ACCESS
Arctic Climate Change
Economy and Society

SEVENTH FRAMEWORK PROGRAMME

Project no. 265863

ACCESS

Arctic Climate Change, Economy and Society

Instrument: Collaborative Project

Thematic Priority: Ocean.2010-1 "Quantification of climate change impacts on economic sectors in the Arctic"

D2.21 – Review of rules and regulations for Arctic shipping/ recommendation for changes due to Climate Change

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Dissemination Level		
PU	Public	X
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

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1. Introduction

1.1 General

Increased industrial activities in acrtic and sub-arctic regions for purpose of transport and resource exploration and production lead to the demand for comprehensive international rules. The regulations have to cover following aspects:

- Safety of life at Seas (SOLAS)
- Environmental protection, pollution prevention
- Sub tasks are:
- Casualty Prevention
- Structural integrity and Manoeuvrability of Ships
- Functionality of On-board Systems (Winterization)

Currently a lot of basic rules with different objectives are defined by different authorities. The rules are mandatory within specific territories in arctic and sub-arctic regions. Additionally superior rules are to be applied for all sea areas including those in ice covered regions.

1.2 Task Description

Task 2.2 Rules and Regulations for Marine Arctic Transport in view of the changing ice conditions. The aim of this task is to (1) review existing rules and regulations for shipping in the Arctic, (2) identify gaps and shortcomings with respect to environment impact and risk assessment and (3) provide suggestions for adjustments and consequences from the impact of climate change (D2.7). HSVA will use its long experience in full scale trials of different type of vessels in arctic and subarctic regions (more than 20 expeditions in ice invested waters). During these trials not only the icebreaking capability of the vessels was determined but also the load on the hull of the vessel and the propulsion system was observed in different ice conditions and Features. HSVA together with the partners UCAM and JSC will collect and compile available public information regarding those ice trials and benchmark this against the existing rules and regulations of different classification societies and national and international organizations and authorities to identify weaknesses and gaps. Reports of incidents and accidents with vessels in arctic and subarctic regions will also be reviewed**,** analysed and taken into consideration in this subtask. The results of this study will be updated for the predicted ice scenarios in the Arctic.

The results will be transmitted to WP5 for further use in governance actions. (HSVA, UCAM, JSC) [1]

2. Legal Situation in the Arctic

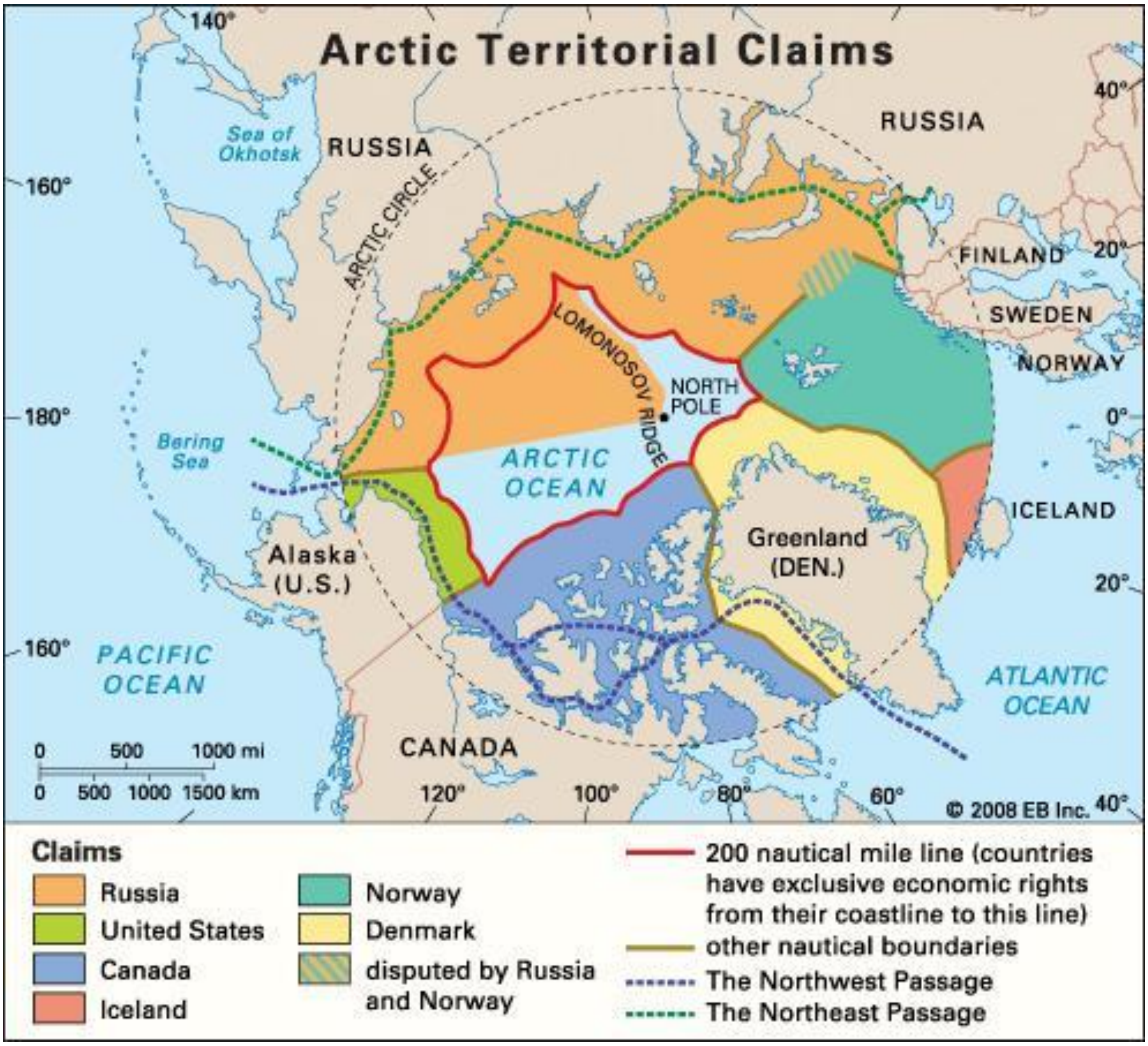


Figure 1 Territorial claims in the arctic ocean [2]

When discussing rules and guidelines, which are covered by national law in the arctic waters, an important fact is the actual territory of application for the laws. As the official process of territory definition is not yet finalised, national rules and guidelines can only be defined for coastal areas within the three mile zone. This includes for example obligation for icebreaker assistance and special environmental protection rules for sensitive sea areas.

International rules on the other hand have to be ratified by a large number of member states within organisations like IMO and are therefore more difficult and less fast to be developed.

3. Incidents and Accidents in Arctic Waters

3.1 Accidents in the past

Kara Sea:

Collision of merchant vessel Arkhangelsk with assisting icebreaker due to unforeseen stop in a ridge

Laptev Sea:

Damage of Steamship Vetlugales in compressive ice in 1986, following a convoy assisted by three nuclear icebreakers, leakage and flooding of several cargo holds

ChukchiSea:

More than 30 Vessels damaged in ice compression in 1983, 19 Ships of Far Eastern Shipping Company damaged

Nina Sagaydak, Shipwreck, 1937, Convoy, led by icebreaker, ice 8/10 - 9/10, compression due to old ice drift of ice massive origin, damage of screw and rudder, collision with two other vessels of convoy, damage of surface plating, additional hull damage on several cargo holds and engine room in multi-year ice, vessel abandoned [3]

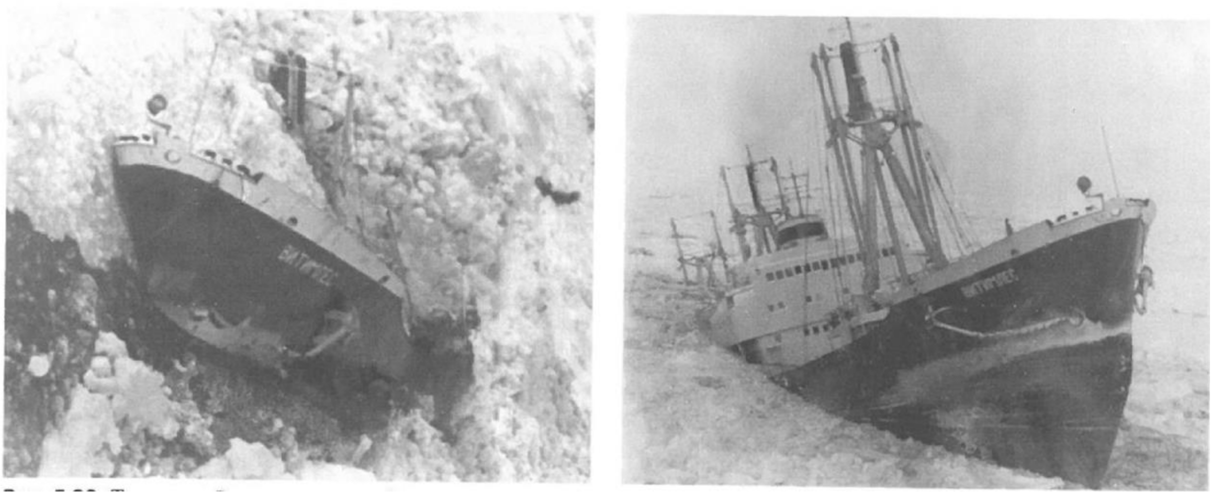


Figure 2 Accident of the steamship Vitimles in East Siberian Sea [3]

3.2 Recent accident with Tanker on Northern Sea Route

Figure 3 Nuclear powered icebreaker Taimyr escorting the tanker Nordvik after an accident [4]

The following article published in the Barents Observer in 2013 presents an example of a recent incident with a relative low ice classed vessel that could have led to fatalities**.**

"The 138 meter long, 6403 dwt tanker "Nordvik" was struck by ice while sailing in the Matisen Strait to the north of the Taimyr Peninsula on September 4. The vessel, which was loaded with diesel fuel, struck an ice floe and started taking in water. "Nordvik" was built in Bulgaria in 1985.The vessel is sailing towards Murmansk at 4 knots. There is no information on any oil leaks or other damages to the environment."

