheelhouse windows should be heated. Water should be drained from window washing systems, if installed.
- Equipment should be provided to assist with ice detection, e.g. high definition ice radars, infra-red cameras.
- If possible, radars should be sited to give optimum performance, taking into account issues such as snow clutter and close-up ice feature identification.
- If escort duties are anticipated, the radars should be sited so as not to have astern blind sectors.
- Radar scanner units should be provided with trace heating.
- A sufficient number of searchlights should be available and they should be properly positioned and suitable for operation in ice and snow and preferably controlled remotely from inside the wheelhouse.
- Enclosed bridge wings are preferable.
- Two speed/distance devices that work on different principles, showing speed either over the ground or through the water should be available.
- If navigating at high latitudes, a satellite compass or equivalent system should be available due to low reliability of magnetic and conventional gyrocompasses in this area.
- Two independent echo sounding devices available to display/record depth under the keel.
- Devices available to receive ice and weather information charts and ice imagery.
- Provision of a global navigation satellite system (GLONASS and/or GPS) having due regard of performance limitations in high latitudes.
- Consider de-icing equipment for aerials/antennae on top of wheelhouse due to the effects of rime ice.

Figure 4.2: *Icing on antennas*

4.2.4 Hull and propulsion

Hull and propulsion systems should be designed for operation in ice and consideration should be given to;

- The design rating of main and auxiliary engineering systems should be suitable for the anticipated conditions.
- Main propulsion should be designed for resultant loads and vibrations from ice interactions and additionally designed to operate when the vessel is inclined at angles of heel or trim as a result of riding up onto ice.
- All vessels should be provided with a directional control system (steering system) of adequate strength and suitable design to enable efficient operation in ice.
- A double bottom construction should extend over the full length and breadth of the vessel from the fore peak to aft peak bulkheads.
- Design should be such that pollutants are not carried against the hull in areas at risk from significant ice impact.
- Equipment required for the safe operation of the vessel should be capable of repair by onboard resources.
- Sufficient damage control materials should be carried to enable temporary repairs to be made to a minor hull breach.
- Systems should be in place to keep sea chests free of ice.
- Hull steel should be of a grade suitable for exposure to the low temperatures which are anticipated.
- The propeller should be kept sufficiently submerged below expected level ice conditions.
- The propeller should be made of steel or equivalent material, suitable for operation in ice conditions. Note: ordinary bronze propellers should be avoided due to high risk of blade damage.

- The design of the anchor housing should be such as to protect the anchor from being dislodged from its stowed position and from jamming or damaging the hull by direct impact with ice.
- Accommodation heating systems should be adequate and have the capability of sustaining life in the event of an emergency and/or extended vessel entrapment with provision for power to also be supplied from the emergency generator, if necessary.
- Systems should be in place to prevent freezing or snow blockage of essential air intakes and venting systems (including cargo and ballast venting systems).
- If applicable, cargo tanks should be provided with means to prevent freezing such as heating coils. Ballast and fresh water tanks may be provided with heating coils or other arrangements, such as air bubbling systems.
- Electrical installations should be designed to operate in the anticipated conditions.
- Reserve supplies of fuel and lubricants should be carried, taking into account the effect of on fuel consumption of operating in heavy ice.
- Consider hull protrusions such as bilge keels, echo sounder transducers etc.

4.2.5 Lifesaving and emergency equipment

The lifesaving and emergency equipment required to be carried will need to be winterised and additional equipment may need to be carried as follows:

- Lifeboats, if required to be carried, should be of a totally enclosed design with engines capable of being started in sub-zero temperatures.
- Lifeboats should be provided with heating and doors should be trace heated.
- Fuel used in survival and rescue craft should be of Arctic grade or equivalent, suitable for use in low temperatures without waxing.
- Accumulator batteries should be stored in heated locations or provided with another means of heating.
- Consideration should be given to the provision of Personal Survival Kits (PSK) for the number of persons on board, when the mean daily temperature is less than 0°C.
- Consideration should be given to the need for Group Survival Kits (GSK) for the number of persons on board plus 10%, where ice may prevent the lowering of survival craft.
- Adequate supplies of protective clothing should be available, including thermal insulating materials for the expected conditions.
- Fire pumps, including the emergency fire pump, should be in heated spaces or protected from freezing. Fire-fighting equipment should remain operable under all anticipated conditions. Consideration should be given to fitting trace heating to fire mains.
- The correct operation of equipment such as lifesaving appliance davits and winches, breathing apparatus, life rafts and man overboard boats should be assured in the anticipated low temperature conditions.

4.3 Vessel preparation for operations – specific considerations

4.3.1 General support vessel operations

The following topics provide guidance on specific areas where support vessels may experience problems;

Working decks

Additional protection should be provided around main and working decks for the crew in order to shield them from the wind and elements.

Ideally, deck equipment such as winches should be located under cover.

Equipment on exposed decks should be properly protected. Specialist equipment may require screening, protecting or heating. All equipment should be confirmed as being suitable for operation in the anticipated conditions. This includes ancillary equipment such as hydraulic hoses and the impact of cold on hydraulic systems.

Ideally, deck equipment such as winches should be located under cover. Procedures should address the handling of wires subjected to freezing after immersion.

Lifting operations and the use of cranes

In freezing fog or conditions of ice accretion, care should be taken with regard to falling ice. In such conditions there is also a risk of crane sheaves becoming iced and the crane wire being dislodged from the sheave and becoming trapped between the sheave and cheek plate.

For any lifting operation, it is important that the crane driver has good visibility, particularly if visual signals are used in addition to verbal signals over the radio. The windshield of the operator's cab may need to be heated, either by blowers or by a heating element. The cab should be pre-heated and hydraulic systems warmed through in advance of being required for operation. Safe access to and from the cab should be provided. Exposed ladders may not be suitable if they are liable to icing.

Moon pools

On vessels equipped with moon pools, the moon pool should preferably be located in an enclosed heated area so as to allow support personnel, umbilical tenderers, remotely operated vehicle (ROV) operators and/or dive supervisors to remain warm and alert.

Care should be taken regarding any water that may come out from the top of the moon pool or be introduced with retrieved equipment as this may freeze and cause a slipping hazard.

It is possible that ice may form in the moon pool or be pushed under the vessel, due to low temperatures, and surface in the moon pool. Procedures should be in place to clear ice from the moon pool and from other through-hull penetrations. Methods employed may include the use of air bubbling systems, heating the water (for example by introducing engine cooling water) and the use of pressurisation to blow down the ice.

Deployment of equipment overside

Any equipment deployed over the side may be subjected to risk of contact with ice and will require protection. Alternatively, deployment using a moon pool should be considered.

Hull coatings

The waterline coating systems of offshore vessels may suffer heavy abrasion damage in ice. In addition, some impact deformation of hull plating is possible. Owners should consider arranging independent inspections of the hull before and after ice voyages.

Specialised coatings are available which have significant resistance to ice abrasion and may be of benefit if a vessel is to spend considerable time in ice-covered waters.

Figure 4.3: *Icebreaking offshore support vessel*

4.3.2 Offshore supply operations

Matters for consideration related to the offshore support vessel's particular service when operating in ice and/or severe sub-zero temperatures are summarised below.

The listed operational categories are based on those contained in the OCIMFS's Offshore Vessel Inspection Database (OVID).

It is important that the crew working on deck are kept safe and are able to retreat to warm areas. An assessment of environmental conditions including wind-chill exposure limits should be undertaken and shift routines should be adjusted to suit the prevailing working conditions to ensure that exposure is minimised.

Effective procedures should be in place to ensure that cargo deck areas are maintained clear of ice and/or snow. It is also important that clear access is maintained to cargo securing points. Drill pipes and casing carried as cargo should be provided with end caps to prevent water ingress and subsequent freezing.

When operating in conjunction with platforms, care should be exercised with regard to the hazards of falling ice emanating from the platform or from the cargo being lifted.

Figure 4.4: *Working deck in heavy weather*

When handling bulk cargoes, hoses used will be vulnerable to damage through contact with ice and should therefore be kept under constant supervision and, preferably, should be raised clear of the ice using a crane. On completion of transfer operations, hoses should be thoroughly drained to minimise the potential for residues to freeze.

The vessel's pumping performance when handling bulk cargoes such as brines, muds and cement should be evaluated, taking into account the operating temperatures. When handling dry bulk cargoes, driers fitted to compressors should be fully operational to ensure the air has a low dew point and the risk of freezing is minimised.

4.3.3 Emergency response and rescue vessel/stand-by vessel operations

Ice conditions at offshore installations can significantly restrict the ability of stand-by vessels (SBVs) to carry out their designated duties. In order to effectively carry out emergency response functions, SBVs should have sufficient manoeuvring capabilities in all ice conditions likely to be encountered in the installation area.

Requirements regarding response time and the distance of the SBV from the offshore installation should take into account existing ice and icing conditions. Realistic performance standards should be established based on the anticipated environmental conditions and the temporary refuge time of the installation.

In order that the SBV can move close to the offshore installation to evacuate personnel in the event of an emergency, rescue and recovery routes should be maintained through ice management.

Transfer of personnel from the installation to the SBV, using the installation's crane and personnel transfer basket or evacuation system, can be hindered by rubble fields piled up on the weather side of the installation, preventing the close approach of the vessel. In areas where large rubble fields and ridges are common, consideration should be given to using SBVs which are capable of clearing rubble fields. Rubble field clearing is performed by going astern through the rubble field using propellers to flush and mill ice pieces. Good operating practice would indicate that this should be carried out downdrift to prevent a vessel drifting onto the platform in the unlikely event power is lost. Rubble field clearing capability is normally specified as the volume of ice cleared in an hour.

Figure 4.5: *Ice rubble at an offshore platform*

Another factor which can impede the evacuation of personnel from the installation by a SBV is ice drift. Sea ice, drifting in an unfavourable direction, can overwhelm the station-keeping capabilities of the vessel and move it from the required position, or even threaten a collision with the installation.

Routes and methods of approach to the installation in different ice conditions, as well as the vessel's capabilities and limitations, should be discussed with the Offshore Installation Manager (OIM). The Master and the crew should be trained to perform evacuation in different ice conditions.

When recovering persons from the water in open pack ice conditions, the technique employed is similar to that used in open waters. Care should be exercised to avoid damage to the rescue boats by contact with sea ice. Boats with glass reinforced plastic (GRP) hulls are not ideal for use in icy waters due to their susceptibility to damage through ice contact.

SBVs cannot normally use their rescue boats to pick up survivors from the water in close pack or compact ice conditions due to the high risk of damage to the boat and its poor manoeuvrability in ice.

When the use of a rescue or working boat is considered dangerous or impracticable, survivors should be transferred from the water to the SBV using alternative rescue procedures, such as rescue baskets or nets. Care should be exercised by the Master of the SBV when approaching a person in the water in high concentrations of ice, in order not to push ice towards the person and risking crush injuries or damage to immersion suits and flotation aids.

Sea ice with a thickness of more than 15cm can support a person with a weight of up to 100kg. An option in these conditions may be to evacuate persons from an installation directly onto the ice. In such cases, the evacuees can be taken on board the SBV using the vessel's gangway or by personnel transfer basket. Before personnel going onto the ice it should be tested for adequate load bearing capability, using an extended pole or similar method.

