ABS
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IMO Polar Code Advisory

January 2016

Our Mission

The mission of ABS is to serve the public interest as well as the needs of our members and clients by promoting the security of life and property and preserving the natural environment.

Health, Safety, Quality & Environmental Policy

We will respond to the needs of our members, clients and the public by delivering quality service in support of our mission that provides for the safety of life and property and the preservation of the marine environment.

We are committed to continually improving the effectiveness of our health, safety, quality and environmental (HSQE) performance and management system with the goal of preventing injury, ill health and pollution.

We will comply with all applicable legal requirements as well as any additional requirements ABS subscribes to which relate to HSQE aspects, objectives and targets.

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Forward

On 21 November 2014 and 15 May 2015, the International Maritime Organization (IMO) formally adopted the safety and environmental parts of the Polar Code at its Maritime Safety Committee (MSC) and Marine Environmental Protection Committee (MEPC) meetings in London, UK. This milestone is the result of a 20+ year international effort led by the IMO to promote safety and reduce the potential for environmental pollution from the increasing number of vessels operating in Arctic and Antarctic waters. The Polar Code introduces a broad spectrum of new binding regulations covering elements of ship design, construction, onboard equipment and machinery, operational procedures, training standards, and pollution prevention.

This Advisory Note offers a high level overview of the recently adopted *International Code for Ships Operating in Polar Waters* (IMO Polar Code). Its objective is to introduce the various parts of the Polar Code to all stakeholders in the marine industry, each of whom will play an important role in continued Arctic and Antarctic maritime safety and environmental protection. ABS has directly participated in the development of the Polar Code and strongly supports its adoption as a mandatory set of regulations. We continue to work with our clients, regulatory bodies, and industrial partners to develop and improve supplementary standards, guidance, unified interpretations, and harmonized requirements that will support a consistent implementation of the Code's regulations.

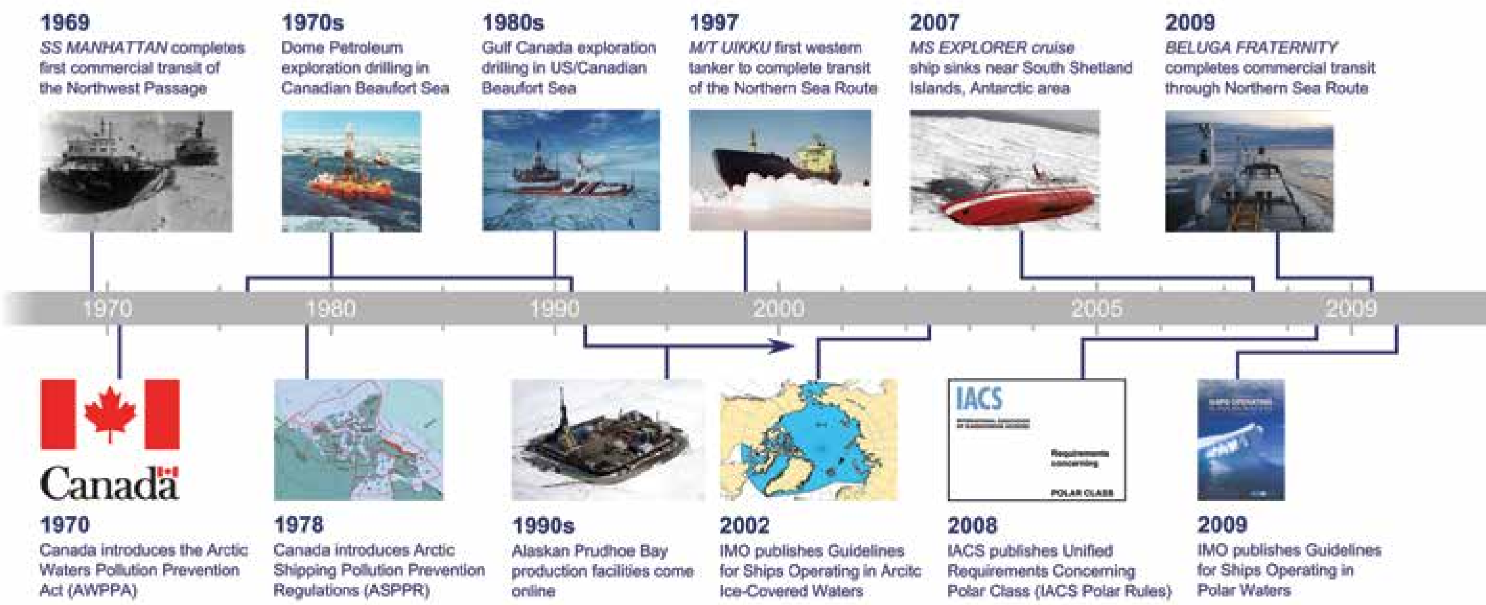
ABS is preparing for entry-into-force both internally and externally, to raise awareness for our engineering and survey divisions globally and our customers on the upcoming regulations and certification regimes. Active and prospective clients are facing new questions and compliance challenges and we are prepared to provide support including coordination with flag administrations to best understand and clarify any varying interpretations.

A Brief History

In the late 1970s and early 1980s, the Arctic witnessed a surge in maritime and offshore oil exploration activity. Industry, flag, and coastal administrations raised concerns at that time over a complex and fragmented regulatory climate that existed across different national and regional jurisdictions. It was further recognized that unique safety and environmental risks existed for operations in the Arctic region that were not addressed by any international regulations. The International Maritime Organization (IMO), a specialized agency of the United Nations with responsibility for the safety and security of shipping and the prevention of marine pollution by ships, agreed to take on the challenging task of developing a unified international Polar Code to harmonize the various national and regional regulations.

The earliest concept of an IMO instrument to cover maritime activity in Polar waters dates back to the early 1990s. Contrary to typical IMO processes, an outside working group was established in 1993 with the task of developing the framework for an international polar code which built on existing IMO instruments. The strategy was not to duplicate existing standards for international safety, pollution prevention, and training but rather to develop the additional measures to mitigate the elevated risks of Polar operations. With consideration to the United Nations Convention on the Law of the Sea (UNCLOS), in particular Article 234 on the Protection of the Marine Environment, the outside working group considered existing practices and the domestic regulatory regimes of the Canadian Arctic, Russian Arctic, and Baltic Sea (Finnish-Swedish Administrations). The following principal conclusions of the outside working group were endorsed by IMO; however, concerns over jurisdiction and other issues were raised about implementing the Code as a mandatory instrument.

- Ships should have suitable ice strengthening for their intended voyages and
- Ice strengthening construction standards should be unified for Polar Ships
- Oil should not be carried against the outer shell
- All crew members should be properly trained
- Appropriate navigational equipment shall be carried



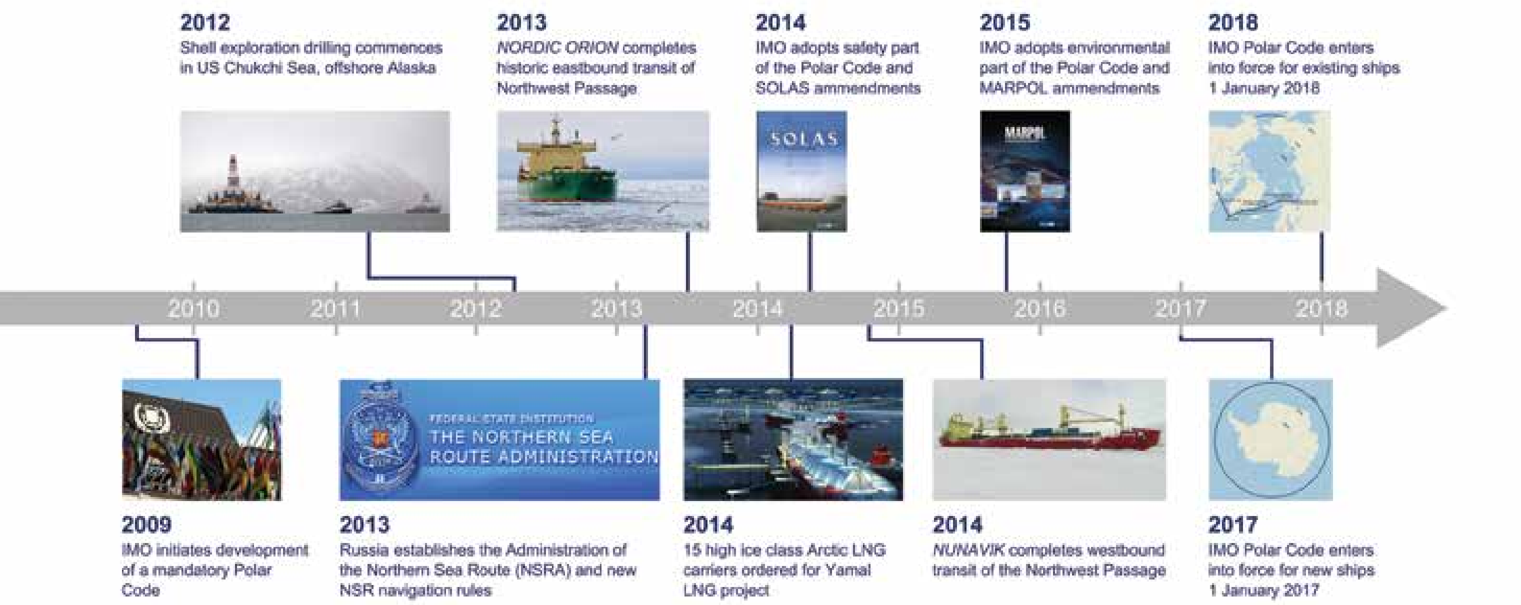
- Suitable survival equipment shall be carried for each person
- Consideration of vessel installed power and endurance must also be made

In 2002, IMO first introduced the voluntary MSC Circular 1056/MEPC Circular 399 "*Guidelines for Ships Operating in Arctic Ice-covered Waters*" which promulgated the work of the outside working group. The guidelines established the initial boundaries of the IMO-defined "Arctic Waters" and covered aspects of ship construction, equipment provisions, operational matters, and environmental protection. The guidelines were widely accepted, but without any mandatory enforcement mechanisms, they offered little to achieve IMO's original goals of enhancing safety and environmental protection in the region.

Meanwhile, the International Association of Classification Societies (IACS) with support from several key Arctic coastal states, was delegated to develop the IACS Unified Requirements Concerning Polar Class (IACS Polar Class Rules). This harmonized rule set established seven new Polar Ice Classes (PC1 – PC7) and prescribes detailed construction and machinery requirements that would later be incorporated by direct reference in the mandatory IMO Polar Code. The IACS Polar Class Rules were formally published in 2008 and were quickly implemented by various classification societies. More information on the IACS Polar Class Rules is offered in Appendix 1.

In the years following adoption of the 2002 IMO Arctic Guidelines, a number of unfortunate but highly visible maritime incidents occurred in both the Arctic and Antarctic regions. Perhaps the most infamous was the sinking of the MV Explorer in 2007 near the South Shetland Islands in the Southern Ocean. These incidents combined with pressure from the Antarctic Treaty signatories and increased shipping activities prompted IMO to quickly revise and extend the application of the guidelines to cover waters in both Polar regions. In 2009, IMO adopted Resolution A1024, "*Guidelines for Ships Operating in Polar Waters*". This represented a significant recognition by IMO that there are additional hazards to Polar operations other than simply ice presence.

Also in 2009, proposals were submitted by several Arctic states to add "Mandatory application of the polar guidelines" to the IMO Maritime Safety Committee's agenda. Over the next five years, dozens of working groups met to debate the contents of the Polar Code at IMO headquarters



in London, UK. Work was carried out via committees, subcommittees, during inter-sessional meetings, and through addition email correspondence groups. Between 2009 and 2014, hundreds of papers were formally submitted to the IMO to propose regulations and to develop the mandatory Polar Code. The voluntary guidelines were used as the starting point but the final product has evolved much further as a result of the focused deliberations.

Background

Drivers for the Mandatory Polar Code

The demand at IMO to develop the mandatory Polar Code was driven by a recognition of increased maritime activity in both the Arctic and Antarctic regions and a need for modern and effective regulations at the international level to mitigate risks not adequately addressed by other instruments. Four principal drivers are attributed to the increased traffic in Polar waters.

1. Reduced ice cover
2. Arctic shipping sea routes
3. Arctic destination shipping
4. Arctic and Antarctic tourism

Reduced Ice Cover

Evidence of a long-term downward trend of Arctic sea ice is clear. In particular, the minimum extent of summer Arctic sea ice is declining year upon year, as much as 10% per decade by some measures. Thicknesses and concentrations of multi-year ice are also reducing, enabling more ships to access new shipping routes, tap into a vast wealth of natural resource deposits, and venture into remote areas for cruise ship tourism. Typically, the ice extent reaches its minimum in September. Figure 1 presents the Arctic sea ice extent as it recedes in the summer months. The last five years are plotted along with the average and two standard deviation band from a 20-year period (1981 – 2010). Three of the last five summers (2011, 2012, and 2015) have seen minimum ice extents outside the two standard deviation range. These statistics have been widely reported in the public media and are attracting new players to consider the Arctic for prospective marine operations.

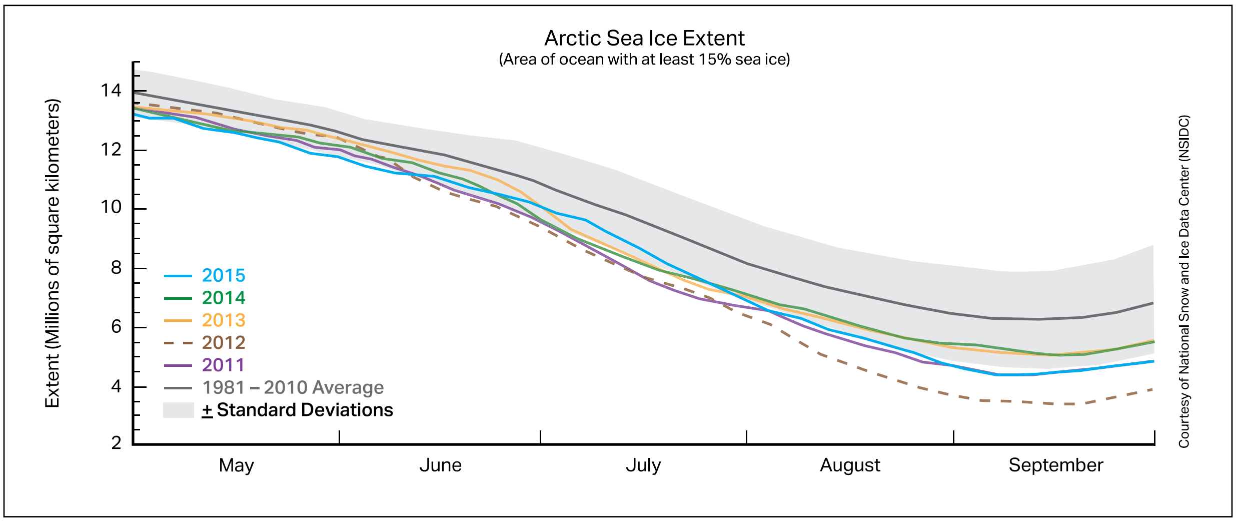


Figure 1: Monthly Arctic sea ice extent
Courtesy of National Snow and Ice Data Center (NSIDC)

Snapshots of the 2014 Arctic ice extent from different seasons is shown in Figure 2. Winter ice coverage (March) is not significantly different from the 20-year median ice edge, while late summer (September) extents show a clear divergence from the median. The charts also illustrate key regional differences across the Arctic. For example, ice tends to stay longer around choke points within the Canadian Archipelago but recedes much earler and further along the Russian Arctic coast. This is reflected in summer traffic patterns along the Northern Sea Route (Russia) compared with the Northwest Passage (Canada).

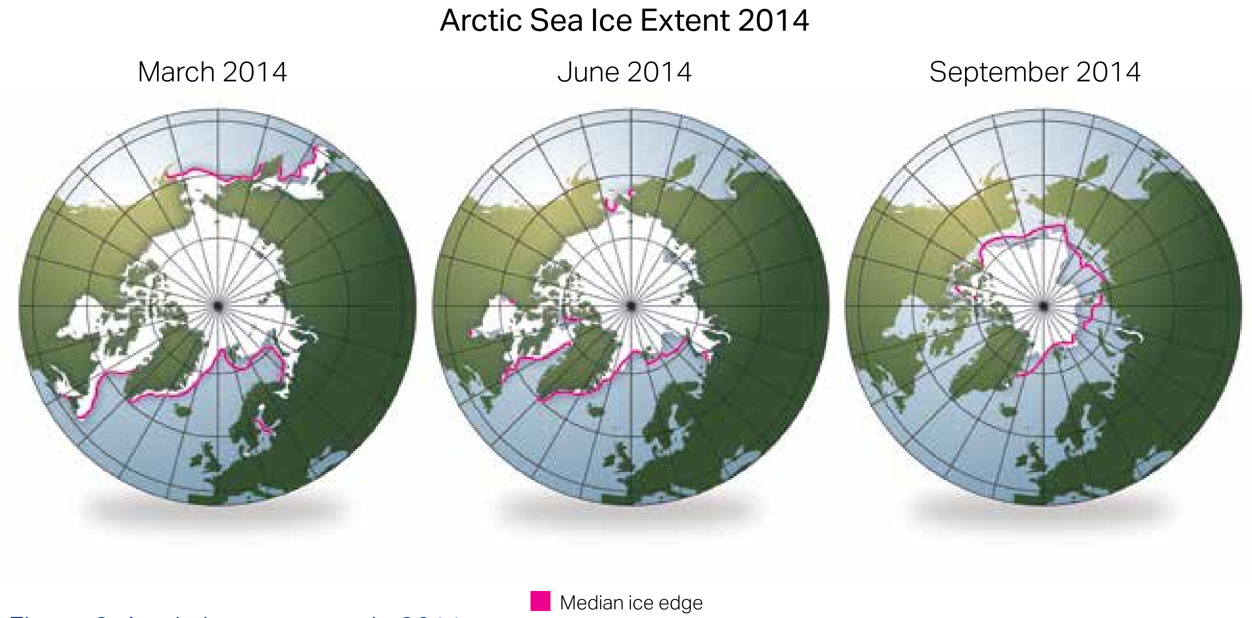


Figure 2: Arctic ice coverage in 2014

Arctic Shipping Sea Routes

The promise of shorter sea routes across the north, potential fuel savings, and even reduced piracy risks are attractive to ship owners in the always competitive shipping markets. Several different Arctic sea routes have been considered as potential transit options as shown in Figure 3. Distance savings compared with traditional blue-water trading routes, which make use of the Suez or Panama canals, can be as high as 35%.

- Northern Sea Route (NSR): The NSR stretches across the Russian Arctic linking Asian and Northern European markets. It typically is the first route to be ice free in the summer. Maritime traffic has started to develop along the NSR since the creation of the Northern Sea Route Administration (NSRA) in 2012.
- Northwest Passage (NWP): The NWP is a complex of channels through the Canadian Archipelago. A few trial transits of dry bulk cargo and cruise operations have been successfully carried out to date, but some projections estimate the NWP to become usable on a regular basis by 2020-2025.
- Arctic Bridge: The Arctic Bridge is a potential route that links the Port of Churchill in northern Manitoba, Canada with western parts of Russian and Scandinavia. The Port of Churchill is ice-free in the summer months and is served by a rail line extending to the Canadian national railway system.
- Transpolar Sea Route: The Transpolar Sea Route extends directly across the Arctic Ocean to link the Bering Strait with the North Atlantic. This route is currently hypothetical as it requires an essentially ice-free Arctic Ocean.