According to information from the Northern Sea Route Administration's web site, the vessel had permission to sail in the Kara Sea and the Laptev Sea.

The Seafarer's Union of Russia says the tanker should never have sailed in the area, and blames the ship owner, Khatanga Commercial Port, for putting the crew's and the fragile Arctic ecology in danger.

"Yesterday's accident was a direct threat to the lives of sailors and the ecology of the Arctic", Aleksander Bodnya says to the union's web site. "Vessels like that should not be sailing on NSR, simply because they are not capable of withstanding the ice conditions."

The Seafarer's Union underlines that the system for search and rescue is not yet fully developed in the area where the incident happened, and that a serious accident could have been crucial for the crew. "Not to forget the ecology – a large amount of diesel fuel could have leaked out into the sea, and who would be there to clean it up, is quite unclear."

"Nordvik" is an Ice 1 class (L4) tanker and is only allowed to sail on the Northern Sea Route (NSR) in light ice conditions. The ice conditions in the northeastern parts of the Kara Sea were regarded as "medium" by Roshydromet in the period when the accident happened. [5]

4. Review of Existing Rules and Guidelines for Arctic Marine Operation

4.1 Overview of Existing Rules for Polar Operation

Presently many rules and guidelines defined and enforced by different institutions in different sea areas coexist. Namely the institutions involved in the rules development are the IMO, the major classification societies and the local administrations of the states.

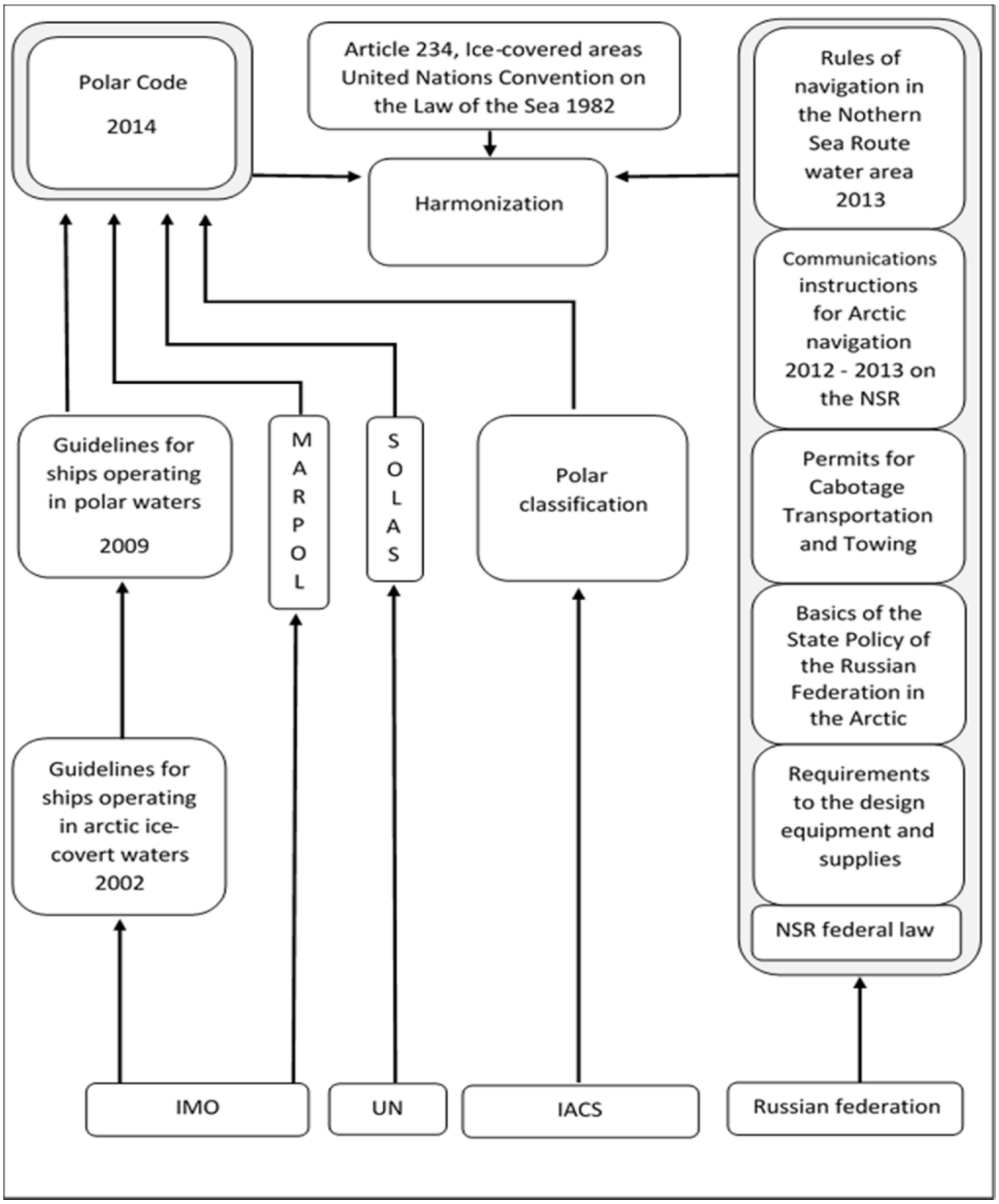


Figure 4 Overview of Existing Rules specified and monitored by different authorities [6]

4.2 IMO Polar Code

The IMO “Polar Code”, to be published in 2014 and presumably ratified in 2015, is under development on an international level. This set of regulations will be the result of “Guidelines for Ships Operating in Polar Waters” created in 2009, which in turn result from “Guidelines for Ships Operating in Arctic Ice-Covered Waters” of 2008, and other SOLAS and MARPOL requirements. As opposed to previous IMO Guidelines the Polar Code is expected to be compulsory.

In May 2014, the Maritime Safety Committee (MSC) approved, for consideration with a view to adoption at its November 2014 session (MSC 94), the draft new SOLAS chapter XIV “Safety measures for ships operating in polar waters”, which would make mandatory the Introduction and part I-A of the International Code for Ships Operating in Polar Waters (the Polar Code). [7]

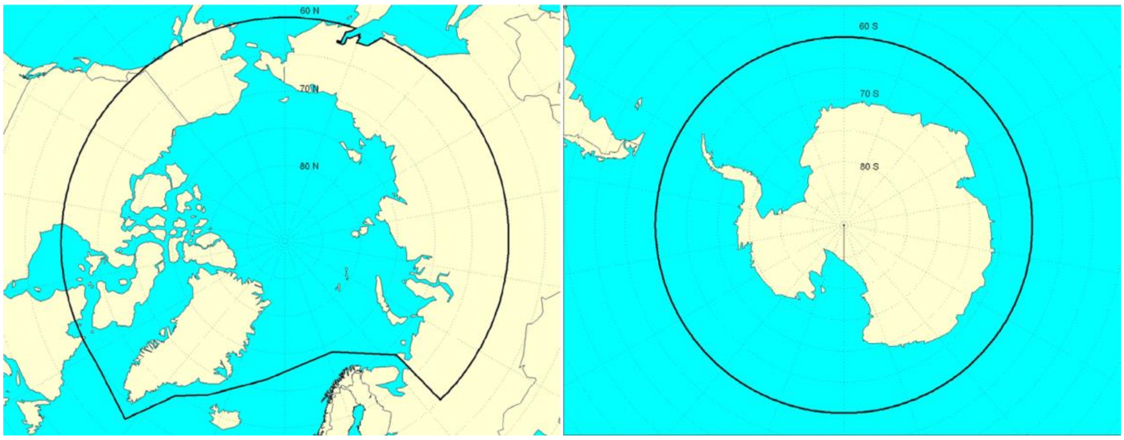


Figure 5 Designated application zone for polar code in arctic and Antarctic waters [7]

The polar code defines required standards for several areas of ship technological safety:

- Structure

  Global / local ice loads

  Materials / corrosion protection

- Intact Stability

  Sufficient positive stability (also when riding up on ice)

- Stability in Damaged Condition

- Subdivision

Double skin construction to separate pollutants from surrounding water

- Accommodation and Escape Measures

Sufficient facilities for life sustaining environment when trapped in ice

Emergency heating

Escape access doors from accommodation or working spaces must not be blocked by ice accretion

- Anchoring and Towing Arrangements

- Main Machinery and Propulsion System

Designed to avoid release of pollutants in low ambient temperatures

Designed to withstand loads and vibrations induced by propeller / hull / rudder –ice interaction

Designed to be operable also in heeled or trimmed condition during ice breaking process

Sufficient main propulsion power for safe operation in design ice condition

Auxiliary Machinery Systems

- Electric Installations

Emergency power for communication, batteries to be protected from low temperatures

Fire Safety

- Life Saving Appliances and Survival Arrangements

Protective clothing

Personal survival kits

Group survival kits

Lifeboats

fully enclosed lifeboat type

ice accretion removed frequently from all life saving devices and launching installations

- Navigational Equipment

Ice Routing Equipment (Ice information display on electronic navigation chart)

- Operational Arrangements
- Crewing
- Emergency Equipment
- Environmental Protection and Damage Control

4.3 Classification Societies

In order to account for higher operational loads due to ice, different ice classes for ships are defined by many classification societies. Theses ice classes include different levels of reinforcement of main structural components of the ships hull like shell plating, frames and stringers. Additionally special caution is given to the design of manoeuvring components and the shaft train (see section 2.4.2). Usually there are similarities between the ice classes defined by different societies with regard to the design ice conditions and the resulting impact on the design of the ship. Nevertheless each classification society has developed rules with specific differences such that for an ice class of one institution complete equivalent rules may not be found in all other institutions.