4.3.4 Towing, pushing and anchor-handling operations

Risks to personnel on the working deck should be identified and managed appropriately.

Anchor handling vessels typically have a low freeboard and operations may have to be conducted with the stern to the weather. As a consequence, the deck is often ice-covered and crew working on deck are exposed to the harsh conditions. Appropriate clothing should be worn and work routines should be adjusted to provide frequent breaks.

Risks to personnel on the working deck should be identified and managed appropriately. Remedial measures to prevent slips and falls should be considered, such as the wearing of spiked shoes, gritting of the decks, the marking of 'no go' areas on the deck, the use of inertia reel safety harnesses and methods to keep the deck clear of ice. The provision of automated anchor handling systems may remove the need for crew to be on the working deck and serve to minimise personnel exposure to the environmental conditions.

The freezing conditions may also adversely impact the operation of anchor handling equipment such as rollers, pins, sharks claws and other mechanical stoppers, and arrangements should provide for their de-icing. The use of synthetic stretchers should be avoided to prevent damage caused by ice and water freezing inside the stretcher. As an alternative, consideration should be given to using a length of chain.

Towing operations undertaken in light ice conditions may use tow lines of normal length. Tow lines are typically shortened to increase control of the vessel being towed in pack ice - the higher the ice concentrations or the greater the ice pressure, the shorter the tow line. In new ice without ice management, the tow line is deployed to allow the vessel being towed to remain in the broken track. In heavy pack ice conditions with medium to large floes, tows should preferably be conducted with ice management, if available, and the tow line should be deployed to a length that allows it to remain clear of the ice to prevent fouling on ice keels and sails.

Specialist vessels for towing in ice are usually equipped with towing notches, dedicated winches and bridle arrangements.

4.3.5 Remotely Operated Vehicle and diving operations

The use of Remotely Operated Vehicles (ROV) and divers in areas where ice may be located presents a risk to divers and ROV of the umbilicals being nipped and damaged or cut by ice. For this reason it is recommended that all such operations are carried out through a moon pool in the ship's hull to prevent interaction with drifting ice. There should be sufficient space and height in the moon pool area for the installation and use of an appropriate ROV or diver launch and recovery system (LARS).

Divers working in arctic and sub-arctic conditions will need to be equipped with hot water suits for safe and efficient diving. There should always be at least two hot water machines available to supply the divers with hot water. Such an arrangement means that, should one hot water unit fail, another can immediately be brought on line. Hot water machines may be oil-fired or electrically powered units.

Divers' helmets and other items of personal diving equipment will need to be checked to ensure that they are capable of operating in the anticipated temperatures. It may be necessary to heat the divers' breathing gas supplies.

Battery life in cold conditions can be very short and all batteries should be fully charged and load tested for specific time periods in the cold conditions prevailing to ensure their proper performance.

Divers not used to diving in cold waters should be trained in cold weather physiology and the prevention of cold injuries.

For surface oriented diving operations the decompression chamber should be sited as close to the moon pool as possible, preferably on the same level, and the access route to the chamber should be kept free of ice, snow and other obstructions.

Consideration should be given to the means of safely evacuating saturation divers from the vessel in the event of an emergency. A hyperbaric evacuation system (HES) should be provided which has been tested and found to be suitable for use in arctic and sub-arctic conditions.

Consideration should be given to the means of safely evacuating saturation divers from the vessel in the event of an emergency.

4.3.6 Seismic and geotechnical survey operations

At present, it is only possible to conduct 2D seismic survey operations in light to moderate ice concentrations. Technologies are being developed to enable seismic work to be completed under ice, but this would not be carried out from vessels.

For vessels engaged in seismic surveys, risks will be associated with ice damaging the towed arrays which may be many kilometres long and may stretch out hundreds of metres on either side of the vessel. These arrays are not able to withstand any ice interaction and care should be taken to ensure that the area ahead of the vessel is clear of any floating ice. The industry has gained limited experience in pack ice with a seismic vessel towing only a single streamer and no tail buoy, while following an ice breaker. This method will not work in the presence of (glacial) ice with a deep keel unless there are vessels available capable of towing icebergs out of the survey path. This is not normally practicable due to the speed required for the survey to prevent the streamers sinking and the length of time it takes to tow an iceberg.

Assurance may be gained by the use of ice radars but predominantly will be provided by the use of chase vessels moving ahead of the seismic vessel. If any ice is seen, chase vessels will alert the seismic vessel which will then either move offline so as to avoid the ice, or the chase vessel will need to reduce the ice to a size that will not cause damage. The ability of the seismic vessel to turn will be limited by the towed array and any ice obstructions will need to be identified several miles in front of the vessel. The ability of the chase vessel to manage the ice is also compromised by the need of the seismic vessel to maintain a forward speed of around 4-4.5 knots to ensure that the towed array floats in the correct pattern.

Moving offline is very disruptive to the planned survey lines, so a good reconnaissance ahead of the start of deployment, using the chase vessels and possible helicopter overflights, is recommended.

Geotechnical surveys may be more tolerant to an increased level of ice concentration but this will depend on the activities being carried out, the station-keeping abilities of the vessel and any ice management assistance provided.

Seismic work may be particularly disruptive to wildlife. For information on interaction with wildlife see section 4.6.

4.3.7 Drilling/coring operations

The extent that a drilling/coring vessel can work in ice will be largely determined by the ice class of the rig/vessel and the amount of ice management that is applied.

If drilling for extended periods in severe sub-zero temperatures, it is important to ensure that the drilling rig is winterised and personnel are protected from wind-chill. Heated areas in the drill floor area should be available to allow rig workers to warm up. Particular attention should be taken to protect the workforce from ice falling from the drill rig when there is freezing fog or ice accretion.

The equipment used for drilling should be checked to ensure that steel and other materials used are rated down to the temperatures that will be encountered.

If dynamic positioning (DP) is to be used for station-keeping, the operator should ensure that the DP is capable of operating in the ice conditions prevalent on site, or there is ice management available to reduce the ice to a size such that the DP system will operate in a satisfactory manner. Joystick control may allow for greater operability in ice.

If using water-based drilling fluids, precautions should be taken to ensure that the mixture does not freeze before, during or after it enters the hole.

The ability of the vessel to quickly move offsite in the event of an unmanaged or unmanageable ice incursion is paramount and the vessel should be able to safely secure the drilling operations and move offsite in the event of a potentially hazardous ice condition.

4.3.8 Accommodation vessel and flotel operations

Vessel systems, such as fresh water supply lines and tanks and sewage systems, will require additional environmental protection to ensure they remain functional. In the event of a loss of power, emergency generators should be sized for additional heating loads during an emergency and be provided with fuel appropriate for the lowest anticipated temperatures and batteries for cold starting.

Depending on the ice conditions, consideration may have to be given to the launching arrangements for emergency craft onto the ice, provision of ice gangways and escape chutes. Personnel should be made aware of details such as the fact that the lights on Emergency Position-Indicating Radio Beacons (EPIRB) and Personal Floatation Devices (PFD), automatically activated by contact with water, may not activate when vessels are evacuated in ice-covered waters. Escape routes should be maintained clear of ice.

Passengers should be provided with information on survival on ice and human responses to cold. Appropriate clothing, together with hand, eye and foot protection, should be readily available.

Passengers should be provided with information on survival on ice and human responses to cold.

Vessels should be provided with appropriate waste disposal facilities, taking into account the extended duration of operations and the limited availability of shore-based disposal facilities. Consideration should be given to the provision of waste compactors and incinerators. Requirements restricting the discharge of, for example, oil, grey and black water may require additional on board storage or treatment. The proper functioning of chemical and biological waste treatment plants may be impacted in freezing conditions.

4.3.9 Heavy lift operations

Due to the normal requirements for heavy lifts to be accurately deployed on the platform/object that they are being lifted to, it is important that the lifting vessel is able to maintain position accurately during the lift. The presence of ice may be beneficial if the vessel can hold station as it will minimise rolling.

If carrying out a lift in severe sub-zero temperatures, the crane and associated equipment should be rated for the anticipated temperatures. Crane sheaves should be kept clear of ice to prevent wire runners riding off the sheave.

4.3.10 Pipe lay, cable lay and trenching operations

During pipe and cable-laying operations, care will need to be taken to prevent equipment being damaged through contact with ice. In addition, the ability of the vessel to maintain position in ice may be compromised.

In addition to the normal hazards that personnel may be exposed to when working in freezing conditions, there may be a danger of ice falling from heights during pipe lay, cable lay and trenching operations.

4.3.11 Gravel/stone discharge operations

When conducting operations in ice, side-launched fall pipes will be exposed to damage through contact with passing ice. If practical, consideration should be given to using equipment deployed through a moon pool.

Transfer equipment including vibration motors, belts, hydraulics and roller bearings, will require protection from freezing conditions. Main decks and elevator areas should be provided with extra environmental protection.

Deck crew should be aware of the hazards associated with ice falling from equipment such as moving belts.

4.3.12 Oil spill response operations

An offshore vessel may have a primary or secondary role as an oil spill response vessel (OSRV) for the work area. The vessel should be provided with equipment suitable for operations in the anticipated conditions in accordance with the oil spill response plan for the operational area. Response equipment should be capable of recovering oil from the icy water and the sea ice surface. Equipment in a particular area may need to support activities that include in-situ burning, dispersant application and containment stack deployment.

Particular attention should be given to the capacities of the vessel's tanks for recovered oily water, since facilities to receive such contaminated water ashore may be limited, particularly in the Arctic. Consideration should be given to the possibility that collected oily water may need to be transferred to an offshore installation or another vessel. Onboard storage should be provided with heating to facilitate oil/water separation and to prevent freezing.

Depending on the ice concentration, the deployment of boom using small boats may not be practicable. However, it may be possible to use the ice itself as a boom with an area being cleared for the oil spill response vessel to sit in and recover the oil contained by the ice.

4.4 Limitations of dynamic positioning operations in ice and/or severe sub-zero temperatures

The following are among issues that should be taken into account when considering Dynamic Positioning (DP) operations in ice and/or severe sub-zero temperatures:

Issues relating to reference systems:

- The effect of icing and fog on fan beam (laser-based) and artemis (radar-based) signals. In addition, icing may impact scanner operation.
- Laser-based reference systems may suffer from false reflections from the surface ice and from ice accretion on the installation.
- Consideration should be given to using above-water systems such as a Differential Global Positioning System (DGPS) station situated on the installation to act as a default reference source. High latitudes and ice accretion on aerials may impact signal strength.
- Acoustic systems may suffer from degraded performance through cold water thermoclines, as well as false reflections from ice keels.
- Potential damage to hull-mounted equipment, such as hydroacoustic transducers from fast moving ice under the hull.
- The option of operating taut wire systems through a moon pool instead of over the vessel's side. Similarly, the option of deploying acoustics through a moon pool should be considered.