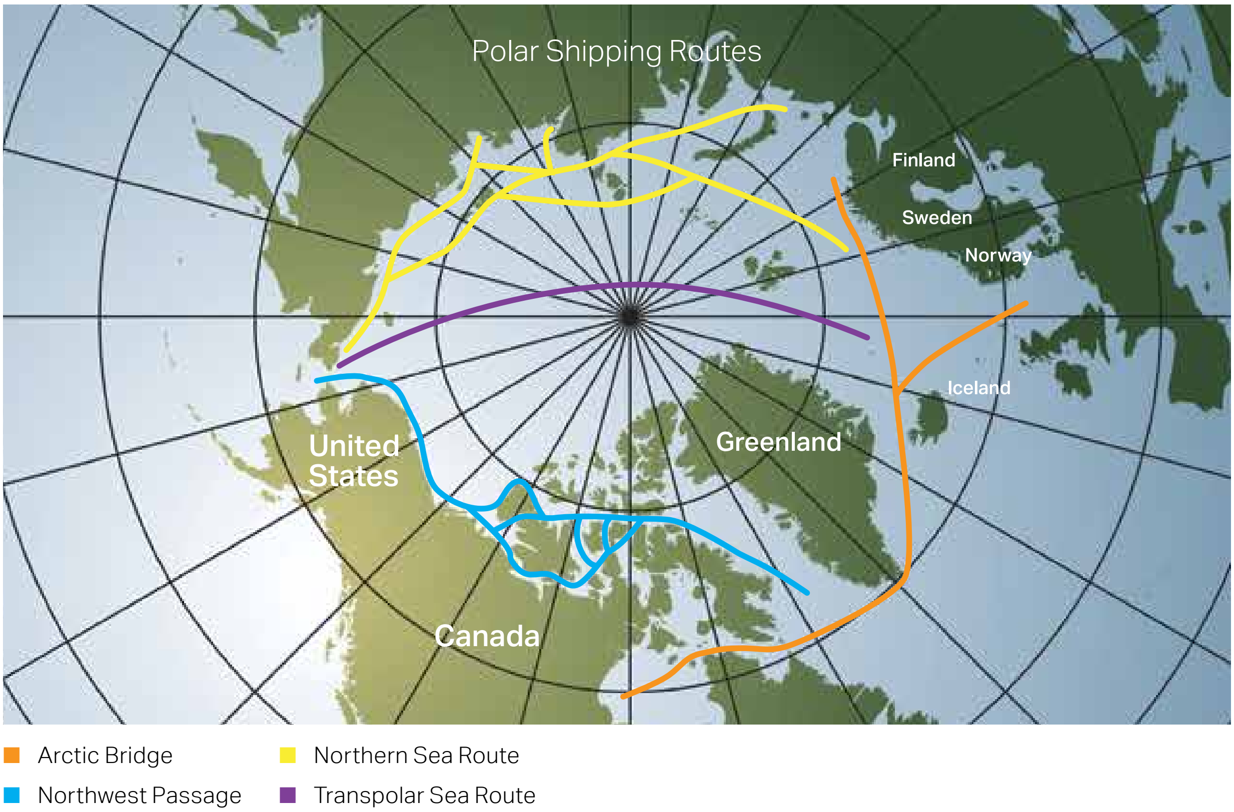


Figure 3: Polar shipping routes

Courtesy of Dr. Jean-Paul Rodriguez, Hofstra University

Arctic Destination Shipping

The Arctic is rich with natural resources which will require destination shipping for development and extraction activities. In 2008, the United States Geological Survey (USGS) reported on enormous estimates of undiscovered oil and natural gas resources expected north of the Arctic Circle. Significant portions of the world's undiscovered oil, natural gas, and natural gas liquids were reported.

Aggressive and expensive exploration projects have recently taken place in the Chukchi Sea (USA), Kara Sea (Russian), and offshore western Greenland. Due to lack of shore-side infrastructure in these remote regions, the summer season drilling campaigns alone bring dozens of ships to Arctic waters. If and when these projects reach production phases, new purpose-built fleets are expected in order to support production and extraction. As one recent example, 15 high ice-classed state-of-the-art Arctic LNG carriers were ordered for a major gas field under development on the Yamal peninsula east of the Kara Sea.

There is a further potential for new and reopening mining developments in the Arctic driven by a global demand for raw materials and minerals. Advanced planning is underway for a high quality iron-ore project in the Canadian Arctic. Large zinc and lead deposits are currently being produced and exported out of western Alaska in addition to nickel mines in both Russia and Canada. Some of these mining projects stockpile product throughout the winter months and export only during summer seasons on the spot charter market when the ports are ice-free. Others require specialized icebreaking bulk carriers to independently bring product to market year-round. As the mines continue to produce and as new mines are brought on line, this will inevitably lead to more ships operating in Arctic waters.

Arctic & Antarctic Tourism

Cruise ship tourism in Polar waters is one of the greatest concerns to Arctic coastal states and southern nations which lack the necessary infrastructure and search-and-rescue capabilities to respond to incidents in remote Polar regions involving hundreds or possibly thousands of passengers. Cruise ship traffic in the Arctic and Antarctic regions has increased significantly over the last 15 years and new operating players are entering the market. While commercial tanker, bulk carrier, and offshore vessel operators typically aim to avoid ice and remote areas, cruise ship companies see an opportunity to cater to passengers eager to witness the pristine Polar landscapes, unique wildlife, sea ice, glaciers and icebergs. Tens of thousands of visitors arrive by ship every summer in the Arctic and each austral summer in the Antarctic with itineraries designed to get close to the ice, which can present elevated risk levels.

Risk-based Framework

Early in the process, the IMO endorsed the notion of following a risk-based approach to determine the scope of the Polar Code and adopted the use of Goal-Based Standards (GBS) as the framework for regulations. IMO has recently changed its approach to ship design regulations and has started to incorporate the GBS philosophy for several new Codes and other instruments. GBS are comprised of at least one goal, functional requirements associated with that goal, and verification of conformity that rules/regulations meet the functional requirements including the goals.

A list of hazards related to ship operations in Polar waters were initially identified as a basis for developing the goals and functional requirements in the Polar Code. These hazards are laid out in the Introduction section of the Code and are the result of extensive deliberations at IMO. They represent a minimum list of hazards for Polar Ships considered to be above and beyond the shipping hazards typically encountered by SOLAS ships.

Each chapter in the safety part of the Polar Code begins with an established goal and subsequent functional requirements which are linked to the relevant hazards. Each of the functional requirements is then supported by prescriptive regulations as a means for compliance. In some instances the regulations make reference to international standards or classification requirements, such as different IACS Unified Requirements. Perhaps the simplest example of the GBS framework is in Chapter 3 – Ship Structure. The goal is an obvious high-level statement related to ship structure:

"to provide that the material and scantlings of the structure retain their structural integrity based on global and local response due to environmental loads and conditions"

Polar Hazards

- **Ice** affects structures, stability characteristics, machinery systems, navigation, the outdoor working environment, maintenance and emergency preparedness tasks, and may cause malfunction of safety equipment and systems
- **Topside icing** potentially reduces vessel stability and equipment functionality
- **Low temperature** affects the working environment and human performance, maintenance and emergency preparedness tasks, material properties and equipment efficiency, survival time and performance of safety equipment and systems
- **Extended periods of darkness or daylight** affect navigation and human performance
- **High latitude** affects navigation systems, communication systems and the quality of ice imagery information due to limited satellite coverage
- **Remoteness** and possible lack of accurate and complete hydrographic data and information, reduced availability of navigational aids and seamarks with increased potential for groundings compounded by remoteness, limited readily deployable SAR facilities, delays in emergency response and limited communications capability, with the potential to affect incident response
- **Lack of ship crew experience** in Polar operations comes with the potential for human error
- **Lack of suitable emergency response equipment** with the potential for limiting the effectiveness of mitigation measures
- **Potential for escalation of incidents** due to rapidly changing and severe weather conditions
- **Environmental sensitivity** to harmful substances and other environmental impacts and its need for longer restoration

This goal is further broken down into functional requirements which address two hazards that pose risks to ship structures in Polar waters; 1- low air temperature and 2 - the presence of ice:

1. "materials used shall be suitable for operation at the ships polar service temperature"
2. "the structure of the ship shall be designed to resist both global and local structural loads anticipated under the foreseen ice conditions"

The regulations then make reference to relevant IACS Unified Requirements for Polar Ships. Compliance with the functional requirements is achieved by obtaining approval from the flag state or recognized organization that the scantlings and materials meet the relevant class requirements or other standards which "offer an equivalent level of safety". This approach is intended to give sufficient flexibility for alternative designs and arrangements. It keeps the Code from being one-size-fits-all and permits the use of other recognized best practices as a means for compliance.

Class Society rules, national standards, and other best practices should be used to justify any alternatives to the regulations in the Code. This might include operational procedures for mitigation of certain risks instead of prescriptive equipment requirements. Owners will need to strike an appropriate balance between equipment specification and onboard procedures.

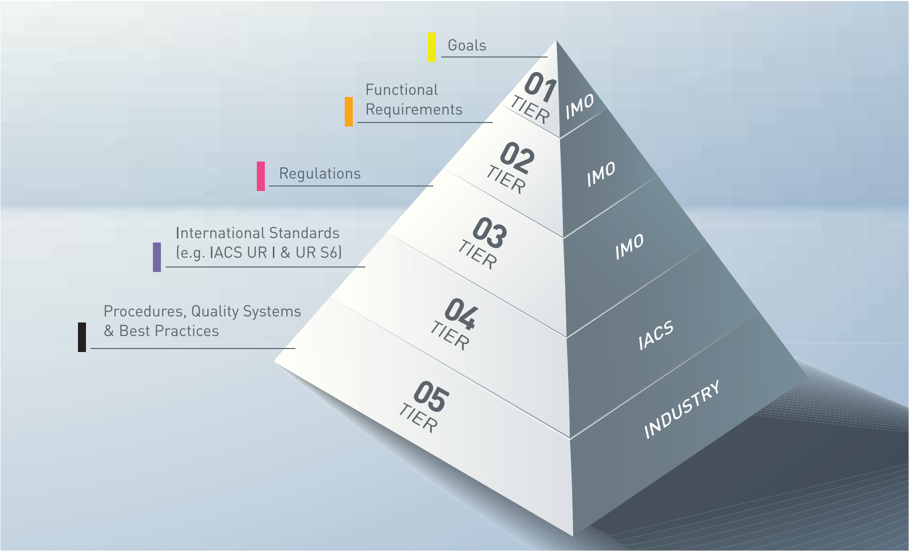


Figure 4: Goal-Based Standards Framework

Adoption

The core development work for the mandatory Polar Code was primarily carried out by the IMO Subcommittee on Ship Design and Equipment (DE), later reorganized and named the IMO Subcommittee on Ship Design and Construction (SDC). Other subcommittees were tasked to develop and review certain chapters within their respective scope of expertise. Every time a different subcommittee was delegated work on a particular section of the Code, the feedback loop took up to one year before incorporating the updates into the Polar Code. Several iterations of input were received from the following subcommittees.

- Subcommittee on Navigation, Communications and Search and Rescue (NCSR)
- Subcommittee on Human Element, Training, and Watchkeeping (HTW)
- Subcommittee on Ship Systems and Equipment (SSE)

The parent committees, MSC and MEPC, were ultimately responsible for approval and adoption of the Polar Code and the associated amendments to other instruments that make it mandatory. After SDC finalized the contents, actions were taken by MSC and MEPC to approve and adopt the Code's safety part (Part I), environmental part (Part II), amendments to the International Convention for the Safety of Life at Sea (new SOLAS Chapter XIV), and amendments to the International Convention for the Prevention of Pollution from Ships (MARPOL annexes). Amendments to the Standard for Training, Certification and Watchkeeping (STCW) Code and Convention are expected to be formally adopted by MSC in 2016. Also, supplemental work is continuing at MSC to develop a Circular which outlines methodologies for determining ship operational limitations. This is discussed later in the Advisory Note.

- Resolution MSC.385(94) - *International Code for Ships Operating in Polar Waters (Polar Code).* Adopted 21 November 2014
- *Resolution MSC.386(94) - Amendments to the International Convention for the Safety of Life at Sea, 1974, As Amended.* Adopted 21 November 2014
- *Resolution MEPC.264(68) - International Code for Ships Operating in Polar Waters (Polar Code).* Adopted 15 May 2015.
- *Resolution MEPC.265(68) - Amendments to MARPOL Annexes I, II, IV, and V.* Adopted 15 May 2015.

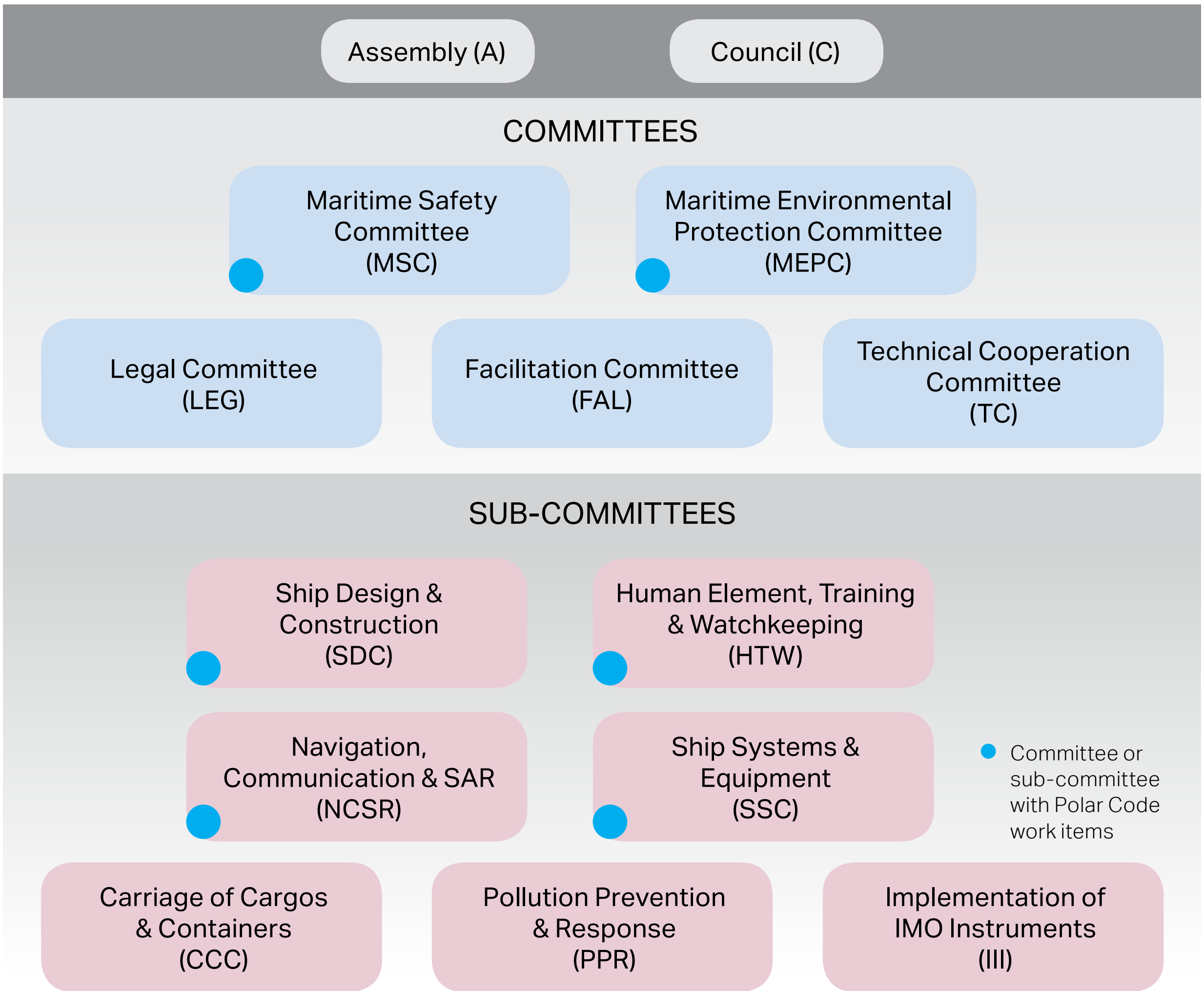


Figure 5: IMO Organizational Structure

IMO Organizational Structure

The International Maritime Organization is a specialized agency of the United Nations responsible for development of maritime shipping regulations addressing safety, security, and environmental performance. Member states represent 171 individual governments (or flag states) in addition to 3 associate members. Many commercial, non-governmental, and other interested organizations have observer status at IMO and may contribute to technical or policy discussions but do not have voting privileges.

Technical work at IMO is facilitated through two parent committees which typically meet twice annually, the Marine Environmental Protection Committee (MEPC) and the Maritime Safety Committee (MSC). Seven subcommittees convene once per year and report up to the parent committees after each session. IMO publishes numerous Conventions, Codes, and Guidelines along with other publications dealing with a wide range of subjects. The responsibility of implementation and enforcement generally rests with the member governments or “flag states”. New conventions must be adopted by the organization and ratified by member governments. Amendments to conventions must be approved and adopted at the Committee levels but don’t require re-ratification.

Section 1 | IMO Polar Code Overview

Organizational Structure

The Polar Code contents are aligned in a manner that allows for a logical integration into the parent IMO instruments. It was recognized that SOLAS was the most appropriate venue for making the Code's safety-related provisions mandatory and MARPOL could be used to incorporate the additional environmental regulations. Each of these conventions has slightly different applicability clauses, ratification and amendment procedures, so it was decided to divide the Polar Code into two parts – Part I: Safety Measures and Part II: Pollution Prevention Measures. Approval and adoption of the Code's contents and the associated SOLAS and MARPOL amendments would then be synchronized between MSC and MEPC, with a single entry-into-force date.

The Polar Code begins with common preambular and introductory text which lay out the principles, objectives, key definitions, and the considered sources of hazards. Part I-A is subdivided into twelve (12) mandatory chapters of safety measures. Additional guidance and recommendations on safety is provided in Part I-B. Part II-A is organized into four (4) mandatory chapters of environmental protection measures. These chapters are aligned with their respective MARPOL Annexes (I, II, IV, and V) and introduce additional discharge limitations above and beyond what is already prescribed by MARPOL. Part II-B is offered to provide additional non-mandatory guidance related to pollution prevention.

- Preamble, Introduction
- Part I-A: Safety Measures
  - Chapter 1 – General
  - Chapter 2 – Polar Waters Operational Manual (PWOM)
  - Chapter 3 – Ship Structure
  - Chapter 4 – Subdivision and Stability
  - Chapter 5 – Watertight and Weathertight Integrity
  - Chapter 6 – Machinery Installations
  - Chapter 7 – Fire Safety/Protection
  - Chapter 8 – Life-saving Appliances
  - Chapter 9 – Safety of Navigation
  - Chapter 10 – Communication
  - Chapter 11 – Voyage Planning
  - Chapter 12 – Manning and Training
- Part I-B: Additional Guidance
- Part II-A: Pollution Prevention Measures
  - Chapter 1 – Prevention of Pollution by Oil (MARPOL Annex I)
  - Chapter 2 – Prevention of Pollution by Noxious Liquid Substances (MARPOL Annex II)
  - Chapter 4 – Prevention of Pollution by Sewage from Ships (MARPOL Annex IV)
  - Chapter 5 – Prevention of Pollution by Garbage from Ships (MARPOL Annex V)
- Part II-B: Additional Guidance

Application

In general, the Polar Code is mandatory for all ships, both new and existing, operating on international or domestic voyages within the IMO-defined boundaries of Arctic waters and the Antarctic area. Polar waters generally cover the areas north of 60°N or south of 60°S although there are slight deviations for Arctic waters intended to include the entire southern exposure of Greenland while excluding Iceland and the Norwegian coastline. These geographical limits, illustrated in Figures 6 and 7, were decided early at IMO and are a result of extensive international negotiations balancing vessel traffic, ice cover, safety considerations, and environmental ecosystems.