	Ice Class				
RS (Rules 2003)	LU8	LU7	LU6	LU5	LU4
RS (Rules 1995)	-	ULA	-	UL	L1
IACS POLAR	PC2	PC3	PC4	PC5, 6	PC7
ASPPR, 1995	CAC2	CAC3	CAC4	A	B
ABS	A4	A3	A2	A1	A0
DNV	POLAR-20	POLAR-15	POLAR-10 ICE-15	ICE-10 ICE-1A*	ICE-05 ICE-1A
LR	AC2	AC1.5	AC1	1AS	1A
GL	Arc3	Arc2	Arc1	E4	E3
FSICR	-	-	-	IA Super	IA
BV	-	-	-	IA Super	IA
ClassNK	-	-	-	IA Super	IA
KR	-	-	-	ISS	IS1
CCS	-	-	-	B1*	B1
RINA Italian	-	-	-	1AS	IA

Table 1 Approximate Correspondence Table by CNIIMF [8]

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

Table 2 Polar Class Description [9]

In order to illustrate the impact of ice class on a ships design some exemplary restrictions for hull shape characteristics specified within the RMRS [10] ice class requirements are shown below.

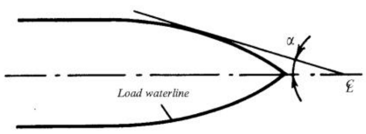


Fig. 3.10.1.2-1:
α — slope of summer load waterline at the section considered, in deg.

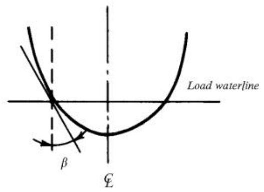


Fig. 3.10.1.2-2:
β — slope of frame on the level of summer load waterline at the section considered, in deg.

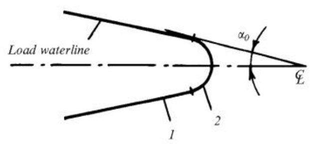
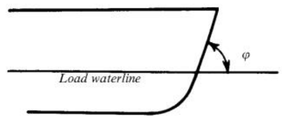


Fig. 3.10.1.2-3:
α_0 — slope of summer load waterline at the fore perpendicular, in deg;
1 — shell plating; 2 — stem



Distance from section to fore perpendicular	0,1L	0,2 — 0,25L	0,4 — 0,6L	0,8 — 1,0L
Permissible range of the angle variation β, in deg.	40° — 55°	23° — 32°	15° — 20°	Approximately coinciding with the angles β of within 0 — 0,2L

Hull configuration parameter	Category of ice strengthening			
	Arc8, Arc9	Arc7, Arc6	Arc5	Arc4	Ice1, Ice2, Ice3
φ not greater than	25°	30°	45°	60°	—
α_0 not greater than	30°	30°	40°	40°	50°
β within 0,05L from fore perpendicular, min	45°	40°	25°	20°	—
β amidships, min	15°	—	—	—	—

Figure 6 Example of hull shape requirements for ice classed vessels, RMRS **[**10]

4.4 Local Administrations

Baltic Sea:

In order to ensure safe traffic on the Baltic Sea in winter season in the early 20th century the Finnish transport authorities introduced minimum requirements for ships travelling in specified ice conditions [1]. The requirements were further developed throughout the years including introduction of different ice thickness related ice classes (IA, IB, IC) and specification of ice waterlines. Today the guidelines comprise requests for the structural integrity, outfitting and minimum required engine power. The requirements are assessed by guidelines including ice loads to be applied to certain components of the ship and formulas to determine the corresponding scantling.

For the required engine power a minimum speed of five knots has been specified which the ship shall attain in a broken ice channel while the thickness of the broken ice layer Hm is to be assumed depending on the designated ice class.

H_M

= 1.0m for ice class IA and IA Super

= 0.8m for ice class IB

= 0.6m for ice class IA

For this condition the resistance is determined based on the work of Rika et. al. including the influence of main dimension and characteristic hull shape angles (see Figure 7).

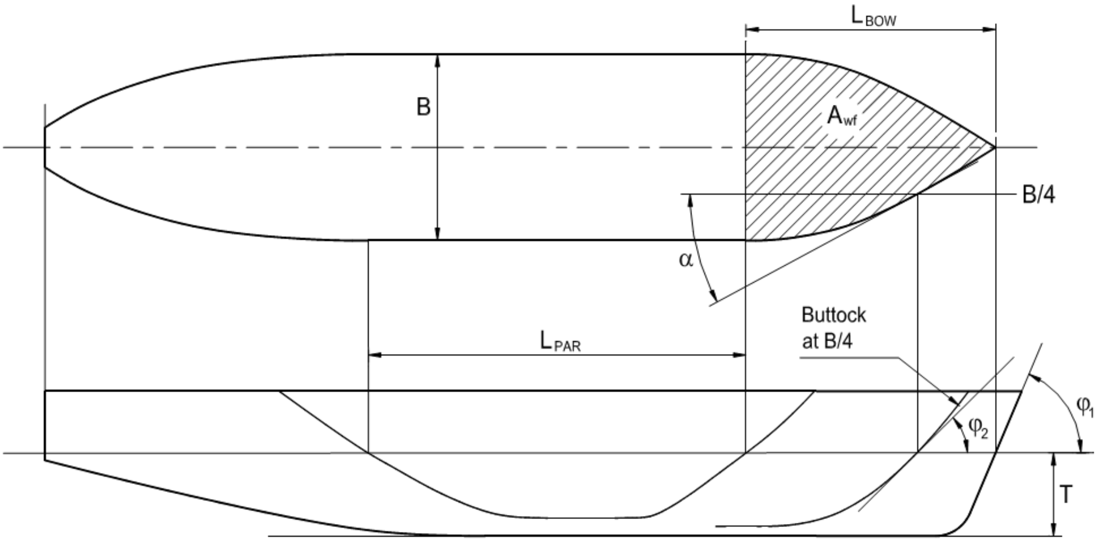


Figure 7 Extracts from the TraFi rules [11]

$$P = Ke \cdot \frac{(R_{CH}/1000)^{3/2}}{D_P} \text{ [kW]}$$

With:

P: Power

Ke: Factor for Propulsion Arrangement (CPP / FPP, Diesel Electric)

R_{CH}: Ship Resistance in Brash Ice Channel

Dp: Propeller Diameter

The ship resistance in brash ice is calculated according to an estimation formula taking into account an assumed brash ice thickness distribution, the main dimensions and some characteristic hull shape data of the ship. The required minimum engine power is defined to ensure that a ship is able to proceed at a constant speed of 5knots. Therefore the formulas are restricted to provide data for this speed condition.

Besides the definition of a minimum required engine power the Finnish Swedish Administration has developed comprehensive rules for the constructional design of the ship's hull and appendages. The rules inlcude definitions for sensitive areas along the hull (Fig 8) and ice related load assumption for dimensioning of scantling of plates and stiffeners (Fig 9).

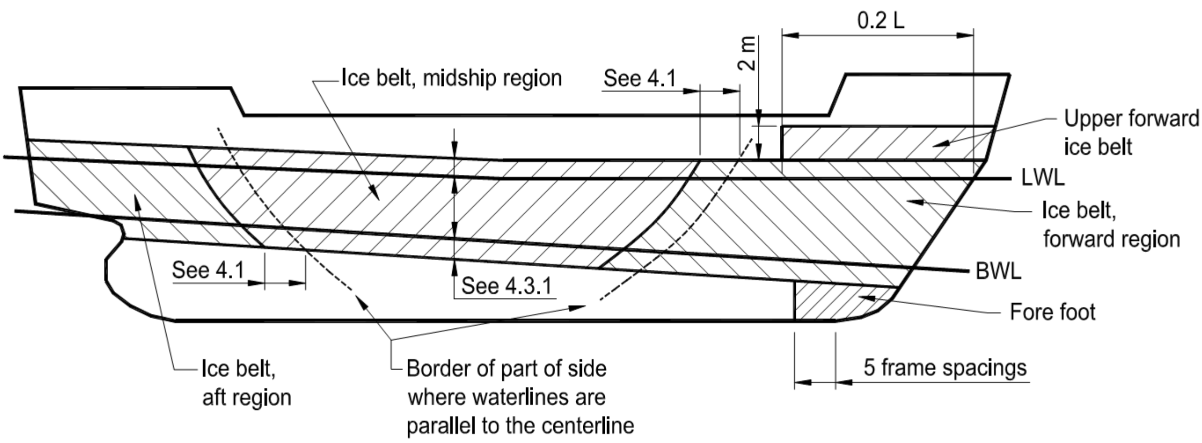


Figure 8 Ice strenghtening requirement of "Finnish Swedish Ice Class" [11]

For the pressure acting on the outer shell of the ship only a certain persentage of ice thickness is assumed to be effective (Table). Therefore a corresponding load height for each ice class is defined.

Ice Class	h_0 [m]	h [m]
IA Super	1.0	0.35
IA	0.8	0.30
IB	0.6	0.25
IC	0.4	0.22

Table 3 Load heights 14corresponding to Finnish Swedish Ice Classes [10]

Further it is assumed that the pressure on a panel will mainly be bared by the frames and therefore a load distribution as shown in Fig 9 is assumed.

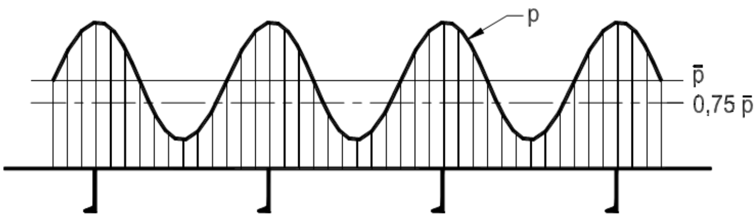


Figure 9 Design pressure distribution on a ship panel [11]

Finally the arrangement of all appendages which might be exposed to ice, is proposed. This typically includes bilge keel, rudders brackets and other shaft bearings. Protecting elements like ice knifes at the upper rear edge of the rudder are requested (Fig 10).