Some issues relating to DP operations and station-keeping in ice:

Figure 4.6: *Broken ice in the wake of a platform*

- Where possible, the bow should be maintained heading into the direction of ice drift unless an installation provides good shelter from the drifting ice (see figure 4.6). The ice conditions and station-keeping capability, especially the ability to maintain the heading, should be assessed.
- Allowances should be made for a larger station-keeping envelope in ice.
- Efficient and effective ice management will be required, possibly using assisting icebreakers, preferably with azimuth and/or podded propulsion, in order to minimise ice loads on hull and reduce stress on the DP system.
- The DP control system should be capable of compensating for quickly changing ice forces. This may result in increased thruster/propeller utilisation, possibly leading to additional component wear and maintenance.

- The DP control system should be capable of constructing an accurate picture of the environmental situation with regard to the impact of ice forces in addition to the normal impact of wind waves and current.
- DP operators should receive specific training to understand the additional variable and often high environmental loads from ice and the system's ability to manage these and the unpredictable nature of the loadings.

4.5 Controls on vessel emissions

Increasingly in Arctic regions, restrictions are being placed on the maximum allowable quantities of air emissions from vessels working in the particular region. Controls may be in the form of air permits and may significantly restrict the ability of the vessel to operate.

Owners should consider the range of mitigation measures available to them, which can include fuel saving initiatives, low sulphur fuels, use of diesel instead of heavy fuel oil (HFO), selective catalytic reduction and the use of alternative fuels such as LNG, when submitting their applications for air permits.

Permits may be issued on a maximum continuous emission basis or may be on a seasonal basis. Accurate measuring systems will need to be fitted and records should be maintained to show compliance. In some cases, it may be a requirement to carry a compliance officer who will monitor the discharges on behalf of the authorities.

Concern is raised due to the possible effects of carbon black deposits from ships on sea ice, which may act to accelerate the rate of ice melting and the emission of global warming gases into an area that is considered to be vulnerable to their impact.

Leaning the support vessel's stern hard onto the installation may allow the use of less power for station-keeping, thus reducing emissions. However, due account should be taken of prevailing weather conditions and both the installation and the vessel should be designed to utilise this method.

4.6 Interaction with wildlife

Due to the relatively low freeboard of offshore vessels and the fact that they may be stationary for extended periods, there is the possibility of interaction with local wildlife.

Some administrations require marine mammal observers to be carried on board, which may have to be local indigenous people, to monitor wildlife concentrations and migrations and to ensure that vessels maintain a safe separation distance from marine life.

Plans should be carried onboard to set out how wildlife should be handled, should it interact with the vessel. Details of migration patterns of wildlife in the Arctic can be found at the following website www.amap.no/documents/doc/Identification-of-Arctic-marine-areas-of-heightened-ecological-and-cultural-significance-Arctic-Marine-Shipping-Assessment-AMSA-IIc/869.

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4.6.1 Noise

Underwater noise is a major concern. Typically vessels produce a low frequency sound from machinery installed on board, hydrodynamic flow around the hull, propeller cavitation and the noise of breaking ice. The sound a vessel produces can be related to its age, installed power, hull shape and speed of movement. Vessels may also use hydroacoustic devices such as echo sounders and multi-beam sonars, all of which add to the noise footprint.

For the majority of marine vertebrates, sound is used for foraging, reproduction, predator avoidance and navigation. Any excessive noise disturbance can interrupt these behavioural patterns and may, for example, alter the range at which whales can communicate effectively.

If vessels are to be designed specifically for operation in areas covered by the publication, consideration should be given to minimising noise impacts by, for example, hull design, propeller design, soft start motors and hull coatings. Authorities are increasingly asking for noise profiles of vessels to be conducted and this should be considered when tendering for new build vessels.

4.6.2 Polar bears

Polar bears are large, carnivorous bears that are well-adapted for life in their frozen Arctic environment. They have no natural predators in the Arctic and therefore fear nobody and present a great danger to humans.

Figure 4.7: *Polar bear on the working deck of an offshore vessel*

A polar bear's sense of smell is acute and it is the most important sense for detecting prey. Any food wastes generated by the vessel should preferably be encapsulated in plastic to prevent smells escaping.

A plan should be in place to ensure that a lookout is kept for polar bears. Refuge areas should be provided and an appropriate alarm warning given to ensure that all routes into the accommodation are sealed, should a bear manage to climb on board. Particular care is required when working outside during evening hours and hours of darkness, or when fog or blowing snow reduces visibility. Personnel should remain within lit work areas.

4.6.3 Whales

Due to their large size and sometimes curious nature, whales are vulnerable to contact with offshore vessels. Vessel strikes can result in death, haemorrhaging, broken bones, propeller wounds and major trauma. Whales and other marine mammals, which rely on thin ice or open water to breathe, can get trapped in sea ice after attempting to follow open leads created by vessels.

The main risks of collision or entrapment are during migration periods when the whales are moving from their feeding grounds to breeding grounds. The breeding and feeding grounds are generally protected areas and respective governments may put restrictions on transiting the migration corridors at certain times of the year. Vessel operators should be aware of these migration corridors and should avoid them where possible. Local indigenous populations should be consulted, where possible, to gain a better understanding of the migratory patterns.

4.6.4 Seals

In general, seals will be aware of the presence of vessels and will enter the sea to swim away prior to the vessel approach.

The biggest risks to seals from vessels in the Arctic/Antarctic are from pollution either by oil or from discarded garbage. Both discharges are controlled under The International Convention for the Prevention of Pollution from Ships (MARPOL).

4.6.5 Walrus

The main risks to walruses are of injury through collision with offshore vessels. This is particularly acute during migration periods when they move in large concentrations which may comprise of many thousands of individual animals.

Vessel operators should be aware of migration patterns and likely routes, for example from the Bering Sea into the Chukchi Sea through the relatively narrow Bering Strait.

4.6.6 Birds

During the dark winters, offshore vessels provide a source of light and, as a result, attract birds. During the non-breeding period in ice-free waters, as the presence of lighted ships and structures increases, there is a heightened risk of collisions with vessels. In order to mitigate these collisions, vessels should consider shading lights or minimising external lighting where it is safe to do so.

Birds should not be fed to avoid attracting and retaining them on a vessel.

5. Winterisation of vessels

For vessel operations, two aspects should be taken into account; the presence of ice and the cold environment. The ice class notation covers a vessel's structural strength, propulsion power and arrangements. The notation does not cover suitability from the standpoint of commercial and environmental operability in low temperatures. Such operability is increasingly addressed by the use of a Winterisation notion, issued by Classification Societies. It should be noted that winterisation requirements are not bound to ice class and may be applicable to vessels without any ice class operating to ice-free ports where extremely low temperatures may be encountered.

Figure 5.1: *Thick first-year ice (Courtesy ©Arno Keinonen)*

A classification society will consider the following elements before assigning a winterised notation:

- The design temperature requested by the vessel operator.
- The selection of material grades for hull structures and equipment, which are suitable for the Design Air Temperature.
- Ice accretion criteria for stability calculations.
- Adoption of means to maintain engine room, steering gear, storerooms accommodation and other essential spaces at temperatures that are acceptable values for the crew and machinery.
- Sea inlet arrangements, to maintain the operability of cooling water systems.
- Protection of on-deck piping, e.g. by thermal insulation and trace heating.
- Heating systems for fresh water and ballast tanks to protect against water freezing in tanks and associated piping.
- Suitability of navigation equipment and systems for the anticipated conditions.
- Ice removal measures for deck working areas, e.g. steam hoses, manual tools, covers and non-slip/heated decks.

It is recommended that vessel operators have written procedures in their Safety Management System (SMS) addressing risk management and risk mitigation when preparing for and operating in cold weather and ice.

5.1 Practical guidance on winterisation of vessels

The considerations for the winterisation of offshore vessels contained in this Section are structured according to the following broad areas:

- Bulk Cargo, Bunker and Ballast Systems (section 5.1.1).
- Deck Operations (section 5.1.2).
- Engine and Machinery Rooms and Systems (section 5.1.3).

Figure 5.2: *Sea fog (Courtesy ©Arno Keinonen)*

- Safety and Lifesaving Equipment (section 5.1.4).
- Fire-fighting Systems and Equipment (section 5.1.5).
- Pollution Prevention and Response (section 5.1.6).
- Ice Accretion and Snow Accumulation (section 5.1.7).

In the event that the nominated vessel has a voluntary winterisation notation, reference can be made to the details of the specific notation to determine the preparations that have been undertaken.

Figure 5.3: *Ice accretion on supply boat manifold*

Bulk tank and bunker tank vents

It is recommended that vent valves are thoroughly overhauled prior to entry into the area of sub-zero temperatures. Valves can be protected on passage from the effects of ice accumulation/accretion with canvas covers or steam heating. In extremely low temperatures, canvas covers have been shown to be more effective than steam heating. It is recommended that checks are carried out to ensure that the presence of a canvas cover does not inhibit the effective operation of the vent valve.

Before any bulk or bunker operation commences, it is recommended that any canvas covers are removed and that pressure/vacuum arrangements are checked to be free of ice blockage, in particular, that the drain holes are clear and free to operate.

Transfer and deep well pumps

It is recommended that the hydraulic system is started on low load at least 30 minutes before the system is required for operations.

The motors and shafts of pumps located on deck can be protected with canvas covers to avoid delays caused by having to de-ice pumps before discharging.

Submerged hydraulic pump systems

It is recommended that the grade of hydraulic oil used in the submerged pump system is typically suitable for operation in air temperatures down to -50°C and that its properties are verified. It is recommended that the hydraulic system is started on low load at least 30 minutes before the system is required for operations.

Some thickening of the hydraulic oil due to increased viscosity may be experienced when ambient temperatures fall to zero and below. Minimising dead-legs will assist in the pump's operation, therefore it is recommended that the pump is initially started very slowly to enable the warm hydraulic oil from the main to slowly displace the cold oil in the pump and consequently warm the pump through slowly. An increase in the normal loading may be placed upon the supply pump on starting a hydraulic pump due to the change in viscosity of the hydraulic oil.

Tank heating coils

If not in use, heating coils and lines should be drained and blown through with air. Steam delivery lines should be blanked off, preferably where they spur off from the main line, in order to avoid dead-legs.

Transfer lines

Differences in temperature experienced by the vessel can cause contraction of the deck lines that may not be taken up in the designed manner. There is a possibility of flange leakage and it would be prudent to check the integrity of the lines prior to use to ensure they are tight.

After loading or discharging bulk liquid cargoes or bunkering in cold climates, the vessel's lines are drained and the drain valves left open until the ambient temperature rises sufficiently. Where possible, it is recommended that at least one tank-filling valve is left open to allow the line to drain, thereby preventing the line from becoming pressurised with temperature changes.

The pour point of the cargo being carried or to be loaded can be checked to determine whether line blockages may occur if cargo operations are stopped for any reason. Similarly, bunker fuel specifications need to be checked for pour point.

Figure 5.4: *Ice accretion on deck*

Ballast systems

If fitted, hydraulic ballast valves in empty tanks can be frequently activated to avoid freezing/blockage, unless other positive means are employed to prevent freezing. Consideration should be given to changing the hydraulic fluid to one which has better performance in low temperature conditions if the vessel is to spend time in Arctic conditions.