The detailed application of the Polar Code can be slightly more complicated and different between Parts I and II. The safety measures (Part 1-A) will be mandatory for any ship operating within Polar waters that are certified under the SOLAS Convention, regardless of whether or not the ship is engaged on an international voyage. That implies any ship inside the geographical limits carrying either *Passenger Ship Safety or Cargo Ship Safety Certificates*. In general, this

New vs. Existing Ships

Ships with keel laying dates on or after 1 January 2017 are considered "New Ships" under the Polar Code. Ships constructed before 1 January 2017 are considered "Existing ships". Existing ships are exempted from several requirements that may otherwise be impractical to accommodate. These include:

- Ice damage residual stability
- Escape routes arrangements for persons wearing 'polar clothing'
- Navigation equipment redundancy (i.e., two independent echo-sounding devices)
- Enclosed bridge wings on ice class ships
- Oil tank separation distance from the side shell

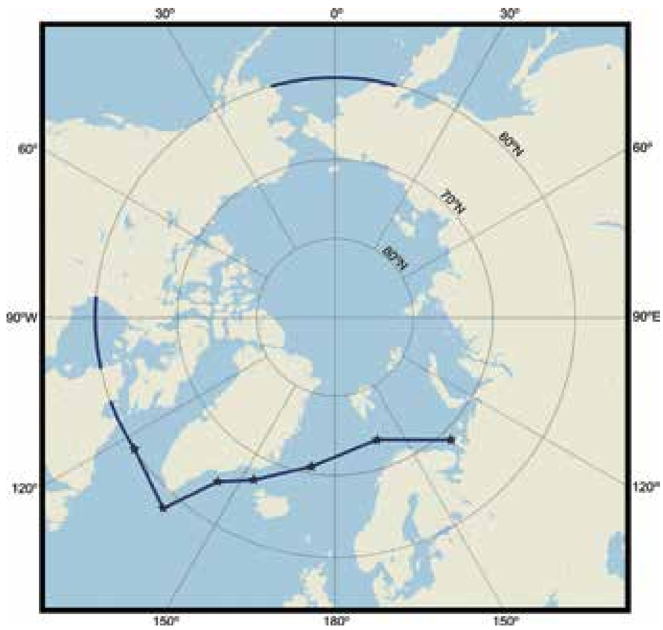


Figure 6: Arctic Waters

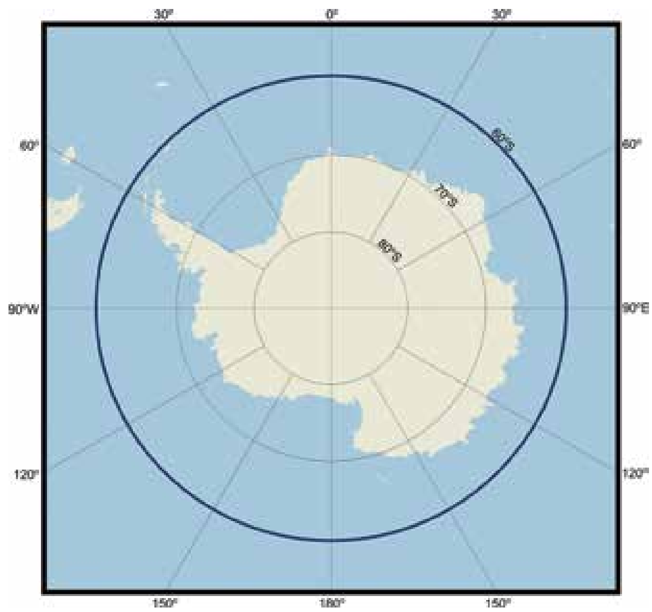


Figure 7: Antarctic Area

covers cargo ships greater than 500 gross tons and passenger ships carrying more than 12 passengers. The environmental chapters (Part II-A) will each follow the applicability of their respective MARPOL Annexes. For example, MARPOL Annex I (dealing with oil pollution) applies to ships of 400 gross tons or above. The same application will be enforced for Part II-A, Chapter 1 of the Polar Code.

The Code will enter into force for new ships on 1 January 2017. Existing ships have until their first intermediate or renewal survey after 1 January 2018 to comply. As with most IMO instruments, government vessels not engaged in commercial service are exempted from the Code's regulations; however, governments are strongly "encouraged to act in a manner consistent, so far as reasonable and practicable" to meet the requirements of the Polar Code.

Thresholds for Regulations

The Polar Code is not a one-size-fits-all regulatory instrument. Several thresholds are established to invoke regulations based on the intended operational profile of the vessel. Fundamentally, more severe operating conditions will lead to a more extensive application of requirements. It is important for designers, owners, and operators of Polar ships to make appropriate decisions and assumptions about a ship's intended operation. Discussions should be held as early as possible with the flag state or recognized organization to ensure a clear understanding of the applicable regulations. The primary thresholds for regulations in the Polar Code are based on the following conditions:

- Ships intended to operate in ice
- Ship categories
- Ships intended to operate in low air temperatures
- Ships intended to operate in areas where ice accretion is likely to occur

Ice

Several requirements of the Polar Code are only applicable for vessels that are ice-strengthened or intended to operate in ice. These include:

- Operational procedures for ice conditions and prolonged entrapment by ice
- Ice strengthening (structural scantlings)
- Protection of machinery installations from ice ingestions from sea water
- Machinery strengthening (propellers, propulsion line, steering equipment, and appendages)
- Navigation equipment redundancy and protection from ice
- Means for safe evacuation in ice-covered waters
- Special training for masters, chief mates, and navigational officers

There are many different forms of ice and it is important to be able to distinguish between the different types that may be encountered. The two most fundamental properties of ice cover are thickness and concentration, both of which are reported on standard ice charts using World Meteorological Organization (WMO) terminology.

Ice cover is rarely uniform or homogeneous in nature. In nature, sea ice is typically a mix of ice types, thicknesses and floe sizes at various total ice concentrations. Near the coast, ice may be 'land fast', anchored in place by the shoreline or possibly grounded pressure ridges. Land fast ice tends to have relatively consistent properties, but may still include ridges and rubble piles. At the edge of the land fast ice, shear zones may occur where the free-floating pack and land fast ice collide. The shear zone can be a chaotic combination of ridging and rubbling. It can be both difficult and dangerous to transit, especially if the pack is in motion. Even the most powerful ice breakers have become trapped, and less capable vessels have suffered damage or been sunk by pressure events in shear zones. Shear zones should be transited, where necessary, with extreme caution.

Broken first-year pack ice conditions

Icebergs in surrounding pack ice

The general ice pack is typically a mix of ice types, thicknesses and floe sizes at various total ice concentrations and will usually be characterized as an 'ice regime'. Patches or stretches of open water can be found even in the winter polar pack as floes move relative to each other. In some areas, more or less permanent polynyas of open water exist due to water upwelling. When ice floes and sheets converge under pressure caused by wind and current driving forces, they may begin to raft, form rubble fields, or generate ridges. All of these increase the difficulty of ice transit. Ridges may have sail and keel heights totaling in the tens of meters which can only be penetrated by repeated ramming.

Old ice is ice that has survived one or more melt seasons. It encompasses both second-year and multi-year ice, but the term multi-year is frequently applied to either old ice form. Multi-year ice becomes much stronger than first-year ice, due in part to its reduced salinity. Floes also tend to have much more variable thickness than younger ice, as they incorporate weathered ridges and other features. This and other features help experienced ice navigators to distinguish between first-year and multi-year ice.

Ice "of land origin" is generally glacial ice, formed over thousands of years by the accumulation and re-crystallization of packed snow. Ice islands and icebergs enter the sea from glaciers and ice sheets and may in turn 'calve' smaller bergy bits and growlers as they degrade. Glacial ice is very hard, and represents a major hazard for vessels with even the highest level of ice transiting capability. Growlers and bergy bits have small freeboards, and can be very difficult to detect either when part of the general ice cover or in open water with moderate sea states. Due to their origin, they are usually found in proximity to icebergs, whose own presence is a good indicator of the potential risk of encountering larger fragments.

More information on sea ice formation, WMO ice nomenclature, and ice charting is provided in Appendix 2.

Ship Categories

The concept of ship categories was introduced in the Polar Code with the intent to organize requirements together for certain classes of ships. Three Polar Ship categories – A, B, and C – are linked to ice class notations and provide a broad indication of a ship's capability to navigate in ice. Depending on the ship's ice class notation, or lack thereof, the ship will fall into one of the three categories.

- **Category A** ships are those designed for operation in at least medium-first year ice (i.e., nominal ice thickness > 70 cm), which may include old ice inclusions. In general, Category A ships will be purpose built with design features and primary responsibilities for operating in difficult Polar ice conditions, and for the most part independently. Scantlings must be compliant with at least IACS Polar Class PC5 or another standard if an equivalent level of safety can be demonstrated.

Example of a Category A ship – TIMOFEY GUZHENKO, Ice Class ARC6 icebreaking tanker

Example of a Category B ship – MISS MADELINE TIDE, Ice Class PC7 OSV

- **Category B** ships are those not included in Category A, designed for operation in at least thin-first year ice (i.e., nominal ice thickness > 30 cm), which may include old ice inclusions. Typically, Category B ships will operate in the Polar ice conditions on a seasonal basis, independently or with icebreaker assistance. Scantlings must be compliant with at least IACS Polar Class PC7 although a flag state can accept another ice class notation (e.g. Finnish-Swedish Ice Class 1A Super or 1A) if an equivalent level of safety can be demonstrated.

- **Category C** covers any other ship operating within Polar waters. These ships may be intended for open water or very light ice conditions and don't necessarily need to be ice-strengthened. Depending on the intended operation and ice conditions, the flag state will require the ship to be ice-strengthened to an appropriate standard.

Example of a Category C ship – MARVELLOUS, Non-ice class bulk carrier

The proper selection of an ice class, and subsequently the Polar Code ship category, should be determined based on the anticipated ice conditions of the intended sailing area. More detailed information about the ship's ice limitations will need to be included in the Polar Ship Certificate and the Polar Water Operational Manual.

Ship categories are used in the Polar Code for the following regulations:

- Survey requirements (exemptions for certain Category C cargo ships)
- Structural scantlings (ice strengthening)
- Ice damage stability (only applicable for new Category A and B ships)
- Machinery requirements (propellers, propulsion line, steering equipment, and appendages)
- Oil pollution prevention (delayed application date for existing Category A ships)
- Oil tank separation distance from the side shell (exemptions for existing Category A and B ships)

Low Air Temperature

Recognizing the additional risks to materials, equipment, and human performance due to encountering low temperatures, the Polar Code is the first IMO instrument to introduce the concept of a design temperature. Previously, design temperatures have been a defining component of optional "winterization" rules and guidelines offered by classification societies; however, calculation methods have been inconsistent and often misinterpreted. The Polar Code's *Polar Service Temperature (PST)* definition is a harmonized approach that will help standardize the treatment of temperature.

Low temperatures are a seasonal phenomenon. Even in Polar areas, summer temperatures can exceed winter temperatures of other areas of the world. The majority of shipping in the Arctic and Antarctic is carried out in warm temperatures and therefore should not be exposed to any special requirements beyond those already covered by SOLAS and standard class requirements. For ships expected to encounter low temperatures, the Polar

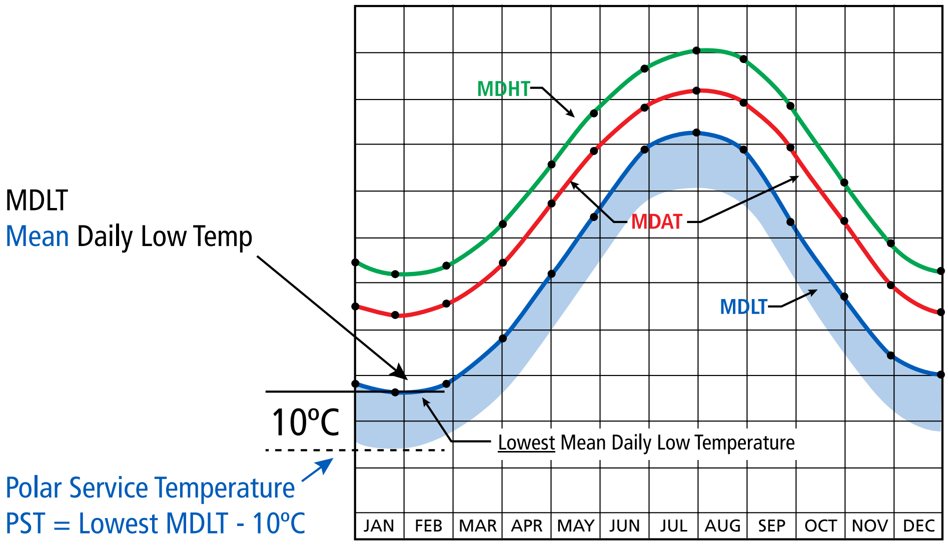


Figure 8: Polar Service Temperature definition

Code introduces a new term called the *Polar Service Temperature (PST)*. The PST is referenced throughout the code for various regulations and is required to be listed on the Polar Ship Certificate.

The threshold for "ships operating in low air temperature" is based on the *Mean Daily Low Temperature (MDLT)* for the intended area and season of operation. This is a statistical mean of daily low temperatures for each day of the year, over a minimum 10 year period. Ships that operate in areas and seasons where the *Lowest MDLT* is below -10°C are considered to be operating in low air temperature and therefore a PST must be specified for the vessel and shall be at least 10°C below the lowest MDLT. Figure 18 illustrates how a designer may specify an appropriate PST based on available historical data. Further guidance and examples are provided in Appendix 3.

The PST is referenced by several regulations in the Polar Code. Some examples include:

- Systems and equipment shall be fully functional at the PST
- Survival systems and equipment shall be fully operational at the PST
- Materials used for ship structures, exposed machinery, electrical installations, and fire safety systems shall be suitable for operation at the PST
- Fire safety systems and appliances shall be available and effective at the PST
- Two-way portable radio communication equipment shall be operable at the PST

It is essential for designers and owners to specify a proper PST. This requires a clear understanding of the potential geographical areas and seasons the ship may operate (both "where and when") throughout its life and then assigning the correct environmental operational profile. The consequences of "getting it wrong" by either under or over-specification can be quite severe. It would be very expensive to retrofit equipment for a lower PST after a ship has been delivered. On the other hand, over-specification can also be quite costly. If an unrealistically low PST is selected, equipment costs will be prohibitively more expensive and the number of equipment suppliers may be limited - impacting both initial cost and through-life parts supply. Beyond establishing the ship's future operations, "getting it right" requires proper data mining and processing.

Ice Accretion

Another threshold for regulations in the Polar Code is "ships intended to operate in areas and during periods where ice accretion is likely to occur". Ice accretion occurs when temperatures are low and there is a source of water for wetting the deck, superstructure and other exposed parts of a vessel or equipment. Generally speaking, ice accretion is most severe in sub-freezing temperatures and open water conditions where there is wave-induced sea spray. When ice is present, waves are suppressed and sea spray is minimized, which significantly reduces the chance of ice accretion.

Topside icing can potentially have a negative effect on a vessel's stability, especially for smaller ships. Ice accretion can hinder access to safety critical equipment and reduce functionality of deck machinery. It poses a safety hazard to escape routes and other exposed passage-ways.

Some environmental and operational factors that affect the severity of ice accretion are the air temperature, sea water temperature, ship speed, and ship heading relative to wind, waves and ocean swell. Design features that influence the probability of icing mainly include the ship's length and freeboard height. Generally, for the same environmental conditions, there will be more sea spray reaching the vessel deck, superstructure, etc., when the vessel is traveling faster, into the wind and waves, and for smaller vessels and ships with less freeboard.

Several examples of regulations imposed on vessels subject to ice accretion include:

- Intact stability
- Watertight integrity (means for removal or prevention)
- Protection of machinery from ice accretion
- Protection of fire safety systems from ice accretion
- Escape routes, muster stations, embarkation areas, survival craft, launching appliances and access to survival craft (means for removal or prevention)
- Navigation and communication antenna (means for prevention)
- Operational procedures (e.g. monitoring, de-icing, removal, etc.)

The actual likelihood and severity of ice accretion will depend on many factors such as air temperature, water temperature, salinity, wind speed, wave conditions, ship size, hull form, and ship heading relative to waves. Figure 9 presents example ice accretion rates as a function of wind speed and air temperature. In general the Polar Code's ice accretion regulations will apply to ships operating in areas and seasons where the lowest mean daily low temperature is below -3°C, corresponding with light to moderate ice accretion rates. The temperature isothermal plots in Appendix 3 show examples of the -3°C contour. If the designer or owner can provide more specific information about the intended operational profile of the vessel, ABS will consider ice accretion thresholds on a case-by-case basis.

Table 1: Icing categories

Icing Class	None	Light	Moderate	Heavy	Extreme
Icing Rates (cm/hour)	0	< 0.7	0.7 - 2.0	2.0 – 4.0	> 4.0
Icing Rates (inches/hour)	0	< 0.3	0.3 - 0.8	0.8 – 1.6	> 1.6

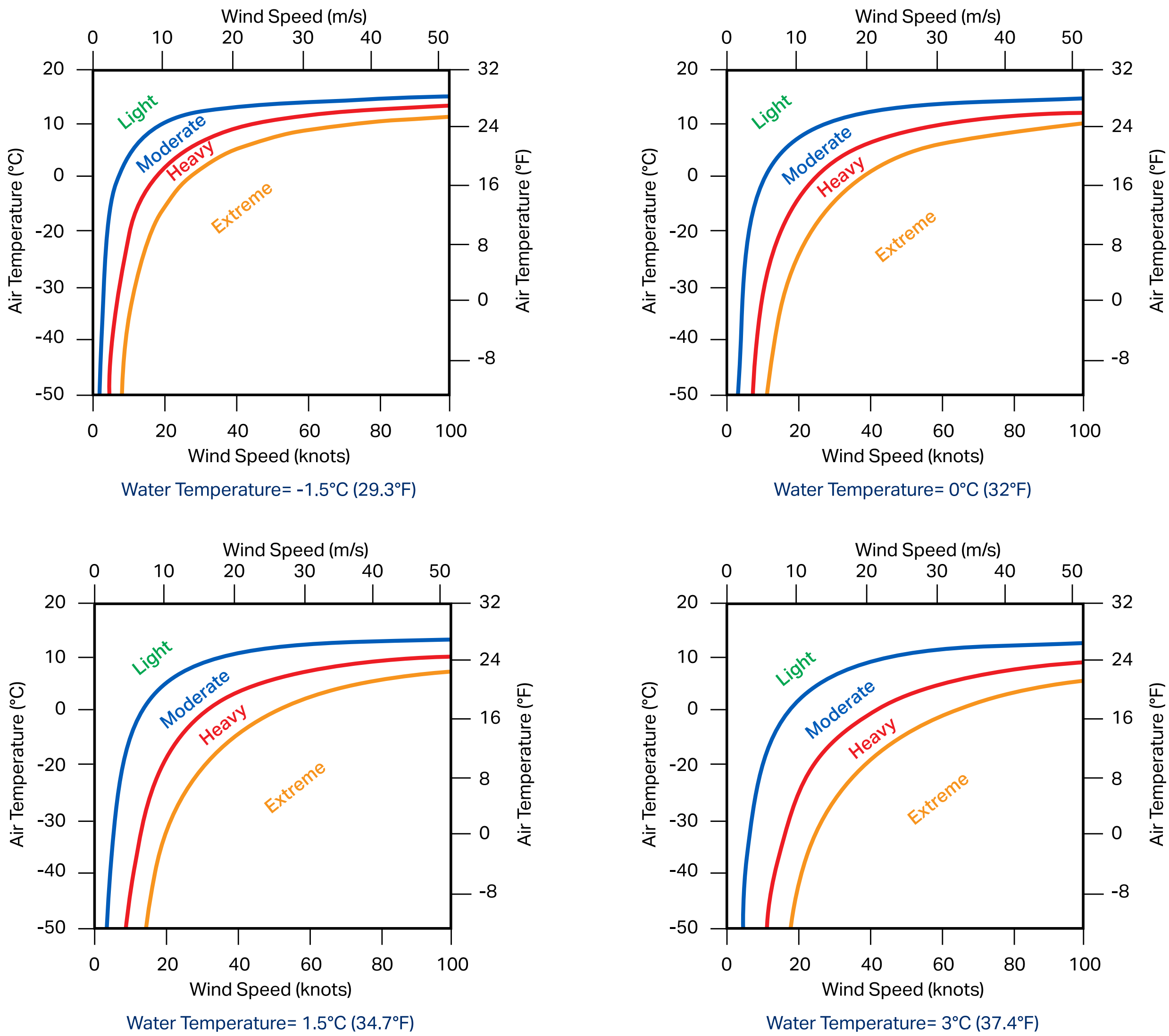


Figure 9: Ice accretion severity plots

Section 2 | Certification & Documentation

Polar Ship Certificate

The Polar Ship Certificate (PSC) is the ultimate confirmation that the ship complies with the applicable regulations of the Polar Code. It is an essential document that will be reviewed by Port and Coastal States and utilized by owners, charterers, crew, and others in assessing the capabilities and limitations of the ship. The PSC is a mandatory document issued by the flag state or classification society after a survey and is required to be on board every ship entering Polar waters where the Polar Code is applicable. A model PSC is provided on the following page highlighting four principal components. There are four principal components in the PSC:

A. Ship category and ice class information

B. Other thresholds for applicable regulations (ship type, ice operations, low air temperature

C. Provisions for alternative design and arrangements

D. Operational limitations (ice conditions, temperature, high latitudes)

Category C Survey Waiver

Some Category C ships may undertake one-off polar voyages on an opportunistic basis where there is no ice or limited ice presence. A large number of ships currently operate in this way. For example in the North American Arctic, over the five years from 2009 to 2013, the Red Dog zinc-lead mine in western Alaska exported product on 87 different ships, flagged by 14 different countries, making 119 distinct voyages. During the same period, some 85 voyages were made to the Canadian port of Churchill, each voyage by a different ship from 16 different flag states. The majority of these ships operated in open water and since they come from the "spot" market, single-voyage charters are often confirmed only a few weeks in advance. In order to relieve the administrative burden associated with preparing and obtaining new or modified documents, a waiver to the physical survey is permitted if no structural modifications or additional equipment are required by the Code.