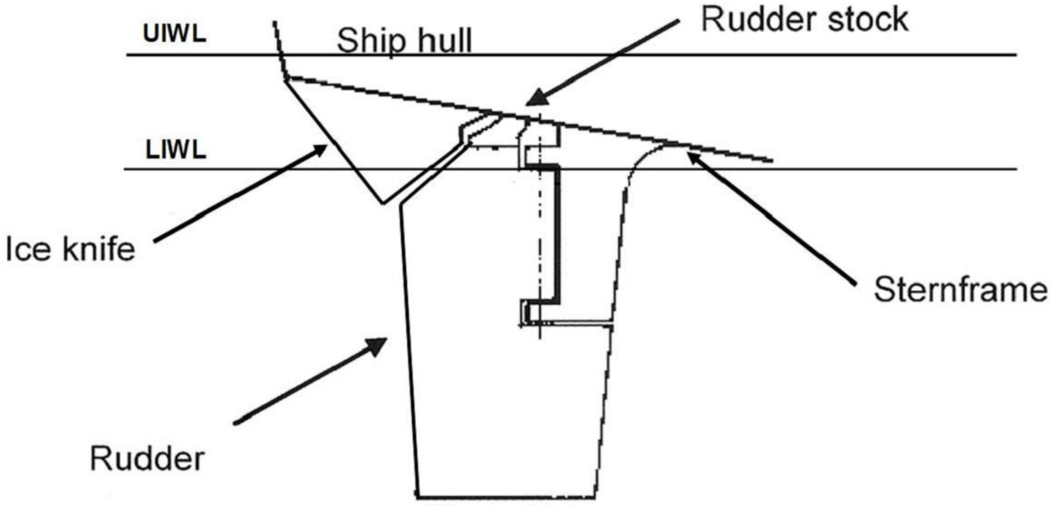


Figure 10 Recommendations for constructional arrangement of appendages [11]

Russian Administration:

Looking into the legal background of the NSR one also needs to consider the tensions between polar neighbouring states, as huge oil and gas deposits are expected in the area. Therefore, controlling the sea ways means controlling ships which also implies a certain control over transportation of commodities and natural resources.

Officially the Northeast Passage is open for civil navigation since 1991.

Navigation on the NSR is submitted to both international regulations and Russian Law. In order to justify their jurisdiction on the NSR Russia used to refer to article 234, chapter 8 “Ice Covered Areas” in the United Nations Convention on the Law of the Sea of 1982. Accordingly, coastal states in areas with a certain ice coverage jeopardizing ship traffic and environment are entitled to issue and enforce non-discriminating laws and regulations in order to prevent, reduce and monitor sea pollution by ships within the exclusive economic zone.

On the 28th July 2012 the NSR was declared the historical, national transportation route of the Russian Federation. The law signed by the President of the State is called “Federal Law on

Amendments to Specific Legislative Acts of the Russian Federation Related to Governmental Regulation of Merchant Shipping in the Water of the Northern Sea Route"[12] and grants control over all navigable waters of the NSR to the Russian government. Included are internal waters, territorial waters, contiguous zone and the exclusive economic zone, in the course of redefining the limits to the NSR widely expanded. Thus Russia will have the ability to issue and enforce laws on traffic through the NSR.

At present and in addition to transit rights the dimensions of the exclusive economic zone are under negotiation as Russia claims 1.2 million square kilometres along the Lomonossov Ridge as an additional continental shelf for itself.

According to the UN Convention on the Law of the Sea an expansion of the economic zone is possible after the UN Continental Shelf Commission has agreed, Russian territories could theoretically grow by 1.2 million square kilometres.

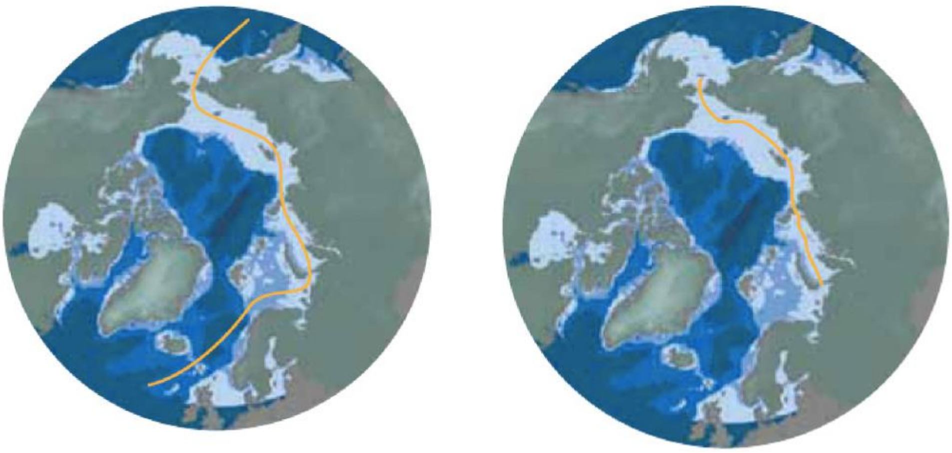


Figure 11 Defined territory of North East Passage (left) and Northern Sea Route (right) [12]

Up to know the traffic along the routes in Russian territories is regulated by several different laws and codes.

The merchant Shipping Code of the Russian Federation 1999 (MSC)

Rules of classification and construction of sea-going ships of RMRS 2008

NSR federal law 2012 (Annex Nr.2)

Rules of navigation in the Northern Sea Route waters area 2013 (Annex Nr.1)

Communications instructions for Arctic navigation 2012 – 2013 on the NSR

Permits for carbonate transportation and towing

Basics of the State Policy of the Russian Federation in the Arctic 2008

Requirements to the design equipment and supplies 1990 (Annex Nr.3)

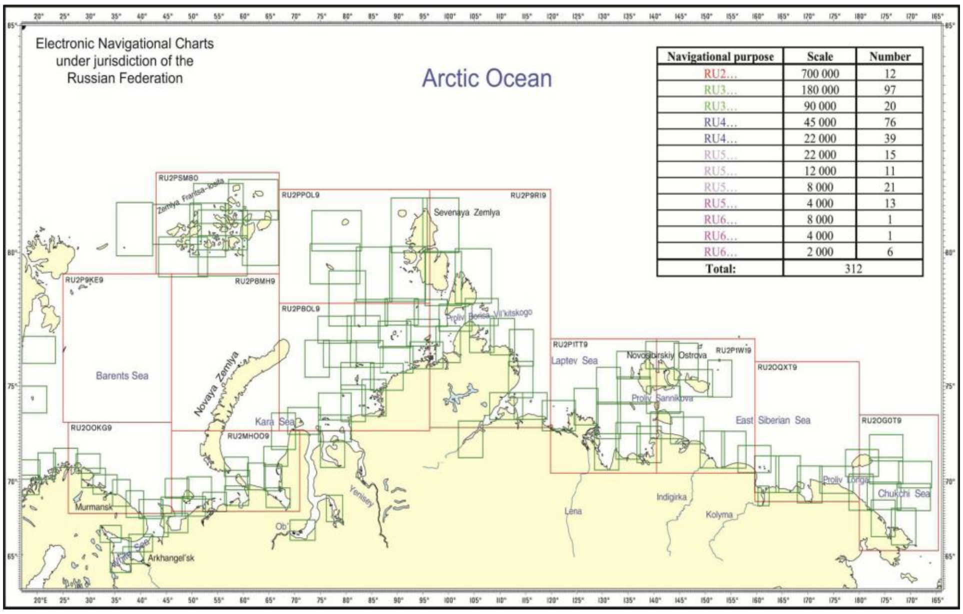


Figure 12 Overview of electronic chart zones defined by the russian jurisdiction [6]

It has to be assumed that ships operating in ice get into ice conditions exceeding their ice class. That is why the NSRA recommends an “Ice-Certificate” and an “Ice-Passport” to be issued. The certificates are designed and issued by the “Central Marine Research and Design Institute” (CNIIMF).

For instance, the Ice-Passport mentions the general qualities of the ship, like e.g. ice conditions the ship could be deployed in. Whereas the Ice-Certificate tells you how the ship can be deployed under conditions mentioned in the Ice-Passport. Starting with the ship’s characteristics, this document shows diagrams which allow to determine speed admissible in ice, safe distance in convoy, and the minimal radius of a curve in the ice channel. Furthermore, the Ice-Certificate includes values of side pressure expected to work on the hull, and recommendations in general. The annex holds information on ice conditions for each month. The certificate allows ships to navigate in ice or call at a port independently or following an icebreaker, even if their ice class actually lies below what either NSRA or the port require. Their Ice-Certificate values just prove their ability to safely operate in ice. The Ice-Certificate is valid for ten years.

The ice certificate will include following information:

- main ship particulars
- diagrams on safe speed while moving in ice of different thickness and concentration with the icebreaker assistance and independently
- diagrams how to determine the safe distance when the ship is guided by icebreaker
- assessment of side strength of ship under ice compression
- recommendations to be given to the ship’s master for special attention during navigation under ice conditions

The CNIIMF generates specific admissible speed values for each ship which are then represented in the diagram.

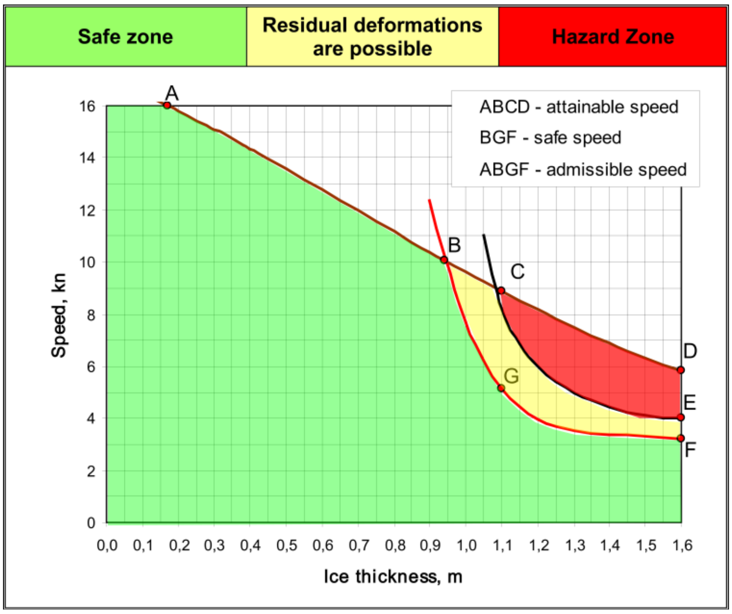


Figure 13 Diagram of attainable and admissible speed [13]

Green Zone: area of operational speed which is safe for the ship

Yellow zone: area of speeds which is accessible for the ship by technical abilities, hull ice interaction might lead to residual deformations