Ballast tank vents may become frozen if not protected by canvas covers or steam/electrical heating on passage. However, it is recommended that, to avoid the risk of over- or under-pressurisation of ballast tanks, the use of covers on vents be strictly supervised to ensure that the vents can still operate as designed. It is recommended that any covers are removed prior to the commencement of ballast operations and that the accumulated ice is frequently removed.

Ice accumulation in ballast tanks

If an offshore vessel is to remain in severe sub-zero temperatures for an extended period, consideration should be given to fitting a system of heating in the ballast tanks, where that water ballast is used during the work programme. If no heating system is fitted, it is recommended that the Master determines the density of the water contained within the ballast tanks before entering cold climates. The more saline the water, the lower the freezing temperature will be. Consideration may be given to exchanging the ballast water to increase its salinity.

The surface of ballast water may freeze in ballast tanks. A considerable danger exists during de-ballasting operations should a layer of ice remain suspended in the tank as it may fall at a later time, risking damage to internal structure and fittings. If possible, and if free surface stability calculations show it to be acceptable, ballast levels can be kept at or below the level of the sea surface. However, due account will also need to be taken of not having sea suctions too close to sea surface where there is increased risk of them getting blocked with ice.

It is recommended that, where fitted, ballast tank heating or bubbling systems are in operation prior to entering areas with sub-zero temperatures, particularly when ballast levels are above the water line.

If stability and the ice belt depth allows, where no ballast tank heating or bubbling systems are fitted, periodic lowering and re-filling of the ballast using the lowest sea suction on the vessel may avoid freezing on the water's surface.

5.1.2 Deck operations

It is recommended that all void spaces, empty tanks, chain lockers and spaces are sounded prior to entering cold weather. If any water is found, it can be educted dry, as far as is practical, to avoid ice damage when these residues freeze. Sounding the spaces regularly is recommended to ensure that they remain water-free.

It is recommended that sounding pipes, vents and remote gauges are protected and remain operational as far as possible.

As well as the natural consequences of sub-zero temperatures, e.g. freezing of liquids, it is also recommended that the accumulation of ice on deck from freezing spray and rain is managed. Consequently, many of the actions below relate to covering equipment with canvas, heavy-duty plastic sheet or similar material. Ice accumulations on unprotected equipment may render the equipment inoperable.

Tank gauging and sampling points can be covered to prevent ice accumulation. Similarly, bulk liquid manifold pressure gauge connections may be covered.

It is recommended that bulk liquid cargo manifold drip trays are kept dry and that the drain valves on the drip tray are drained of any water to prevent them freezing in sub-zero temperatures.

It is also recommended that deck cranes are operated and tested prior to the vessel entering sub-zero temperatures and that the operation of any heating arrangements provided, for example in crane cabs, is also tested.

It is recommended that scupper holes are not allowed to ice over as this makes it difficult for plugs to fit correctly. Coating of the scupper plug rubber faces with petroleum jelly may prevent seizure of the plugs in scupper holes.

Figure 5.5: *Ice accretion on deck passageways*

It is recommended that the main air valve to deck is closed and the airline is drained, taking care to remove any moisture that may be contained within the line, especially at the ends. If air has to be supplied to deck, an air drier should be used.

Deck equipment

Particular attention needs to be paid to the operating temperature range of the hydraulic fluid used in systems serving equipment such as winches and deck cranes.

For hydraulic driven systems, oil can be circulated continuously when the external temperature is below 0°C, to ensure that the fluid systems are maintained at working temperatures. If this is to be achieved by leaving machinery (e.g. winches) running, it is recommended that careful attention is paid to the regular lubrication of the equipment and that the oil manufacturer's stated operating temperature range/viscosity is checked for suitability. Oils may have to be treated with an appropriate viscosity additive or, in extreme cases, the oil may have to be changed for a more suitable grade.

Control boxes and motion levers can be protected by canvas covers.

Mooring wires and synthetic ropes that are not in use should be stored below decks. If this is not possible, they can be protected by canvas covers to stop ice accretion until they are required for use. Ice crystals can form within unprotected ropes and can cause damage to the rope's fibres.

Ice accretion on windlasses

Due to their exposed location, windlasses and winches are likely to be subjected to heavy ice accretion. It is recommended that, prior to arrival on location where anchors may need to be used, that the winches and windlasses are proven to be operational and that additional time is allowed to clear any ice accretion. It is also recommended that anchors are lowered to prove that they are free to run from the pipe (i.e. not frozen in) when safe navigation permits. However, the anchors should be brought fully home and secured prior to any operations over subsea structures or pipelines.

Other

It is recommended that particular care is taken in sealing the chain locker, spurling and hawse pipes.

Figure 5.6: *Ice accretion on deck machinery*

It is recommended that sprinkler systems are drained down free of water. This includes sprinkler systems to chemical, paint and other store rooms, accommodation deluges and any fresh or salt water systems covering other spaces.

5.1.3 Engine and machinery rooms and systems

It is recommended that, prior to entering cold weather areas, the engine room is prepared for the anticipated conditions and that particular consideration is given to deciding when the engine room should be manned.

The provision of heaters in the engine room/machinery spaces will assist in maintaining temperatures above freezing. The use of electrical hot-air space heaters may also be considered within these spaces. Care should be taken to ensure that excessive condensation does not form and cause a slip hazard or drip onto electrical equipment. This is best mitigated by good insulation on surfaces exposed to outside temperatures.

It is recommended that the following points are considered to maintain the safe and effective operation of the ship's propulsion and ancillary systems.

Cooling system intakes (sea chests)

The maintenance of effective cooling arrangements is a prime consideration in sub-zero sea temperatures. It is important that all seawater strainers are cleaned, since a clogged filter will lead to reduced flow, resulting in rapid ice formation within the strainer.

It is recommended that particular care is taken to ensure that the heating arrangements of the cooling water sea chests are working at optimum efficiency. It is also recommended that steam heating systems to sea chests are checked to confirm their good working condition and that they are operated continuously when the ship is in ice infested waters. Any flexible steam hoses should be connected to the sea suctions prior to arrival in ice or cold waters.

It is also recommended that consideration be given to the following:

- The risk of damage to the engine as a result of severely over-cooling the jackets.
- Optimising the number of coolers in service.
- Raising cooling temperatures.
- Adjusting charge air coolers.
- Monitoring the scavenge temperatures to ensure that they are maintained within limits.
- The risk of engines overheating due to insufficient water flow through a frozen or blocked cooling system.

When re-circulating cooling systems are fitted, it is recommended that the levels of cooling water are checked before entering sub-zero conditions and the condition of all valves and pumps is verified. It is recommended that the system is placed in service before entering ice conditions.

Recommendations on the design of sea chests may be found in MSC/Circ. 504 Guidance on Design and Construction of Sea Inlets under Slush Ice Conditions and in the Finnish/Swedish Ice Class Rules.

Fuel systems

It should be ensured that installed heating systems are operating on all bunker storage tanks, bilge tanks, bilge overflow tanks and main engine sump, settling and service tanks. Bunker storage tank temperatures should be kept at least 5ºC above the minimum transfer temperature given in the fuel's specification.

If applicable, consideration should be given to changing from heavy fuel oil (HFO) to marine diesel oil (MDO) prior to closing down the main engine so that the fuel lines are primed with diesel oil instead of fuel oil. This ensures that any cooling of fuel lines will not result in oil solidifying within the lines.

Many operators only use marine gas oil or diesel oil when in Arctic areas and it should be ensured that the fuel used has a sufficiently low wax point to prevent blockages. When considering changing from HFO to marine gas oil (MGO) or MDO, engine manufacturers should be consulted for advice on possible alterations required in the fuel system, such as the fitting of coolers and modifications to nozzles.

Stern tube

Stern tube oil systems should not contain any free water or be contaminated with water/oil emulsion. Consideration should be given to draining any water from the system or replacing the stern tube oil charge.

It is recommended that stern tube bearings and seals located outside the hull are designed not to leak pollutants. In this context, non-toxic biodegradable lubricants are not considered to be pollutants.

The temperature of the stern tube cooling water tank should be closely monitored and consideration should be given to sourcing a suitable additive or temporarily draining the tank when the temperature of the contents approach 0ºC.

When commencing ice breaking operations, a close watch should be kept to ensure that the stern tube seal remains oil-tight.

Ventilation

Consideration needs to be given to stopping all but one main engine room ventilation fan to maintain a reasonable ambient temperature in the machinery space. However, suitable air flow should be maintained to allow the correct operation of boilers, main and auxiliary engines if they are not provided with separate ducting.

As far as possible, vents feeding off the main ventilation system should not blow directly on to fuel lines or pipes containing fuel oil or onto HFO transfer pumps.

Ventilation fans in spaces, such as the steering gear space, may be stopped and vent flaps closed to maintain a reasonable ambient temperature.

It is recommended that pneumatic and manual fan flaps are regularly operated to ensure they are operating correctly and to prevent freezing/seizing.

Hydraulic machinery

Before entering areas of sub-zero temperature, hydraulic systems, including valve hydraulic systems, should be bled free of water.

Hydraulic pumps servicing external equipment, such as cranes and winches, should be run regularly to maintain the temperature of the oil and machinery.

Stairwells, handrails and walkways may be fitted with electrical heating to provide safe access.

Heating systems

Trace heating tape is an adhesive tape which contains wire and can be used to heat pipes and machinery. The tape comes with the necessary documentation to calculate current, load and wattage. It provides a temporary, quick and cost-effective solution to heating pipes and machinery. Tape intended for use in hazardous areas should be appropriately rated for such use.

Stairwells, handrails and walkways may be fitted with electrical heating to provide safe access.

Electrical systems

Generators

It is recommended that the fuel temperature of any generator running on diesel or gas oil is monitored and arrangements are made for temporary local heating if the temperature approaches the fuel's cloud point.

Emergency generators

The emergency generators on some vessels have electric heating on the alternator end. Regular testing is recommended to ensure its satisfactory operation.

It is recommended that external vent flaps and supply fan damper in the emergency generator room are kept closed. Notices advising the status of the flaps and dampers should be posted in the emergency generator room and main engine control room. The emergency generator's cooling water should always contain the correct amount of anti-freeze.

Emergency batteries and battery lockers

The emergency batteries and power for communications equipment should be protected from extreme low temperatures. Spaces containing batteries may need to be provided with space heaters, dependent upon their location/exposure.

General service batteries are unlikely to freeze in anticipated conditions but, as a precaution, can be covered with a plastic sheet.

Water

When not generating water

It is recommended that, where possible, gauge glasses to domestic/distilled water tanks are drained. If gauge glasses are not drained, there is a possibility that the lower section of the gauge glass will become frozen and shatter. Remote sensing gauges cannot be relied upon.

If the evaporator is not in use, lines to the storage tanks should be drained.

When generating water

It is recommended that the temperature of the water in the storage tanks is monitored and generated water is pumped to the tanks as necessary to maintain a reasonable temperature. As the distillate discharge from the evaporator is at about 50°C, it should prevent the water in the tanks becoming cold enough to freeze.

The supply lines from domestic fresh water tanks to pressurising pumps may be susceptible to freezing, depending upon their location, and appropriate precautions should be taken, including insulation.

Compressed air

If ice contaminates the general service and/or instrument air system, there is a possibility of problems with on board instrumentation air supply. It is therefore recommended that driers are fitted to all air systems.