A supplemental Record of Equipment will accompany the PSC listing any additional equipment specifically required by the Polar Code and beyond the minimum requirements of SOLAS. The Record of Equipment will include information on life-saving appliances, navigation equipment, and communication equipment.

The survey required to issue a PSC does not necessarily need to be separate from existing SOLAS-related surveys and certificate validity dates and endorsements can be harmonized with the relevant SOLAS certificates. Under certain conditions, it is recognized that verification of compliance could be possible without a physical survey. A waiver for the physical survey is permitted for Category C cargo ships where no structural modifications or additional equipment are required by the Code. This is intended to relieve the administrative burden from ships that may call to a Polar port on an occasional basis (e.g. single voyages), and will only encounter warm temperatures without any significant risk of ice. Such ships will be subject to a 'documented verification' that confirms the ship is compliant with all relevant requirements of the Polar Code and will still be required to have a Polar Waters Operational Manual (PWOM) onboard.

THIS IS TO CERTIFY:

1 That the ship has been surveyed in accordance with the applicable safety-related provisions of the International Code for Ships Operating in Polar Waters.

2 That the survey[3] showed that the structure, equipment, fittings, radio station arrangements, and materials of the ship and the condition thereof are in all respects satisfactory and that the ship complies with the relevant provisions of the Code.

A

Category A/B/C[4] ship as follows:

Ice Class and Ice Strengthened Draft Range

Ice class	Maximum draft		Minimum draft	
	Aft	Fwd	Aft	Fwd

B

2.1 Ship type: tanker/passenger ship/other[4]

2.2 Ship restricted to operate in ice free waters/open waters/other ice conditions[4]

2.3 Ship intended to operate in low air temperature: Yes/No[4]

2.3.1 Polar Service Temperature: ....°C/Not Applicable[4]

2.4 Maximum expected time of rescue ....days

C

3 The ship was/was not[4] subjected to an alternative design and arrangements in pursuance of regulation(s) XIV/4 of the International Convention for the Safety of Life at Sea, 1974, as amended.

4 A Document of approval of alternative design and arrangements for structure, machinery and electrical installations/fire protection/life-saving appliances[4] and arrangements is/is not[4] appended to this Certificate.

D

5 Operational limitations

The ship has been assigned the following limitations for operation in polar waters:

5.1 Ice conditions: ....

....

5.2 Temperature: ....

....

5.3 High latitudes: ....

3 Subject to regulation 1.3 of the International Code for Ships Operating in Polar Waters.

4 Delete as appropriate.

Model Polar Ship Certificate

Polar Water Operational Manual

Throughout the development of the IMO Polar Code it was recognized that there is a need for ships operating in Polar waters to maintain comprehensive documentation that provides the owner, operator, master, and crew with sufficient guidance on operational safety in the anticipated environmental conditions and how to respond to any incidents that may arise. Chapter 2 of the Polar Code mandates that all ships have a Polar Water Operational Manual (PWOM) onboard in order to support the decision-making processes during operations.

The PWOM is a supplement to the Polar Ship Certificate and should include a collection of risk-based operational procedures specific to the Polar environment. In developing the risk-based procedures, the hazards identified in the Introduction section of the Code should be assessed against probability of occurrence and consequence for the intended operational profile of the vessel. A general list of procedures required in the Manual are as follows:

- Operations in ice
- Operations in low temperatures
- Measures to be taken if ice or temperature conditions exceed ship design capabilities
- Communication and navigation capabilities in high latitudes
- Voyage duration
- Voyage planning to avoid ice or temperatures that exceed the ship's design capabilities or limitations
- Arrangements for receiving forecasts of environmental conditions (e.g. ice imagery)
- Means of addressing limitations (or lack thereof) of hydrographic, meteorological, and navigation information
- Special measures to maintain equipment & system functionality under low temperatures, icing, and sea ice (e.g. ingestion) if applicable
- Contacting emergency response service providers (salvage, SAR, OSR, etc.) for intended operational areas
- Life support and ship integrity in the event of prolonged entrapment by ice
- Escort operations or icebreaker assistance, where appropriate

In concept, the PWOM is similar to safety management documentation already required on all SOLAS-certified ships by the IMO ISM Code. The PWOM will not be subject to an approval by the flag state, although it is envisaged that a similar audit and verification scheme to ISM will apply.

The most effective PWOMs will come from companies and operators with extensive experience in Polar operations. It is important that new owners and operators engage with experienced personnel to develop the appropriate procedures for the Manual. Not every ship will include the same content for its PWOM nor follow the same format. For example, cruise ships may include very specific procedures related to passenger safety while entering cold temperatures or various concentrations of ice. Alternatively, a Category C cargo ship undertaking a single summertime voyage into the Arctic may not require such extensive procedures for very low probability situations. Relevant experience and, in most cases, a reflection of local knowledge of the region are paramount.

Table 2: Polar Water Operational Manual

1 - Operational Capabilities & Limitations	**1.1**	**Operations in ice**
	1.1.1	Operator guidance for safe operation
	1.1.2	Icebreaking capabilities
	1.1.3	Maneuvering in ice
	1.1.4	Special features
	1.2	**Operations in low air temperatures**
	1.2.1	System design
	1.2.2	Protection of personnel
	1.3	**Communication and navigation capabilities in high latitudes**
	1.4	**Voyage duration**
2 - Ship Operations	**2.1**	**Strategic planning**
	2.1.1	Avoidance of hazardous ice
	2.1.2	Avoidance of hazardous temperatures
	2.1.3	Voyage duration and endurance
	2.1.4	Manning
	2.2	**Arrangements for receiving forecasts of environmental conditions**
	2.2.1	Ice information
	2.2.2	Meteorological information
	2.3	**Verification of hydrographic, meteorological and navigational information**
	2.4	**Operation of special equipment**
	2.4.1	Navigation systems
	2.4.2	Communications systems
	2.5	**Procedures to maintain equipment and system functionality**
	2.5.1	Icing prevention and de-icing
	2.5.2	Operation of seawater systems
	2.5.3	Procedures for low temperature operations
3 - Risk Management	**3.1**	**Risk mitigation in limiting environmental condition**
	3.1.1	Measures to be considered in adverse ice conditions
	3.1.2	Measures to be considered in adverse temperature conditions
	3.2	**Emergency response**
	3.2.1	Damage control
	3.2.2	Firefighting
	3.2.3	Pollution response
	3.2.4	Escape and evacuation
	3.3	**Coordination with emergency response providers**
	3.3.1	Ship emergency response services
	3.3.2	Salvage
	3.3.3	Search and rescue
	3.3.4	Spill response
	3.4	**Procedures for prolonged entrapment by ice**
	3.4.1	System configuration
	3.4.2	System operation
4 - Joint Operations	**4.1**	**Escorted operations**
	4.2	**Convoy operations**

Operational Limitations

The operational limitations listed in the PWOM and referenced on the PSC are central to the effectiveness of the Polar Code. As highlighted above, three sets of limitations must be referenced on the Polar Ship Certificate – ice conditions, temperature, and high latitudes.

Temperature limitations will be linked to the ship's Polar Service Temperature for which the safety systems and materials have been certified. In nature, temperature variability can be highly dynamic. This is especially true in Polar Areas. Within a matter of hours, air temperatures can change rapidly and may be unpredictable. The temperature documented on the PSC are not intended as hard-and-fast or strict limitations. Operating at temperatures below the certified PST may not result in any immediate catastrophic failure but rather a progressive degradation of performance or factors of safety. If extreme low temperatures are encountered, in most cases, it would trigger a progressive response to increasing levels of risk rather than an immediate suspension of all operations. Procedures for such scenarios should also be included in the PWOM.

Some communications and navigation equipment will have inherent limitations when operating in extreme high latitudes. Most maritime digital communication systems were not designed to cover Polar waters. GEO systems may experience instability or signal dropout issues as low as 70° north or south. Any high latitude limitations should be listed on the certificate, if applicable. Some general information on high latitude navigation challenges are provided in Appendix 4.

From a structural risk perspective, the ship's category and ice class provide only a very basic and broad indication of its capabilities and limitations in ice. The Polar Code places an emphasis on having ice operational limitations referenced on the certificate with more detailed procedures in the PWOM. Several methodologies exist to provide guidance to masters on how to tailor their operations to the ice conditions and IMO has developed a harmonized methodology, called POLARIS, which will be acceptable for use under the Polar Code. Several available systems are explained in more detail below. The Polar Code requires that an approved methodology be used to determine the ship operational limitations and the master and navigation officers must be instructed in its use. The PSC itself cannot incorporate all of this information, but should indicate what type of methodology has been provided and where any additional information can be found.

Canadian Zone-Date System

Since the introduction of the Canadian Arctic Shipping Pollution Prevention Regulations (ASPPR) in the mid-1970s, an access control regime has been in place called the Zone / Date System. Transport Canada divided the Canadian Arctic into 16 zones. Zone 1 is generally considered to have the most demanding conditions, while Zone 16 has the least severe. Access to each zone is dependent on a ship's ice class or 'type' and the historical ice statistics at different times of the year. The least capable ships would never be permitted access to the most stringent zones, while the most capable may never be denied access. For any combinations of ship class and zone, allowable operating windows can be determined from a fixed published schedule. One example case of the Zone/Date System is illustrated in Figure 10 for an open water vessel (Canadian Type 'E') in the summer season. In this case, a non-ice-strengthened ship would be prohibited from operating outside of the zones highlighted in green.

Although simple and predictable, this system does not consider the fact that ice conditions vary significantly from year to year. In a relatively harsh ice season where the conditions are more severe than historically recorded, an inexperienced operator might attempt a voyage well beyond the capabilities of the ship. In a lighter ice year, the rigidity of the regulatory system may prevent ships from transiting areas which could be completely free of ice.

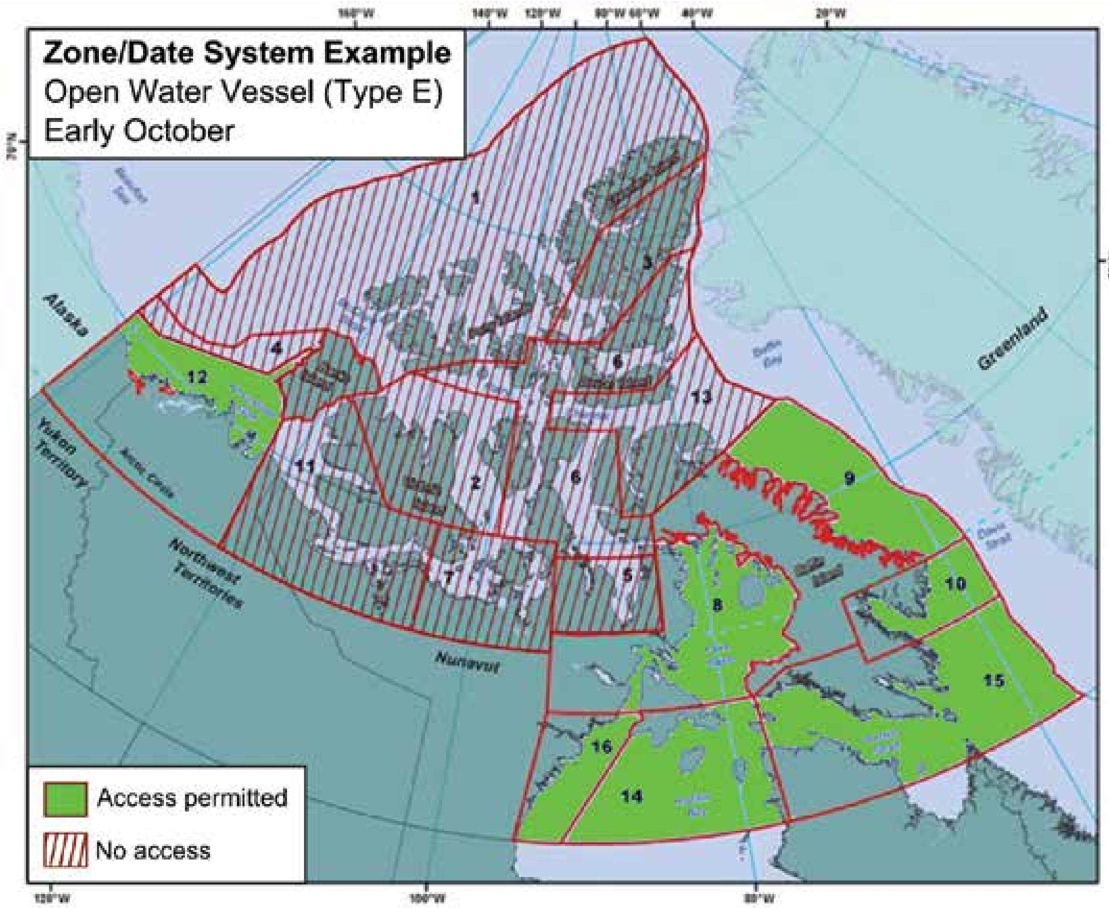


Figure 10: Canadian Zone/Date system
Courtesy of Transport Canada

Canadian Arctic Ice Regime Shipping System

The Arctic Ice Regime Shipping System (AIRSS) involves comparing the actual ice conditions along a route to the structural capability of the ship. AIRSS is a flexible alternative that overcomes the inherent weaknesses in the Zone/Date system and was developed through collaborative efforts between Canadian government agencies and industry. AIRSS recognizes that realistic ice conditions tend to manifest in an 'ice regime' which is composed of any mix or combination of ice types, including open water. An ice regime is defined as a region covered with generally consistent ice conditions, i.e., the distribution of ice types and concentrations does not change very much from point to point in this region.

Under AIRSS, the decision to enter a given ice regime is based on the quantity of dangerous ice present, and the ability of the vessel to avoid the dangerous ice along the route to (and from) its destination. Every ice type (including Open Water) has a numerical value which is dependent on the ice class of the vessel. This number is called the Ice Multiplier (IM). The value of the Ice Multiplier reflects the level of danger that the ice type poses to the particular category of vessel.

For any ice regime, an Ice Numeral (IN) is the sum of the products of the concentration (in tenths) of each Ice Type, and the Ice Multipliers relating to the Type or Class of the ship in question. These multiplications are repeated for as many Ice Types and each of their respective concentrations that may be present, including Open Water. Ice Numerals can be calculated from ice conditions observed on the bridge or from ice "egg codes" typically found on ice charts. The Ice Numeral is therefore unique to the particular ice regime and ship operating within its boundaries. To use
the system, the master or ice navigator needs to identify the ice types and concentrations along the route.

Russian Ice Certificate

It is widely acknowledged that risks of hull damage while operating in ice are predominantly a factor of the ice thickness, ice strength and the speed of the ship. In general, ship structural damage from ship-ice interaction accidents can be avoided if appropriate speeds are considered and the ship structure is accordingly strengthened. More than 25 years ago, the Arctic and Antarctic Research Institute (AARI) developed, and later patented, the "ice passport" (also referred to as an ice certificate) as a means of providing the correlation between safe ship speed and ice thickness. The ice passport also advises on other aspects of ice operations such as the radius of curvature for directional course changes, the maximum permissible ice thickness when in pressure, and safe following distances while under icebreaker assistance.

POLARIS

IMO has developed a harmonized methodology for assessing operational limitations in ice called the *Polar Operational Limit Assessment Risk Indexing System* (POLARIS), that will likely be published as a recommendatory IMO Circular through the Maritime Safety Committee in 2016. The system incorporates experience and best practices from the Canadian AIRSS system and the Russian Ice Certificate concept with additional input provided by other coastal administrations with experience regulating marine traffic in ice conditions. The basis of POLARIS is an evaluation of the risks posed to the ship by ice conditions using the WMO nomenclature and the ship's assigned ice class.

POLARIS can be used for voyage planning or on-board decision making in real time on the bridge although, as with any methodology, it is not intended to replace an experienced master's judgement. POLARIS assesses ice conditions based on a Risk Index Outcome (RIO) determined by the following simple calculation:

$RIO=(C_1 \times RV_1)+(C_2 \times RV_2)+(C_3 \times RV_3)+(C_4 \times RV_4)$

Where;

- $C_1 \ldots C_4$ – concentrations of ice types within ice regime
- $RV_1 \ldots RV_4$ – corresponding risk index values for a given Ice Class

A positive RIO indicates an acceptable risk level where operations may proceed while a negative RIO indicates an increased risk level, potentially to unacceptable levels. Criteria is established for negative RIOs that suggest the operations should stop and be reassessed or proceed cautiously with reduced speeds.

The Risk Values (RV) are a function of ice class, season of operation, and operational state (i.e., independent operation or icebreaker escort). An example table of RVs for winter independent operations is Figure 11. Risk levels increase with increasing ice thickness and decreasing ice class. POLARIS provides RVs for the seven IACS Polar Classes, four Finnish-Swedish Ice Classes, and non-ice-classed ships.

Increasing Ice Thickness (Severity)

Decreasing Ice Class

Winter Risk Values (RVs)

Polar Ship Category	Ice Class	Ice Free –	New Ice 0-10 cm	Grey Ice 10-15 cm	Grey White Ice 15-30 cm	Thin First-year Ice 1st Stage 30-50 cm	Thin First-year Ice 2nd Stage 50-70 cm	Medium First-year Ice 1st Stage 70-95 cm	Medium First-year Ice 2nd Stage 95-120 cm	Thick First-year Ice 120-200 cm	Second-year Ice 120-200 cm	Light Multi-year Ice 250-300 cm	Heavy Multi-year Ice 300+ cm
A	PC 1	3	3	3	3	2	2	2	2	2	2	1	1
	PC 2	3	3	3	3	2	2	2	2	2	1	1	0
	PC 3	3	3	3	3	2	2	2	2	2	1	0	-1
	PC 4	3	3	3	3	2	2	2	2	1	0	-1	-2
	PC 5	3	3	3	3	2	2	1	1	0	-1	-2	-2
B	PC 6	3	2	2	2	2	1	1	0	-1	-2	-3	-3
	PC 7	3	2	2	2	1	1	1	-1	-2	-3	-3	-3
C	IA Super	3	2	2	2	2	1	0	-1	-2	-3	-4	-4
	1A	3	2	2	2	1	0	-1	-2	-3	-4	-4	-4
	1B	3	2	2	1	0	-1	-2	-3	-3	-4	-5	-5
	1C	3	2	1	0	-1	-2	-2	-3	-4	-4	-5	-6
	No Ice Class	3	1	0	-1	-2	-3	-3	-3	-4	-5	-6	-6

Figure 11: POLARIS Risk Values for Winter Ice

Increased Risk

POLARIS Example

Two example applications of the POLARIS system are presented in the figures below. These maps make use of historical ice charts from the Canadian Ice Service (CIS) to compute the POLARIS RIOs for ships navigating along the Northwest Passage.

In the first scenario (Figure 12), an Ice Class 1A ship operates in mid-late September 2014 in the Canadian Arctic. Several ice charts are assembled and overlaid and the minimum RIO values are calculated on a high-resolution grid. The outcomes highlight elevated risk levels (orange and red areas indicate RIOs below -10) throughout most of the Archipelago, but the ship may be able to safely navigate if an appropriate route (green areas) is taken.

The second scenario (Figure 13) uses five years of ice chart data for mid-late July and the computed average RIO values for an Ice Class PC6 ship. This can be used for longer term voyage planning to better understand the months and weeks where navigable routes are accessible. The outcomes of this POLARIS assessment suggest that July is likely too early for this class of ship to make the Northwest Passage voyage.

ABS is continuing to develop tools to better assist our customers in understanding and applying POLARIS and other systems for operational limitations in ice.