Red Zone: Area which is accessible for ship by its technical abilities, loads induced by hull-ice interaction could lead to failure of the hull structure

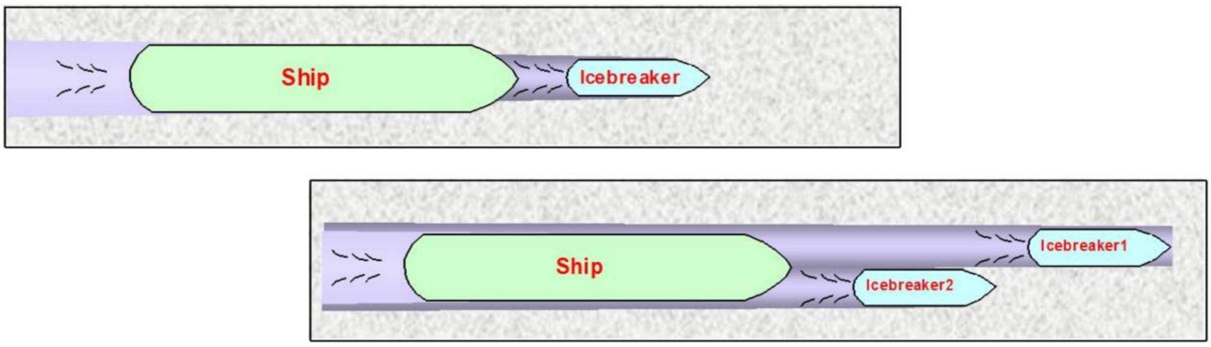


Figure 14 Schematic view of cargo ship being escorted by one or two icebreakers

Entry values for determining safe distance in convoy are similar to those for identifying the admissible speed: the ship's trim (loaded or in ballast), ice thickness, speed and ice concentration in the channel. Figure 15 shows this type of diagram. The different curves are marked by (h) indicating ice thickness. The curves allow to read out distance (L), at speed (V) and ice concentration(S). Values for (S) and (h) can be found right next to the diagrams in the ice certificate.

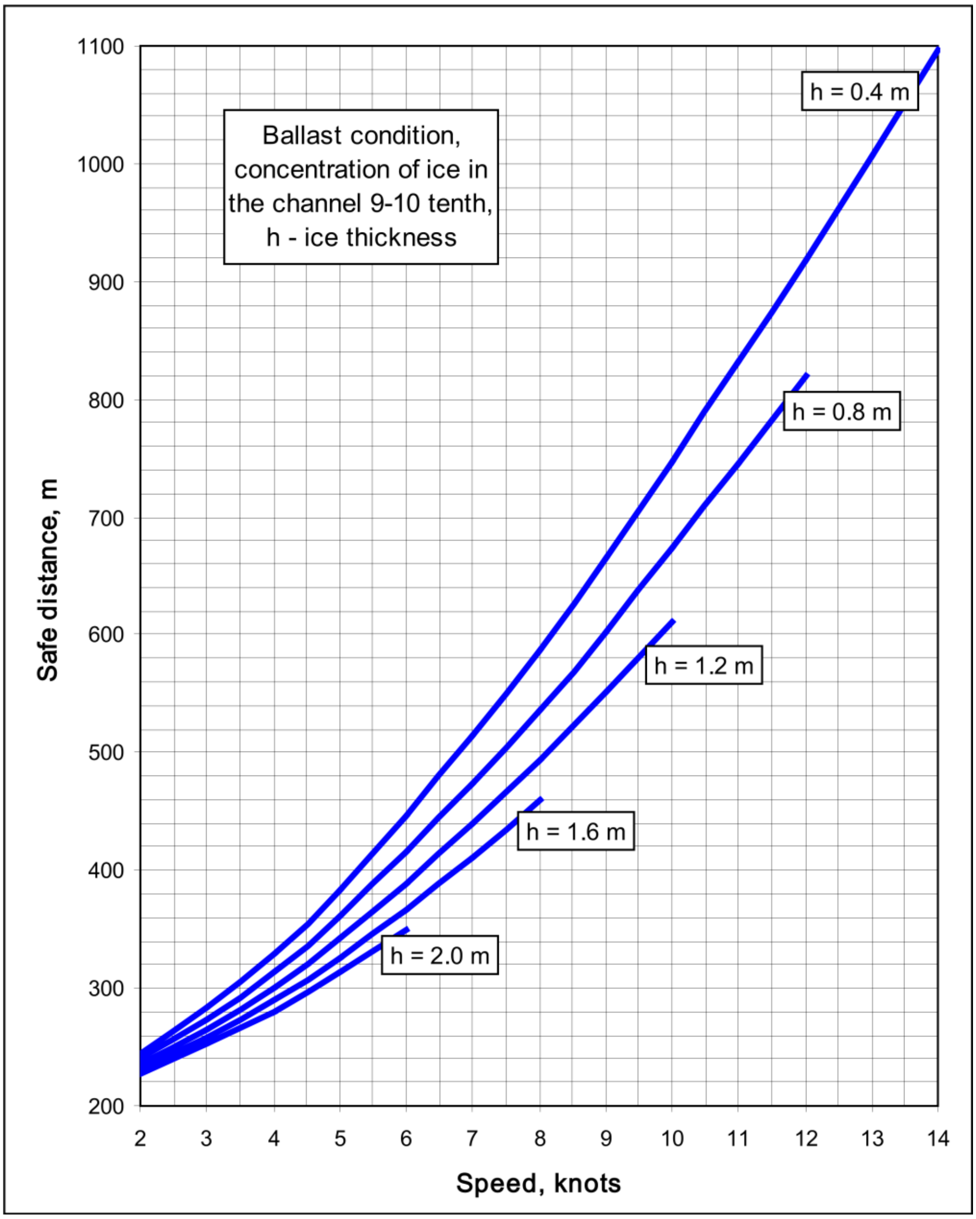


Figure 15 Distance requirement between icebreaker and escorted ship [13]

The requirement for side shell plating is defined by comparing the baring capacity and the maximum pressure which is acting due to compressive ice. The maximum pressure is assumed as the pressure before local failure of ice under static load condition occurs.

The maximum load before occurrence of plastic hinges is determined based on the plate thickness, frame spacing and yield point of corresponding steel.

The maximum ice strength is depending on the mechanical properties of the ice formation. Additionally a thickness dependence is taken into account (Fig. 16).

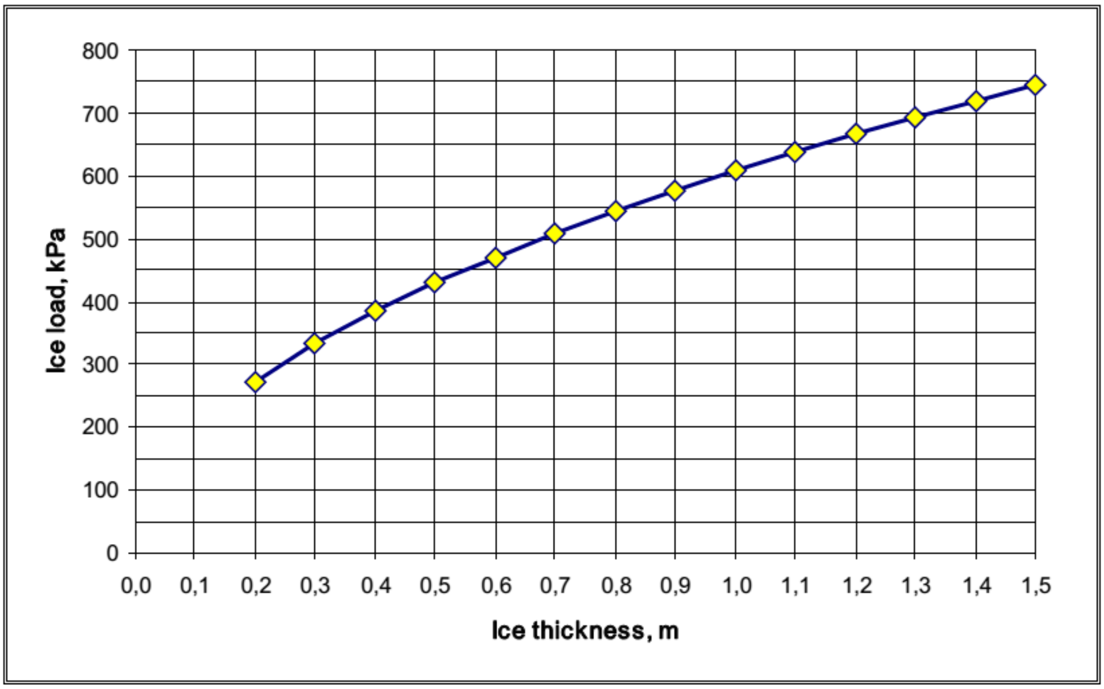


Figure 16 Degressive shaped load curve with ice thickness [13]

The diagram shows a degressive shaped curve with increasing ice thickness. The reason is that the relative effective load transmitting intersection between hull and ice is decreasing with increasing ice thickness. For deformed ice the development of load intersection can even be more complex.

Based on the technical abilities of the ship the ice certificate will define in which period of the year permission for access to certain sea areas along the Northern Sea Route is given (Table 4).