Steering gear

Steering gear motors should be kept running at all times to keep the oil warm. Space heaters may be used in the steering flat to ensure that the equipment is maintained at a satisfactory temperature. The use of heaters in the steering flat may result in significant condensation forming on deckheads and bulkheads and equipment may have to be protected from condensate dripping from these surfaces. Non-slip decking should be provided.

Lubricants and oils

It is recommended that only oils and greases that are suitable for the anticipated temperature are used.

Diesel oil blends

If there are concerns over the suitability of the fuel pour point with regard to cold operating conditions, the engine manufacturer should be consulted to identify the appropriate fuel grade to use.

If suitable grades of diesel are not available for operating ancillary equipment in the anticipated temperatures, blended fuel may have to be procured. Diesel oil may be blended with kerosene to depress the pour point.

It should be noted that, as the proportion of kerosene is increased, the lubricity of the blend will be reduced and machinery may require more frequent checks and maintenance. In addition, it should be ensured that the flash point of the final blend remains within IMO regulatory limits.

5.1.4 Safety and lifesaving equipment

It is recommended that all life rafts are rated for safe operation according to the environmental conditions likely to be experienced. Arctic-rated life rafts and Hydrostatic Release Units (HRU’s) are available that incorporate electrical heating elements to ensure the contents do not freeze.

Ice accretion should be regularly removed from the life rafts, cradles, cradle release pins and launching equipment to retain their preparedness for launching and inflation.

Similar precautions may be taken for lifeboats, rescue boats and their launching appliances, if carried. Particular checks should be made to ensure that brake release securing pins are maintained free to move and capable of being extracted.

It is recommended that an ice removal mallet is readily available in the vicinity of survival craft.

It is recommended that an ice removal mallet is readily available in the vicinity of survival craft. Care should be exercised when using mallets to avoid inadvertent damage to equipment.

Manual inflation pumps, proven to work in the anticipated temperatures, should be provided for the life rafts and stowed in a warm space in the vicinity of the life rafts.

The overall condition of the gel coat of lifeboats should be regularly inspected for any damage, particularly penetration of the gel coat and fibre sub-structure. This should be done in good time prior to entering the cold zone, due to the hygroscopic nature of fibreglass. If the repairs are undertaken in a warm dry climate, this will limit water ingress which, if subjected to freezing, can cause severe damage to the boat’s structure.

Lifeboat engines

Lifeboat engines should, at all times, remain available for immediate use within two minutes of starting in the environmental conditions likely to be experienced. The process of starting an extremely cold engine is quite different from normal starting procedures. It is recommended that the correct procedure is drawn to the attention of all persons likely to be involved in starting the engine in very cold conditions to ensure they are familiar with the operation and the frequency of starting the engines should be increased.

Manufacturer's instructions for the grade of oil to be added to the cold starting pots, if fitted, should be followed and the oil should be readily available in the lifeboats. It should be recognised that the performance of the starting batteries in cold conditions might be diminished.

If fitted, sump or space heaters in lifeboat engines may be used. Consideration may also be given to fitting trace heating around the doors of enclosed lifeboats to ensure that they do not freeze in the closed position.

It should be recognised that the performance of the starting batteries in cold conditions might be diminished.

Lifeboat fuel systems

An appropriate grade of Arctic diesel or gas oil may be used to prevent waxing in fuel systems leading to lack of engine start and impaired reliability. It is recommended that, when replacing the fuel grade, lifeboat fuel tanks and the fuel line contents are changed out and the engine run on the new fuel to ensure that the system is properly flushed and primed.

Lifeboat cooling water systems

Where the lifeboat cooling water system is self-contained and re-circulating, it should be adequately protected with an anti-freeze solution. If the system is not self-contained, it should be checked to ensure that no obstructions or contamination prevent the natural drainage of the system.

Lifeboat water spray systems

The spray systems, including pumps, on the lifeboats should be drained of water. In some classes of boat, if the spray pump is frozen, it will inhibit starting of the lifeboat engine by locking the propeller shaft.

Lifeboat water rations

Precautions should be taken to avoid the freezing of water rations stowed in lifeboats. This may include their removal to a warm storage area, in which case a person must be designated on the muster list to return them to the boat.

Free-fall lifeboats

In general, free-fall lifeboats can be used only in partially ice-covered waters where the ice concentration is such that the boat can be safely launched and manoeuvred to a safe distance from the vessel.

It is not safe to release a free-fall lifeboat onto ice. The lifeboat may be winched out and down to rest upon the ice surface. When in ice, it will be necessary to break the ice, either by judicial use of the vessel's engines or by other craft.

Rescue boats with water jet engines

The rescue boat should be maintained in a condition that will allow immediate use but will also protect the boat from the extremes of weather.

Subsidiary lifesaving appliances

Immersion suits

Commonly supplied immersion suits have a design operational range in immersed (seawater) temperatures from -1.9°C up to +35°C. Immersion suits are available that have enhanced insulation properties.

Caution should be exercised when wearing an immersion suit, if evacuated on to ice, as the suit does not provide foot protection against the cold nor grip, risking slips and falls.

Thermal Protective Aids

Thermal Protective Aids (TPAs) should be effective within a temperature range appropriate to the temperatures likely to be encountered.

Lifebuoys

Lifebuoys should be maintained so that they are not iced into position and are free to be removed and used.

External pyrotechnics

Bridge wing lifebuoy/smoke float release pins should be well-greased to ensure their proper operation.

Emergency position-indicating radio beacons

Emergency Position-Indicating Radio Beacons (EPIRB) should be maintained ice-free.

Breathing apparatus and oxygen therapy units

In sub-zero conditions, the use of compressed air/oxygen breathing or resuscitation apparatus should be considered with care. Hazards involved include the freezing of the demand valve and exhale valve due to the freezing of exhaled vapours from the user, leading to premature emptying of the gas bottle or failure of the system. The effect of low temperature (below -4°C) on the lungs of the user, can lead, in protracted cases, to frostbite of the lung tissue.

When air bottles are being re-charged, the moisture content of the compressor output should be checked. (The American National Fire Protection Authority (NFPA), rules specify, for example, that breathing air in SCBA bottles should have a dew point no warmer than -65°F (NFPA 1500, 1997 Edition).

Eyewash stations

Eyewash fluid is typically effective in a fluid temperature range of +5°C to +25°C. Below +5°C the effectiveness of the fluid may be reduced. At 0°C fluid temperature, the fluid should not be used except in cases of extreme urgency as it may cause damage to the eye. Consideration may be given to withdrawing temporarily exposed eyewash stations into the accommodation while the vessel is operating in sub-zero conditions.

Hard hats

The safe operating temperature range for hard hats is marked within the hat by the manufacturer. Some hard hats are certified for safe operation to -40°C and their use is recommended.

Suitable warm helmet liners should be provided.

5.1.5 Fire-fighting systems and equipment

Fire extinguishing systems should be designed or located so that they are not made inaccessible or inoperable by ice or snow accumulations or low temperatures.

Equipment, appliances, systems and extinguishing agents should be protected from freezing and the minimum temperatures anticipated for the voyage.

Precautions should be taken to prevent the nozzles, piping and valves of any fire extinguishing system from becoming clogged by impurities, corrosion or ice build-up. Fire mains should be lagged, drained or trace heated to prevent freezing.

The exhaust gas outlets and pressure/vacuum arrangements on gas detection systems should be suitably protected from ice build-up that could interfere with the system's effective operation.

Water or foam extinguishers should not be located in any position that is exposed to freezing temperatures. These locations should be provided with extinguishers capable of operation under such conditions. The following is general guidance on typical operating temperatures for portable extinguishers. Operators should check the actual performance limitations of extinguishers by referencing manufacturer's data.

Water, gas and low expansion foam

Fire extinguishers located in exposed areas are susceptible to freezing. Foam extinguishers will be ineffective and, when they do thaw out, the foam compound will have been 'frost damaged', rendering them useless.

Unprotected foam and water extinguishers

Unprotected foam and water extinguishers are rated for safe and effective operation to +1ºC. If protected with ethylene glycol, this figure may be revised downward to -10ºC.

If an additive is used, it may enable water and foam extinguishers to be operable at temperatures down to -20˚C.

CO2 extinguishers

CO_2 extinguishers are typically rated for safe and effective operation to -20°C. However, if operated at these temperatures, caution should be taken to avoid contact with any part of the extinguisher or expelled gas to avoid low temperature burns.

Dry powder extinguishers

These extinguishers are typically rated for safe operation from -30°C to +60°C. The extinguishing medium presents no additional special precautions. However, the propellant, CO_2, needs to be treated with caution to avoid personnel injury through exposure to the cold gas.

Aqueous Film Forming Foam

Aqueous Film Forming Foam (AFFF) extinguishers typically have a nominal safe operational range of temperatures between +5°C and +60°C.

Fire and foam systems

Hoses and nozzles

Most hoses are typically rated for safe operation at temperatures down to -20°C and nozzles to -25°C. Cold-weather hoses are available that are rated to -40°C and are marked accordingly.

Fire and foam lines

Fire and foam lines on deck should be well-drained and maintained ready for immediate use at all times. Monitors, hydrant valves and any other moving parts should be well-greased and protected by canvas covers to avoid ice/snow accumulation that may prevent their immediate operation. Their movement should be regularly checked to ensure that they remain free. The change in frequency of maintenance should be recorded in the planned maintenance system (PMS) if operating for extended periods in sub-zero conditions.

Pipework serving water curtains, deluges and spray systems should be confirmed to be drained and empty.

Any items drawing water from the fire main, such as hawse pipe cable washer lines, should be drained, particularly if a re-circulatory fire main line is in use, to avoid any dead-legs.

Equipment should be stored in an area not subjected to heavy icing.

The storage locations of fixed foam system bulk storage tanks may need heating to ensure that the temperature in these spaces remains above zero. Consideration may have to be given to using temporary space heaters to maintain an adequate temperature.

Portable foam equipment

Drums and canisters of foam for portable branch pipe appliances are subject to the same considerations as portable fire extinguishers.

Fire hose boxes

The catches, locks, dogs and hinges on fire hose boxes should be kept ice-free and the spray nozzles and couplings should be well-greased and water-free. All hoses should be completely drained of water to avoid damage and to facilitate their rapid use.

5.1.6 Pollution prevention and response

Prevention of pollution to the environment in areas of extreme environmental sensitivity is of great importance. Care should be taken to follow all regulations in force and, in particular, to the vessel's operating area. Local requirements include, for example, the prevention of grey water discharges.

Oil spill response procedures should be reviewed to ensure that they take due account of issues associated with operations in ice and/or cold temperatures.

It is recommended that the pollution response arrangements are not compromised by the effects of ice accretion. Equipment should be stored in an area not subjected to heavy icing.

The vessel's sewage system should be in good operating condition and suitable storage should be available in the event that discharge to sea is not permitted by local regulation.

Any oil spill response equipment required onboard an oil spill response vessel (OSRV) for recovery of oil from the water should be capable of working in broken ice and should be heated to avoid oily water mixes freezing and rendering the equipment inoperable. For this purpose steam generators or hot water machines may be required to ensure the correct functionality.