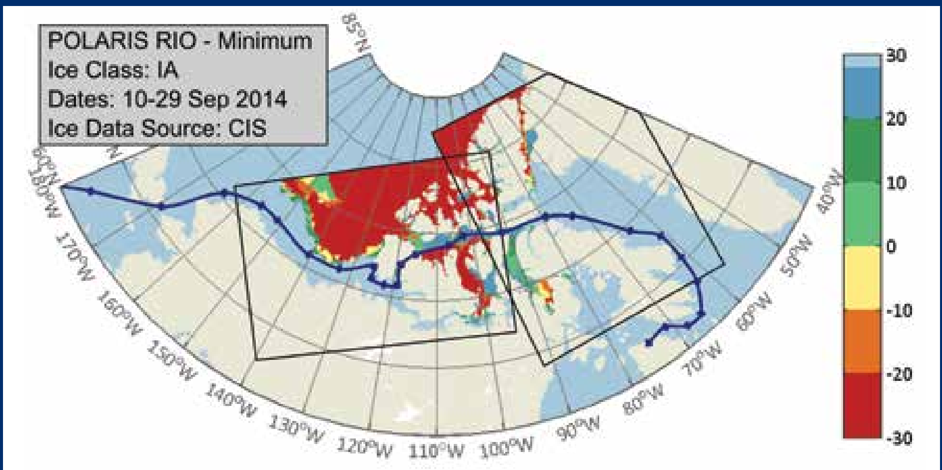


Figure 12: Minimum POLARIS RIOs for Ice Class IA – late September NWP transit

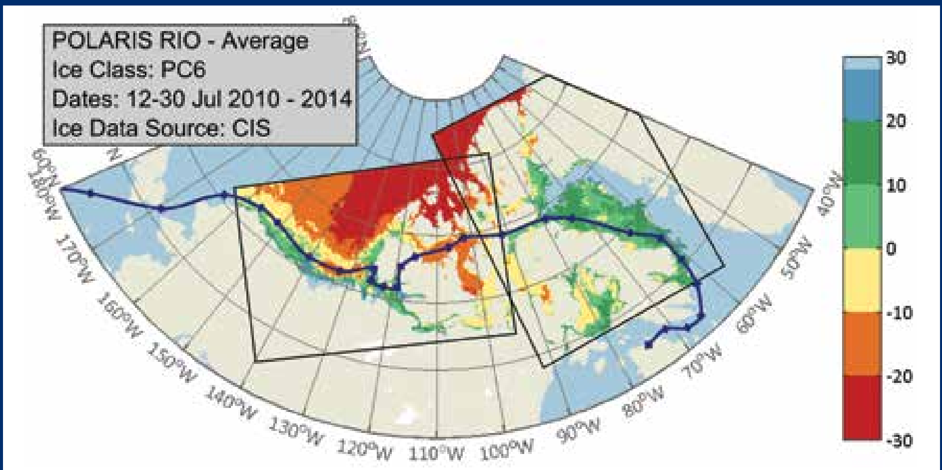


Figure 13: Average POLARIS RIOs for Ice Class PC6 – late July NWP transit

Operational Assessment

Under the Polar Code, companies are required to undertake an operational assessment for all ships entering Polar waters. The outcomes of the assessment are important and are linked to other regulations in the Code. For example, the assessment should help define the operational limitations and capabilities of the vessel that are described in the PWOM and referenced on the PSC. Additionally, the Polar Code's life-saving appliances chapter contains several conditional regulations about survival resources that must be determined specifically for each operation. Most prudent operating companies already carry out these types of assessments (e.g. risk assessments) on a regular basis as part of their internal safety management systems. The required assessment in the Polar Code is not intended to replace existing risk management practices, rather it aims to formalize best practices. At a minimum, the assessment should cover the following items:

- Operations in low air temperature, ice conditions, and high latitudes
- Potential for abandonment on ice or land
- Hazards identified by the Polar Code and any additional identified hazards

While no standard assessment format is stipulated, the Code offers some guidance on how the operational assessment may be carried out. Class can support owners and operators in facilitation and further defining the scope. It is recommended that a formal workshop is held that brings together experienced and competent operational personnel (e.g. crew members, captain, ice navigators) as well as design and technical staff. Preferably, the assessment would be carried out early in the design process so outcomes can be feasibly incorporated into the construction or operational procedures in the PWOM. The following basic steps are suggested to be taken:

1. Identify relevant hazards based on a review of the intended operations. Operations in low air temperature, ice conditions, and high latitudes should be considered.
2. Develop a model for analyzing risks considering probability and consequence levels for potential accidental scenario
3. Assess the risks using a selected methodology and determine acceptability
4. Identify current or develop new risk control options that aim to reduce the frequency (i.e., probability) or mitigate the consequence of failures through design features, operational procedures, or company training policies
5. Incorporate risk control options as applicable

Section 3 | Ship Design & Construction

Ship Structures

Two primary hazards which pose risks to hull structures are addressed by the Polar Code in Chapter 3, low air temperature and the presence of ice. The goal of this chapter is for materials and scantlings to retain structural integrity based on global and local response due to environmental loads and conditions.

Two conditional functional requirements are then imposed, the first of which applies to ships intended to operate in low air temperature where a PST is assigned on the certificate. For these ships, materials of exposed structures should be approved against the PST. Two IACS standards are referenced for demonstration of compliance.

1. IACS Unified Requirement UR S6 - Use of Steel Grades for Various Hull Members – Ships of 90 m in Length and Above
2. IACS Unified Requirements UR I Requirements Concerning Polar Class

IACS UR S6.3 has selection criteria for minimum steel grade requirements of ships operating in low air temperature environments. Based on the ship's design temperature, a structural member's thickness and material category (i.e., criticality), minimum steel grades are prescribed. IACS has incorporated changes to IACS UR S6.3 to account for the new definition of the Polar Service Temperature introduced by the Polar Code. If a ship has a Polar Class notation, IACS UR I2 contains ice class-dependent prescriptive material requirements that should be used.

The second functional requirement deals with appropriate levels of ice strengthening. As discussed earlier, the Polar Code established three categories linked to recognized IACS Polar ice classes. Table 3 shows which ice classes are required for each category.

Table 3: Polar Ship Categories

Category	Description	Ice Class	Approximate Correspondence of other ABS Ice Class Notations
A	Designed for operation in Polar waters in at least **medium first-year ice** which may include old ice inclusions	IACS PC1, PC2, PC3, PC4, PC5*	ABS Ice Class A5, A4, A3, A2, A1
B	Designed for operation in Polar waters in at least thin **first-year ice** which may include old ice inclusions	IACS PC6 - PC7*	ABS Ice Class A0 ABS Baltic Ice Class 1AS
C	Designed to operate in open water or in ice conditions less severe than those included in Cat A or B	Scantlings adequate for intended ice types and concentrations	ABS First-year Ice Class B0, C0, D0, E0 ABS Baltic Ice Class IA, IB, IC

*Or alternative standard offering an equivalent level of safety

The question of ice class equivalency and the phrase "equivalent level of safety" received a great deal of attention and debate during the Polar Code deliberations. One-to-one equivalency between class notations simply does not exist. Each ice class system has a different treatment of structural and machinery design philosophies. Some, for example, depend heavily on installed power or impose minimum performance requirements. Different assumptions related to elastic or plastic design points are employed and the extent of ice-strengthened areas can be quite different, even between seemingly comparable notations. In Table 3, the approximate corresponding ABS Ice Classes are shown for each category, but these should not be interpreted as de facto equivalencies.

Damage from iceberg impact

The IACS Polar Class rules are the accepted new construction standard with several new ships built to the harmonized rule set, but it is a relatively new standard and it will take time to grow the Polar Class fleet. It is therefore recognized that thousands of ice-classed ships exist in the world fleet without an IACS Polar Class notation (certified to one of the Finnish-Swedish Ice Classes or one of the many other ice classes offered by individual classification societies). Nevertheless, the Polar Rules are the principal basis of comparison and incorporated into the Polar Code by direct reference. Without a Polar Class notation, a ship-specific quantitative assessment will be necessary to accept an alternative ice class for Category A and B ships. The process should be the same for new and existing ships, although existing vessels are permitted to use "service experience" to some extent if non-compliance areas are found. Ultimately, the decision for ice class equivalency will rest with the Flag State (or an RO acting on its behalf). The Polar Code offers guidance for a "simplified equivalency assessment" in Part 1-B that is intended to assist in determining the equivalent level of safety required by Chapter 3 (Ship Structure) and Chapter 6 (Machinery). The following steps are to be followed:

1. Offered material grades should be compared with the IACS Polar Class material grade requirements (or IACS URS6 with specified design temperature / PST) to demonstrate compliance with at least PC5 for Category A or PC7 for Category B
2. A quantitative assessment of the IACS PC structural requirements (plating and framing would be sufficient) should be carried out for each icebelt region to demonstrate compliance with at least PC5 for Category A or PC7 for Category B
3. A quantitative assessment of the IACS PC machinery requirements should be carried out to demonstrate compliance with at least PC5 for Category A or PC7 for Category B
4. If gaps or noncompliance areas are identified above, additional risk mitigation measures can be taken and documented to still obtain Category A or B.

The approval of Category C scantlings for ice operations remains a controversial topic and was heavily debated at IMO. Many ships currently in operation are capable of navigating safely in and around light ice conditions without any ice strengthening and certainly within open water, even in Polar areas. IMO determined it would be unjustifiably conservative to require ice strengthening for every ship in Polar waters. Instead, the Code puts an emphasis on minimum training requirements for navigational officers and on well-defined and clearly documented ship-specific operational limitations. Again, it is critical that designers, owners, and operators clearly establish the intended operational profile of a vessel in order to appropriately select a level of ice strengthening, especially for Category C ships.

Subdivision & Stability

Intact Stability

Sea spray combined with subzero air temperatures can produce ice accretion on decks or equipment leading to a potential impairment of stability. Smaller ships are especially vulnerable where the added topside weight, aggravated by changes in trim, can raise the ship's center of gravity and increase the rolling moment, significantly changing the stability profile of the vessel. For ships operating in areas and during periods where ice accretion is likely to occur, the Polar Code prescribes specific allowance levels of ice accretion on exposed weather decks, gangways, and lateral projected areas that must be included in the intact stability calculations.

For new ships, it is fairly straight-forward to include the icing allowances to loading conditions in the trim and stability booklet. Certain design features can also be incorporated to passively reduce the severity of ice accretion on global stability. These typically include bow hull forms

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designed to minimize slamming actions and thereby sea spray events, enclosed forecastles, reduced equipment profiles, congestion, and complex surfaces to which ice can adhere, increased freeboards, and effective deck drainage systems to avoid stagnant water.

For existing ships, this will require a resubmission of the trim and stability booklet if icing allowances were not previously considered. If the ship is unable to comply with the regulations, it may result in operational limitations from ice accretion-prone areas. The Code also includes procedural requirements for monitoring ice accretion levels and the use of equipment for ice removal. Operational procedures and more detailed information are to be given in the PWOM. Some conventional methods for icing removal include electrical or pneumatic devices, steam systems, and wooded mallets and clubs used for manual removal.

Some questions have been raised regarding the validity of the ice accretion allowances and their application to SOLAS ships. The allowances were retained from the IMO Intact Stability Code (2009) but were originally derived for fishing vessels operating in the areas such as the North Atlantic, Norwegian Sea, Bering Strait, and the Grand Banks offshore Newfoundland. The Polar Code working group elected to mandate the same criteria for all ships under the Polar Code.

Ice Damage Stability

New ships of category A and B are required to be able to withstand flooding resulting from hull penetration due to an ice damage event where specific damage extent dimensions are prescribed. The criteria had previously existed in the voluntary IMO Polar Guidelines and becomes mandatory under the Polar Code.

In general, the criteria are considerably less onerous than other typical IMO damage criteria, but since the damage can be applied anywhere along the length of the ship, it may lead to two-compartment damage. For some ships and arrangements, this may require design changes to the subdivision. The list below attempts to provide some general implications of the new mandatory regulations; however, many different subdivision arrangements exist and each may result in different outcomes.

- Tankers already meet two compartment damage requirements with a larger transverse penetration extent. The Polar Code regulations are not expected to require any subdivision design changes.
- Bulk carriers will typically follow probabilistic damage criteria, meaning the vessel does not need to survive all one and two compartment damage cases needed to meet the criteria. If the non-surviving cases have to change to survive and meet the criteria, design changes will be necessary.
- Offshore Support Vessels currently must meet a one-compartment damage requirement. Compliance with a two compartment damage case will, in most cases, require a design/subdivision change.
- Cruise ships must meet probabilistic damage criteria per SOLAS with the added caveat that all two-compartment and less damages must meet the criteria.

The damage stability regulations are not applicable to Category C ships despite several proposals from delegations concerned about the risks of lightly-strengthened ships susceptible to ice damage scenarios.

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Watertight & Weathertight Integrity

All closing appliances and doors relevant to watertight and weathertight integrity shall be operable under the anticipated environmental conditions in Polar waters. Two conditional regulations are introduced in Chapter 5 of the Polar Code.

For ships operating in ice accretion areas, means must be provided to either remove or prevent ice and snow accretion around hatches and doors. The Polar Code does not prescribe any specific solutions. Owners must make decisions about design features or procedural mitigation methods to comply with the regulations. De-icing procedures for the use of wooden mallets, or steam and hot water spray are viable solutions. Alternatively, trace heating cables can be fitted around seals to prevent bonding between seals and the hatch cover. For new ships, or when retrofitting, the selection of hatch sealing material should be carefully considered in light of their reduced ductility in extremely cold temperatures.

In addition, for ships intended to operate in low air temperature, two regulations are imposed:

- Means must be provided to prevent freezing or excessive viscosity of hydraulic liquids used in hydraulically-operated doors and hatches.
- External hatches and closing devices designed to be operated by personnel wearing heavy winter clothing including thick mittens

Some available hydraulic fluids may have certified operability for the ship's Polar Service Temperature; otherwise, heating arrangements can be installed. To accommodate for heavy winter clothing, larger manual closing devices with effective grips are suggested. Crewmembers should test out the onboard winter clothing to ensure they can effectively open and close hatches.

Section 4 | Machinery, Equipment & Systems

Machinery Installations

Chapter 6 of the Polar Code covers machinery and electrical systems that are critical to the safe operation of the ship. The regulations are similar to winterization rules offered by individual classification societies, but help to establish a minimum safety level as opposed to a comprehensive set of considerations. Functional requirements are linked to the following main identified hazards that may affect machinery while operating in Polar waters:

For all Polar ships:

- Ice accretion and/or snow accumulation
- Ice ingestion from seawater
- Freezing and viscosity of liquids
- Seawater intake temperature
- Snow ingestion

For ships operating in low air temperature environments:

- Cold and dense air intake
- Stored energy (e.g. batteries) performance in low temperature
- Materials exposed to low temperature

For ships operating in ice:

- Propulsion line loads due to ice interaction

Ice accretion and snow accumulation can block the crew's access to controls and potentially inhibit functionality of exposed deck machinery. The Polar Code regulations require machinery installations and associated equipment to be protected from the effects of ice accretion and snow accumulation. Some examples of applicable machinery include deck winches, anchor windlasses, and mooring fittings. Owners may also elect to protect other deck machinery, such as cargo handling gear (e.g. cranes, pumps, securing equipment), depending on their intended operations. Snow ingestion into air intakes presents an elevated risk of clogging screens. Snow may build up on screens and cause a blockage or a severe restriction of airflow. This could result in machinery starving for air or under pressure of the space being supplied with air.

Sea Chests

Sea chests and sea water intakes can present a problem to ships operating in waters where there is a potential for ice and slush conditions. Ingestion of ice and slush can lead to blocking of seawater flow to the cooling system or firefighting systems. As a general principle, sea chests used in ice or slush-infested waters should:

a) Maintain essential seawater by using inlets situates as low and as far aft as possible, near the centerline,

b) Use sea boxes and sea bays,

c) Use diversion arrangements to introduce warm cooling water to seawater inlets and strainers.

d) Provide means to manually clear sea inlets of ice blockage by introducing low pressure compressed air or steam.

e) Allow ice and slush ice introduced in the system to float freely away from pump intakes.

f) Allow the use of ballast water for:

- Back flushing sea boxes
- Cooling the engines as a short-term solution

Typically methods for controlling and minimizing blockage include the use of waste heat from the cooling water and intake arrangements which help separate ice from the intake water.

Two examples are sketched in the figures below. Figure 14 makes use of the waste heat from cooling water as suggested by IMO MSC/CIRC. 504. Figure 15 is a weir-type commonly used in Baltic icebreakers as well as several Polar Class vessels. The suction is separated from the sea inlet grills by a vertical plate weir. Any ice entering the sea box can float to the top and is unlikely to be drawn back down to the suction level. These arrangements are usually fitted with a means of clearing excessive ice from the ice box (upper area above waterline).

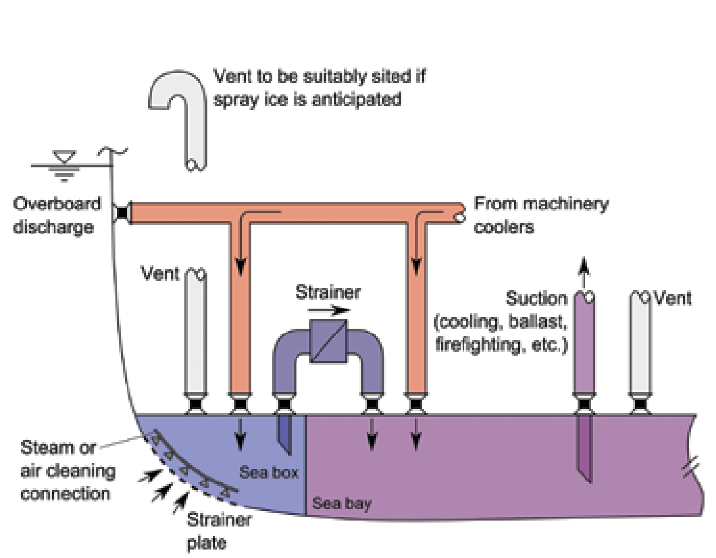


Figure 14: IMO suggested sea chest arrangement for slush and ice conditions

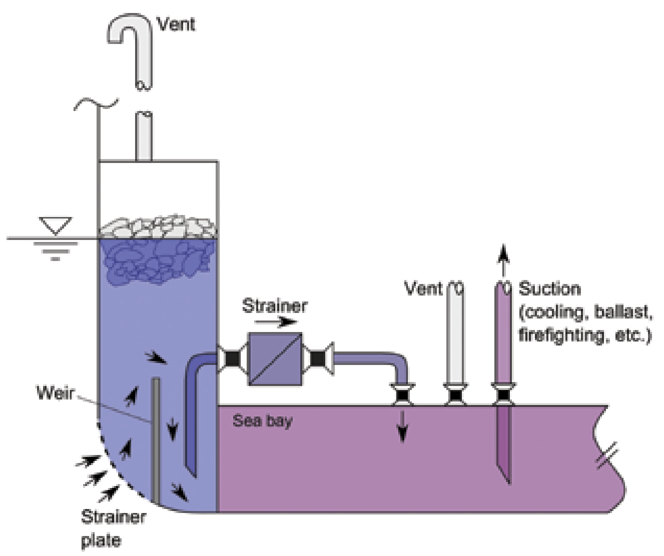


Figure 15: Typical sea chest arrangement for slush and ice conditions

Sea water temperature in Polar regions is typically much lower than in temperate climates, and in some cases can drop below 0°C. Low temperature water can pose several hazards to a ship's systems. Even when no ice cover is present, super cooled seawater can plug suction systems almost immediately often with little warning. If the machinery systems are designed for operations in warmer waters the cooling systems may over cool the machinery resulting in anything from a loss of efficiency to mechanical failures. Traditional machinery arrangements without effective sea inlets may experience operational difficulties when exposed to slush or frazil ice conditions due to blockage by ice. Polar ships should be equipped with a system to prevent icing and choking of sea chests and to maintain an essential cooling water supply. IMO MSC/Circular 504 provides guidance on design and construction of sea inlets under slush ice conditions. In addition some Arctic coastal administrations publish recommendatory information or have mandatary domestic regulations in place for such systems. For example, Transport Canada requires certain sea water cooling systems for ships operating in the Gulf of St. Lawrence and the St. Lawrence River during winter months.

Damaged propeller blade from ice impact

For ships intended to operate in low temperature (i.e., Lowest MDLT below -10°C), the machinery must be capable of safe operation at the specified Polar Service Temperature. This requires consideration for special materials, cold and dense air intake, and performance degradation in low air temperatures. The IACS UR S6 standard is referenced as a basis for material selection. High density air can lead to over-pressurization of machinery or failure to ignite the fuel. Some battery chemistries suffer decreased performance in low air temperatures.

The ABS *Guide for Vessels Operating in Low Temperature Environments (LTE Guide)* contains guidance for dealing with many of the hazards on machinery systems operating in Polar waters. The LTE Guide is available for free download from www.eagle.org.