July to November

Category of ice strengthening of ship	Mode of ice navigation	Kara Sea		Laptev Sea		East-Siberian Sea		Chukchi Sea
		south-western part	north-eastern part	western part	eastern part	south-western part	north-eastern part	
		HML	HML	HML	HML	HML	HML	HML
Arc4	Ind	– + +	– + +	– – +	– – +	– – +	– – +	– + +
	IA	+ + +	+ + +	– + +	– + +	– + +	– + +	– + +
Arc5	Ind	+ + +	+ + +	– + +	– + +	– + +	– + +	– + +
	IA	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +
Arc6	Ind	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +
	IA	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +
Arc7	Ind	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +
	IA	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +
Arc8	Ind	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +
	IA	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +
Arc9	Ind	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +
	IA	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +

3. For ships with category of ice strengthening Arc4 – Arc9 during the period of navigation from January to June and in December

Category of ice strengthening of ship	Mode of ice navigation	Kara Sea		Laptev Sea		East-Siberian Sea		Chukchi Sea
		south-western part	north-eastern part	western part	eastern part	south-western part	north-eastern part	
		HML	HML	HML	HML	HML	HML	HML
Arc4	Ind	– – +	– – +	– – +	– – +	– – +	– – +	– – +
	IA	– – +	– – +	– – +	– – +	– – +	– – +	– – +
Arc5	Ind	– – +	– – +	– – +	– – +	– – +	– – +	– – +
	IA	– – +	– – +	– – +	– – +	– – +	– – +	– – +
Arc6	Ind	– – +	– – +	– – +	– – +	– – +	– – +	– – +
	IA	– + +	– + +	– – +	– – +	– – +	– – +	– + +
Arc7	Ind	+ + +	– + +	– – +	– – +	– – +	– – +	– + +
	IA	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +
Arc8	Ind	+ + +	+ + +	– + +	– + +	– + +	– + +	+ + +
	IA	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +
Arc9	Ind	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +
	IA	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +

Table 4 Admittance criteria for navigation in the Northern Sea Route water area according to the vessels ice class [14]

«IA» –with icebreaker assistance;
«H» – heavy ice conditions according to the Rosgidromet official information;
«M» – moderate ice conditions according to the Rosgidromet official information;
«L» – easy ice conditions according to the Rosgidromet official information;
«+» – navigation is allowed;
«–» – navigation is not allowed.

5. Gaps, Shortcomings and Conflicts within Existing Rules

5.1 General Remarks

When evaluating existing rules and guidelines following facts should be kept in mind:

To be applicable, rules and guidelines are often defined for a large number of different ship types and sea areas and are therefore naturally suffering from generalisation.

Simplifications within algorithms and formulas in rules are necessary to enable ship designers to apply these rules within reasonable time in an iterative ship design loop.

Loads induced by sea ice occur with to strong variations related to ice properties and dynamic processes. Therefore simplified assumptions have to be used, which should include sufficient safety margins. Usually it will be difficult to predict the ice performance of a ship with high accuracy in the very early design stage.

In the past most of the developed rules and guidelines for ship operation in ice were mainly driven by the states located in areas with frequently ice infested waters. As the interest to explore arctic oil and gas fields and to use arctic shipping routes will rise among the international community, upcoming rules and guidelines might be a compromise developed by a larger number of states. This might bring advantages and disadvantages at the same time.

5.2 Including Ice Breaking Capability in Rules

Actual direct mandatory requirements for minimum ice breaking capability are only specified for certain regional areas e.g. Baltic Sea and areas close to the Russian coastline. Most of the rules applied to ice classed vessels are concentrating on the structural reliability defining the ice class depending scantling of a ship (e.g. increased plate thickness and number of stiffeners in ice belt).

Polar class	General description of navigational conditions	Minimum level of icebreaking capability, m
PC1	Year-round operation in all Polar ice-covered waters	[3.0]
PC2	Year-round operation in moderate multi-year ice conditions	[2.4]
PC3	Year-round operation in second-year ice which may include multi-year ice inclusions	[1.8]
PC4	Year-round operation in thick first-year ice which may include old ice inclusions	[1.3]
PC5	Year-round operation in medium first-year ice which may include old ice inclusions	[1.0]
PC6	Operation during the summer-autumn period in open floating residual and young ice	[0.7]
PC7	Operation during summer period in open floating residual ice cake	[0.5]

Table 5 Recommendation minimal ice breaking capability corresponding to pc classes [15]

5.3 Load Case Scenarios

For all load assumptions including collision scenarios the dynamic condition of the ship / structure and the ice is of concern. The ice drift speed and ship speed at the time of the ice impact are to be taken into account. Presently the dynamic impact between ice and ship structure is only included implicitly. As an example the calculation of ice pressure within the Finnish –Swedish ice class rules is shown below.

The formula for the design ice pressure is given by:

$$p = c_d \cdot c_1 \cdot c_a \cdot p_0 \text{ [MPa]}$$

The coefficient cd takes into account the size and engine output of the vessel:

$$cd = \frac{a \cdot k + b}{1000}, \text{ with } k = \frac{\sqrt{\Delta \cdot P}}{1000}$$

While Δ is the displacement of the ship at maximum ice class draft and P is the actual continuous engine output. The maximum possible impact speed in ice for potential collision is therefore only roughly taken into account.

5.4 EEDI vs. Required Engine Power for Safe Operation

On January 1st, 2013 IMO members ratified the amendments to MARPOL Annex IV, Regulations for prevention of air pollution from ships including the mandatory status of the energy efficiency design index (EEDI). The index is meant to define standards for permissible carbon dioxide emission representing the social cost of a ship in relation to its hauling capacity representing the benefit for society. The index in a simplified form is defined as follows:

$$EEDI = \frac{\sum Pi \cdot SFOCi \cdot CFi}{fi \cdot DW \cdot v}$$

A more detailed version of this formula can be applied already in the design stage of a ship:

$$EEDI = \frac{\left(\prod_{j=1}^{M} f_j\right)\left(\sum_{i=1}^{nME} P_{ME(i)} \cdot C_{FME(i)} \cdot SFC_{ME(i)}\right) + \left(P_{AE} \cdot C_{FAE} \cdot SFC_{AE}\right)}{f_i \cdot Capacity \cdot V_{ref}}$$

With:

Pi: Power consumption of power supplying unit on-board (e.g. main / auxiliary engine)

SFCi: Specific Fuel Oil Consumption of power supplying unit on-board

Cfi: Carbon Emission Factor

DW: Deadweight of the Ship[1]

v: Service speed of the Ship

fi: factor taking into account the ice class of the ship

The EEDI is currently applied to following ship types:

Bulk Carrier

Tanker

Gas Tanker

Containerships

Combined Bulk Tanker

General cargo Vessel

The calculated energy efficiency design index has to be combined to deadweight depending baselines which are based on regression of data from the existing merchant fleet (Fig. 15).

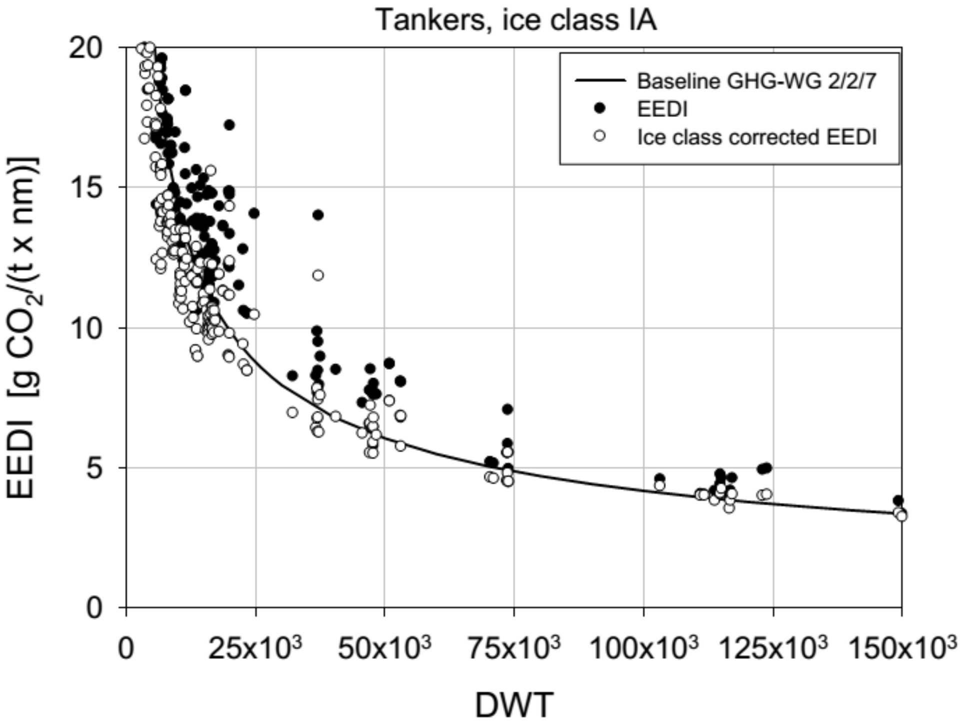


Figure 17 Comparison of EEDI values of ships with and without ice class correction [16]

For ice classed ships the deadweight is usually lower compared to a similar sized ship without ice class because additional weight is required for reinforcement. Additionally the installed engine power is significantly higher to ensure sufficient manoeuvring capability in ice.

To account for these design specialities additional factors have been introduced to compare ice classed vessels to the same baselines defined for conventional ships. The factors slightly reduce the power to be applied in above formula and increase the value in the denominator to compensate smaller deadweight.

Factor taking into account the increased installed power for ice operation:

$$f_{j0} = \frac{0.308 \cdot L_{PP}{}^{1.920}}{\sum_{i=1}^{nME} P_{ME(i)}}$$

Factor taking into account the decreased deadweight due to higher steel weight (reinforcement for ice loads):

$$f_{i0} = \frac{0.00138 \cdot L_{PP}{}^{3.331}}{Capacity}$$

A conflict occurs as still after application of these factors many typical ship types will not be able to fulfil the requirement for minimum installed engine power in ice and EEDI at the same time. This specially counts for all vessels with a propulsion arrangement that is not capable to provide efficient manoeuvring capability at low speeds like Bulk Carriers and Tankers with single shaft low speed diesel engines in combination with fixed pitch propellers.

A conflict is determined for certain ships which have to fulfil both requirements:

- Minimum required engine output according to the Finnish Swedish Ice Class Rules
- EEDI

HSVA has carried out an investigation on ships with ice class IA included in the databases. A high number of ships turned out to exceed their permissible EEDI if the required power was determined throughout the TraFi formula calculation (Figure 18).