5.1.7 Ice accretion and snow accumulation

Ice accretion and snow accumulation pose hazards for personnel having to work onboard, as well as to the vessel itself. De-icing is a complex, time-consuming and hazardous operation. Efforts need to be taken to minimise, as much as possible, sea spray on deck by either reducing speed and/or altering course. It needs to be borne in mind that the ice accumulation also results in the potential for falling ice and associated dangers.

Figure 5.7: *Danger posed by falling ice (Courtesy ©Arno Keinonen)*

In certain conditions, ice formed of fresh water or sea water accumulating on the hulls and superstructures of vessels can pose a serious hazard. Fresh-water ice can form from fog, drizzle, rain or snow. Icing from seawater is generally experienced with air temperatures of below -2°C and in conditions of strong winds that generate waves and spray.

Where deck icing is evident, additional care needs to be exercised when moving and working around the vessel, remembering that ice can be found both on the external surfaces and, in some conditions, in internal spaces.

Figure 5.8 illustrates sea spray icing potential as a function of wind speed and air temperature for a given sea temperature. Generally, icing is not a problem at sea temperatures greater than 7°C, and no cases with higher temperatures were considered when the algorithm was derived.

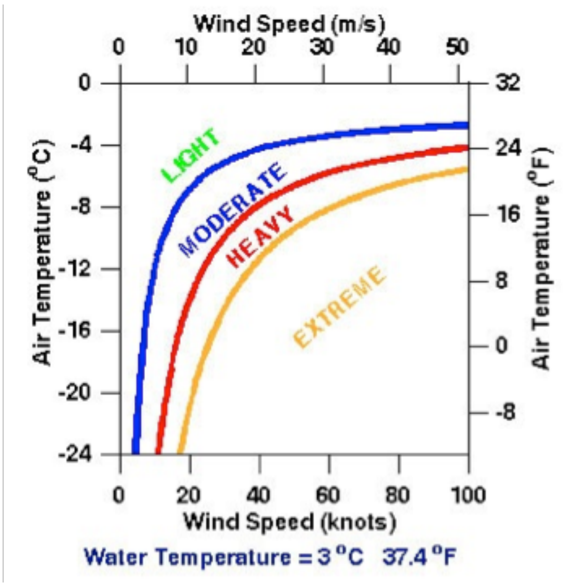


Figure 5.8: *Relationship between Wind Speed, Temperature and Icing*
Source: Overland, J.E., 1990: Prediction of vessel icing at near-freezing sea temperatures.

Note: The above provides only an approximate guide for ships steaming into the wind and waves. The actual potential for icing depends on the type, load, and handling characteristics of a particular ship. Masters and bridge watch-keepers should be well aware of the wind speeds which cause sea spray to reach the deck and superstructure and should base their assessment on the potential for icing on this knowledge.

The build-up of icing should be monitored and any stability implications identified. If the level of icing is cause for concern, ice removal operations should be initiated.

6. Environmental Protection and Damage Control

6.1 Summary

Marine oil spills may result from any phase of oil extraction, storage or transportation. Potential sources of oil spills include:

- Well blowouts during sub-sea exploration or production.
- Acute or slow releases from sub-sea pipelines.
- Collisions with exposed risers at platforms, releases from on-land storage tanks or pipelines that are located at or near the coast.
- Accidents involving oil transportation vessels or vessels carrying large quantities of fuel oil.

Conditions, such as dynamic ice cover, low temperatures, reduced visibility or complete darkness, high winds and extreme storms add to the risk factors that must be mitigated.

6.2 Environment

The Arctic environment presents unique challenges to spill response. Impacts of spills in Arctic regions will depend largely on the timing of the incident in relation to the presence of concentrations of wildlife. There are several characteristics of the environment and wildlife species that exacerbate the potentially negative consequence of an oil spill to ice-covered waters. Oil persists longer in freezing conditions because it evaporates more slowly or may be trapped in or under ice and is thus less accessible to bacterial degradation, although recent research may indicate otherwise. Population recovery after an incident may be slowed because many species have relatively long life spans and slower generational turnover.

Compared to the world's temperate oceans, Arctic marine waters have lower temperatures and lower salinity profiles. Typical winter conditions include cold temperatures, the formation and movement of sea ice, extreme and unpredictable weather conditions and long periods of darkness. Any of these conditions may increase the risks of a significant accidental oil spill, while limiting the potential effectiveness of clean-up options.

Certain aspects of the Arctic environment may increase the persistence of oil in the coastal environment. For example, the relative lack of wave exposure and associated natural cleaning along Arctic coastlines that are frozen for up to nine months of the year. On the other hand, the same fast ice that slows natural cleaning also protects shorelines from being oiled for much of the year in the case of spill occurring outside the summer season.

6.3 Oil spill response in ice

The scope of the Shipboard Oil Pollution Emergency Plan (SOPEP) and/or Shipboard Marine Pollution Emergency Plan (SMPEP) of offshore vessels (for vessels over 400 gross tonnes) operating in ice should address specific issues associated with the response to oil spills in such conditions. The vessel operator's procedures will accord with those of the licensee and should demonstrate that attention has been paid to the unique hazards posed by spills in the extreme cold or in ice.

Oil spilled in, on and under ice offers unique challenges versus open water spills.

Oil spilled in, on and under ice offers unique challenges versus open water spills. Ice may act as a natural barrier and prevent the oil from spreading. Oil spilled on ice will usually be contained in a small area. The actual amount of spreading will be dependent on air temperature, density and viscosity of the oil spilled, and snow cover. Snow is an excellent sorbent. Oil spilled under the ice may also be contained in a very restricted area which is influenced by the under-water ice roughness and currents. The spread and surface area of the spill will vary as a function of ice concentration, wind and current conditions.

Oil slick surveillance and tracking in ice demands the use of special techniques. For this purpose, special tracking buoys or remote sensing equipment can be utilised. Tracking buoys, equipped with navigation system receivers, are released into an oil slick in ice and move with the slick, providing continual position data through built-in radio transmitters. The remote monitoring of oil slicks in ice may be conducted using infrared sensors or laser fluorosensors installed on aircraft.

The primary clean-up technique for oil in ice environments is mechanical containment and recovery, either by heavy equipment or traditional spill response equipment. In broken ice conditions, traditional open water mechanical containment and recovery systems can be used with the noted caution that most oil spill booms cannot withstand the forces encountered when operating in heavy ice conditions. High oil viscosity can also impose some limitations on the operation of oil recovery systems. As a result of low temperatures, some heavy oil products, such as heavy fuel oil, may become denser than water and sink.

Under certain conditions, such as low ice thickness and high current velocity, oil can be moved under ice. Driven by the current, oil migrates through the lower part of ice floe and accumulates in the pockets of the rough surface of ice or comes up to surface through cracks or fractures in the floe. One of the recovery methods, based on this oil behaviour, is to drill holes in the ice and collect the oil as it comes up to surface through the hole, using a skimmer or vacuum pump. The holes should be drilled in the estimated area of the oil slick, making due allowance for any current.

The secondary option that works well in both solid ice and broken ice conditions is in-situ burning and in some circumstances this can be the primary option. This requires minimal logistics and provides high removal rates. Nevertheless, emulsified or weathered oil can reduce the effectiveness of in-situ burning or even make it impracticable. In order to burn effectively, the oil slick should have a minimum ignitable thickness, which will depend on the oil grade and environmental conditions. Cautions associated with burning relate to the risk of unwanted fires and detrimental effects on the environment caused by the smoke plume and residues of burning.

Dispersants potentially can be used in ice-covered waters. The most critical parameters for obtaining an effective dispersants operation under extremely cold conditions are:

- Good application of dispersant on the oil.
- Sufficient energy for the dispersion process, using propeller wash to assist.
- Oil properties at low temperature – weathering.
- Dispersant performance and properties under relevant conditions (salinity, temperature, oil type).

It should be noted that both the use of dispersants and in-situ burning as response techniques will require pre-approval from the relevant authorities.

Annex A: Reference Sources for Regulatory Information

The following provides some details of web sites that may be useful to vessel operators when seeking information on regulations applicable to a particular operating area:

Canada – Marine Safety	www.tc.gc.ca/MarineSafety/menu.htm
Canada – Arctic Ice Regime	www.tc.gc.ca/eng/marinesafety/tp-tp12259-arctic-ice-regime-2871.htm
Denmark – Danish Maritime Authority	www.dma.dk/Sider/Home.aspx
Russian Federation – in Russian only	www.morflot.ru/about/sevmorput/index.php
United States Coast Guard	www.uscg.mil/history/docs/IceOps.asp

Annex B: Arctic Ice Class Notations

Note: Following the development by International Association of Classification Societies (IACS) of the Polar Class notations, some IACS members have withdrawn their Arctic Ice Classes. However, details are included here as they may still be referenced in the Class notation of existing vessels.

American Bureau of Shipping Arctic Ice Classes

Ice Class	Navigating independently or when escorted by an icebreaker of the following ice classes	Polar Waters with Multi-year Ice			
		Central Arctic basin	Arctic offshore shelf	Antarctic ice-covered waters	Year round navigation in water with first-year ice with the ice conditions
A5	Independently	Year around	Year around	Year around	Extreme
A4, A3	Escorted by A5 Ice Class Vessel	Year around	Year around	Year around	Extreme
A4	Independently	July through November	Year around	Year around	Extreme
A3, A2	Escorted by A4 or higher Ice Class Vessel	July through November	Year around	Year around	Extreme
A3	Independently	Short term, short distance entries during July through September	July through December	February through May	Extreme
A2, A1	Escorted by A3 or higher Ice Class Vessel	Short term, short distance entries during July through September	July through December	February through May	Extreme
A2	Independently		August through October	March through April	Extreme
A1	Escorted by A2 or higher Ice Class Vessel		August through October	March through April	
A1	Independently		August through September		Very Severe

Table B1: *American Bureau of Shipping Arctic Ice Classes*

Det Norske Veritas Arctic Ice Classes

Class notation	Type of ice encountered	Nominal ice strength, N/mm2	Nominal ice thickness, m	Limiting impact conditions
ICE-05	Winter ice with pressure ridges	4.2	0.5	No ramming anticipated
ICE-10		5.6	1.0	
ICE-15		7.0	1.5	
POLAR-10	Winter ice with pressure ridges and multi-year ice floes and glacial ice inclusions	7.0	1.0	Occasional ramming
POLAR-20		8.5	2.0	
POLAR-30		10.0	3.0	

Table B2: *Det Norske Veritas Arctic Ice Classes*

Germanischer Lloyd Arctic Ice Classes

Ice class notation	Age of ice	Thickness [m]
Arc 4		3,0
Arc 3	multi-year	2,0
Arc 2		1,5
Arc 1	one-year	1,0

Table B3: *Germanischer Lloyd Arctic Ice Classes*

Lloyd's Register Arctic Ice Classes

Ice Class	Description
Ice Class AC1	The requirements for the assignment of this class are intended for ships designed to navigate in Arctic or Antarctic ice conditions equivalent to unbroken ice with a thickness of 1,0 m.
Ice Class AC1, 5	The requirements for the assignment of this class are intended for ships designed to navigate in Arctic or Antarctic ice conditions equivalent to unbroken ice with a thickness of 1,5 m.
Ice Class AC2	The requirements for the assignment of this class are intended for ships designed to navigate in Arctic or Antarctic ice conditions equivalent to unbroken ice with a thickness of 2,0 m.
Ice Class AC3	The requirements for the assignment of this class are intended for ships designed to navigate in Arctic or Antarctic ice conditions equivalent to unbroken ice with a thickness of 3,0 m.