For ice-strengthened vessels, the Polar Code also requires propulsion line machinery to be appropriately strengthened with applicable requirements for the category and ice class. In general, this implies compliance with IACS UR I3 – Polar Class machinery requirements (ABS Steel Vessel Rules 6-1-3) for Category A and B ships. For Category C ships, the machinery requirements of either the ABS First-year Ice Class rules (ABS SVR 6-1-5) or the Baltic Ice Class rules (ABS SVR 6-1-6) would apply, depending on the intended operational profile of the vessel. Ice class machinery requirements typically follow a similar progression:

- Propeller blade scantlings for impacts with ice and design for fatigue
- Response of propulsion line components including blade bolts, CP mechanisms, shaft line torque excitation, gear transmissions, bearings, and couplings
- Steering equipment
- Appendages

Fire Safety/Protection

Firefighting systems have several aspects susceptible to the hazards associated with polar operations. Ice accretion can hinder access to controls such as valve handles or control panels; water can freeze inside exposed piping; fire extinguishers can freeze and become ineffective; and individuals assigned to firefighting teams could be wearing bulky cold weather clothing which can affect their ability to use equipment. For all ships under the Polar Code, the following fire safety regulations are imposed in Chapter 7:

- Exposed isolating and pressure/vacuum valves protected from ice accretion
- Fire pumps located in compartments maintained above freezing
- Exposed sections of fire main arranged with means for drainage
- Firefighters outfits stored in warm locations
- Independent sea suction for separate fixed water-based firefighting systems

Ships intended to operate in low air temperature must comply with additional provisions, taking into account the ship's specified Polar Service Temperature (PST);

- Two-way portable radio communication equipment operable at the PST
- Portable fire extinguishers protected from freezing or operable at the PST
- Materials of exposed systems approved for PST

Material failure due to freezing and expansion of non-drained fire main

The Code mandates that all isolation valves in the fire main remain accessible at all times. In other words, valve handles should not be buried under ice or snow and access to the valves should be safely passable by the crew (i.e., the walkway is not buried under snow or dangerously slippery). Compliance can be demonstrated by design features or operational mitigation measures.

An essential part of effective firefighting is the communication between the command and control center and individuals assigned to firefighting teams. SOLAS recognized this and requires two-way radio communication. The Polar Code adds additional requirements for all two-way portable radio communication equipment to be operable at the PST.

Fire pumps exposed to extreme low temperatures may be susceptible to freezing. To mitigate this risk, the Polar

Code requires fire pumps to be located in heated compartments. In addition, all fire pump suctions (intake sea chests) are to be capable of being cleared of ice accumulation.

Portable items such as hoses and nozzles may be stored in a heated compartment to protect them from the elements. Firefighter's outfits and portable extinguishers that may freeze at the PST shall be stored in a heated compartment.

The ABS LTE guide offers practical design and operational guidance on most of the systems for which the Polar Code will require protection. In line with the ABS LTE guide, the Polar Code requires a plan (the PWOM). This PWOM may contain procedures for protection for the firefighting systems from the effects of ice accretion or low temperatures. For example, a fire main may be drained when not in use, it may be heat traced and insulated, or the design altered to relocate it into a heated compartment. The plan will also include procedures to follow in the event that a system's design load (temperature) is exceeded.

Life-saving Appliances & Arrangements

Chapter 8 of the Polar Code introduces regulations for lifesaving appliances and arrangements above and beyond the minimum requirements of SOLAS and the IMO Life-saving Appliances Code. The chapter follows a logical order beginning with escape, then evacuation, and ultimately survival.

Escape

Escape routes must remain accessible and safe, taking ice accretion and snow accumulation into consideration. A variety of solutions are available to mitigate these risks. Some designers may elect to enclose escape routes in protected locations as

Escape Routes

During the early stages of planning a winterization project, consideration must be given to the escape routes and means to access critical safety equipment. Winterization of escape routes can be solved in many different ways and it is up to the owner to determine the appropriate balance for their specific operation. A passive means could be established where the entire escape route is enclosed. Enclosures protect the escape routes from sea spray action and, without a water source, will eliminate the possibility of ice accretion.

Another solution is to apply heating to the deck in way of the escape route. If properly designed and installed, heat tracing works to elevate the surface temperature above the melting point of ice and snow. Designers should be cognizant to the added electrical demand required to power such systems. A third solution, re-active, is proper ship handling and monitoring of ice accretion rates. This requires a well-trained and experienced crew to recognize adverse conditions and that effective rerouting and operational procedures be in place. These procedures should be clearly established in the ship's PWOM and/or the winterization plan.

Ice accretion of stairway

a passive design solution. Heat-traced deck plates or heated mats around critical paths may also serve as a prevention (i.e., anti-icing) mechanism. Alternatively, the PWOM may include procedures for physical removal of ice and snow as necessary, or the application of chemicals such as salt when temperatures drop below freezing. For new ships built in accordance with the Code, the escape routes must also be wide enough for the passage of persons wearing bulky clothes.

In addition to the escape routes, the survival craft's launching appliances and the crew's means of accessing these devices is to be protected from the effects of ice accretion and snow accumulation.

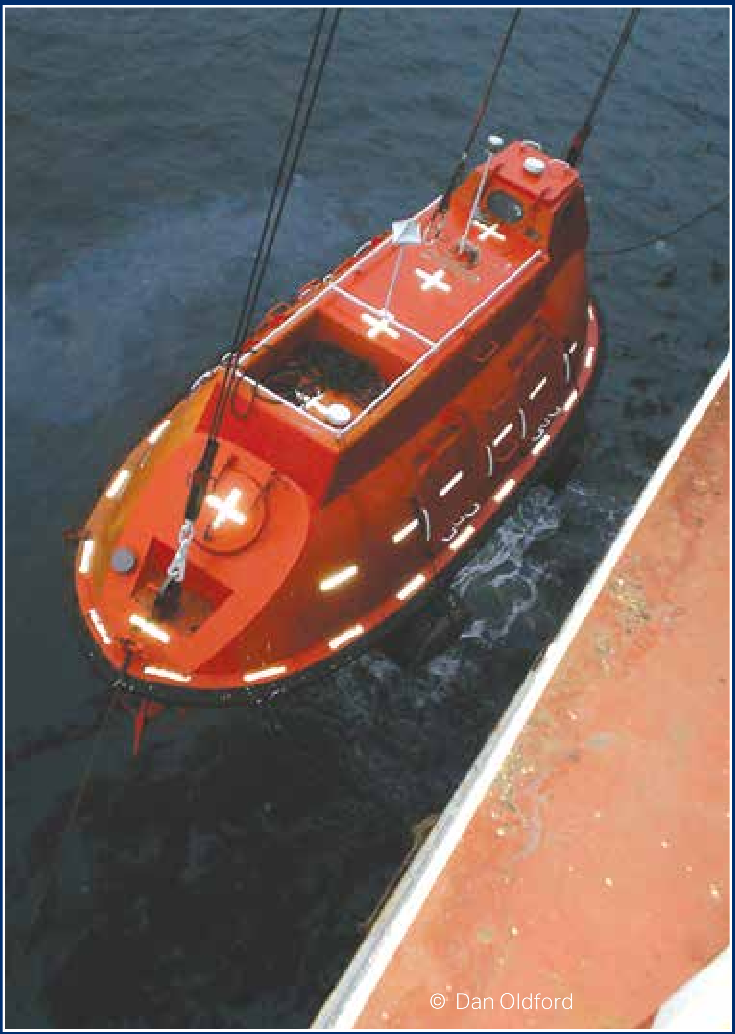
Evacuation

The survival craft are to provide the crew with a means of safely evacuating the vessel, considering the hazards present in the Polar regions, such as low air temperature, winds, low water temperature, long hours of sun or darkness, presence of ice and natural wildlife.

The craft must also be capable of effective evacuation at any time up to the maximum expected time of rescue (at least five days).

Evacuation

The key components of a safe evacuation are the effective mustering of crew members, boarding into the escape craft and abandoning ship. While mustering, the crew should be protected from the elements such as cold and wind. When the crew is embarking the craft, the passages should be large enough for persons wearing large, bulky clothing. Survival craft are often connected to the vessel by means of an on-load release hook. These hooks must be free to release when needed and therefore may require protection from the effects of ice accretion, and lubricated with oil/grease that will continue to function in low air temperatures.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Launching of fully enclosed lifeboat

Survival resources must consider survival on land, in water or on ice

Survival

The Polar Code only permits the use of partially or totally enclosed lifeboats. Open lifeboats are prohibited from use in Polar regions. Personal thermal protection devices (either thermal protective aids or properly sized immersion suits) must also be provided for every person onboard and must take into consideration immersion into polar waters. If a voyage is expected to experience extended hours of darkness, lifeboats must be also fitted with search-lights.

Appropriate survival resources must be provided to support survival on land, in water or on ice for the maximum expected time of rescue (at least five days). The extent of the 'appropriate' survival resources, for example the use of personal survival kits (PSKs) or group survival kits (GSKs), is determined by the operational assessment described in Section 1. These resources must provide a habitable environment that offers protection from the cold, the wind, and the sun. The ship's normal lifesaving appliances such as lifeboats and/or life rafts may be considered, but the space inside should account for persons wearing bulky thermal protection, including the access and exits points. The survival resource must also have the means to provide food and water for persons and communication between other rescue assets.
Part I-B of the Polar Code contains suggested lists for personal and group survival equipment (see Table 4).

Whenever the assessment indicates a possibility of survival on land or onto ice, group survival equipment must be carried. Survival equipment for 110% of the persons onboard must be stowed as close as practical to the muster station or embarkation stations. The containers for equipment must be capable of easily moving over ice and floating on water. If they are to be carried in survival craft in addition to persons, the craft and launching appliances are to be appropriately sized. The ship's crew must in all cases be trained in the use of the survival equipment and any passengers are to be provided with instructions.

Table 4: Survival

Personal Survival – Suggested Equipment
Protective clothing (hat, gloves, socks, face and neck protection, etc.)
Skin protection cream
Thermal protective aid
Sunglasses
Whistle
Drinking mug
Penknife
Polar survival guidance
Emergency food
Carrying bag

Group Survival - Suggested Equipment
Shelter – tents or storm shelters or equivalent – sufficient for maximum number of persons
Thermal protective aids or similar – sufficient for maximum number of persons
Sleeping bags – sufficient for at least one between two persons
Foam sleeping mats or similar – sufficient for at least one between two persons
Shovels – at least 2
Sanitation (e.g. toilet paper)
Stove and fuel – sufficient for maximum number of persons ashore and maximum anticipated time of rescue
Emergency food – sufficient for maximum number of persons ashore and maximum anticipated time of rescue
Flashlights – one per shelter
Waterproof and windproof matches – two boxes per shelter
Whistle
Signal mirror
Water containers & water purification tablets
Spare set of personal survival equipment
Group survival equipment container (waterproof and floatable)

Navigation & Communication Systems

Chapter 9 of the Polar Code covers the required enhancements to safety of navigation. The chapter imposes regulations to ensure that ships have the ability to receive up-to-date information and navigation equipment retains functionality during operations is Polar waters. The remoteness of Polar regions and proximity to the magnetic Poles can have an effect on the charts that are supplied and the navigation instruments that are used with them. Additional general information on high latitude navigation in provided in Appendix 4.

Polar ships must have a means of receiving and displaying current ice conditions such as ice charts. Ships are also required to be able to detect the conditions around them. Many of the regulations for navigation systems are conditional, as shown in the list below:

- Redundant echo-sounding devices (new ships)
- Clear view astern from the navigation bridge (all ships)
- Means to prevent ice accumulation on navigation equipment antennas (ships operating in ice accretion prone areas)
- Means of protecting submerged sensors from ice contact (all ice-strengthened ships)
- Enclosed bridge wings (new Category A and B ships)
- Two nonmagnetic means to determine and display heading (all ships)
- At least one GNSS compass or equivalent (ships operating in high latitudes, over 80 degrees)
- Two remotely rotatable, narrow-beam search lights (exemption for ships operating in 24 hour daylight)
- Manually initiated flashing red light, visible from astern (for vessels operating with an icebreaker escort)

Ice accretion of navigation systems

Chapter 10 of the Polar Code offers regulations for shipboard communication systems in Polar waters and their ability to provide two-way communications (voice and/or data) for ship-to-shore, ship-to-ship, and ship-to-air. The chapter also includes regulations for survival craft and rescue boat communication.

The ship-to-shore regulations stipulate that consideration be given to the communication networks available at high latitudes as well as in low temperatures. Ship-to-ship regulations are primarily concerned with sound signaling. An aft-facing system to indicate emergency maneuvers is required for vessels providing icebreaking services. Ships shall have two-way on-scene and SAR coordination communication capabilities. These capabilities must include communications with relevant rescue coordination centers and means of voice communication with aircraft (121.5 and 123.1 MHz). In the event of a medical emergency, the ship is to have equipment for voice and data communication with a Telemedical Assistance Service (TMAS).

For ships operating in low air temperature, additional regulations are imposed for rescue boats and lifeboats where each must carry:

- One device for transmitting ship-to-shore distress alerts
- One device for transmitting signals for location
- One device for two-way on-scene communications

Furthermore, all survival craft other than life boats and rescue boats (e.g. life-rafts) must carry:

- One device for transmitting signals for location,
- One device for two-way on-scene communications

Communications equipment powered by batteries must be protected considering the limitations of battery life in low temperatures. These batteries are to be protected and available for operation during the maximum expected time of rescue.

Section 5 | Operational & Environmental Regulations

Voyage Planning

The goal of voyage planning is to ensure that the operator, master and crew are provided with sufficient information to enable operations to be conducted with due consideration to safety of ship and persons on board and, as appropriate, environmental protection. The voyage plan shall take into account the potential hazards of the intended voyage. The master shall consider a route through Polar waters, taking into account the following:

- Any limitations of the hydrographic information and aids to navigation available
- Current information on the extent and type of ice and icebergs in the vicinity of the intended route
- Statistical information on ice and temperatures from former years
- Places of refuge
- Current information and measures to be taken when marine mammals are encountered relating to known areas with densities of marine mammals, including seasonal migration areas
- Current information on relevant ships' routing systems, speed recommendations and vessel traffic services relating to known areas with densities of marine mammals, including seasonal migration areas
- National and international designated protected areas along the route
- Operation in areas remote from search and rescue (SAR) capabilities
- The procedures required by the PWOM

Polar regions are ecologically sensitive to native species and the indigenous people's cultural heritage is also to be respected. In this regard, ships should also consider the following:

- In the event that marine mammals are encountered, any existing best practices should be considered to minimize unnecessary disturbance; and
- Planning to minimize the impact of the ship's voyage where ships are trafficking near areas of cultural heritage and cultural significance.

Manning & Training

Competent and qualified personnel are the most effective way to ensure safety of navigation in ice conditions. The Polar Code establishes new training requirements for "ice certification". Masters, chief mates and navigational officers must complete certain training curriculums depending on the ship type and anticipated ice conditions. Chapter 12 establishes the minimum required number and level of ice-certified personnel to be onboard Polar ships. Two levels of competency are used, Basic and Advanced. Table 5 indicates when each competency level is required. Detailed training requirements and curriculums are currently under development by the Human, Training, and Watchkeeping (HTW) Subcommittee at IMO. Several training institutions have already developed their own curriculums and training regimes and these will likely be acceptable until a comprehensive standard is developed.

The Polar Code also makes allowance for an ice navigator to supplement the navigation team. The purpose of the ice navigator is to offer specialized experience for operations in ice conditions. It is common practice in the both the Canadian and Russian Arctic for ice navigators or ice pilots to be onboard vessels. The Polar Code requires that these 'additional personnel' be STCW certified and that enough qualified personnel are available to cover all watches with minimum hours of rest requirements satisfied.

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Aside from the navigation officers, it is important that every crew member be familiar with the onboard procedures and equipment referenced in the PWOM that are relevant to their duties.

Table 5: Polar Code Training Requirements

Ice Conditions	Ship Type		
	Tankers	Passenger Ships	Others
Ice Free	Not applicable	Not applicable	Not applicable
Open water	Basic training for master, chief mate and officers in charge of a navigational watch	Basic training for master, chief mate and officers in charge of a navigational watch	Not applicable
Other waters	Advanced training for master and chief mate. Basic training for officers in charge of a navigational watch	Advanced training for master and chief mate. Basic training for officers in charge of a navigational watch	Advanced training for master and chief mate. Basic training for officers in charge of a navigational watch

- Ice free waters means no ice present. If ice of any kind is present this term shall not be used.
- Open water means a large area of freely navigable water in which sea ice is present in concentrations less than 1/10. No ice of land origin is present.
- Other waters means any ice concentration above 1/10 or a presence of glacial ice including icebergs and bergy bits.

Environmental Protection Regulations

Part II of the Polar Code includes additional mandatory pollution prevention measures above and beyond MARPOL regulations. The environmental regulations do not follow the goal-based standards framework and instead are written in a prescriptive format. Four MARPOL annexes, each controlling different waste streams, are amended by the Polar Code:

- MARPOL Annex I – Oil
- MARPOL Annex II - Noxious Liquid Substances
- MARPOL Annex IV – Sewage
- MARPOL Annex V - Garbage

MARPOL Annexes III and VI (packaged goods and air emissions) were discussed at IMO, but it was decided that additional regulations were not warranted for the Polar waters at this time. A debate continues to take place around proposals to ban the use and carriage of heavy fuel oil (HFO) in the Arctic (already banned in the Antarctic). The impetus for an HFO ban relates to air pollution, black carbon, and the elevated risk in the event of a fuel spill; however, no additional regulations are currently in place.

The implications of the environmental regulations result in a need to provide adequate (potentially increased) waste storage capacity. Waste reception facilities are extremely limited in Polar waters so operators should be cognizant of how to retain the waste and legally discharge outside of Polar waters.

NATHANIEL B. PALMER ice class research and supply vessel in Antarctica

Oil Pollution

The Polar Code imposes a complete prohibition on any discharge into the sea of oil or oily mixtures from any ship in Polar waters. Furthermore manuals, Oil Record Books, and the shipboard oil pollution emergency plan required by MARPOL Annex I must take into account operation in Polar waters. New Category A and B ships are further required to have 760 mm of oil tank separation from the outer shell. An exemption to this regulation is available for small tanks (< 20 m3) in way of the machinery spaces.

Pollution from Noxious Liquid Substances

Discharge of any Noxious Liquid Substances (NLS) is also subject to a 100% prohibition in all Polar waters. Similar to the oil pollution regulations, the ship's Cargo Record Book, Manual, and the shipboard marine pollution emergency plan required by MARPOL Annex II must take into account operation in Polar waters. New Category A and B ships are also required to have 760 mm of NLS tank separation from the outer shell.

Pollution from Sewage

Sewage discharge limitations in Polar waters are slightly more onerous than the current MARPOL Annex IV regulations. Discharge of comminuted and disinfected sewage must be at least 3 nautical miles for any ice-shelf or fast ice and far from ice concentrations greater than 1/10th coverage. Non-comminuted and non-disinfected sewage is subject to further restriction, more than 12 nautical miles from any ice shelf or land-fast ice. Even with approved sewage treatment plans, discharges must be kept as far as practicable from the nearest land, ice shelf, land-fast ice or areas of ice concentration greater than 1/10.

Pollution by Garbage

Food and garbage discharge limitations are imposed on ships operating in Polar waters to consider concentrations of ice in a similar way as the sewage restrictions. Discharge of garbage is only permitted when comminuted (capable of passing 25 mm openings) and far from land and ice concentrations greater than 1/10th coverage. Animal carcasses are also not permitted to be discharged at all. Furthermore, plans and records required by MARPOL Annex V shall take into account operation in Polar waters.

Conclusions & Recommendations

Marine traffic in Polar regions is expected to grow as reduced ice cover presents new opportunities for shorter shipping routes, access to natural resource deposits, and increased cruise ship tourism. To support the increased traffic, a modern and effective international regulatory framework is essential. The adoption of the IMO Polar Code represents the culmination of a long-term effort by IMO to promote safety and reduce environmental pollution from the increasing number of vessels. The Code is scheduled for entry into force on 1 January 2017 and introduces a sweeping set of mandatory regulations covering all stages of a ship's life including design, construction, operations, and maintenance.

Upon entering into force, the mandatory sections of the Code will come into effect via amendments to SOLAS, MARPOL, and STCW. There will also be nonbinding recommendatory provisions. The Code may have significant implications on some operators, shipbuilders, and designers looking to mobilize assets in Polar areas, although well-prepared and experienced operators of ice class vessels are not expected to have significant additional burden.