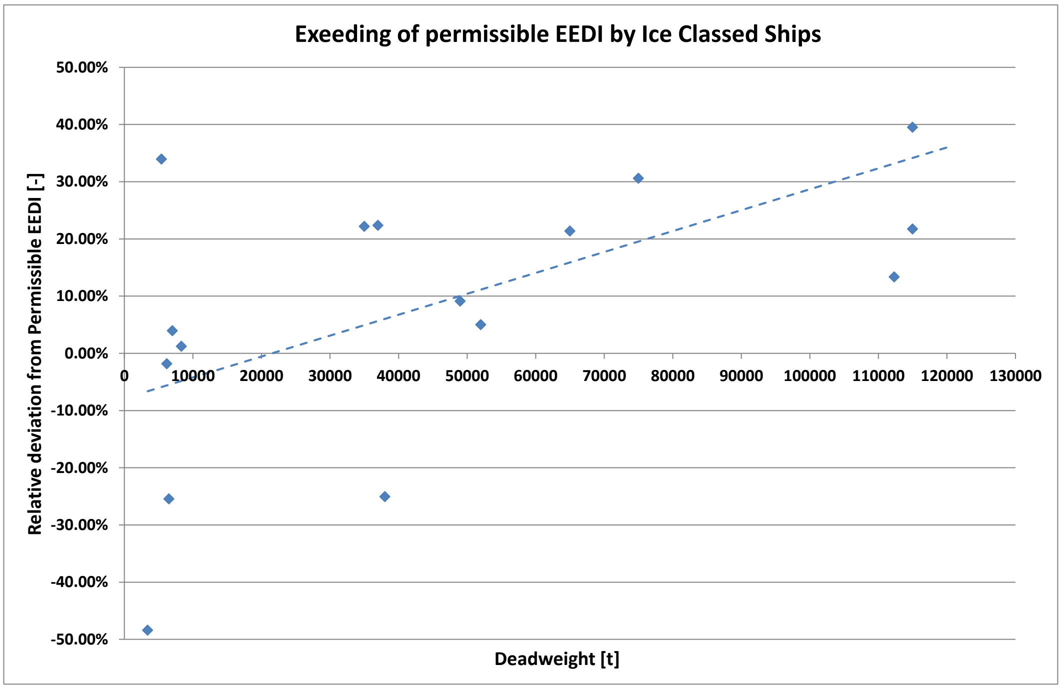


Figure 18 Ice classed ships exceeding EEDI due to TraFi power requirement

To overcome the conflict the ice class factors for EEDI have to be harmonized with the requirements for Finnish Swedish ice class rules as they are applied by most classification societies.

6. Proposals for General Rule Concept Development for Arctic Shipping

6.1 Risk Based Rule Development

In order to ensure the safety of life on-board and at the same time prevent any pollution to the sea individual risk analysis should be carried out for specific routes and high frequented sea areas in the arctic. The risk analysis shall include information and potential impact from local environmental conditions (e.g. ice conditions and seasonal change, water depth and coastal structure, wind and currents). Additionally the emergency response capacity and estimated time of arrival of SAR ships or icebreakers shall be calculated specially for routes through remote areas.

A high number of casualties with ships involved are initiated by an unforeseen limitation or loss of manoeuvring capability while the reason for the restricted manoeuvre capacity can be a technical problem / damage, a rapid change of sea / ice condition or an insufficient propulsion power or number of manoeuvring organs.

Murmansk	1	Novyy Port	13
Kandalakscha	2	Yamburg	14
Vitino	3	Zelëny Mys	15
Onega	4	Dikson	16
Archangelsk	5	Dudinka	17
Mesen	6	Igarka	18
Indiga	7	Khatanga	19
Narjan-Mar	8	Tiksi	20
Varandey	9	Pevek	21
Amderma	10	Mys Shmidta	22
Kharasavey	11	Provideniya	23
Sabetta	12		

Table 6 List of ports along the Northern Sea Route

6.2 Specification of Required Ice Performance

The required ice breaking capability will always depend on the designated area of operation and corresponding ice conditions and frequency of traffic in this area. If level ice has to be broken by the ship independently the requirements for power and available thrust will increase significantly. Besides a nominal power requirement the reliability and efficiency of propulsion organs has to be assessed for different ice conditions as well.

Finally the manoeuvring capability of the ship especially at low speed has to be included to account for scenarios in which the ship encounters ice formations above its nominal capacity and has to back turn or widen its channel to proceed or reverse. To assess only steady ahead operation at constant speed is not sufficient as for many ships the main obstacle can be to start from zero speed in heavy ice.

Harmonization of Ice Performance and Structural Reliability Requirements

For many scenarios of ship operations in ice the load assumption for dimensioning the ship structure is depending on the dynamic impact and therefore related to the ship speed in the specific ice formation. During ridge ramming for example the bow will encounter the highest loads when the ship is continuously backing and accelerating within a broken channel where it can reach higher speeds than in level ice.

6.3 Responsibilities for Emergency Response

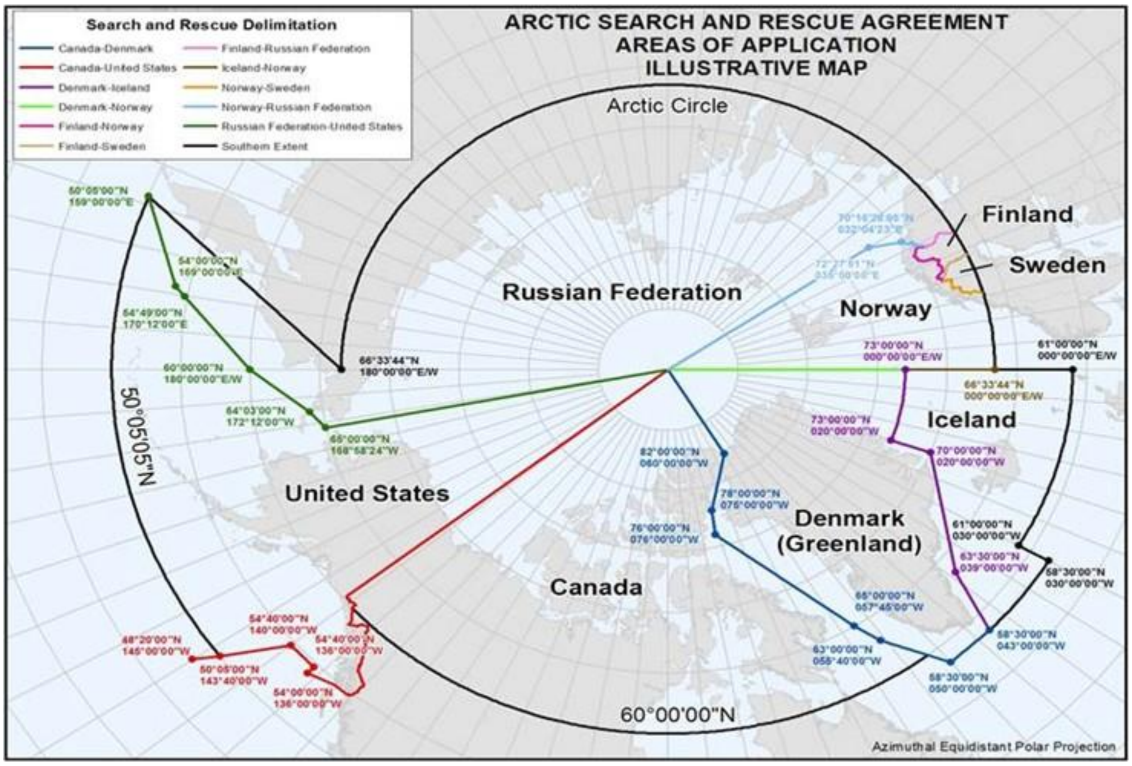


Figure 19 Search and Rescue Delimitation in the Arctic [14]

The issue "safety" on one hand results from topics already covered, and from factors each interested party will add to its own "risk analysis" for navigating on the Northern Sea Route. On the other hand, safety depends on appropriate safety and rescue facilities. So far, they must be considered unsatisfactory. The Russian development plan, however, apart from changes already mentioned, includes intensive improvements of safety facilities.
The Russian government, respective the Russian Ministry of Transport published their plans for erecting 10 SAR-facilities along the NSR. These facilities are so-called EMERCOM-Stations. EMERCOM is the international acronym for Ministry of the Russian Federation for Affairs for Civil Defence, Emergencies and Elimination of Consequences of Natural Disasters, also known as the Emergency Control Ministry. Three main stations are to be erected in Naryan-Mar, Dudinka and Pevek, and seven local branches in Murmansk, Arkhangelsk, Vorkuta, Nadym, Anadyr, Tiksi and Provideniya. Dudinka will be the first EMERCOM station to come into service. The Naryan-Mar station starts operating in August 2013, stations in Murmansk and Arkhangelsk take up service 2014 to 2015, and the Vorkuta station is expected to start operating in 2017. Manning level will range from 60 to 165 individuals. Icebreakers too have a crucial role in executing search and rescue operations.
Hence in December 2012 the Russian Ministry of Transport concluded a contract with the German Shipyard "Nordic Yards" for building two icebreakers. These icebreakers shall primarily be deployed for rescue and recovery missions on the NSR, or, more exactly, for patrol and rescue operations in offshore oil and gas fields in the Murmansk and Sakhalin areas. Moreover, by Nordic Yards press releases, these ships are highly specialized ice breakers of the second highest ice class furnished with complex equipment. They can be used in ports as well as on sea with an ice thickness up to one meter. With these preconditions they

are especially suited for search and rescue of ships in distress, evacuation of and medical care for individuals, and for fighting fires and oil pollution. In addition the ships are equipped to allow examinations of the sea floor and damaged objects in depths up to 1000 meters. Their construction starts in 2013, delivery is expected in 2015.