Table B4: *Lloyd's Register Arctic Ice Classes*

Russian Maritime Register of Shipping Arctic Ice Classes

Ice class	Typical speed, knots	Ice concentration and type	Ice thickness, m		Methods of surmounting ice ridges
			Winter – spring	Summer – fall	
Arc 9	12	Very close floating and compact multi-year ice	3.5	4.0	Surmount of ice ridges and episodic ramming of compact ice fields
Arc 8	10	Close floating second-year ice	2.1	3.0	Regular ramming
Arc 7	6-8	Close floating first-year ice	1.4	1.7	Episodic ramming
Arc 6		Open floating first-year ice	1.1	1.3	Continuous motion
Arc 5		Open floating first-year ice	0.8	1.0	
Arc 4		Open floating first-year ice	0.6	0.8	

Table B5: *Russian Maritime Register of Shipping Arctic Ice Classes*

Transport Canada CAC Definitions

Ice Class	Description
CAC 1	Is an icebreaker which can operate anywhere in the Arctic and can proceed through multi-year ice continuously or by ramming according to the owner's performance requirements. A CAC 1 ship is capable of navigation in any ice regime found in the Canadian Arctic and unrestricted ramming of the heaviest ice features (except icebergs or similar ice formations) for the purpose of ice management.
CAC 2	Is a commercial cargo carrying ship which can trade anywhere in the Arctic, but would take the easiest route. It could proceed through multi-year ice continuously or by ramming according to the owner's performance requirements. A CAC 2 ship is capable of navigation in any ice regime found in the Canadian Arctic and ramming of heavy ice feature restricted by its structural capability.
CAC 3	Is a commercial cargo carrying ship which can trade in the Arctic where ice regimes permit. It would proceed through multi-year ice only when it is unavoidable and would do so in a controlled manner usually by ramming. It would be unrestricted in second- and heavy first-year ice.
CAC 4	Is a commercial cargo carrying ship which can trade in the Arctic where ice regimes permit. It would be capable of navigating in any thickness of first-year ice found in the Canadian Arctic, including first-year ridges. It would avoid multi-year ice and when this is not possible it would push or ram at very low speeds.

Table B6: *Transport Canada CAC Definitions*

Annex C: Icebreaker Assistance to Offshore Vessels

Note: for the purposes of this Annex Icebreaker means any vessel whose operational profile may include escort or ice management functions, whose powering and dimensions allow it to undertake aggressive operations in ice-covered waters.

Offshore support vessels require ice-breaking assistance when the vessel's capability to navigate or manoeuvre is severely restricted by the existing ice conditions.

Generally, it may not be economically justifiable to build or charter an icebreaker designed for operation in the worst ice conditions which can occasionally occur in the region. As a result, the provision of such additional ad hoc icebreaking support should be considered. These resources will not normally be retained on site but arrangements should be in place to identify and procure them. However, for very remote locations, it may be necessary to keep the required ice class vessels on site to support normal operations.

Offshore support vessels can be assigned different tasks, depending on the vessel's design, but for the purpose of requiring icebreaker assistance they can be condensed to:

- Navigation through ice (e.g. from shore base to the operating area and back).
- Manoeuvring and station-keeping during operations in ice.

Navigation through ice

In order to pass through ice which exceeds the vessel's own icebreaking capabilities, the vessel will require icebreaker escort. There are two main methods of escorting in ice – leading and towing. In both cases the escorted vessel follows the ice channel made by the escorting icebreaker or icebreakers.

Push-towing may sometimes be considered but the method is rarely used, since the assisted vessel should have sufficient strength to withstand ice stress. In addition, the stern of the assisted vessel and the bow of the icebreaker have to be compatible to facilitate such an operation.

Responsibilities

Icebreaker assistance is usually offered to a vessel at its own risk and the vessel being assisted is solely responsible for its navigation. Good communications, crew experience, defined responsibilities and adherence to well thought out procedures are important to the safe execution of escort operations.

The assisting icebreaker is in command of the escorting operation and the escorted vessel should adhere to all recommendations issued by the escorting icebreaker, especially with regard to speed and distance between the vessels. If more than one icebreaker is used in escorting, one of them should be nominated as being in command of the escorting operations.

Route planning

The route of the convoy should be planned on the basis of the latest available ice and weather information with the aim of avoiding heavy ice areas, such as ice ridges. The use of ice information, obtained from aircraft or helicopters, if available, can be very useful for route planning, especially in heavy ice conditions. The Master of the icebreaker is responsible for route planning.

Ice channel/track

An icebreaker will normally make an ice channel (track) by constant movement through the ice. However, in difficult ice it may have to resort to successive backing and ramming. In this case, the icebreaker's average speed of passage generally will be subject to the characteristics of the ice regime such as ice type, concentrations and pressures. The escorted vessel's capability will also influence the transit speed.

In some situations, the icebreaker may break the ice moving stern first. The use of this method allows the breaker to attain a higher average speed when compared to ramming. However, this method presents the risk of damage to the vessel's propellers and rudders unless they are specifically designed for the purpose.

Particular care should be taken by the escorted vessel when making turns in the ice channel due to the risk of the escorted vessel getting stuck or damaging its rudders, hull plating or propellers through contact with the ice channel edge.

Figure C1: *Close escort in broken ice channel*

Azimuth podded as well as azimuth stern drive (ASD) icebreakers can break significantly wider ice channels in young ice than their beam by directing the azimuth thrust forwards and outwards and this layout is being used for the majority of new-build designs. Conventional, high-powered icebreakers can also achieve wider ice channels than their beam by breaking thin or medium thickness ice at high speeds of advance by using the wake generated.

More than one icebreaker may be needed in heavy ice conditions, or when the beam of the escorted vessel/unit is larger than the beam of the icebreaker.

Ice channels made in fast ice can be used for a period of time until they are filled with brash ice of high thickness. Frequent use of the ice channel may result in the creation of thick ice walls of refrozen rubble ice on the edges of the channel with a thickness higher than the surrounding ice.

Distance between the escorted vessel and the icebreaker

The escorted vessel should travel at a safe distance behind the nearest icebreaker and at a safe speed nominated by the Master of the icebreaker, who controls and manages the escorting operation. The safe distance is set depending on the severity of the ice condition (ice concentration and ice pressure) and the escorted vessel's stopping distance in the ice channel at the speed at which they are travelling. This is important because, if the icebreaker comes to a sudden halt due to an ice feature such as a ridge, the escorted vessel immediately behind the icebreaker must be able to stop to avoid collision. The safe speed for an escorted vessel is determined by the speed that it will not be damaged by contact with ice floes within the channel. The attainable speed may or may not be less than the safe speed depending on the ice conditions within the channel and the power of the escorted vessel. In pressure and/or deformed ice conditions the channel will be more likely to become blocked by ice floes and ice rubble but this will also reduce the safe distance as the escorted ship will be able to stop in a shorter distance.

The Master of the escorted vessel should always be alert to the risk of collision between the vessel and icebreaker, particularly if the icebreaker comes to a sudden stop and should not hesitate to decrease speed or stop at immediate notice.

The escorted vessel should be particularly cautious and take care not to miss the ice channel when navigating from open leads or nilas into thicker ice, thereby risking damage.

Towing in ice

Towing may be utilised when the escorted vessel has insufficient power or manoeuvring capabilities.

There are three methods of towing in ice:

- Close-coupled towing, when the bow of the vessel is fixed in a special notch at the stern of towing icebreaker.
- Towing with a short towline. The distance between the bow of the vessel and the towing icebreaker's stern will normally be 50m or less.
- Towing with a long towline. The distance between the bow of the vessel and the towing icebreaker's stern being more than 50m.

The length of the towline is subject to the bollard pull of the towing vessel, vessel or structure being towed, ice concentrations, type of ice, ice pressure and ice management support. The tow wire length will vary during the tow, depending on the prevailing conditions, always with the aim of having as much wire out as possible.

Figure C2: *Towing in ice*

Icebreakers with a special notch at the stern and protected by fenders can conduct close-coupled towing of the escorted vessel, provided the vessel's bow profile is compatible with the notch in the icebreaker's stern. This method provides the highest speed of passage when compared with other methods and can be the safest and most effective option to conduct escorting operations in extreme ice conditions.

Towing with a short towline provides better steering capability and enables the icebreaker to tow vessels having a length and displacement that significantly exceeds the length and displacement of the icebreaker. Short line towing may be conducted only through a pre-broken ice channel and at low speed, so that the risk of the icebreaker's sudden stop is avoided. In some situations, a second icebreaker may be needed to create or refresh the ice channel ahead of the towing icebreaker.

Towing with a long towline provides the advantage of preventing the towed vessel from direct impact with ice pieces that may be thrown astern by the icebreaker's propulsion wash. This method cannot be used where there is a high concentration of thick ice or high ice pressure.

Icebreaking assistance for manoeuvring and station-keeping

Even if the offshore vessel is suitable for making passage in the ice, it may still lack the ability for manoeuvring and station-keeping during offshore operations such as supply and bunkering operations, cargo transfer to shuttle tankers, diving and Remotely Operated Vehicle (ROV) operations. In such cases, operations may be conducted with the assistance of an icebreaker, conducting active ice management functions.

Stationary ice (e.g. land-fast ice) can facilitate station-keeping, restricting the movements of the offshore vessel. Drifting ice can make manoeuvring and station-keeping extremely difficult and in some cases impracticable. Ice pressure created by onshore ice drift is another factor which can impede the offshore vessel's operations by severely restricting a vessel's manoeuvring capabilities.

Icebreaking support for manoeuvring and station-keeping associated with offshore operations may be undertaken in the following ways:

- Breaking ice floes in the area before the start of operations, taking into account ice drift direction and intensity. Manoeuvring and station-keeping of the assisted vessel is conducted in brash ice or ice cakes, pre-broken by the icebreaker.
- Breaking ice floes drifting to the assisted vessel into smaller pieces to reduce the stress on the assisted vessel caused by the floes' impact. In this method, a safe distance between the icebreaker and the assisted vessel should be set and maintained. The icebreaker should have sufficient power reserve in order to avoid drifting onto and colliding with the assisted vessel. This method is not used in high ice pressure conditions due to its low effectiveness.
- Breaking ice around the assisted vessel. This method reduces the ice pressure on the assisted vessel's hull and facilitates the manoeuvring of the assisted vessel. This assistance may be required to enable the assisted vessel to turn bow against the ice drift, when ice drift changes (e.g. during the tide change).
- Updrift ice management by icebreaker with azimuth propulsion (clearing the site by propeller wash) can be very efficient, especially if the ice is pre-broken by another icebreaker further updrift.