The development of the Polar Code has been a major challenge for IMO and it will take time for industry to catch up with the regulations. It is not a perfect regulatory instrument and industry collaboration is not finished. Service experience and feedback will help improve the Code's regulations and guidance for implementation. Classification societies, through IACS, and other bodies are working on guidance to support consistent implementation of the Code's regulations. The priority work areas include:

- Development of the POLARIS system for operational limitations in ice
- Guidance and procedures for establishing ice class equivalency for Category A and B ships
- Guidance on the required operational assessment and interpreting the outputs
- Updated survey checklists
- Consistent testing and acceptance criteria for certification of equipment

It is expected that Class will be called upon for guidance to designers, owners and operator as well as flag administrations for approval as recognized organizations. The following recommendations are offered to designers and owners that may consider Polar operations in the future:

1. Engage with the RO and flag early in the process
2. Determine a realistic operational profile for the ship including ice conditions and temperature profiles in order to select the appropriate ice class, ship category, and Polar Service Temperature
3. Consider an appropriate balance of design specification and operational procedures during the required operational assessment
4. Work with experienced personnel to develop the PWOM

Appendix 1 | IACS Polar Class Rules & ABS Ice Class Rules

As part of the IMO effort in developing "Guidelines for Ships Operating in Arctic Ice-covered Waters (2002)", the International Association of Classification Societies (IACS) with support from several key Arctic coastal states were delegated to develop the IACS Unified Requirements Concerning Polar Class (IACS Polar Class UR). The Polar Classes were referenced in the Guidelines as the principal construction provisions for new ships operating in Polar waters and were formally adopted by the members of IACS in 2008. The IACS Polar Class UR consist of three parts:

Table 6: IACS Polar Class UR

IACS Reference	ABS SVR Section	Description
UR I1	6-1-1	Definition and Application of the Polar Classes
UR I2	6-1-2	Structural Requirements
UR I3	6-1-3	Machinery Requirements

Seven Polar Classes are defined based on descriptions of nominal ice conditions as shown in Table 7. IMO Arctic Guidelines noted that the lowest two Polar Classes, PC7 and PC6, were commonly accepted as nominal equivalencies to Finnish Swedish Ice Class Rules (FSICR, commonly known as Baltic Ice Class Rules) Class 1A and 1A Super, respectively. The intent of the highest Polar Class PC1 is to offer the capability for a ship to operate year-round in all Polar waters, subject to due caution by the crew.

Table 7: Polar Classes

Polar Class	Ice Description (based on WMO Sea Ice Nomenclature)
PC1	Year-round operation in all Polar waters
PC2	Year-round operation in moderate multi-year ice conditions
PC3	Year-round operation in second-year ice which may include multi-year ice inclusions.
PC4	Year-round operation in thick first-year ice which may include old ice inclusions
PC5	Year-round operation in medium first-year ice which may include old ice inclusions
PC6	Summer/autumn operation in medium first-year ice which may include old ice inclusions
PC7	Summer/autumn operation in thin first-year ice which may include old ice inclusions

Structural Requirements

Part II of the IACS Requirements for Polar Class provides definitions and requirements for hull area, design loads, shell plate requirements, framing requirements, corrosion/abrasion addition and steel renewal, material grades and longitudinal strength requirements. The design load for Polar Class ships takes a physics-based approach that ice loads can be rationally linked to a specified design scenario. The design scenario is a glancing collision with an ice edge, such as the edge of a channel or of a floe. The form of the load equation is derived from the solution of an energy-based collision model in which the available kinetic energy (assuming a ship speed) is equated to energy expended into ice crushing. Ice thickness, ice crushing strength, hull form, ship size and ship speed are all taken into account. The flexural failure of the ice sheet is also considered as force limit state during the collision. The results of the model are in close agreement with a variety of past studies and operational experience. The forces generated during a glancing impact are represented in ways that allow them to be used in developing scantlings for individual structural elements, grillages, and supporting structure.

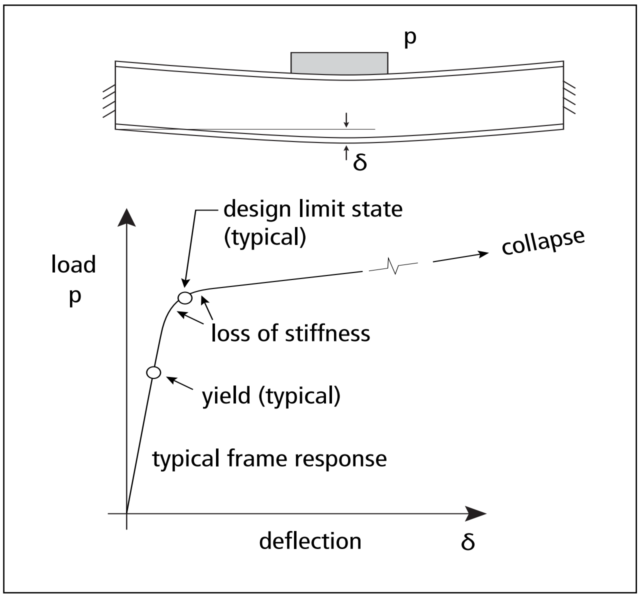

Figure 16: IACS Polar UR plastic design philosophy

Although most traditional ship structural rule formulations are based on elastic criteria, the IACS Polar Class UR incorporate plastic design criteria. Using plastic design can help provide a better balance of material distribution to resist design and extreme loads. This is particularly important because the unintended extreme ice loads can be considerably in excess of design values. The use of plastic methods should provide a considerable strength reserve. In plastic design, there are many possible limit states ranging from yield through a final rupture. The IACS Polar Class UR selected a design limit state representing a condition of substantial plastic stress, prior to the development of large plastic strains and deformations. Figure 16 shows a typical load deflection curve for a frame showing the design point.

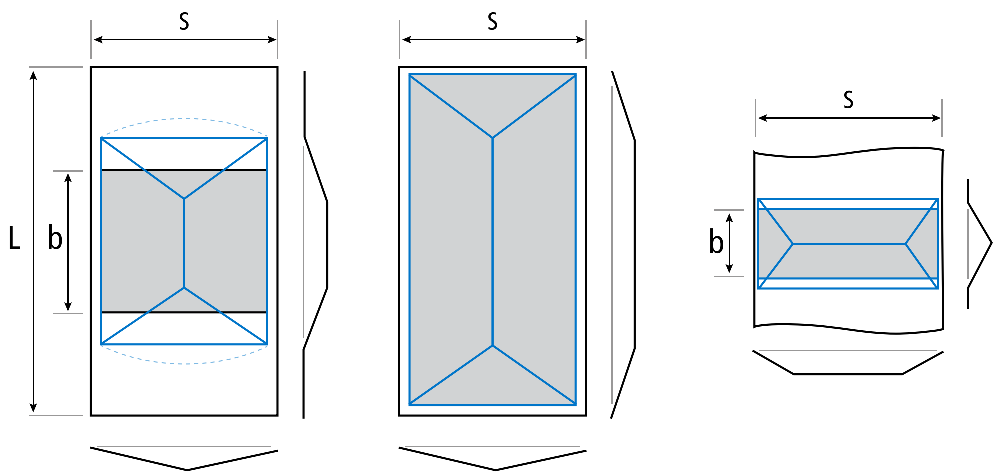

Figure 17: Plating design load cases

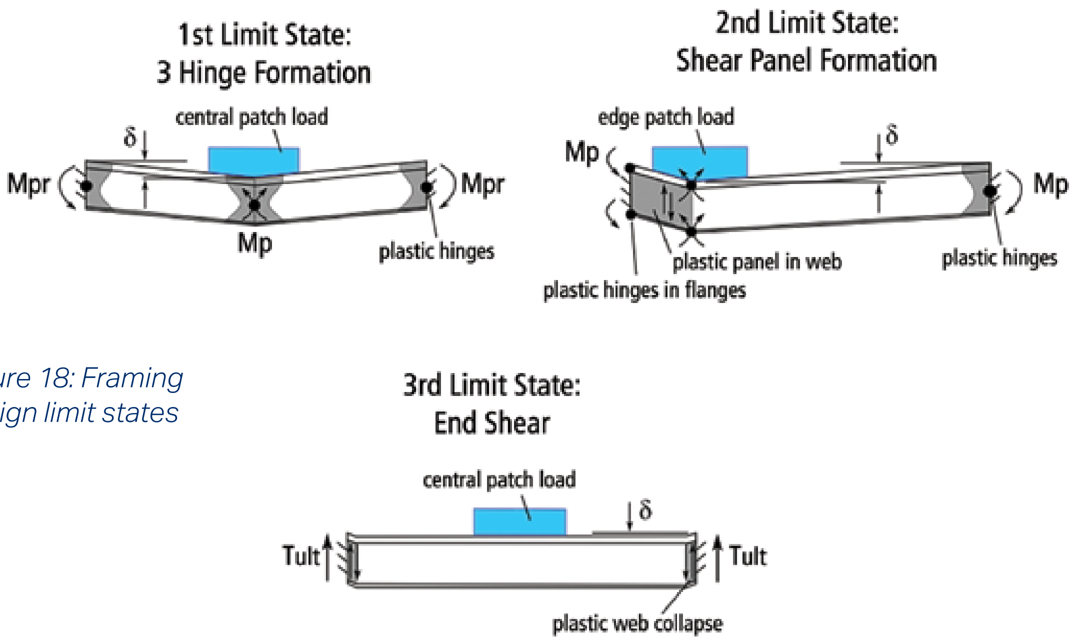

Figure 18: Framing design limit states

The shell plate thickness requirements are derived using ultimate strength criterion where the ultimate state is determined when plastic folding occurs due to perfectly plastic hinge formation. Figure 17 shows the ice load application and deformed shell plate transition in the ultimate state.

The local frames in side structures and bottom structures are to be dimensioned such that the combined effects of shear and bending do not cause the development of a plastic collapse mechanism. The plastic section modulus requirement is derived from an analytical energy method considering three limit-states shown in Figure 18. The IACS Requirements for Polar Class rigorously treat bending and shear interaction by taking into account actual section shape in the calculation procedure. The application of an iterative procedure may be advantageous for the designer to optimize the frames for the shear requirement and section modulus requirement. The scantling requirements are provided for both transversely and longitudinally framed structures.

Machinery Requirements

Part III of the IACS Requirements for Polar Class provides specific machinery requirements related to the strength of main propulsion, steering gear, emergency and other essential auxiliary support systems. Propeller ice interaction load formulas form the basis of the propulsion line component strength calculations. The calculated loads are the expected, single occurrence, maximum values for a ship's entire service life in normal operation conditions. Design load formulas are provided for both open and ducted propellers and include the maximum backward and forward blade bending forces, blade spindle torque, propeller ice torque, and propeller ice thrust applied to the shaft. The propeller blades should be designed with respect to two overall limit states, namely extreme static and fatigue. The extreme criterion is based on the calculated maximum expected loads applied via finite element analysis with acceptance criteria for permissible stress levels. Propeller blade fatigue criterion is based on a load distribution for the ship service life and an S-N curve of the blade material. The propulsion line components should be designed according to the "selective strength principle" so that the first damage does not cause significant risk to the ship's safety and other shaft line components. In most cases, the propeller is considered the weakest component.

ABS Advantage in Ice Class Rules

Although the IACS Polar Class UR adopt many modern technologies, they should be considered as the minimum requirements. Some important issues which are normally addressed in other ice class rules are subject to the requirements of each of the classification societies. These gaps include icebreaker notation, propulsion power requirements, scantling requirements for large structure members, inertial force for internal structures, ice loads for non-icebreaking bow forms, ice loads for stern icebreaking, among others. To support the industry demand for a complete ice class requirements and reliable design tools,

- ABS has fully adopted the IACS UR Polar Class UR in ABS Rules and offers an optional PC "ENHANCED" notation that covers the numerous requirement gaps left in the IACS UR.
- ABS offers the PolarQuickCheck software to easily verify the compliance to the Polar Class structural requirements by designers.
- ABS offers web-based software, WebCalc, to carry out machinery rule checks.

Other ABS Ice Class Rules

ABS continues to offer lighter ice class notations under the ABS First-year Ice Class Rules (SVR 6-1-5) and the Finnish-Swedish Ice Class Rules (or 'Baltic Rules', ABS SVR 6-1-6). These ice classes offer options to ship owners seeking limited ice capabilities. Under certain ice conditions, the Baltic and First-year ice classes can be used within the Polar Code for Category C and possibly Category B ships.

ABS Advantage in Novel Ice Class Ship Design

Although the Polar Class rules are adequate for most traditional ice-strengthened designs, vessels with novel design features or intended for unique operations need to be supplemented with additional methods of structural and operational assessment. For example, naval vessels may have quite unique operational scenarios that may cause additional structural risks. In this regard, ABS has developed "scenario-based" design tools that can be used for the ice load estimation for the ice-hull interaction scenarios that have not been considered in the IACS Polar Class UR. ABS has also developed the use of nonlinear FEA procedures to assess the structural responses considering the plastic design approach and grillage effects for hull structures including large members.

Appendix 2 | Ice & Ice Charts

Sea ice and glacial ice are often found in Polar oceans. Sea ice grows during the winter months as the ocean surface freezes and can melt during the warmer summer months, although some sea ice remains all year in certain regions. An illustration of sea ice development is shown in Figure 19. Glacial ice is "of land origin", formed over thousands of years by the accumulation and re-crystallization of packed snow. Ice islands and icebergs enter the sea from glaciers and ice sheets that 'calve off' from the land. Many will turn into smaller bergy bits or growlers as they degrade in the open ocean.

Sea Ice Types

Sea ice is any form of ice found at sea which has originated from the freezing of sea water. It can be broadly described as new ice, young ice, first-year ice and old ice. These categories reflect the age of the ice and include different forms and thicknesses at various stages of development.

In winter, sea ice typically starts growing close to the coastline. This 'land fast' ice is attached to the coast and does not move. Further offshore ice is typically in the form of 'pack ice'. This is a region of highly variable ice conditions present in varying areal concentrations, including broken pieces (floes) with a range of sizes, ages and thicknesses. The pack is highly mobile, moving with the wind and currents, with its characteristics constantly changing. Sea ice is generally classified by stages of development that relate to thickness and age.

First-year Ice

New ice is a technical term that refers to ice less than 10 cm thick. As the ice thickens, it enters the young ice stage, defined as ice that is 10 to 30 cm thick. Young ice is split into two subcategories based on color: grey ice (10 to 15 cm thick) and grey-white ice (15 to 30 cm thick). First-year ice is thicker than 30 cm, but not more than one winter's growth. First-year ice can get up to 2m thick and is further subdivided into thin first-year ice (30 to 70 cm thick), medium first-year ice (70 to 120 cm thick), and thick first-year ice (1.2 to 2 m thick).

Multi-year Ice

Multi-year ice or old ice is ice that has survived a summer melt season and is much thicker than first-year ice, typically ranging from 2 to 4 meters thick but much thicker formations are also present. It has distinct properties from first-year ice, based on processes that occur during the summer melt. Multi-year ice contains much less brine (i.e., salt water) which makes the ice much stronger and significantly increases risks to vessel navigation.

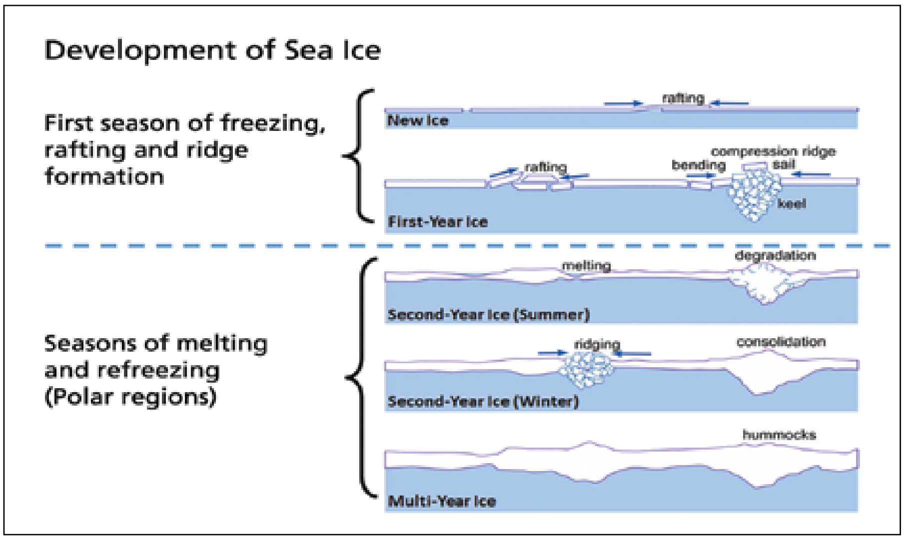

Figure 19: Sea ice formation process

Sea Ice in Nature

Sea ice is rarely a continuous, uniform, smooth sheet of ice, but rather a complex surface that varies dramatically across even short distances. When wind, ocean currents, and other forces push sea ice around, ice floes (sheets of ice floating in the water) collide with each other, and ice piles into ridges and keels. Ridges are small "mountain ranges" that form on top of the ice; keels are the corresponding features on the underside of the ice. The total thickness of the ridges and keels can be several meters, in some cases 30-40 meters thick. Ridges are initially blocky with very sharp edges. Over time, especially during the summer melt, the ridges erode into smaller, smoother "hills" of ice called hummocks.

Leads are regions of open water shaped in narrow, linear features. When they freeze, leads tend to contain thinner and weaker ice that allows vessels to more easily navigate in the ice. A diverging ice field refers to ice fields that are subjected to a diverging motion, reducing ice concentration and relieving stresses in the ice. A compacting ice field occurs when pieces of floating ice are subjected to a converging motion, which increases ice concentration and produces stresses. This may result in ice deformation or pressured ice condition. Beset is a situation in which a vessel is surrounded by ice and unable to move. It often occurs in pressured ice condition.

Sea Ice & Ice Navigation

The presence of sea ice is one of the increased risk factors identified during the development of the Polar Code. Due to the complex nature of sea ice, an 'ice regime' is typically used to define any mix or combination of ice types, including open water, and it can be related to the level of risk on the navigation of the vessel in the region. The ice regime is used in the Polar Code as a measure to establish the operational limitations of the vessel in the POLARIS and AIRSS systems. This section describes how the ice regime is defined based on information included on an ice chart.

Concentration is the ratio expressed in tenths describing the area of the water surface covered by ice as a fraction of the whole area. Total concentration includes all stages of development that are present while partial concentration refers to the amount of a particular stage or of a particular form of ice and represents only a part of the total.

The Egg Code

Ice charts consolidate all available information on ice cover using the "ice egg code", which in most sea areas will be formatted according to standard WMO principles and terminology. An example of how the ice egg code is defined is shown in Figure 20.

The basic data concerning (1) concentrations, (2) stages of development (age) and (3) form (floe size) of ice are contained in a simple oval form. Typically, three ice types are described within the oval, although a fourth can be added to describe trace amounts of certain ice types.

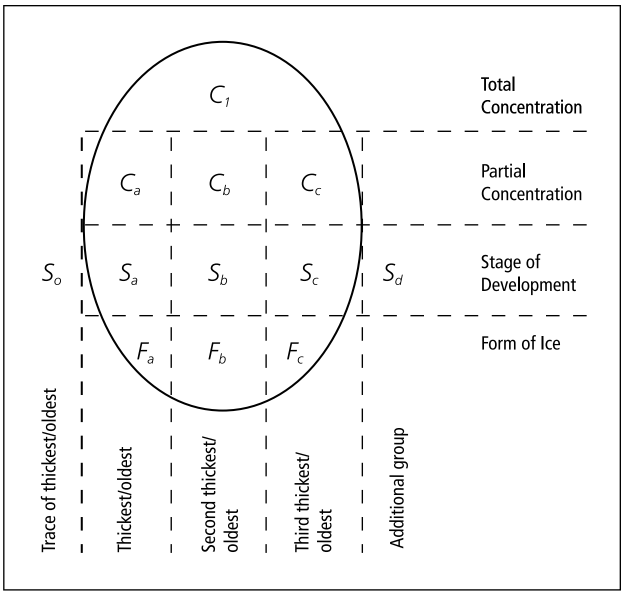

Figure 20: Egg code

- The symbols Ca, Cb, Cc and Fa, Fb, Fc correspond to Sa, Sb, Sc respectively
- Concentration (C) - Total concentration (Ct) of ice in the area reported in tenths and partial concentrations of thickest (Ca), second thickest (Cb), third thickest (Cc) and fourth thickest (Cd) ice in tenths
- Stage of Development (S) - Stage of development of thickest trace of ice (So), thickest (Sa), second thickest (Sb) and third thickest (Sc) ice and any thinner ice type Sd, of which the concentrations are reported by Ca, Cb, Cc, Cd, respectively.
- Form of Ice (F) - Floe size corresponding to Sa, Sb, Sc, Sd, and Se. Floe sizes also follow standard WMO terminology and are grouped into ranges.