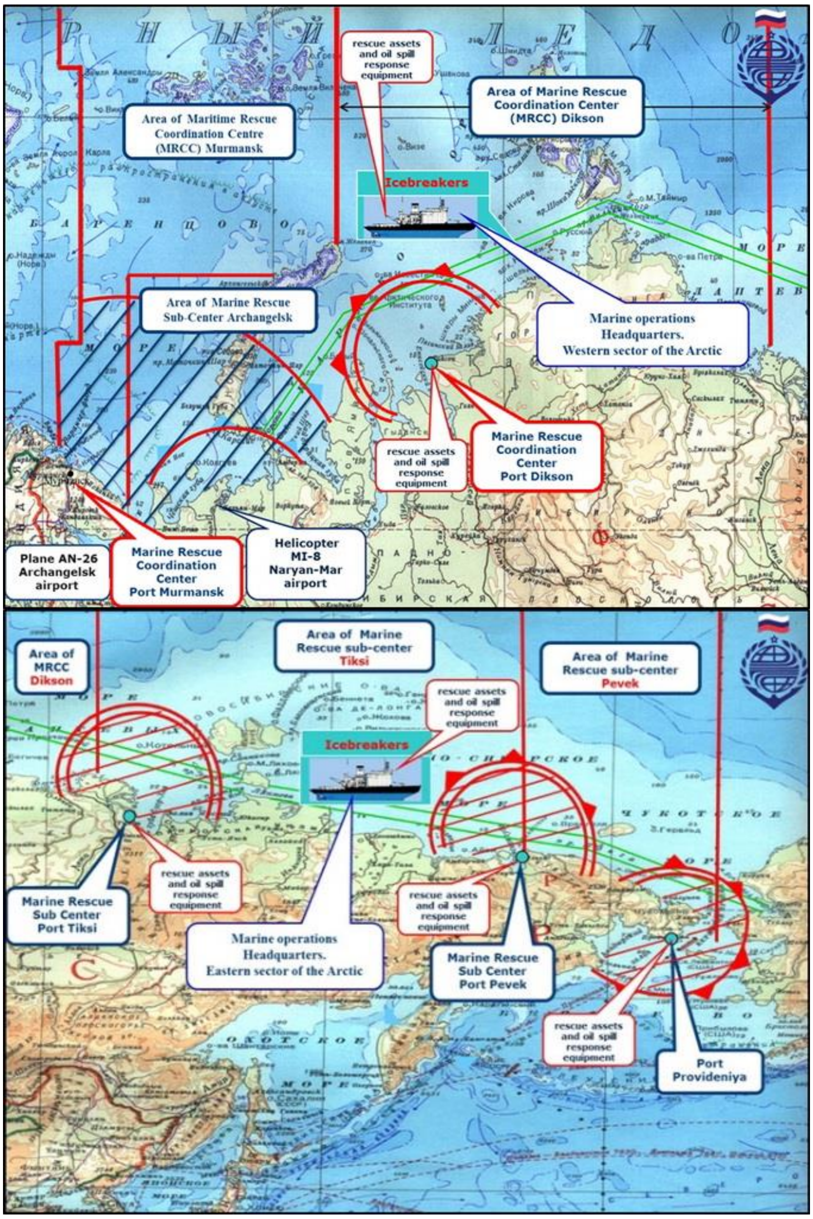


Figure 20 Search and rescue centres in western and eastern sector of the Russian Arctic [14]

For remote places like many sea areas in the arctic a crucial point is the time required for emergency response vessels to reach a disabled vessel from their station. A common scenario is a defect of a manoeuvring organ that leads to uncontrolled drift of a vessel in heavy seas or ice.

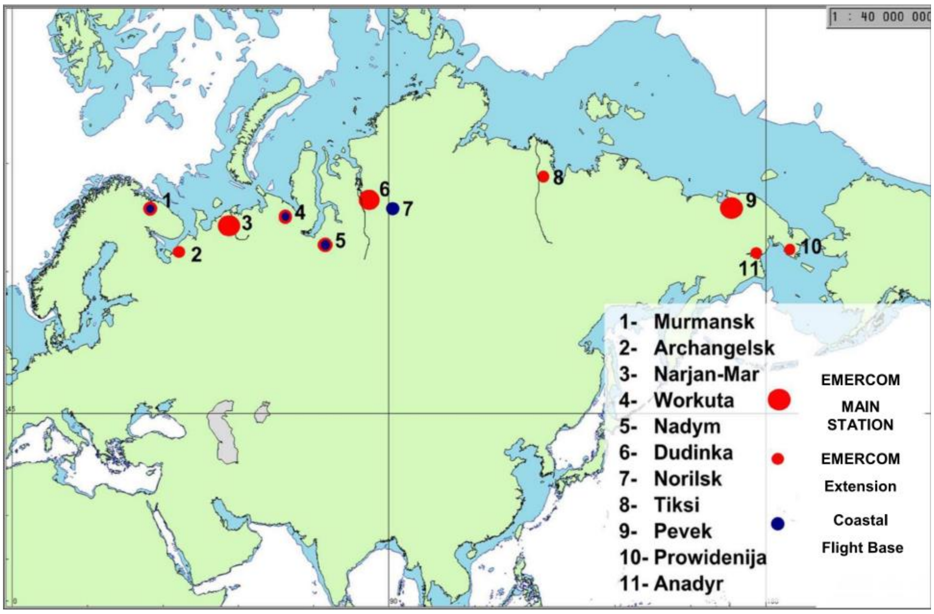


Figure 21 Overview of location of EMERCON stations along the Northern Sea Route [15]

Most of the merchant ships travelling along the Northern Sea Route are not capable of operating independently over the whole year. Therefore sufficient icebreaker assistance capacity must be provided by the Russian State. The existing fleet (Table) is currently renewed and additional icebreakers and emergency responds ships are under construction.
The Russian Federal Sea and River Transport Agency Rosmorrechflot, for instance, ordered five icebreakers from "Baltic Shipyard" (Baltysky Zavod JSC) in St. Petersburg, two icebreakers of 25 megawatt engine capacity each, and three icebreakers of 16 megawatt engine capacity each. All these icebreakers have diesel-electric propulsion. Delivery is planned for 2015.

Name	**Year of Build**	**Engine**	**Performance in PS**
Rossiya	1985	nuclear, 2 reactors	75.000
Sovetsky Soyuz	1990	nuclear, 2 reactors	75.000
Yamal	1993	nuclear, 2 reactors	75.000
50 Let Pobedy	2006	nuclear, 2 reactors	75.000
Taymir	1989	nuclear, 1 reactor	47.600
Vaygach	1990	nuclear, 1 reactor	47.600
Krasin	1976	diesel-electric	36.000
Admiral Makarow	1975	diesel-electric	36.000

Table 7 List of icebreakers

The icebreaker fleet includes ships with different power and icebreaking capability while the most powerful are the nuclear- icebreakers having a power of 60MW to operate in ice thicknesses up to 3m.

When defining rules for the common routes along the arctic ocean, the emergency respond capacity should be taken into account such that a basic level of icebreaker assistance is always assured and additional capacity can be demanded depending on the ships own manoeuvring capability and strength in ice.

7. Conclusions

Presuming a further decrease of the average ice extent in the upcoming decades, an increasing transit along the north east and north west passage can be expected. For the shipping companies the trend of keeping their flat flexible for different operation services leads to a scenario of ships with moderate ice classes operating in sub-arctic regions (e.g. Baltic Sea) in winter period and in arctic waters in summer period. The safety of these ships can be threatened as collisions with stronger ice formations drifting in a more unpredictable marginal ice zone have to be

7.1 Review of Accidents on Northern Sea Route

When analysing the accidents on the Northern Sea Route a striking point is that numerous of those casualties were taking place in compressive ice or involved collision events in drifting ice fields with ice fragments of high strength (multi-year ice). These ice conditions are usually driven by weather and current and strongly influenced by local topology and can therefore change rapidly. For the same reason these special ice conditions are difficult to be predicted by models. An assumed decreasing overall ice extent in the arctic will not eliminate ice covered areas of high compression and the prediction of drift of single multi-year ice fragments can even be more difficult. The risks for ships of moderate ice classes operating in the freeze up or melting period is still regarded as high. In order to assess this risk for development of rules and guidelines not only the overall average ice extent and volume shall be taken into account. Furthermore areas along preferable shipping routes or offshore activities with high potential risk due to local pressure or strong dynamic ice processes should be detected and evaluated for a risk concept.

7.2 Findings for Future Rule Development for Arctic Waters

Presuming a further decrease of the average ice extent in the upcoming decades, an increasing transit along the north east and North West passage can be expected. For the shipping companies the trend of designing their fleet flexible for different operation services leads to a scenario of ships with moderate ice classes operating in sub-arctic regions (e.g. Baltic Sea) in winter period and in arctic waters in summer period. In order to improve and enhance current rules for the demands of high frequent sea traffic in arctic waters the main threads and potential hazards are defined:

As some predictions of ice distribution in future decades show more open areas on the upper northern routes (close to North Pole) it has to be assumed that ship traffic will tend to increase on these routes. As ships travelling on these routes will be further away from any SAR stations the ships have to be outfitted to provide safe accommodation for a sufficient time in case of an emergency (ship getting stuck and drifting in ice).

challenge	**potential hazard**
difficult ice forecast, prediction of drift of strong ice formations in low overall ice concentrations	collision with strong ice floes (multi-year ice inclusions), navigating into compressive ice zones
lack of ice navigation experience of the nautical crew	wrong decision navigation, navigation in convoys, damage due to wrong usage of propulsion systems
insufficient manoeuvrability of ships in stronger ice conditions	getting stuck in thick or compressive ice, collision during convoy operation, grounding in coastal areas,
operation of higher number of vessels in remote areas with low SAR capacities, responsibilities	high emergency response time, difficult coordination of SAR operations due to lack of communication capabilities,
environmental conditions, low temperatures darkness, ice and snow accretion	Deterioration of relevant systems (communication), decrease of ship stability,
increasing operation in sensitive sea areas with rare species	fuel spills, exhaust emission and noise discharge, ballast water discharge, local disturbance of ice and ocean conditions
Decrease of sea ice coverage, large free water surfaces, increasing fetch => wave development	wave loads, ship motions, capsizing, insufficient manoeuvrability in waves, grounding

Glossary

CNIIMF	Central Marine Research and Design Institute
EEDI	Energy Efficiency Design Index
EMERCOM	Ministry of the Russian federation for Civil Defence, Emergencies and Elimination of Consequences of Natural Disasters
HSVA	The Hamburg Ship Model Basin
IACS	International Association of Classification Societies
IMO	International Maritime Organisation
MARPOL	International Convention for the Prevention of Pollution From Ships
MSC	Maritime Safety Committee
NSR	Northern Sea Route
PC	Polar Classes
RMRS	Russian Maritime Register of Shipping
SAR	Search and Rescue
UN	United Nations

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