Comprehensive procedures addressing ice-breaking support should be developed that include responsibilities and communication between all parties involved, together with limitations and techniques used during the operation. All parties involved should be familiar with these procedures before operations commence.

Annex D: Ice management and operations at offshore terminals

Ice management can be defined as operations intended to modify ice conditions in order to prevent or mitigate ice-induced hazards and problems specific to various marine activities.

The ultimate goal of ice management is to increase the safety and efficiency of marine operations.

Ice management is the combination of activities aimed at reducing or avoiding actions from various ice features. An ice management system is an integral part of the operation of any Arctic offshore terminal or system whether floating, fixed, sub-sea or otherwise. Offshore vessels may act as part of the assets providing ice management protection, as in the case of icebreakers or ice classed multi-purpose supply vessels, or may be the recipients of the ice protection.

An ice management system may include the following services:

- Ice detection, tracking and forecasting.
- Ice threat evaluation.
- Physical ice management, e.g. ice breaking, ice clearing, iceberg towing.
- Ice alert procedures.

All of the system components associated with ice management should be demonstrated as being capable of operating in the anticipated environmental conditions. In addition, all responsible personnel should be properly trained in the operation and performance of the system.

The ultimate goal of ice management is to increase the safety and efficiency of marine operations.

Ice management should be implemented through a location-specific ice management plan. Among issues that the plan should address are:

- Definition of the scope and expected range of ice management operations.
- Equipment required to support ice management activities and guidance on its use.
- Anticipated operations at the location that could be impacted by the presence of ice.
- Ice events requiring action in the context of the ice management operation and any precautionary actions required that could impact on normal operations.
- A clear definition of roles and responsibilities for initiating action when such ice events occur.

The ice management plan should be regularly reviewed and maintained up-to-date in order to reflect knowledge and experience gained at the location.

a) Ice detection, tracking and forecasting

Ice detection should be designed to facilitate the identification and tracking of all potentially hazardous ice features or ice situations. The system should provide:

- Adequate ice detection capability for the expected ranges of environmental conditions and visibility.
- Sufficient information to enable the potential threat of ice features to be identified and characterised.
- Sufficient information to enable the ongoing tracking of potentially hazardous ice features.
- A long-range detection and tracking capability to support forecasting accuracy.

b) Threat evaluation

Adverse ice scenarios that could potentially lead to allowable operating parameters being exceeded should be pre-defined and the ongoing threat evaluation should have the aims of:

- Considering the information provided by the ice detection system.
- Forecasting movements and changes to any ice threats and their expected time of arrival at the location.
- Characterising the ice threats in terms of the potential consequences to ongoing operations.

- Identifying those circumstances where active intervention involving physical ice management may be required.
- Identifying limits requiring specific operational response actions, such as suspension of operations and removal of vessel.
- Planning scenarios for emergency disconnect procedures and vessel/offshore system separation.

c) Physical ice management

Resources required to support physical ice management should be available on a timely basis, consistent with ice detection capabilities, threat evaluation systems and operational requirements. Resources should include qualified personnel and appropriate vessels.

Resources should include qualified personnel and appropriate vessels.

All vessels used for ice management operations should be:

- Classed with an IACS member classification society for operations in the ice conditions likely to be experienced in the area of operation.
- Suitable for undertaking the required ice management operations on a timely basis.
- Staffed with personnel who are familiar with the ice management plan and trained in the performance of the various ice management duties.
- Equipped in accordance with the ice management plan.

For vessels receiving ice management protection, clear limitations on the type and dimensions of ice that the vessel can encounter should be specified. The time required to get the vessel back to a safe condition to be able depart the site of operations, should be made clear to the ice management team (e.g. time to secure a load and stow a crane boom for passage).

Annex E: Ice operations training course

The basic ice navigation course is intended for Masters, chief officers and experienced watch-keeping officers and other persons with responsible duties in navigation work. The course prepares the crew to enter any ice regime in a safe manner with a full understanding of the likely hazards. The focus is to provide a broad knowledge of icebreakers, how to communicate with them and how to take advantage of their available services. The participants should achieve awareness of the risks involved in navigating in ice and how to avoid damage to the vessel while on passage in ice-covered waters, as well as in berthing operations. The course should make participants aware of limitations of rescue operations and provide an understanding of how to act and survive in case of an emergency.

The course prepares the crew to enter any ice regime in a safe manner with a full understanding of the likely hazards.

Example topics for inclusion include the following:

- Legal aspects and regulations.
- Ice physics and ice classification.
- Ship ice classes and construction.
- Ships and ice.
- Icebreakers and reporting systems.
- Icebreaker operation.
- Operating in ice and hazards.
- Gathering information and voyage planning.
- Preparation of vessel for sub-zero temperatures.
- Independent operation in ice.
- Icebreaker assistance.
- Pilotage and fairway.
- Berthing – alongside – unberthing.
- Precautions in port.
- Case studies and oil recovery in ice.
- Stay healthy in sub-zero temperatures.
- Survival and rescue in ice conditions.

Annex F: Hazard risk assessment of operating in the Arctic

Many offshore vessel owners and operators have a formal Hazard Risk Assessment (HRA) process in place and conduct HRAs when changes to activities lead to significantly higher risks or when circumstances create uncertainty over the safety of an operation.

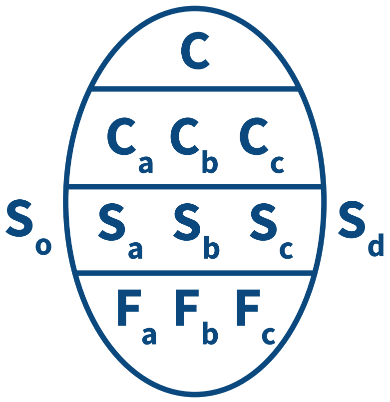
It is recommended that the operation of offshore vessels in ice and/or severe sub-zero temperatures is subjected to a formal risk assessment process in accordance with individual company guidelines.

The following are among issues that may be considered for risk prevention or mitigation:

- Compliance with applicable rules and regulations.
- Ice class notation; winterisation class notation.
- Ice certificate.
- Appropriateness of insurance coverage in place due to breach of the International Navigating Limits (INL). Ascertain limitations that may be described in individual charter parties, if applicable, or the ship's insurance.
- Redundancy of power and propulsion systems.
- Operational duration in propulsion machinery critical range.
- Protective location of fuel tanks.
- Viscosity of hydraulic oils used in steering gear, stern tube and deck machinery.
- Use of Ice Advisors (particularly if the ice navigation experience of the bridge team is limited).
- Assessment of ice and weather forecast services.
- Convoy strategy.
- Availability of icebreaker escort.
- Navigational risks in ice, including besetment.
- Crew experience and training.
- Increased manning levels.
- Protection of crew against wildlife, e.g. polar bears.
- Additional Under Keel Clearance (UKC) – to allow for ice accretion impact on draught and trim and reliability of survey information.
- Availability of ice management at the worksite.
- Evacuation procedures into water, onto ice or into a combination of the two.
- Maximum towing speeds and towing loads, where applicable.
- Procedures for checking the integrity of hull structures.
- Any operating limitation of the ship and essential systems in anticipated ice conditions and temperatures.
- Emergency response activities that may be required.
- Reporting of ice hazards.

Annex G: Egg Codes

Egg Codes are a coding system used in ice charts to provide information on concentration, development and form of ice. It is referred to as the Egg Code due to the oval shape of the symbol. The information below, using World Meteorological Organisation nomenclature, explains the information contained within the codes.



Concentration (C)

C - Total concentration of ice in the area, reported in tenths (see symbols in table G.1). Note: Ranges or concentration may be reported.

C_a C_b C_c – Partial concentrations of thickest (C_a) second thickest (C_b) and third thickest (C_c) ice, in tenths.
Note: Less than 1/10 is not reported. 10/10 of one stage development is reported by C, S_a and F_a or C, S_a, F_p and F_c.

Stage of development (S)

S_a, S_d, S_c – Stage of development of thickest (S_a), second thickest (S_b) and third thickest (S_c) ice, of which the concentrations are reported by C_a, C_b, C_c respectively (see symbols in table G.2).

Notes:

(1) If more than one class of stage of development remains after selection of S_a and S_b, S_c should indicate the class having the greatest concentration of the remaining classes (see also Note (2))

(2) Reporting of S_a, S_b, and S_c should generally be restricted to a maximum of three significant classes. In exceptional cases, further classes can be reported as follows:
S_o – stage of development of ice thicker than S_a but having a concentration of less than 1/10,
S_d – stage of development of any other remaining class.

(3) No concentration are reported for S_o and S_d.

Form of ice (F)

(a) First variant
F_a, F_b, F_c – Form of ice (floe size) corresponding to Sa, Sb and Sc respectively (see symbols in table G.3)

Notes:

(1) Absence of information on any one of these forms of ice should be reported with an “X” at the corresponding position.

(2) When icebergs are present in sufficient numbers to have concentration figure, this situation can be reported with F_a = 9, the appropriate symbol for S_a and the corresponding partial concentration c_a.

(3) In situation when only two stages of development are present a dash (-) should be added in place of F_c to separate these situations from those when F_p and F_s are being reported.

(b) Second variant
F_p F_s – Predominant (F_p) and secondary (F_s) floe size, reported independently from S_a, S_b and S_c respectively (see symbols in table G.3).
Note: If only the predominant floe size (form of ice) is reported, only the symbol for F_p shall be reported.

Table G.1
Total concentration of ice (C)

Concentration	Symbol
Ice free	
Less than one tenth	0
1/10	1
2/10	2
3/30	3
4/10	4
5/10	5
6/10	6
7/10	7
8/10	8
9/10	9
More than 9/10 less than 10/10	9+
10/10	10
Undetermined or unknown	x

Table G.2
Stage of development and thickness (S_a S_b S_c S_d S_o)

Number from WMO Sea Ice Nomenclature	Element	Thickness	Symbol
	No stage of development	-	0
2.1	New ice	-	1
2.2	Nilas; ice rind	< 10 cm	2
2.4	Young ice	10 - 30 cm	3
2.4.1	Gray ice	10 - 15 cm	4
2.4.2	Gray-white ice	15 - 30 cm	5
2.5	First-year ice	30 - 200cm	6
2.5.1	Thin first-year ice	30 - 70 cm	7
2.5.1.1	Thin first-year ice, first stage	30 - 50 cm	8
2.5.1.2	Thin first year ice, second stage	50 - 70 cm	9
2.5.2	Medium first-year ice	70 - 120 cm	1•
2.5.3	Thick first-year ice	> 120 cm	4•
2.6	Old ice		7•
2.6.1	Second-year ice		8•
2.6.2	Multi-year ice		9•
10.4	Ice of land origin		▲•
	Undetermined or unknown		x

Table G.3
Form of ice(F_a F_b F_c F_p F_s)

Element	Floe size	Symbol
Pancake ice	-	0
Small ice cake; brash ice	< 2 m	1
Ice cake	2 - 20 m	2
Small floe	20 - 100 m	3
Medium floe	100 - 500 m	4
Big floe	500 m - 2 km	5
Vast floe	2 - 10 km	6
Giant floe	> 10 km	7
Fast ice	-	8
Icebregs, growlers or floebergs	-	9
Undetermined or unknown	-	x

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