Ice Charting

Ice charts are one of the most useful resources to provide a ship with an overview of the ice conditions in a certain area, in advance of when it is needed. The information can be used for strategic planning and is very useful when the ship is confronted with difficult ice conditions, to help determine alternate routes. Figure 21 shows a typical ice chart produced by the Canadian Ice Service. The chart identifies regions of ice regimes and the characteristics are presented in egg codes. More complete explanations, examples, and archived ice charts can be obtained from various national ice services including:

- Canadian Ice Service (https://www.ec.gc.ca/glaces-ice/)
- US National / Naval Ice Center (http://www.natice.noaa.gov/)
- Arctic and Antarctic Research Institute (http://www.aari.ru/)
- Danish Meteorological Institute / Greenland Ice Service (http://ocean.dmi.dk/polarview/)

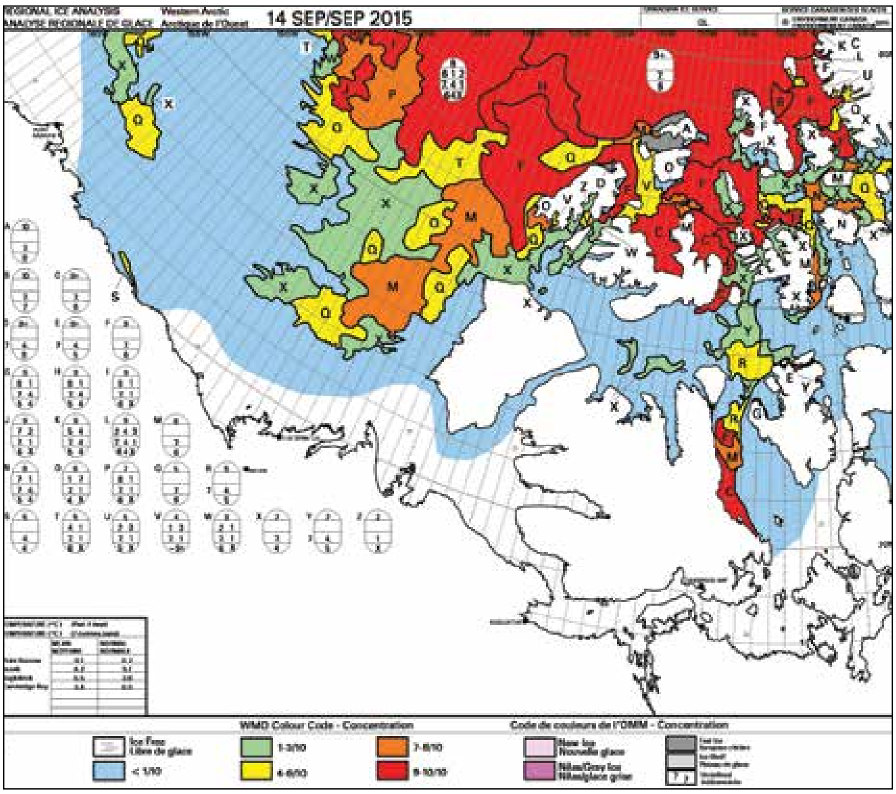

Figure 21: Sample ice chart
Courtesy of Canadian Ice Service

Appendix 3 | Temperature

The Polar Code considers "low air temperature" as a hazard which can lead to elevated levels of risk during operations in Polar waters. Low temperature environments present several challenges, for example:

- Harsh working environment and reduced human performance
- Hindrance to maintenance and emergency preparedness tasks
- Material embrittlement and potential loss of equipment efficiency
- Reduced survival time and performance of safety equipment and systems
- Freezing of sea spray on deck and equipment leading to ice accretion

Prior to the introduction of the Polar Service Temperature (PST), there was a lack of standard approaches for designers and operators to consider temperature when selecting materials and specifying equipment for ships operating in low temperature. Classification societies and other available standards each have their own 'temperature definition' used for winterization notations. The PST is a positive step toward a more consistent application.

Temperature Definitions in Marine Industry

Temperature data can be used for both marine planning and operational activities. Operational and navigational decision making, including short-term voyage planning, will often use short-term forecast temperature data provided by national weather services. These are typically reported as daily highs and daily lows. Longer term planning will generally make use of historical temperature data records, such as weather station measurements or hindcast model data, for the specification of design requirements or route selections for an existing ship. Three different statistical temperature parameters based on available historical data are generally used for cold weather ship design and longer term planning.

- MDHT – Mean Daily High Temperature
- MDAT – Mean Daily Average Temperature
- MDLT – Mean Daily Low Temperature

The International Association of Classification Societies (IACS) recognized the importance of appropriate steel grade selection for low temperature operations and used the Mean Daily Average Temperature (MDAT) to determine the ship's Design Service Temperature (DST) in the IACS Unified Requirements – S6. ABS adopted a similar approach for equipment and materials in the ABS LTE Guide.

Polar Service Temperature (PST)

The Polar Code requires all exposed systems and equipment onboard Polar ships (in particular safety systems) to be full functionality at the anticipated low temperature, defined as the Polar Service Temperature (PST). This is the first formal treatment of temperature in any IMO instrument.

The threshold for "ships operating in low air temperature" is based on the Mean Daily Low Temperature (MDLT) for the intended area and season of operation. This is a statistical mean of daily low temperatures for each calendar day of the year, over a minimum 10-year period. Ships that operate in areas and seasons where the Lowest MDLT is below -10°C, are considered to be operating in low air temperature and therefore a PST must be specified for the vessel and shall be at least 10°C below the lowest MDLT. Figure 22 illustrates how the PST would be defined. An applied example of the determination of an appropriate PST for seasonal operations near Barrow, Alaska is shown in the Figure 34. The following steps should be taken when determining the lowest MDLT:

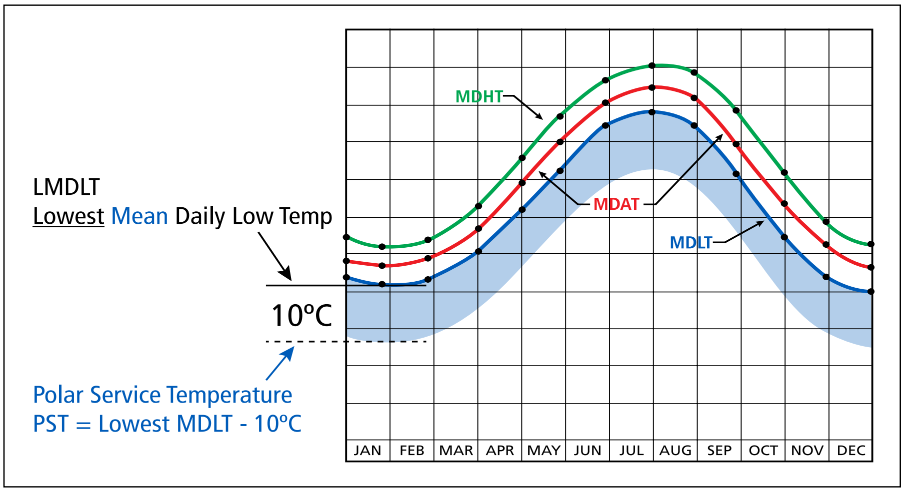

Figure 22: Polar Service Temperature definition

1. Identify the geographical area and time window (e.g. season, months, weeks, etc.) of operation
2. Determine the daily low temperature for each day within the window for at least a 10-year period
3. Determine the average of the daily low values over the 10-year period for each day
4. Take the lowest of the averages for the identified season of operation

The MDLT threshold level (-10°C) was selected by IMO based on historical temperature records from ports just outside of the Polar waters. Ships trading into these ports in winter are not required to have any special provisions for temperature under SOLAS. If a ship with a Polar Ship Certificate was required to carry special equipment or adopt operating restrictions in the same conditions, this would have imposed a competitive disadvantage.

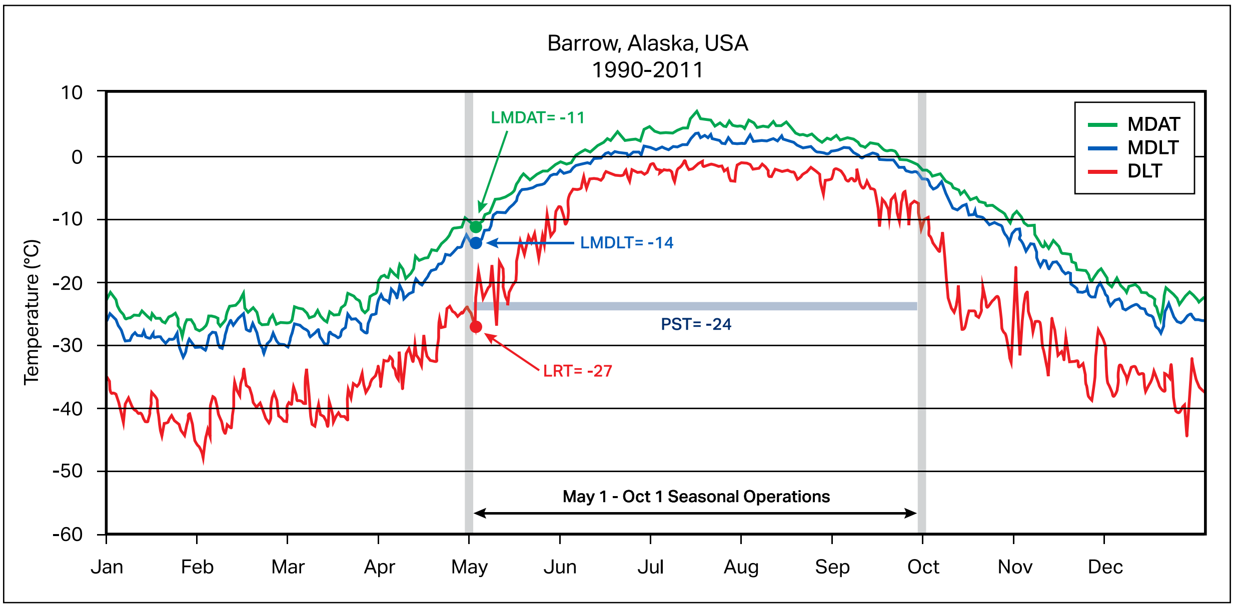

Figure 23: Example PST selection for seasonal operations

ABS Advantage

The availability of low temperature data in the Polar areas can be variable and in some cases scarce. ABS published key statistics of thirteen (13) selected land-based weather stations in the Arctic and Antarctic areas in the latest revision of the *ABS LTE Guide (2015)*. Historical temperature statistics are provided in a bi-monthly tabular form including the MDAT, MDLT, Record Low, and standard deviation of the MDLT. An example for the Aasiaat, Greenland station is presented in Figure 24. These data sets can be used to select a PST for ships operating within nearby areas of these locations.

Also published in the latest revision of the *ABS LTE Guide (2015)*, are bi-monthly isothermal contour plots of surface air temperatures for Arctic waters and the Antarctic area. Several examples are offered below where the temperature data is processed according to the *Mean Daily Low Temperature (MDLT)* parameter. To estimate the appropriate Polar Service Temperature (PST), 10°C is subtracted from the values in these plots. These plots can be a useful reference for designers and owners who are interested in the application of the PST.

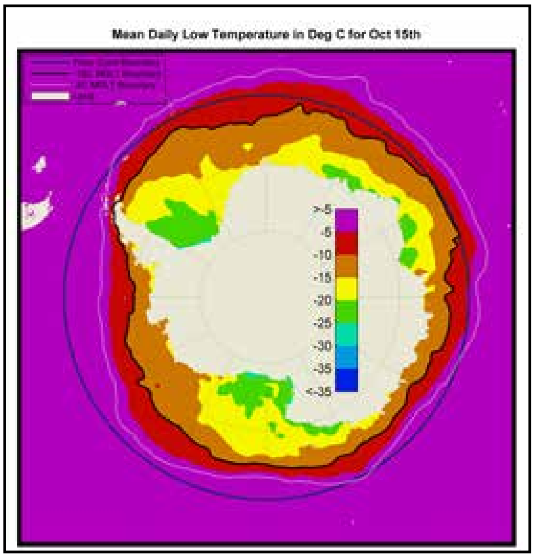

Figure 25: Antarctic October 15th MDLT isothermal contour plot

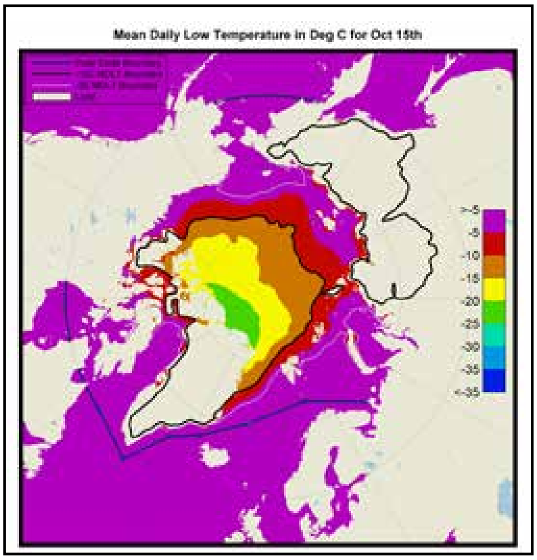

Figure 26: Arctic October 15th MDLT isothermal contour plot

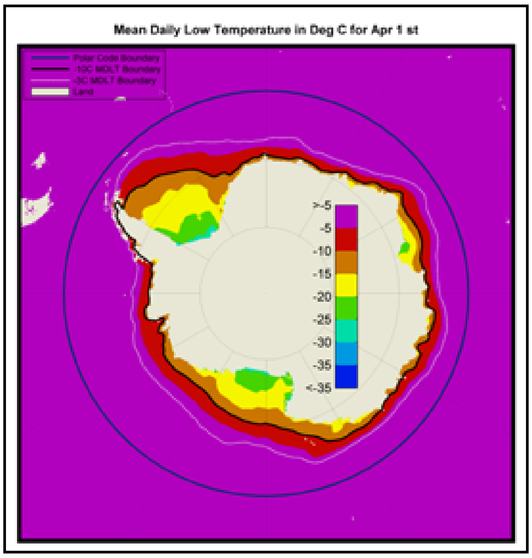

Figure 27: Antarctic April 1st MDLT isothermal contour plot

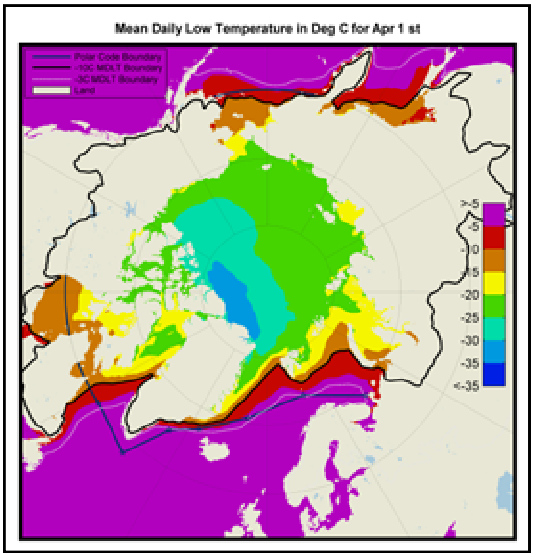

Figure 28: Arctic April 1st MDLT isothermal contour plot

Appendix 4 | High Latitude Navigation

Navigating in high latitudes requires increased care in the procedures and in the use of information. The remoteness of the Arctic and the proximity to the North Magnetic Pole has an effect on the charts that are supplied and the navigation instruments that are used with them. This section discusses some of the effects and limitations on charts and instruments used in the Arctic.

Navigational Equipment and Navigational Information

Vessels intended to operate in high latitudes are recommended to be equipped with radar, gyro compass, echo sounder, searchlights, and facsimile receivers. The quality of charts covering Arctic regions can be poor compared to the low latitude areas. Regarding the use of charts in the Arctic areas, the projections method and the accuracy of the surveys are of primary concerns.

Projections & Accuracy of Navigation Charts

To compensate for the fact that the meridians converge as they near the pole, the scale of the parallels is gradually distorted. In the Arctic waters, the common projections are Lambert Conformal Conic, Polyconic, and Arctic Stereographic while the Mercator projections suffer too much distortion in latitude. The number of different projections makes it important to check the type of projection and any cautions concerning distances, bearings, etc. For example, the common practice with Mercator charts is to use the latitude scale for distance, which is not possible in Arctic waters. To eliminate the corrections required by the use of compass bearings for fixing positions, three radar ranges of known features can provide an accurate position.

The accuracy of charts in the Arctic can vary widely according to the date of survey and the technologies available at that time. In general, the more recent the survey, the more reliable and accurate the results. Even new editions of charts may contain a mix of older and newer data. Hence, precautions are to be taken, such as:

- Checking the projection and understanding its limitations for the method of measuring distances and taking bearings
- Checking the date of the hydrographic survey
- Checking for evidence of reconnaissance soundings.

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Mariners should always cross-reference positions plotted on electronic charts with the largest possible scale paper charts of the same area, as different electronic chart systems available on the market may vary greatly in the information presented on the electronic display. Mariners should proceed with due caution and prudent seamanship when navigating in the Arctic, especially in poorly charted areas or when planning voyages along new routes.

Compasses

The magnetic compass depends on its directive force upon the horizontal component of the magnetic field of the earth. As the North Magnetic Pole is approached in the Arctic, the horizontal component becomes progressively weaker until at some point the magnetic compass becomes useless as a direction measuring device. Hence, the magnetic compass is frequently of little use for navigation. If the compass must be used, the error should be checked frequently by celestial observation. The gyro compass starts losing accuracy from about 70°N and it becomes unusable north of about 85°N. The numerous alterations in course and speed and collisions with ice can have an adverse effect on its accuracy. Therefore, when navigating in the Arctic, the ship's position should be cross-checked with other navigation systems, and in very high latitudes approaching the North Pole, the GPS is a more reliable alternative. A new type of compass called "Satellite Compass" has been recently introduced which uses the GPS signal.

Radar for Position Fixing

In general, Arctic or cold conditions do not affect the performance of radar systems. A real problem with radar in the Arctic concerns interpretation of the screen for purposes of position fixing. Problems arise from either mistaken identification of shore features or inaccurate surveys. Low relief in some parts of the Arctic makes it hard to identify landmarks or points of land. Additionally, ice piled up on the shore or fast ice may obscure the coastline. In this regard, radar bearings or ranges should be treated with caution and visual observations should always be made. The Automatic Identification System (AIS) has now become mandatory for most large vessels and is a useful tool in such a case to separate echoes of vessels from icebergs on a radar display. It is also very useful to be able to identify a nearby but unseen vessel when working in ice, for the trading of ice information, details of progress.

Global Positioning System (GPS)

The Global Positioning System (GPS) is a space-based radio-navigation system that permits users with suitable receivers, on land, sea or in the air, to establish their position, speed and time at any time of the day or night, in any weather conditions. The navigational system consists nominally of 24 operational satellites in six orbital planes, and an orbital radius of 26,560 km. The satellites continuously transmit ranging signals, position and time data that is received and processed by GPS receivers to determine the user's three-dimensional position (latitude, longitude, and altitude), velocity and time. With a ship at or near the North Pole all the satellites would be to the south, but well distributed in azimuth, creating a strong fix. The exception to this is the vertical component of a position which will grow weaker the further north a ships sails because above 55°N there will not be satellites orbiting directly overhead. One minor advantage of the drier, polar environment is the efficiency of the receiver to process satellite data.

Global Navigation Satellite System (GLONASS) is a radio-based satellite navigation system operated for the Russian government. It complements and provides an alternative to the United States GPS and is currently the only alternative navigational system in operation with global coverage and the same precision. The GLONASS constellation has 24 operational satellites to provide continuous navigation services worldwide.

Radios

Radio communications in the Arctic, other than line of sight, are subject to interference from ionospheric disturbances. Whenever communications are established, alternative frequencies should be agreed upon before the signal degrades. Use of multiple frequencies and relays through other stations are methods of avoiding such interference.

INMARSAT

Inmarsat owns and operates three global constellations of 11 satellites flying in geosynchronous orbit 37,786 km (22,240 statute miles) above the Earth. Use of INMARSAT services in the Arctic is the same as in the south, until the ship approaches the edge of the satellite reception at approximately 82°N. At high latitudes where the altitude of the satellite is only a few degrees above the horizon, signal strength is dependent on the height of the receiving dish and the surrounding land.

As the ship leaves the satellite area of coverage, the strength of the link with the satellite will become variable, gradually decline, and then become unavailable.

Mobile Satellite (MSAT) / SkyTerra Communications Satellite System

MSAT-1 and MSAT-2 geostationary satellites have been delivering mobile satellite voice and data services to North America since 1995. The satellite phone network and local cellular networks are compatible, allowing a user to communicate over the regular cellular network, and only rely on the satellites in areas outside the range of cell phone towers. This is useful in sparsely populated areas where the construction of cell towers is not cost-effective, as well as to emergency-response services which must remain operational even when the local cellular network is out of service.

Iridium Satellite System

The Iridium satellite constellation consists of 66 cross-linked Low Earth Orbit (LEO) satellites that orbit from pole to pole with an orbit of roughly 100 minutes. This design means that there is excellent satellite visibility and service coverage at the North and South poles.

Credit: The information is from the Canadian Coast Guard. (http://www.ccg-gcc.gc.ca/Icebreaking/Ice-Navigation-Canadian-Waters/Navigation-in-ice-covered-

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